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Survival of Progeny in Developing Countries: An analysis of Evidence from Costa Rica, Mexico, East Pakistan, and Puerto Rico

Frank Sloan

A Report prepared for

AGENCY FOR INTERNATIONAL DEVELOPMENT

Rand
SANTA MONICA, CA. 90406

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PREFACE

Sources of variations in infant and preschool child mortality in developing countries are currently inadequately understood. These variations are of more than academic interest. Infant and preschool child mortality has a direct impact on fertility, and public policies that promote good child health will also reduce population growth. To the extent that health in childhood contributes to labor productivity in adulthood, economic growth is affected. The purpose of this study is to identify sources of geographic variation in infant and preschool child mortality in four developing countries, Costa Rica, Mexico, East Pakistan, and Puerto Rico. The choice of countries is based in part on data availability. East Pakistan, by far the poorest in terms of both living standard and data, was selected to extend the applicability of the findings to countries at greatly varying stages of development. Regression analysis is the principal statistical tool. All data are from published sources.

This study was supported by the Agency for International Development, Department of State, under Contract CSD-2533 with The Rand Corporation. The objectives of this AID-sponsored research are to formulate and test a comprehensive theory of fertility and to suggest survey data that should be collected at a future date for testing alternative theories of fertility. Theoretical and empirical phases of the research are directed toward both identifying public policies that can accomplish socially desirable changes in reproductive behavior and measuring the contributions of selected policies in effecting these changes.

The author benefited from the assistance of John Enns and Kenneth Maurer in data processing and programming. He is indebted to Rand colleagues William P. Butz, Alvin J. Harman, Peter A. Morrison, and T. Paul Schultz for many helpful comments.

SUMMARY

This study identifies several potential determinants of regional differences in infant and preschool child mortality in less-developed countries. Among the determinants considered, female literacy and nutrition definitely have an impact on mortality of children less than five. The roles of female labor force activity and medical care emerge less clearly. Sanitation variables and variables that characterize the housing stock of the region explain none of the variation in mortality rates.

The contribution of education to a nation's economic and social development is becoming increasingly apparent. Female literacy has an important impact on the health of infants and small children. The mechanism through which education affects child health is not fully understood, but several explanations may be offered: (1) Increased awareness of personal hygiene; (2) the propensity of the literate to seek medical care from scientific rather than folk sources; (3) cognitive development enabling the consequences of particular acts to be anticipated, particularly those associated with child care; and (4) greater efficiency in consumption -- that is, the literate tend to pay lower prices for the goods and services they purchase and thus secure more goods and services from a fixed amount of income.

Previous studies have established the importance of nutrition as a determinant of the health of young children. Malnutrition both causes and aggravates disease and impedes the development of physical and mental capacities. Nutritional deficiencies reflect a number of factors -- income, prices of food and other commodities, family size, intra-family food distribution mores, and lack of knowledge of some of the fundamentals of nutrition. The relationship between nutrition and mortality emerges most clearly in the Mexican analysis. More appropriate measures of nutritional state are available for Mexico than for the other countries. Although the parameter estimates indicate that nutrition has a smaller effect on mortality than literacy, it is quite possible that government programs promoting a better diet have a greater

short-run impact on child mortality than investments in the schooling of female children. The latter involve considerable lags between the time schooling is received and the time the female child becomes a mother.

The amount of time spent by the mother in child care may improve child health. Presence of the mother in the home may reduce household accidents. Healthy children may be more effectively isolated from children with infectious diseases. In countries where breast feeding is the most satisfactory source of food for the young child, female labor force activity may lower child health by causing breast feeding to terminate earlier than would occur if the mother were confined to household duties. The best measure of the maternal input would be data on maternal time allocation. Such data are not available at the present time for households in developing countries, and thus less direct proxies must be selected. Of these, the most appropriate is female labor force participation. The coefficient of this variable has a plausible sign in most of the regressions, but it is significant at the 5 percent level in only one case. More precise data are needed.

The evidence from previous studies of the effects of medical care on infant and preschool child mortality is ambiguous. The results of this study emerge clearly in the case of literacy and nutrition. Some of the ambiguity arises from deficiencies in the data. Measures of the flow of medical services rendered patients are the best representations of the influence of medical care on mortality. Such data are not always available. Significant parameters are often obtained from a flow-of-services measure of medical care, but not when alternative variables are used in the regression equations.

Sound reasons can be given for including several measures of environmental variables and housing. Sanitation and housing characteristics relate to the transmission of infection. Water may serve as a vehicle for the spread of such diseases as cholera and typhoid fever or as a reservoir for malaria-transmitting mosquitoes. Overcrowding, improper ventilation, inadequate facilities for fecal disposal, no readily available water supply, poorly constructed housing, and

improper facilities for food storage have all been linked to family health. However, in contrast to nutrition, the body of evidence supporting a causal relationship of the environmental factors and housing attributes to health is meager. As in most previous investigations, no evidence to support such relationships is found in this study.

This is an exploratory analysis in an uncharted area. Extensions should be grounded in a theory of household decisionmaking. Analysis should be conducted at the level of the household. Several sources of data at this level exist; none is fully adequate, but analysis of these data in combination is likely to be worthwhile. Although further insights may be gained from more analysis of existing information, new surveys also merit attention. These surveys should collect data on vital events, the morbidity record of family members, consumption of goods and services relevant to health, income, occupation, educational attainment, and time budget data indicating how family members (particularly the mother) divide their total time among different activities, especially among income-producing and child-rearing activities.

CONTENTS

PREFACE iii

SUMMARY v

Section

I. INTRODUCTION 1
The Relation of Infant and Preschool Child Morality to Fertility 1
Plan of the Study 2

II. THE FOUR COUNTRIES: A CAPSULE DESCRIPTION 4
Costa Rica 7
Mexico 7
East Pakistan 11
Puerto Rico 14
Consequences of Measurement Error 16

III. DETERMINANTS OF INFANT AND PRESCHOOL CHILD MORTALITY . . . 17
Education 17
Maternal Time Input 19
Nutrition 20
Sanitation and Housing 22
Medical Care 27
Sex of Child 31
Parity and Age of Mother 32

IV. EMPIRICAL SPECIFICATION 34

V. RESULTS OF THE REGRESSION ANALYSIS 42
Costa Rica 42
Mexico 45
East Pakistan 53
Puerto Rico 53

VI. IMPLICATIONS OF THE EMPIRICAL FINDINGS 58

VII. EXTENSIONS OF THIS RESEARCH 61
The Role of a Theory of Consumer Choice 61
Further Use of Data from Existing Sources 62
Data Collection 63
Questions of Health and Population Policy 64

Appendix

A. Measurement Error 67

B. Nutrition Analysis 70

C. Housing Analysis 77

D. Analysis of Births Not Attended by a Physician 79

Bibliography 82

I. INTRODUCTION

Improvements in the health of a nation's population are generally recognized to influence its economic development. Good health raises individual productivity both in the marketplace and in the household.[1] One aspect of health -- infant and preschool child mortality -- is related to population growth and fertility.

Unfortunately, few studies assess the effects of government programs and the concomitants of economic development on health. In part, this reflects the lack of a suitable theoretical understanding of family decisionmaking, especially in developing countries. Probably the principal reason for the lack of analysis, however, is data limitations. Necessary data of sufficient quality -- demographic, medical, economic, and social -- are not now available. This study measures the relative importance of factors contributing to variations in regional death rates of children under five years of age with existing data, and specifies factors based on the empirical analysis, that merit more intensive investigation with survey data collected specifically for analysis of infant and preschool child mortality.

THE RELATION OF INFANT AND PRESCHOOL CHILD MORTALITY TO FERTILITY

Infant and preschool child mortality have been used as indices of a nation's health.[2] This usage is debatable. The relation of infant and preschool child mortality to fertility is not. The decline in mortality of children under five has frequently been advanced as a

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[1]Several studies analyze the effect of health status on economic development. See for example, Barlow [1967, 1968], Correa [1970b], Malenbaum [1970], and Newman [1965]. These studies concentrate on productivity in the marketplace. The effects of improved health on performance of household activities have never been explored.

[2]Infant or preschool child mortality is a poor health index. Factors that are responsible for infant deaths provide poor explanations of deaths of persons in other age groups. Moreover, sources of mortality differ from sources of morbidity, even within the same age group (Taylor and Knowelden [1964]). The frequent use of infant mortality as a health index reflects two factors: Data are available. Infant mortality depends on current rather than on historical factors.

major cause of a decrease in fertility rates.[1] The most commonly stated mechanism is that children are an economic asset to parents -- a means for assuring them support in their old age. Death of offspring contribute both directly and indirectly to fertility. If parents lose a child, they may replace that child through another birth. Moreover, the risk that children may die is responsible for a form of hedging on the part of parents. In communities where infant and child mortality rates are high, parents may increase the number of births they desire as a form of insurance against the eventuality of securing "too few" surviving children.[2] As parents become more confident of the survival of their existing offspring, their need for additional children to ensure the minimum declines. Another mechanism underlying the observed mortality-fertility relationship is of biological origin. When an infant or a young child dies, the mother ceases to lactate, and the probability that she will conceive increases. It is not yet clear which of the two mechanisms is more important. In any case, government programs that promote reductions in mortality also tend to reduce fertility.

PLAN OF THE STUDY

Section II is a brief description of the four countries included in this study and an evaluation of the quality of the data. Section III reviews factors that are hypothesized to account for regional variation in infant and preschool child mortality. Section IV discusses empirical representations of these factors. Unfortunately, given the state of data currently available for this research, some representations are crude. Section V presents the results of a regression analysis of data from the four countries. Of the factors considered, the roles of female literacy and nutrition as determinants of mortality in the

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[1] Adelman [1963], Friedlander and Silver [1967], Harman [1970], Heer and Smith [1968], Nerlove and Schultz [1970], Potter *et al.* [1965], Schultz [1969], and Weintraub [1962].

[2] The motive is sometimes expressed in terms of a minimum number of surviving sons.

under five age group emerge most clearly. Section VI discusses the research and policy implications of these empirical findings. Section VII describes the role of economic theory in future research and indicates where additional data are needed.

II. THE FOUR COUNTRIES: A CAPSULE DESCRIPTION

To achieve a degree of generality across countries with different cultural characteristics and at varying stages of development, infant and preschool child mortality data from Costa Rica, Mexico, East Pakistan, and Puerto Rico will be analyzed. In part, data availability dictates choice of countries. Very few countries are both "developing" and publish data on infant and preschool child deaths by geographic area within the country and on several variables that are likely to account for geographic variations in death rates. Of the four countries selected, only Mexico and Puerto Rico have data that permit analysis of mortality patterns in more than one year.

Data on land area and population and information on the geographic unit of observation are contained in Table 1. The units of observation in Costa Rica and Puerto Rico are small, in terms of both area and population. Table 2 compares the four countries in terms of income, literacy, labor force participation, and housing. Mean family income is considerably higher in Puerto Rico than in the other countries.[1] Other measures, perhaps better indicators of a country's development than income, reveal smaller disparities between Puerto Rico and the others. For example, female illiteracy is lower in Costa Rica than Puerto Rico. The percentage of houses without piped water inside or outside the dwelling unit is virtually the same in both countries. Illiteracy in East Pakistan is far more widespread than in the other countries. There are very small intercountry differences in labor force participation. Judged by these criteria, Costa Rica and Puerto Rico are the most developed of the four, and East Pakistan is the least.

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[1] International comparisons of income provide a crude measure of intercountry differences in living standards, but no better one is available. Income data in Table 2 place Costa Rica in an unfavorable position. For example, according to another source, per capita income in the early 1960s was $295 in Costa Rica compared with $137 in Mexico. Worldmark Encyclopedia of the Nations, Americas, New York: Harper and Row, 1963. International Labour Organization data on wages in agriculture indicate that the Costa Rican agricultural worker earns twice as much as his Mexican counterpart. International Labour Organization Yearbook, 1969, Geneva.

Table 1

AREA, POPULATION, AND GEOGRAPHIC UNIT OF OBSERVATION

Country	Area (sq. miles)	Population (millions)	Geographic Unit of Observation Selected for this Study	Number of Geographic Units
Costa Rica	19,578	1.3 (1963)	Canton	68
Mexico	761,602	25.8 (1950)	State	32
East Pakistan	55,126	50.8 (1961)	District[a] (subdivided on urban-rural basis)	21
Puerto Rico	3,421	2.2 (1950)	Municipality	75

[a]Observational units for which nutrition data are not available are excluded from the analysis. The Chittagong Hill Tracts District is excluded entirely; the population of this district constitute an ethnic group distinct from other East Pakistanis. Sixteen observations pertain to rural areas of the remaining districts. Five represent urban areas in the most populated districts. The observational units are listed in Table 6.

Table 2

COMPARATIVE DATA ON INCOME, LITERACY, LABOR FORCE PARTICIPATION, AND HOUSING ATTRIBUTES

Country	Family Income ($ per year)[a]	Female Population Over Age 15 Unable to Read and Write (percent)	Female Labor Force Participation (percent)	House Without Piped Water Inside or Outside Dwelling (percent)	Potable Water (percent supplied)
Costa Rica	889-1,143 (1963)[b]	16.0 (1963)[f]	17.5 (1963)[h]	31.7 (1963)[i]	73.[j]
Mexico	727 (1961-62)[c] 1,335 (1963)[d]	39.3 (1960)[f]	19.9 (1960)[h]	67.7 (1960)[i]	52.[j]
East Pakistan					
Urban	597 (1964)[e]	59.0 (1961)[g]	8.2 (1961)[g]	NA	NA
Rural	563 (1964)[e]	84.9 (1961)[g]	18.0 (1961)[g]	NA	NA
Puerto Rico	3,273 (1963)[e]	21.7 (1960)[f]	20.0 (1960)[h]	30.0 (1960)[i]	98.[j]

NA means data are not available.

[a]Converted into dollars using a fixed exchange rate.

[b]Computed from wage and salary data for individuals. Low number based on assumption of 1.4 wage and salary earners per family. High number assumes 1.8 wage and salary earners per family. Costa Rica, Census of Population, 1963.

[c]Instituto National de la Vivienda [1963].

[d]Banco de Mexico, Encuesta Sobre Ingressos y Gastos Familiares Mexico, 1963, Mexico City, 1963.

[e]International Labour Organization, International Labour Organization Yearbook, Geneva, 1969.

[f]Latin American Center, University of California at Los Angeles, Statistical Abstract of Latin America, 1967, 1968.

[g]Female labor force participation rate pertains to women 10 and over. Pakistan, Census of Population, 1961.

[h]Costa Rica and Mexico: Female labor force participation rate includes women 15 and over; the Costa Rica and Puerto Rican rates, 14 and over. International Labour Organization Yearbook, 1969.

[i]Statistical Abstract of Latin America.

[j]Stewart [1971].

Table 3, which presents comparative data on crude and infant mortality rates, reveals a similar pattern. Pakistan is clearly the outlier.

COSTA RICA

Costa Rica has published detailed demographic data for a number of years from vital statistics registries, generally held to be of relatively high quality.[1] These data allow analysis of both infant and preschool mortality (deaths of children aged one to four). 1963 has been selected because the 1963 Costa Rican census provides data on variables that are hypothesized to affect mortality. Earlier censuses are far less comprehensive.

The preschool child mortality rates shown in Table 4 in the five lowest mortality rate cantons are very low by "developing" country standards. These rates are close to rates of nonwhites in this age group in the United States in recent years. However, in the highest rate cantons preschool child mortality is much higher than among nonwhites in the United States.

MEXICO

According to most indicators, Mexico is far less developed than Costa Rica. Since the quality of a country's data is positively related to its development, one expects Mexican data to be less accurate. Although these data merit less confidence, they permit statistical analysis of the effect of nutrition on mortality of children under five. Such analysis is possible for very few countries.

As Table 5 indicates, infant and preschool rates have fallen substantially since 1950 as have other rates, such as illiteracy.[2] However, sizable interstate variations remain. And there has been a change in the relative rankings among states.

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[1] Some recording errors are evident. See Appendix A for details.

[2] According to the 1950 and 1960 Mexican censuses, the percentage of the population age six and over who were unable to read and write fell from 44 in 1950 to 38 in 1960.

Table 3

COMPARATIVE CRUDE AND INFANT DEATH RATES[a]

Country	1955-1959[b]		1960-1964[b]		1967	
	Crude	Infant	Crude	Infant	Crude	Infant
Costa Rica	9.6	76	8.5	73	7.1	62
Mexico	12.2	78	10-11	69	9.2	63
Pakistan[c]	NA	NA	19	142	NA	NA
Puerto Rico	7.1	52	6.9	45	5.5	31
United States[d]	9.4	26	9.5	25	9.4	22
Whites	9.3	23	9.4	22	9.4	20
Nonwhites	10.2	44	9.9	42	9.4	36

Source: Population Index, Vol. 36, No. 3, July-September 1970, pp. 424-432.

NA means data are not available.

[a]Crude deaths are total deaths per 1,000 population. Infant deaths are per 1,000 live births.

[b]"Unless otherwise noted, these rates are unweighted arithmetic means of the rates for single years." p. 430.

[c]Data for East Pakistan are not available. "Estimated rate based on data collected by Pakistan's Population Growth Experiment Project (P.G.E.), by combining the results of the longitudinal registration system of the project with the results of the cross-sectional survey and the application of Chandra-Deming formula. The...death rates are for 1963; the infant mortality rate is for 1962-1965," p. 431.

[d]"Alaska is included beginning in 1959, and Hawaii beginning in 1960.... Death and infant death rates for 1969 are based on a 10 percent sample of deaths. Figures for 1962 and 1963 by color exclude data for residents of New Jersey," p. 430.

Table 4

INFANT AND PRESCHOOL CHILD MORTALITY IN COSTA RICA, 1963

Highest Rates		Lowest Rates	
Canton	1963	Canton	1963
Infant Mortality[a]			
Central (Limon)	135	Santa Ana	32
Pococi	129	Santo Domingo	35
Guarco	122	Paraiso	35
Acosta	120	Liberia	38
Oreamuno	117	Belen	13
Preschool Child Mortality[b]			
Tarrazu	19	Curridabat	1
Aguirre	18	Barba	1
Central (Puntarenas)	14	Alfaro Ruiz	1
Nandayure	14	Santa Ana	1
Pococi	14	Tibas	2

Sources: Ministerio de Economia and Hacienda, Direccion General de Estadistica y Censos, Annuario Estadistico de Costa Rica, 1963. San Jose: Publicaciones, 1964; Costa Rica, Census of Population, 1963.

[a]Infant deaths per 1,000 births.

[b]Deaths of persons aged one through four per 1,000 population aged one through four.

Table 5

INFANT AND PRESCHOOL CHILD MORTALITY IN MEXICO, 1950 AND 1960

Highest Rates			Lowest Rates		
State	1950	1960	State	1950	1960
Infant Mortality[a]					
Mexico	145	108	Veracruz	56	50
Tlaxcala	131	110	Sinaloa	61	46
Distrito Federal	130	85	Guerrero	63	51
Guanajuato	120	94	Quintano Roo	70	51
Puebla	120	91	Durango	68	59

Preschool Child Mortality[b]

	1950		1960			1950		1960	
	Male	Female	Male	Female		Male	Female	Male	Female
Tlaxcala	47	52	23	25	Baja Calif.	10	9	5	4
Oaxaco	43	42	30	31	Nuevo Leon	13	11	7	7
Queretaro	43	46	25	25	Baja Calif. T.S.	13	11	7	7
Puebla	42	43	26	24	Sonora	13	12	8	8
Mexico	43	44	21	22	Quintano Roo	12	14	10	7

Sources: Secretaria de Industria y Commercio, Direccion General de Estadistica, Annuario Estadistico de los Estados Unidos Mexicanos, 1950-1951, 1960-1961, and Mexico, Census of Population, 1950 and 1960.

[a]Infant deaths per 1,000 births.

[b]Deaths of persons age one through four per 1,000 population.

EAST PAKISTAN

East Pakistan is far more rural, yet more densely populated, and far less developed than the other three countries. Measurement errors are clearly evident in East Pakistan data, in particular underenumeration of births, infant deaths, and young children. As in Mexico, the data allow tests of the effect of nutrition on mortality. Although mortality data from registries are not available, retrospective mortality data are published in the census.

In comparison with estimates obtained by several demographers, the official Pakistan census infant death rates are high, whether expressed as the number of infant deaths per 1,000 births in Table 6 (Infant Death Rate I) or as the number of infant deaths per 1,000 children aged 2 (Infant Death Rate II).[1] Since infant deaths constitute over half of total deaths in all districts, it is likely that deaths involving persons in other age groups have been classified as infant deaths.[2] This type of misclassification may not be crucial because many of the inappropriately classified deaths are likely to correspond to children below the age of five; many factors affecting infant mortality also affect preschool child mortality. The crude death rates are also below those of other studies, suggesting that enumerators do not record many deaths. The Pakistan Population Growth Experiment estimates 20 deaths per 1,000 population in the early 1960s, approximately double the rates derived from the Pakistan Housing Census.[3]

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[1]Infant Death Rates I are considerably higher than Infant Death Rates II observations in some cases. The rank correlation between the two male series is 0.78; for females, it is 0.67.

[2]Errors in retrospective surveys designed specifically to collect vital statistics are well known. Sabaugh and Scott [1967], for example, estimate that single-round retrospective procedures have an absolute error of 17 percent for births and 36 percent for deaths. Multiple-round procedures improve accuracy. The principal objective of the 1960 Housing Census of Pakistan was to list buildings and establish the number of inhabitants and relationship of family members to household head, rather than to record vital data. Questions relating to births and deaths came at the end of the questionnaire. Report of the Population Growth Experiment [1968].

[3]Stoeckel [1970] estimates that infant deaths in the Comilla District of East Pakistan were at least 40 percent of total deaths in the

Table 6

VITAL DATA -- EAST PAKISTAN, 1960[a]

District	Infant Death Rate I		Infant Death Rate II		Percent Infant Deaths of All Deaths	Crude Death Rate	Birth Rate
	Male	Female	Male	Female			
Rural Areas							
Bakerganj	294	283	212	195	56	15	28
Bogra	302	270	240	191	66	14	13
Chittagong	235	224	169	151	65	9	27
Comilla	276	254	179	149	58	11	26
Dinajpur	402	280	224	138	68	11	22
Dacca	261	240	185	150	65	11	27
Faridpur	286	278	228	193	55	16	31
Jessore	217	201	167	146	69	10	30
Khulna	293	257	243	191	59	14	31
Kushtia	196	168	170	138	73	9	36
Mymensing	258	243	157	126	64	9	24
Noakhali	245	278	155	160	55	12	25
Pabna	208	194	167	134	68	9	32
Rajshahi	210	197	181	159	68	10	35
Rangpur	247	222	165	139	68	10	35
Sylhet	292	261	235	187	58	14	29
Urban Areas							
Dacca	197	182	155	127	74	6	23
Khulna	279	255	227	202	68	10	15

Table 6, continued

District	Infant Death Rate I		Infant Death Rate II		Percent Infant Deaths of All Deaths	Crude Death Rate	Birth Rate
	Male	Female	Male	Female			
Mymensingh	228	211	160	129	65	9	25
Pabna	140	132	150	101	58	7	29
Sylhet	177	159	159	126	60	7	26

Source: Housing Census of Pakistan, 1960, Vol. IX.

[a]Infant Death Rate I is the number of infant deaths per 1,000 born alive. Infant Death Rate II is the number of infant deaths per 1,000 aged two. Crude Death Rate is the total number of deaths per 1,000 population. Birth Rate is number of births per 1,000 population.

The census birth rates are far lower than those obtained in other studies, contributing to the unreasonably high Infant Death Rate I. An alternative measure of infant mortality, obtained by dividing infant deaths by the number of children aged two, also may be biased upward because many children die before reaching the second year; and underenumeration of two year olds may be serious, though not as extensive as underenumeration of births.

This discussion emphasizes the inadequacies of vital data; measurement errors are also possible in some of the measures of determinants of variations in mortality rates. Since Pakistani vital data collected by the census enumerator are based on the respondent's recall, they are more likely to contain errors than other data (such as housing characteristics) that are subject to the enumerator's direct observation.

PUERTO RICO

Table 7 contains Puerto Rican infant mortality rates for 1950 and 1960. These rates are the lowest of the four countries. Vasquez [1968] states that nonreporting of vital events has been negligible since 1950, but presents no evidence to support this assertion. There is evidence of misregistration of infant deaths by place of mother's residence in both 1950 and 1960. In some cases infant deaths are recorded as belonging to the municipality where they occur rather than to the municipality in which the mother resides. Puerto Rican Department of Health registration forms distinguish between deaths by place of occurrence and deaths by place of residence. But since a substantial number of persons receive medical services in a municipality other than the one in which they are resident, the potential for measurement error is substantial.[1]

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late 1950s and early 1960s. The Housing Census data indicate the percentage was 58 percent in 1960. Stoeckel derives estimates of 176 and 148 infant deaths per 1,000 births for the Comilla District in the years 1958-59 and 1963-64 respectively. For a more extensive discussion of Pakistani vital data, see Robinson [1967], Schultz and Da Vanzo [1970], and Mosley et al., [1970].

[1]See Appendix A for a more detailed discussion of this issue.

Table 7

INFANT MORTALITY IN PUERTO RICO, 1950 AND 1960
(per thousand births)

Highest Rates		Lowest Rates	
Municipality	1950	Municipality	1950
Fajardo	148	Ceiba	33
Arecibo	114	Nagubo	34
Guayama	108	Trujillo Alto	35
Arroyo	102	Morovis	36
Aquadilla	100	Coamo	44
	1960		1960
Salinas	66	Morovis	18
Toa Alta	64	Corozal	25
Guayanilla	60	Vega Alta	25
Sabana Grande	60	Fajardo	26
Aguadilla	60	Las Marias	28

Source: Annual reports of the Puerto Rican Department of Health.

CONSEQUENCES OF MEASUREMENT ERROR

Several weaknesses in the data are evident. These may have one of several effects on the parameter estimates obtained by regression analysis as well as on the standard errors of these estimates.

Case 1: If the measurement error in the dependent variable is related to an explanatory variable, the parameter estimate of the explanatory variable will be biased. Fortunately, the direction of the bias can be predicted in advance. For example, if literacy or educational attainment is positively related to a person's propensity to report an infant death, the parameter estimate of literacy or educational attainment (expected in the absence of measurement error to be negative in an equation explaining variations in death rates) will be more nearly zero or perhaps even positive. Since the direction of the bias is known, the parameter estimate is a lower or upper bound (depending on the direction of bias) of the true value.

Case 2: If the measurement error in the dependent variable is unrelated to the explanatory variables, the parameter estimates will be unbiased, but the standard errors of the parameters will be larger than in the absence of error.

Case 3: If an explanatory variable is measured with error, the parameter estimates will be biased downward. In general, explanatory variables included in this study appear to be measured more accurately than the mortality variables.

III. DETERMINANTS OF INFANT AND PRESCHOOL CHILD MORTALITY

This section reviews the principal factors affecting infant and preschool child death rates: education, maternal time input, nutrition, sanitation-housing, medical care, sex of child, and parity and age of mother. The environment that determines these rates is more complex than the one depicted by the single equation proposed here. This single equation allows the measurement of only the partial or direct effects of these factors on mortality. Measurement of the total effects requires a multiple equation model. For example, education of females is expected to lower mortality, but educated women are more likely to enter the labor force; the direct effect of labor force participation on the health of offspring is likely to be negative. Thus, schooling has a positive direct and a negative indirect effect on mortality of children under five. A single equation model captures only the direct effect. Although interdependencies should be kept in mind in an evaluation of the statistical results, it is useful to focus on single equation analysis in this exploratory phase. One may introduce additional equations once reasonable parameter estimates of the mortality equation have been obtained.

EDUCATION

Schooling affects productivity in the marketplace and in the household. The relationship between schooling and earnings is well-documented; it is strongly positive in all countries for which data are available.[1] A variety of mechanisms produce increased earnings, the direct impact of schooling on worker productivity, the increased propensity of the educated to seek and find work, better access to job market information, and larger amounts of on-the-job training that individuals with more schooling receive. Earnings in turn affect

[1] Private rates of return to investments in schooling have been estimated for a large number of countries. Studies pertaining to the countries analyzed in this paper include Carnoy [1967a, 1967b] and Selowsky [1967]. Returns to schooling are shown to be substantial. For a general review of the literature, see Bowles [1969].

mortality in the under-five age group by affecting household consumption of health-related goods and services. On the other hand, schooling increases the value of a mother's time in labor market activities and may thereby induce her to enter the labor force with consequences for child health discussed below.

Education also has an impact on people in their roles as consumers and producers of goods and services in the household. In large part because of data limitations, the nonmarket effects of schooling have received comparatively little empirical analysis.[1] Improved processing of job market information finds its counterpart in the household. Individuals with more schooling are likely to make more efficient purchases of goods and services.[2] They are better as parents in imparting skills to children and in making decisions relevant to child health. Traditional remedies in less-developed countries that exacerbate an existing illness of a sick infant or child are well-known to public health experts. Mothers often lower the fluid intake and remove pulses (peas, beans, lentils, for example) from a child's diet at the time when nitrogen loss due to diarrhea is substantial. Educational attainment may be associated with such preventive health measures as isolating ill from healthy children, preventing accidents in the household, securing innoculations and pre-natal care, separating animals' quarters from family quarters, maintaining appropriate food storage, and cleaning food utensils. The educated mother is more likely to seek health information and treatment from scientific rather than indigenous or folk sources.[3]

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[1] An exception is Michael [1969].

[2] Katona and Mueller [1954] and Fairley [1964].

[3] Although there are numerous descriptive accounts of schooling-induced effects on household behavior, there is little quantitative evidence to support these contentions. Some relevant tabulations for Mexico and Puerto Rico are contained in Instituto Nacional de la Vivienda [1963] and Roberts and Stefani [1949].

MATERNAL TIME INPUT

Presence of the mother in the home may reduce household accidents. Healthy children may be more effectively isolated from children with infectious diseases. In countries where breast feeding is the most satisfactory source of food for the young child, female labor force activity may lower child health by causing breast feeding to terminate earlier than would be the case if the mother were confined to household duties.

The best measure of the maternal input would be data on maternal time allocation. Unfortunately, since these data have not been collected, choices must be made among proxies. Although the female labor force participation rate is the most appropriate proxy, it is deficient in at least two respects. First, as is predictable on theoretical grounds, empirical studies indicate that the number of children present in the household, especially very young children, is clearly negatively related to the woman's participation in the labor force. Because children, and very young children in particular, raise the value of a mother's time in the household relative to other uses on her time, a strong negative relationship between the number of young children and female labor force participation is expected. The participation rate in the labor force of women with small children may bear very little resemblance to the aggregate rate. Mitigating this negative effect is the decline in household income per capita, a factor increasing a mother's propensity to seek employment.[1]

Second, time requirements differ by occupational categories. For example, some jobs in service and crafts industries allow a mother to remain at home. Agricultural responsibilities may take the mother

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[1]See Ben-Porath [1970], and Sweet [1970]. Harman [1970], an analysis of Philippines data at the household level, indicates that the number of siblings is positively related to the female labor force participation rate. Since the other studies utilize data from countries at a higher stage of economic development, it is possible that Harman's results reflect a true rather than a spurious difference. It is quite plausible that the income effect associated with extra children is dominant in a poor country.

away from home during harvests but not during other seasons when livestock and household production are easily combined with child-rearing.

Census data and descriptive accounts of household activities of females in developing countries reveal that a large percentage of women work in occupations that do not require large amounts of time away from children.[1] Since no precise data on time requirements by occupation are available, no adjustment for occupation mix is performed in this study.[2]

NUTRITION

On the basis of numerous scientific studies, nutritionists and experts in public health fields have established causal links between nutrition and a variety of aspects of health -- infectious and non-infectious diseases and development of physical[3] and mental capacities.[4] The FAO recently stated that malnutrition is the predominant cause of child mortality in developing countries.[5] In East Pakistan, at least one-half of all children are said to suffer from some form of malnutrition.[6] Nutritional deficiencies reflect a number of factors -- income, prices of food and other commodities, family size, intra-family food distribution mores, and lack of knowledge of some of the fundamentals of nutrition.[7]

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[1]Lewis [1959] is an excellent descriptive account.

[2]Mexican data on travel time to work reveal substantial inter-occupational differences in travel time. Unfortunately a category "travel time more than an hour" is combined with "travel time irregular." Thus, I did not use these data to perform occupational requirement adjustments. See Instituto National de La Vivienda [1963].

[3]Findings on the relationship of nutrition to physical growth are presented in Cravioto et al. [1966], Downs [1964], and Frisch and Revelle [1969].

[4]For evaluations of existing evidence on the effect of nutrition on mental capacity, see Chase and Martin [1970], Correa [1970a], Cravioto et al. [1966], Eichenwald and Fry [1969], Frisch [1970] and Winick [1969].

[5]Food and Agricultural Organization [1970].

[6]Rulison [1970], p. 32. See also Revelle and Thomas [unpublished].

[7]These factors will be analyzed in greater depth as an extension of this research.

The literature emphasises two causal mechanisms for the well-documented association between malnutrition, especially protein and calorie deficiencies, and infant and preschool child deaths from various infectious diseases. First, resistance to infection is reduced, and infections themselves are frequently more severe and often fatal. Second, an infectious disease may worsen nutritional status and actually precipitate an overt nutritional deficiency disease. The two mechanisms may be mutually reinforcing.[1] Death may result from an infectious disease even though nutritional disorder is the precipitating factor. For example, the ultimate cause of death in kwashiorkor cases is often bronchopneumonia.[2] Because of these interactions, it is difficult to attribute deaths to specific causes on the basis of registration records or even by more careful surveys.[3] On balance, use of multivariate statistical techniques may be a more promising approach for isolating the effect of nutritional state on mortality than attempting to identify the primary and contributory causes of death.

Previous studies indicate that nutrition has a greater influence on preschool child mortality than on infant mortality. Frequently malnutrition first appears in the second six months of life when a large percentage of infants in some countries are in the weaning phase.[4] Both the initial experience with contaminated food after the

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[1]This pattern is observable for such infectious diseases as diarrhea, measles, chickenpox, and yellow fever. See Scrimshaw [1966] for a summary of the evidence. For a more specific discussion of diarrheal disease-nutrition interactions, see Gordon et al. [1964] and Ingram et al. [1966].

[2]Although this pattern is common, it does not apply to all infectious diseases. Malnutrition has been observed to protect against infection, particularly in cases where infections are parasitic on host metabolic processes and in extreme deficiency states. Antagonism is generally restricted to infection by viruses, protozoa, and metazoan parasites. Zucker and Zucker [1968], p. 603; and Albanese and Orto [1968], p. 148.

[3]Behar et al. [1958] assess the quantitative importance of malnutrition as a cause of death.

[4]See the evidence of Navarette and others in Ramos-Galvan [1966a, 1966b]. In Mexico, 46 percent of children were found to be in the weaning stage in the second six months of life. In Pakistan, weaning appears to occur later. See U.S. Department of Health, Education, and Welfare [1966].

safe milk of the mother and the substitution of poor and often insufficient food are sources of infectious disease and malnutrition. Deficiencies in mothers' diets are held to cause low infant birthweight;[1] survival rates of low birthweight infants are substantially lower than infants having the mean birthweight.

There are a number of forms of nutritional deficiency. Analysis of the effects of a large number would be unmanageable. Because the predominant nutritional need for infants and preschool children is protein, this study only considers the effect of protein deficiencies on mortality.[2] Protein has both quantitative and qualitative dimensions. Quality, reflecting the balance among several amino acids, is almost as important as quantity. The pattern of amino acid content varies by food type; animal food products have amino acid patterns that are sufficient for human needs. A vegetable-based protein may be incomplete in isolation, but, when supplemented by protein from another plant source, may be sufficient. Such foods as cereals, legumes, and nuts have low biologic value in isolation, but when consumed together supplement each other. Corn and beans, staple foods in Latin American countries, are better utilized when ingested together. Certain food combinations that form complementary relationships have been eaten together in some traditional cultures, perhaps because the beneficial effects from this practice have been observed by local folk doctors. Mutual food supplementation is by no means practiced universally; measures of animal product consumption are thus reasonable proxies for the quantity <u>and</u> quality of protein intake.

SANITATION AND HOUSING

Nutrition affects mortality essentially by the reaction of the host to the infectious agent; by contrast, sanitation and housing

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[1] See Hillman and Hall [1968], p. 1092. Maternal malnourishment appears to affect the amount more than the composition of mammary secretion. <u>Ibid.</u>, p. 1102.

[2] The relationship of other deficiencies to protein deficiency is analyzed in Appendix B.

characteristics relate to the transmission of infection. Water may serve as a vehicle for the spread of such diseases as cholera and typhoid fever or as a reservoir for malaria-transmitting mosquitoes. Overcrowding, improper ventilation, inadequate facilities for fecal disposal, no readily accessible water supply, poorly constructed housing, and improper facilities for food storage have all been linked to family health.[1]

The body of empirical evidence in support of a causal relationship of sanitation and housing to health is not substantial compared with that of nutrition. As seen below, there is some evidence to indicate no relationship exists; some studies even imply that poor sanitation and housing improve health. The sanitation-housing component may be subdivided into (1) environmental factors affecting the community collectively, and (2) factors involving households on an individual basis; the latter primarily pertain to attributes of the dwelling unit.

Environmental Factors

Although public programs affecting the environment have undoubtedly had dramatic impacts on mortality in some less-developed countries, there are few scientific studies to document these. Fredericksen [1960, 1961, 1962], Newman [1965], and Barlow [1967, 1968] assess the impact of malaria eradication programs on mortality and population growth. The authors do not agree on program impact; however, the evidence that these programs have had a substantial impact on the incidence of malaria is more persuasive than the one that holds that their impact has been minor. Other studies have examined the decline in typhoid fever incidence following the introduction of sanitary sewers, pasteurization of milk, and chlorinated water.[2] Unfortunately, data on these measures are not generally available; lack of emphasis on environmental sanitation in this study reflects the paucity of

[1] Taylor and Knowelden [1964], and Martin [1967].

[2] See Davis [1970] for a summary of these studies.

quantitative source material rather than an acceptance of a hypothesis that sanitation has a negligible impact on mortality.[1]

Housing Attributes

One may list numerous mechanisms relating housing attributes to transmission of infectious disease. Easy access to public water supplies lowers the probability that rivers and streams will be used for bathing, washing, and cleaning. Adequate facilities for fecal disposal protect against soil contamination in the vicinity of the dwelling. Appropriate storage facilities for food keep certain foods from decomposing and make the dwelling less attractive to vermin. Large amounts of square footage in sleeping quarters and other rooms where family members congregate as well as adequate ventilation may also inhibit the spread of disease. Accidents in and around the dwelling may reflect faulty construction or poor maintenance. Although simple positive correlations tend to exist between housing and health variables, strong empirical support for a causal relationship is lacking.[2] Studies have been based on both a test-control procedure and regression analysis. Although the former method is not used in this study, it is of interest because it is, at least superficially, superior to regression analysis.

1. Test-Control Procedure[3] -- In the test control procedure, investigators collect data on the health status and other aspects of

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[1]See the District Reports, Census of Pakistan, 1961 for a descriptive account of sanitation, water supply, and flood control in East Pakistan. Data on bacterial counts of community water supplies are available for the 1940s and early 1950s in reports of the Puerto Rican Department of Health. Data for one year are analyzed in this study.

[2]See Wilner et al. [1962] and Martin [1967] for critical reviews of the literature.

[3]Studies relevant to this subsection are Wilner et al. [1962], Burns [1970], and Healy and Short [1970]. The Burns study is a summary of several studies on the productivity of housing conducted at the Graduate School of Business, University of California at Los Angeles. The UCLA studies were conducted in Mexico and Puerto Rico as well as in other less-developed countries. Some of the methodological problems have been recognized by these authors.

a rehoused group (the test group) before and at several time intervals after rehousing.[1] To hold factors other than housing constant, they also collect data on a control group that remains in poor quality housing throughout the period under study. The data include measures of worker productivity, absenteeism from work and school due to illness, utilization of medical services, mortality and morbidity, and infant birthweight. They employ a variety of indicators because no single performance measure is available on every test site, and similar performance on several criteria might suggest that the findings were general.

Few distinct patterns emerge in any study. In part, the equivocal results reflect numerous methodological difficulties, some difficult to avoid.

Subsidies that are inducements for rehousing are responsible for large percentage changes in the household's income and wealth position. Subsidies may take the form of rent reductions, part or total coverage of the down payment, gifts of land for the dwelling, or interest rates far lower than those obtainable in the marketplace. Capital appreciation on housing purchases made possible by subsidies may produce wealth effects. Although the wealth increase can be translated into current income only by selling or renting the house, it may be seen by the household as a substitute for other forms of saving. Income and wealth increases are also likely to be reflected in the purchases of commodities affecting health status and in additional purchases of leisure. Since workdays lost due to illness is a housing productivity measure and demand for leisure may take the form of feigned illness, rehousing

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[1]The studies provide little evidence on morbidity and mortality of children. Wilner et al. [1962], studying 300 rehoused and 300 control families in Baltimore, find a reduction in infectious diseases of childhood in the test group soon after rehousing and in final measurements performed on the two groups. In an interim period, the control group had fewer diseases than the test group. This inconsistency is explained by a transition period during which children became acquainted with their "new" neighbors and transmitted disease in the process. No differences were found in tests on maternal and infant health.

may seem to generate poor health; yet, one is actually measuring an income-wealth effect.[1]

Furthermore, these subsidies generate substitution effects, measured both in monetary terms and in terms of the time input. Decreases in the price of housing may be expected to induce the household to substitute housing for other goods, holding the effect of income constant; among the goods and services that may be consumed in smaller quantities is medical care, a service with a possibly greater impact on health than housing. Rehoused family members may allocate more time to such household activities as gardening and improvements in the interior of the house, since the marginal product of the household member's input in performing these functions is improved as a result of the move. This time reallocation may also result in increased absenteeism from work as well as increased purchase of commodities that are complementary with the new time allocation.

2. Regression Analysis -- Indirect evidence on the relationship between housing and health status in the United States is provided by Muth [1969]. He specified a two-equation simultaneous equation model with the proportion of substandard central city dwelling units (dilapidated or without private bath) and median income of families and unrelated individuals as endogenous variables. If dwelling unit condition truly affects income, it is likely that the effect is due in part to the influence of the dwelling unit on a person's health.[2] The model is based on a hypothesis that income and other factors affect demand for housing quality, but at the same time, housing quality and other factors affect income. Using Chicago census tract data for 1950 and 1960, the coefficient for the effect of a substandard housing variable is 0.25 and is approximately twice its standard error. This coefficient implies an elasticity less than -0.10, indicating the dwelling-unit

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[1] This point is discussed in Burns [1970], p. 97.

[2] Evidence on infant and preschool child mortality is even more indirect, since determinants of morbidity rates of labor force participants are expected to differ from determinants of infant and preschool child mortality.

quality has a very small impact on income. By contrast, the elasticity corresponding to the income parameter in the housing-quality equation exceeds -2.0.[1] Thus, although income is an important determinant of the quality of dwelling unit, feedback from dwelling unit quality to income is minor.[2]

There are two lessons to be learned from this review of the housing-health literature. First, there is no evidence to support an important causal effect of housing quality on health. Second, although the test-control procedure has attractive features, it is virtually impossible to control for all factors that enter the relationship. In the studies reviewed here, the income-wealth and substitution effects greatly complicate the tests. Regression analysis, though often subject to a similar criticism that variables omitted from the equation may result in biases in the parameters of the included variables, is less expensive and is likely to yield equally satisfactory (or perhaps better) results.

MEDICAL CARE

Methodology and Findings of Previous Studies

Although medical care is commonly held to affect infant and preschool child death rates, there is surprisingly little supporting quantitative evidence.[3] Three approaches have been employed to assess the relationship: comparisons, medical audit, and regression analysis.

1. Comparisons -- Infant death rates with and without prenatal care have been compared; in some cases, statistically significant differences have been detected.[4] Since medical care utilization is correlated with a variety of factors that may also be determinants of death rates, these findings constitute weak evidence at best.

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[1] Muth [1969], especially pp. 241-283.

[2] See Appendix C for an analysis of the income-housing quality relationship in Mexico.

[3] I am not aware of any studies dealing specifically with preschool child death rates.

[4] See, for example, Medina [1969].

2. Medical Audit -- A second group of studies seek to determine the number of deaths that might have been prevented if best-practice obstetrical care had been employed. These studies are principally concerned with quality rather than quantity of care. Estimates on preventability are based on clinical classifications of causes of perinatal deaths. They assume that best-practice obstetrical care would prevent deaths due to toxemia; mechanical complications at birth such as disproportion, malposition of the fetus, and cord complications; unexplained deaths of babies weighing more than 5.5 pounds; and rhesus incompatibility.[1] British and American studies indicate that the number of "preventable" perinatal deaths is substantial.

3. Regression Analysis -- Regression analysis is used to measure the effect of physicians per capita and other variables on infant and crude death rates. Studies based on this statistical technique are in general agreement that medical care, measured either by physicians or health expenditures per capita in a geographic area, has at most a small impact on mortality.[2] The parameter estimates corresponding to medical care variables are likely to be biased toward zero.

There are at least three alternative specifications of medical care in an equation explaining regional variations in mortality rates. Such variables as physicians, medical personnel, and hospital beds per capita are crude proxies for the price of medical services. High ratios presumably reflect lower fees as well as lower costs to the patient in terms of his time input; medical care providers are likely to be more accessible and patient queues shorter. A medical resource to population ratio variable in a mortality equation measures a series of multiplicative effects. This is evident from an examination of the following identity:

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[1]Baird [1969], Kohl [1955].

[2]Newhouse [1968] finds that the number of specialists in obstetrics-gynecology per capita is negatively related to the infant mortality rate, but the elasticity, evaluated at the means, is only 0.1. Auster et al. [1969] show the same elasticity for health expenditures per capita with respect to the crude death rate.

$$\frac{\Delta MR}{\Delta MRPR} \equiv \frac{\Delta MR}{\Delta QM} \cdot \frac{\Delta QM}{\Delta PM} \cdot \frac{\Delta PM}{\Delta MRPR}$$

where

Δ = change in

MR = mortality rate

MRPR = ratio medical resources to population

QM = quantity of medical services consumed

PM = price of medical care in terms of money and patient time

For the ratio of medical resources to population to have an effect on the mortality rate (1) medical care must alter the mortality rate, (2) demand for medical services must be responsive to the price of these services, and (3) the price of medical care in terms of both money and time must be responsive to changes in the ratio of medical resources to population. A sufficient condition for a zero impact of MRPR on MR is that one of the three relationships on the right side of the identity fail to exist. That is, medical care may be an important influence of mortality patterns, but the measured effect is zero because, for example, the medical care price does not respond to changes in the ratio of medical resources to population ($\Delta PM/\Delta MRPR = 0$).

It is quite likely that the ratio of medical resources to population is unrelated to the price of medical care facing the consumer in most developing countries. First, although the ratios are low, there is substantial evidence of physician underemployment, especially among private sector physicians in urban areas.[1] Increasing the physician stock under conditions of excess supply may have only a minor effect on the aggregate quantity of service provided. Moreover, if physicians set fees to achieve an income goal and attempt to minimize their personal inputs to the production of medical services, physician stock increases would tend to <u>boost</u> rather than <u>reduce</u> the price of medical services. Second, since physicians, especially in developing countries, tend to cluster in urban areas, high physician to population ratios may

[1]See Taylor <u>et al</u>. [1968] and Hall [1969] for evidence on underemployment among private practice physicians in Turkey and Peru.

reduce mean distance between patient and physician only slightly. Third, in many less-developed countries, only a small percentage of the population ever contacts a private physician because they are unable to pay the monetary price. The poor may thus not be responsive to price reductions, even if these resulted from increases in physicians per person. Fourth, if the geographical unit of observation is small, large numbers of persons secure medical care in a location other than the one in which they reside. For example, in Puerto Rico, many non-San Juan residents receive medical care in San Juan. Hence, for a true measure of price, one should also consider medical resources in areas surrounding the observational unit. But determining medical areas with precision requires an extensive knowledge of transportation networks and the topography of the region, information not easily obtained.

Some of these comments on the private sector do not apply to government providers of medical services. The number of medical personnel in public clinics and hospitals may affect patient queueing time. Since the monetary price of these services is generally zero, the time price is the sole factor in the total price facing the consumer.[1] Whenever possible, it is useful to disaggregate medical resources by whether they are privately or publicly delivered.

Price is only one determinant of demand for medical services. Whether parents are consensually or legally married may influence parents' demand for medical services for their children. Consensual marriages have a shorter mean life than legal marriages. When the marital bond is dissolved, the children are more likely to remain with the mother than with the father. Thus fathers of illegitimate children may expect to derive fewer benefits from investments in their children than fathers of legitimate children. To the extent that the male partner in consensual marriages makes household expenditure decisions, the household will devote fewer resources to investment

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[1]See Luft [1970] for an excellent description of medical practice in developing countries and physician migration patterns.

in children.[1] Areas with higher proportions of children from consensual marriages are expected to have higher infant and preschool child mortality rates.[2]

Measures of health expenditure per capita are an alternative to the proxies for the price of medical services. These data are superior in the sense that they roughly measure the flow of services actually rendered, rather than just the price of the services. However, geographic price level differences introduce spurious variation. Also, price may vary inversely with quantity, because the negative relationship between the quantity demanded and price dominates a positive supply relationship; price may also vary negatively with quantity of physicians who may set price with a view to a target income -- low quantity is compensated for by high price.

Direct measures of the flow of services rendered, more precise indicators of quantity, are sometimes available. Among these are the percentage of births and deaths and the percentage of total births of births at home. Although these measures are head counts and thus do not directly measure the quantity of services, they are more directly related to medical care consumption then the first two.[3] As indicated above, the others include factors in addition to medical care consumption.

SEX OF CHILD

Male infant and preschool child death rates often exceed corresponding female rates.[4] Reasons for these differences are believed to

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[1]On the phenomenon of consensual marriages in Latin American culture, see Hatt [1952], Lewis [1959, 1965], and Stycos [1955].

[2]Statistical evidence in favor of this hypothesis is presented in Appendix D.

[3]Schultz [1970] uses service flow measures in a regression analysis of infant mortality in the United Arab Republic. As the discussion would predict, the medical care parameter estimates are more plausible than those of other investigators.

[4]This is not always true. In Table 3 some female rates exceed corresponding male rates.

be biological. However, behavioral factors favor males. In some societies females carry dowries and comparatively little status and therefore may receive less attention from parents than males.[1]

PARITY AND AGE OF MOTHER

Data from a number of countries show a systematic relationship between parity and the infant death rate.[2] Frequently, the relationship is U-shaped -- high death rates associated with the first birth reflecting difficult first delivery, a decline corresponding to the next birth, and finally a sharp rise at very high birth orders. Explanations for the sharp increase are: Large numbers of births are associated with shorter birth intervals. Parity relates positively to maternal age, and this is also thought to affect infant survival probabilities.[3] Additional children lower family per capita income, a factor reflected in observed higher incidence of malnutrition among higher birth order children;[4] maternal malnutrition may also be a factor in the lower survival rates of higher birth order infants. Finally, the additional benefits in terms of security in old age and in other less tangible benefits that parents expect from a high birth-order child are probably far less than those derived from a low birth-order child. Although decreasing benefits by birth order are unlikely to result in filicide, fewer resources may be allocated to these children, holding family income per capita constant. Data revealing a positive association between the abortion rate and birth order support this final explanation.[5]

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[1]For a discussion of this behavioral factor in India, see Collver [1963].

[2]See, for example, Baird [1969], Fan [1961], and Shapiro et al. [1968].

[3]Shapiro et al. [1968] find that age is positively associated with the infant death rate after accounting for the effect of parity.

[4]Gopolan [1968].

[5]The data are for Taiwan. See Fan [1961].

The parity-age component is excluded from the regression equations discussed in the following sections because a suitable variable could not be found to express the relationship.

IV. EMPIRICAL SPECIFICATION

The previous section suggests a number of variables that merit inclusion in an equation explaining regional variation in infant and preschool child death rates. Choices among particular variables defined in Table 8 are substantially determined by data availability.

The female literacy rate represents the influence of formal schooling. Underlying the choice of literacy over mean educational attainment is the presumption that reading and writing skills increase maternal productivity in child-rearing, but that additional schooling has a smaller impact. As an empirical matter, the choice between these variables is not crucial since mean female educational attainment in two of the countries, Mexico and East Pakistan, was only one or two years in the period to be analyzed. Moreover, in all four countries, the two variables are highly correlated.

Female labor force participation rates represent the reciprocal of the maternal input into child care. Although the definitions differ, there is surprisingly little intercountry variation. For the countries in which the variable is included, these rates range from 15 percent in East Pakistan in 1961 to 20 percent in Puerto Rico in 1960.[1] Female labor force participation is excluded from the Costa Rica analysis, since data on labor force participation by canton are not available.

As previously stated, the nutrition literature indicates that protein intake makes the greatest contribution to the physical and mental development of the infant and preschool child.[2] Direct measures of protein intake are available for Mexico and East Pakistan. The percentage of the population eating animal products at least once daily

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[1]Because these percentages represent the mean of the geographic observational unit mean, they differ slightly from those presented in Table 2 which are based on pooled data for the entire country.

[2]For an excellent discussion of the relative merits and deficiencies of three methods for measuring nutritional status, see Berg and Muscat [1971].

Table 8

DEFINITIONS OF VARIABLES USED IN THE REGRESSION ANALYSIS

Observational Unit	Variable	Definition
		Costa Rica
Canton	Infant death rate	Infant deaths per 1,000 births occurring and registered in 1963.
	Child death rate	Deaths of children aged 1-4 per 1,000 population in this age category.
	Female literacy	Percentage of females aged 15 to 44 who are literate.
	Birthweight less than 2,000 gms.	Percentage of infants weighing less than 2,000 grams (= 4 lb 6 oz) at birth.
	No water	Percentage of population without access to source of water within 100 meters of the dwelling.
	Rooms per person	Mean number of rooms per person.
	"Unsound" housing	Percentage of population living in dwellings classified by the Census enumerator as "poor quality." Condition may reflect original construction or subsequent deterioration.
	Births at home	Percentage of births at home.
		Mexico
State	Infant death rate	Infant deaths per 1,000 births.
	Child death rate	Deaths of children aged 1-4 per 1,000 population in this age category.
	Female literacy	Percentage of females aged 6 and over who are able to read and write.
	Female educational attainment	Mean number of years of schooling of females aged 6 and over.
	Female labor force participation	Percentage of women aged 12 and over, employed or looking for work.
	No wheat bread	Percentage of population over age 1 habitually eating corn-based bread (tortilla).
	No animal products	Percentage of population over age 1 who generally do not eat meat, fish, or milk, one or more times daily.

Table 8, continued

Observational Unit	Variable	Definition
State (cont.)	No water - 1950	Percentage of dwellings without water from pipes, well, cistern, or any form of storage tank.
	No water - 1960	Percentage of dwellings without water in the dwelling or building.
	Dwellings per person	Number of dwellings per person.
	Rooms per person - 1950	Number of dwellings per person, 1950, times number of rooms per dwelling, 1960.
	Rooms per person - 1960	Number of rooms per person, 1960.
	No doctor available	Percentage of persons without access to a physician
	Accessibility index	$\frac{\text{Number of places with registry office in state}}{\text{area (km}^2\text{)}} \cdot \frac{\text{Kilometers of road in state}}{\text{area (km}^2\text{)}} \; 10^6$
		East Pakistan
District disaggregated on basis of urban-rural distinction	Infant death rate	Infant deaths per 1,000 population.
	Crude death rate	Deaths per 1,000 population.
	Female literacy	Percentage of females aged 5 and over who are able to read and write.
	Female labor force participation	Percentage of females aged 10 and over who are employed or looking for work.
	Population below "acceptable" protein	Percentage of population with less than "nutritionally" acceptable protein intake.
	Rooms per person	Number of rooms per person.
	Poor housing quality	Percentage of houses with bamboo, thatched, and "other" walls of total homes.
	Hospital beds/ population	Hospital beds per 1,000 population.
	Urban Dummy	Urban area = 1. Rural area = 0.

Table 8, continued

Observational Unit	Variable	Definition
		Puerto Rico
Municipality	Infant death rate	Infant deaths per 1,000 births. Two other infant death rates are tested -- (1) Numerator: Number of persons recorded in the 1960 Census aged under one year minus one-fourth times the number of persons aged five and under. Denominator: Number of persons under one divided by 1,000; (2) Infant deaths occurring within the first 28 days of life.
	Female literacy	Percentage of population aged 10 and over able to read and write.
	Female labor force participation	Percentage of females aged 14 and over employed or looking for work.
	No water	Percentage of housing units without hot and cold water inside structure, only cold piped water inside structure, piped water on property, piped water on road or highway.
	No toilet	Percentage of housing units without toilet inside or outside structure, privy.
	Water supply below public standards	$\frac{\text{Number of months water supply found "below std."}}{\text{Number of months water supply sampled}} \cdot 100$
	Births not attended by M.D.	Percentage of registered births occurring without assistance of a physician.
	M.D./Population	Physicians per 1,000 population.
	Import dummy	Variable = 1 if number of births occurring in municipios exceeds number of births to mothers resident in the municipio. All other = 0.
	Sex ratio	Male births/female births.
	Legitimacy	Percentage of legitimate births to total births.

is available for Mexico in 1960.[1] Since this series is not available for 1950, an alternative, the percentage of the population that does not include wheat-based breads in its diet, is included in the 1950 regression, in two variants of the 1960 regressions for purposes of comparison with 1950, and in pooled 1950-1960 regressions. Families that consume wheat-based breads are much more likely in general to purchase foods in the marketplace; flour for wheat-based breads cannot be produced in the home.[2] Families that purchase foods for home use generally have more varied diets. The animal product and wheat bread variables are highly correlated (0.91 in 1960).

The protein variable for the East Pakistan regressions is obtained from a comprehensive nutritional survey of households in 22 communities during 1962-1964. Data are expressed as the percentage of the population whose protein intake is "inadequate" by nutritional standards. Although the observational unit for the regression analysis is the district, subclassified into urban and rural areas within the district, the survey pertains to a community. It is assumed that survey findings from a single community within a given district are generalizable to other areas within that district; this is undoubtedly an unrealistic assumption in some cases, but is unavoidable, given data currently available. For this reason, the parameter estimate relating protein intakes to mortality will be biased toward zero.[3]

No nutritional data are available on a geographic basis for Costa Rica. Thus, the percentage of infants weighing less than 2000 grams is used as a proxy; poor nutrition during pregnancy is held to be a principal, though by no means the only, determinant of low infant birthweight. No nutritional measures are available for Puerto Rico.[4]

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[1]This variable is thought to be the most sensitive indicator of the general quality of diet in a community; as such, it represents general nutritional considerations as well as protein intake. See Buck [1968], pp. 41-42.

[2]Secretaria de Agricultura [1966].

[3]Parameter estimates of other explanatory variables may also be biased. See Section II above.

[4]Data on household food consumption are available from the 1963 Puerto Rican Bureau of Labor Statistics Survey of Income and Expenditures. An analysis of these data is the subject of a forthcoming study.

The bacterial count of municipal water systems in Puerto Rico is included in the 1950 Puerto Rico infant mortality regression as an environmental factor. Data limitations preclude analysis of other environmental variables in Puerto Rico or elsewhere.

A considerable amount of census information for all four countries is available on housing attributes. Candidates for inclusion are variables representing rooms per capita, accessibility of water and toilet facilities, and summary measures of housing stock. Pakistan has not collected these data, but Pakistan's housing census contains data on housing materials. The percentage of houses with bamboo, thatched, and "other" walls is included as a measure of the percentage of houses that are relatively poorly constructed. Descriptive accounts suggest pronounced deficiencies in sanitation facilities in East Pakistan; it is thus unfortunate that a more direct measure cannot be used.

For the aforementioned reasons, measures of the flow of medical services are the most appropriate medical care variables, and these are used in the regressions where possible. Estimates of the population without access to medical services is the medical care variable in the Mexican regressions. Hospital beds per 1,000 and physicians per 10,000 population are included in the East Pakistan and Puerto Rican regressions to account for variations in accessibility to medical care providers.[1] Since offspring of parents who are legally married are likely to receive more medical care than others, the percentage of total births that are legitimate is included in some variants of the Puerto Rican infant mortality regressions.

Sex-related causes of infant deaths enter in two ways. In the Puerto Rican regressions, the ratio of male to female births is an independent variable. Where possible, separate regressions are run for male and female mortality data, and tests of regression coefficient

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[1]Clearly, it is possible that the urban-rural variable will pick up other locational differences as well.

homogeneity performed to determine whether there are significant male-female differences in the parameters.[1]

One variant of the child death rate equation contains the infant mortality rate as an explanatory variable as a test of the hypothesis that where infant death rates are higher, preschool child death rates are lower.

Although the decision whether to report a vital event is a minor one, the household will weigh costs and benefits of reporting it. Arriaga [1967] discusses costs incurred by individuals in reporting a vital event and constructs an index to measure them. The index depends on the number of locations in a Mexican state with registry offices and the number of kilometers of roads in the state relative to the land area.[2] Accessibility to medical professionals and accessibility to registry offices are positively correlated, and there is substantial variation in both series among states.[3] Thus, where registration is dependent on individual initiative, costs associated with poor access are expected to discourage many individuals from notifying government authorities of vital events. Because deaths are less likely to occur with a health professional in attendance than are births, there is probably more underreporting of deaths than births; consequently the parameter estimates of medical care variables are expected to be biased toward zero. Some countries impose a fee for registering a death, but there is no indication that these taxes are levied in the countries included in this study. Arriaga's accessibility index is included to pick up errors in the dependent variable in several variants of the Mexican regressions.

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[1]The regression coefficient homogeneity test is described in Johnston [1963]. A more rigorous treatment is Fisher [1970].

[2]Since this variable is likely to represent factors associated with this geographical unit that cause all mortality rates in that unit to be higher, this is a very weak test of a tradeoff between infant and child mortality. Even if a negative coefficient estimate is derived, it is likely to be biased toward zero.

[3]Detailed data on physician accessibility in Mexico are contained in Bustamente [1960].

Some variants of the Puerto Rican regressions contain an "import dummy," a variable that assumes the value one if the number of births occurring in a municipality exceeds the number of births to mothers resident in that municipality. This latter variable is designed to pick up misregistration arising from border crossing.[1]

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[1]See Appendix A for a discussion of border crossing and other types of misregistration.

V. RESULTS OF THE REGRESSION ANALYSIS

Although some of the effects of observational errors, especially in the dependent variables, are readily apparent in the following tables, the empirical analysis supports several hypotheses. Insignificant parameters lead to the rejection of hypotheses, but in the majority of cases, better quality and more detailed data are needed. Judging by the number of plausible parameter estimates, significance levels, and multiple correlation coefficients, Costa Rican and Mexican results are more satisfactory than the others; the preschool child mortality results merit more confidence than the infant mortality results.

COSTA RICA

Costa Rican results are contained in Tables 9 and 10. On goodness-of-fit criteria, the child mortality regressions are clearly superior to the infant mortality regressions. With one exception, the female literacy parameter estimates are significant at the 1 percent level. The significant literacy parameters in the infant mortality equation indicate that an increase of one percentage point in a canton's female literacy rate will result in three fewer infant deaths per 10,000 live births and two to three fewer preschool child deaths per 10,000 in this age category. Although the literacy parameters in the child death rate equation are slightly smaller, they imply much larger elasticities.[1] The elasticity corresponding to the 0.32 parameter estimate of the second infant mortality rate regression is 0.27; the elasticity corresponding to 0.53, the parameter in the fourth child death rate equation, is 3.17.

Low birthweight, believed to be influenced in large part by nutrition, is significantly different from zero in the infant mortality regressions; although the sign of the parameter is as expected in the

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[1]The formula for the elasticity, calculated at the means of the variables, is:

$$\frac{\partial \text{Dependent Variable}}{\partial \text{Independent Variable}} \cdot \frac{\text{Mean of Independent Variable}}{\text{Mean of Dependent Variable}}$$

Table 9

EMPIRICAL RESULTS -- INFANT MORTALITY RATE, COSTA RICA, 1963[a]

Variant	Intercept	Female Literacy Rate (percent)	Birthweight Less than 2,000 gms. (percent)	No Water (percent)	Rooms per Person	"Unsound" Housing (percent)	Births at Home (percent)	R^2 [b]
I	91.89	-0.31[c]	0.24[c]	EX	EX	-0.14	0.17	$R^2 = 0.21$
	(84.96)	(0.07)	(0.11)			(0.38)	(0.46)	$R^2(C) = 0.17$
II	79.38	-0.32[c]	0.26[c]	-0.30	-20.22	EX	0.30	$R^2 = 0.48$
	(63.1)	(0.08)	(0.09)	(0.51)	(20.6)		(0.31)	$R^2(C) = 0.16$
III	113.4	-0.64	0.19[c]	EX	EX	-0.34	0.38	$R^2 = 0.24$
	(6.79)	(0.57)	(0.08)			(0.39)	(0.24)	$R^2(C) = 0.19$

Number of Observations - 68

Canton Means - Infant Mortality Rate = 53.9

		84.7	20.7	11.7	0.29	38.4	40.6

EX means the variable does not enter the equation.

[a]The numbers in parentheses are standard errors of the coefficients.

[b]$R^2(C)$ is R^2 corrected for degrees of freedom.

[c]Significant at the 1 percent level (one-tail test).

Table 10

EMPIRICAL RESULTS — PRESCHOOL CHILD DEATH RATE, COSTA RICA, 1963[a]

Variant	Intercept	Female Literacy Rate (percent)	Birthweight Less than 2,000 gms. (percent)	No Water (percent)	Rooms per Person	"Unsound" Housing (percent)	Births at Home (percent)	R^2 [b]
I	17.34 (7.11)	-0.19[d] (0.06)	0.15 (0.08)	EX	EX	0.05 (0.04)	0.05[e] (0.02)	$R^2 = 0.53$ $R^2(C) = 0.50$
II	23.60[d] (4.71)	-0.24[d] (0.04)	0.10 (0.07)	EX	0.14 (1.49)	EX	0.05[e] (0.02)	$R^2 = 0.52$ $R^2(C) = 0.49$
III	22.18[d] (6.49)	-0.23[d] (0.06)	0.10 (0.07)	0.02 (0.05)	0.32 (1.60)	EX	0.05[d] (0.02)	$R^2 = 0.61$ $R^2(C) = 0.59$
IV[c]	27.15[d] (6.64)	-0.28[d] (0.06)	0.10 (0.07)	EX	EX	0.002 (0.04)	0.05[e] (0.02)	$R^2 = 0.61$ $R^2(C) = 0.59$

Number of Observations = 68

Canton Means — Preschool Child Death Rate = 7.41

84.7	20.7	11.7	0.29	38.4	40.6	

EX means the variable does not enter the equation.

[a]The numbers in parentheses are standard errors of the coefficients.

[b]$R^2(C)$ is R^2 corrected for degrees of freedom.

[c]Weighted by population.

[d]Significant at the 1 percent level (one-tail test).

[e]Significant at the 5 percent level (one-tail test).

child mortality regression, the coefficient is not significantly different from zero at levels usually accepted in statistical testing. Results would probably have been more satisfactory if a more direct test of the mortality-nutrition relationship were possible with Costa Rican data.

The evidence on the influence of housing, as in previous studies, is very inconclusive. The parameter estimates of housing variables in Table 9 are negative, although positive signs were expected. Positive signs are obtained in Table 10, but the sizable standard errors of the parameter estimates indicate a poor fit of the data.

The parameter estimates of births at home, a proxy for infant and preschool child medical services utilization, are positive, as expected. The parameter estimates in Table 10 are significant at the 5 percent level or better in all variants.

MEXICO

On balance, the Mexican results are the most interesting and conclusive. Data from published sources permit more tests than are possible for the other three countries. Empirical results are contained in Tables 11 through 13. As in Costa Rica, the independent variables explain more of the variance in preschool child than in infant mortality rates. Separate male and female as well as separate 1950 and 1960 regressions were run with Mexican preschool child death rate data. Statistical tests for regression coefficient homogeneity reveal no significant differences in the overall structure between sexes or between years.

The causal effect of female literacy is much stronger on preschool child mortality than on infant mortality. The majority of female literacy parameters in Tables 12 and 13 are significant at the 1 percent level. Raising the female literacy by a percentage point in 1950 (Table 12) corresponds to a reduction of 3.7 to 6.5 in preschool child deaths per 10,000 children in this age group; the range reflects variation in the parameter estimates. In 1960 (Table 13), a 1 percentage point increase results in mortality decreases between 2.3 and 2.8, somewhat lower than in 1950 and approximately the same as Costa Rica

Table 11

EMPIRICAL RESULTS — INFANT DEATH RATE, MEXICO, 1950 AND 1960[a]

Variant	Intercept	Female Literacy (percent)	Female Labor Force Partici-pation (percent)	No Wheat Bread (percent)	No Animal Products (percent)	No Water (percent)	Rooms per Person	No Doctor Avail-able (percent)	R^2 [b]
					1950				
I	77.98[c] (33.8)	-0.39 (0.34)	4.00[d] (1.28)	0.53[c] (0.21)	EX	-0.90 (0.41)	EX	EX	$R^2 = 0.42$ $R^2(C) = 0.34$
Number of Observations = 32									
State Means = Infant Mortality Rate = 90.5									
		55.7	7.3	44.3	EX	21.0[e]	EX	EX	
					1960				
II	7.20 (36.5)	0.31 (0.28)	1.72 (0.91)	EX	0.73[d] (0.18)	EX	EX	0.04 (0.23)	$R^2 = 0.42$ $R^2(C) = 0.33$
III	-44.62 (60.1)	0.14 (0.30)	1.64 (1.14)	EX	0.60[d] (0.14)	0.20 (0.36)	139.17 (77.36)	0.15 (0.25)	$R^2 = 0.49$ $R^2(C) = 0.37$
Number of Observations = 32									
State Means = Infant Mortality Rate = 70.2									
		60.1	13.9	EX	23.7	72.4	0.32	67.4	

EX means the variable does not enter the equation.

[a]The numbers in parentheses are standard errors of the coefficients.

[b]$R^2(C)$ is the R^2 corrected for degrees of freedom.

[c]Significant at the 5 percent level (one-tail test).

[d]Significant at the 1 percent level (one-tail test).

[e]Differences in the means of "no water" between 1950 and 1960 reflect definitional differences. See Table 8 for definitions.

Table 12

EMPIRICAL RESULTS -- PRESCHOOL CHILD DEATH RATE, MEXICO, 1950[a]

Variant	Intercept	Female Literacy (percent)	Female Labor Force Participation (percent)	No Wheat Bread (percent)	No Water (percent)	Dwellings Per Person	Rooms Per Person	R^2 [b]
				Males				
I	44.22[c]	-0.46[c]	0.68	0.15	-0.21	EX	EX	$R^2 = 0.54$
	(15.3)	(0.15)	(0.58)	(0.10)	(0.18)			$R^2(C) = 0.47$
II	-25.70	-0.37[d]	0.39	0.19[d]	-0.26	3.24	EX	$R^2 = 0.62$
	(33.1)	(0.15)	(0.55)	(0.09)	(0.17)	(1.38)		$R^2(C) = 0.55$
III	38.44[d]	-0.52[c]	0.38	0.12	-0.15	EX	31.68	$R^2 = 0.50$
	(16.4)	(0.17)	(0.65)	(0.10)	(0.19)		(32.54)	$R^2(C) = 0.41$
				Females				
IV	56.47[c]	-0.61[c]	0.78	0.10	-0.35	EX	EX	$R^2 = 0.50$
	(17.9)	(0.18)	(0.68)	(0.11)	(0.22)			$R^2(C) = 0.42$
V	-17.83	-0.51[c]	0.48	0.16	-0.40	3.44	EX	$R^2 = 0.57$
	(39.5)	(0.18)	(0.66)	(0.11)	(0.20)	(1.65)		$R^2(C) = 0.49$
VI	-51.99[c]	-0.65[c]	0.55	0.08	-0.31	EX	25.06	$R^2 = 0.50$
	(19.4)	(0.20)	(0.78)	(0.12)	(0.23)		(38.51)	$R^2(C) = 0.41$

Number of Observations = 32

State Means = Male Preschool Child Death Rate = 25.6
Female Preschool Child Death Rate = 25.6

60.1	13.9	44.3	23.7	0.20	0.35	

EX means the variable does not enter the equation.

[a]The numbers in parentheses are standard errors of coefficients.

[b]$R^2(C)$ is R^2 corrected for degrees of freedom.

[c]Significant at the 1 percent level (one-tail test).

[d]Significant at the 5 percent level (one-tail test).

Table 13

EMPIRICAL RESULTS — PRESCHOOL CHILD DEATH RATE, MEXICO, 1960[a]

Variant	Intercept	Female Literacy (percent)	Mean Female Educational Attainment (years)	Female Labor Force Participation (percent)	No Wheat Bread (percent)	No Animal Products (percent)	No Water (percent)	Dwellings Per Person	Rooms Per Person	No Doctor Available (percent)	Accessibility Index	Infant Mortality Rate (1000)	R^2 [b]
						Males							
I	21.18 (12.2)	-0.23[c] (0.08)	EX	0.08 (0.29)	EX	0.14[c] (0.05)	0.13 (0.80)	EX	EX	0.02 (0.06)	EX	EX	R^2 = 0.76 R^2(C) = 0.71
II	13.72 (12.3)	EX	-4.86[d] (2.07)	0.39 (0.28)	EX	0.15[c] (0.05)	0.002 (0.09)	EX	EX	0.01 (0.07)	EX	EX	R^2 = 0.73 R^2(C) = 0.69
III	13.18 (14.0)	-0.26 (0.56)	EX	-0.16 (0.24)	EX	0.32 (0.46)	0.03 (0.06)	-0.16 (0.24)	EX	EX	EX	0.16[c] (0.03)	R^2 = 0.85 R^2(C) = 0.81
IV	18.11 (15.4)	-0.23[c] (0.08)	EX	0.08 (0.29)	EX	0.13[c] (0.05)	0.03 (0.09)	EX	6.72 (19.9)	0.02 (0.06)	EX	EX	R^2 = 0.76 R^2(C) = 0.70
V	16.69 (16.6)	-0.26[c] (0.08)	EX	0.09 (0.32)	0.08 (0.06)	EX	0.02 (0.10)	EX	15.39 (21.05)	0.05 (0.07)	EX	EX	R^2 = 0.72 R^2(C) = 0.67
VI	21.03 (13.8)	-0.23[c] (0.07)	EX	0.08 (0.45)	EX	0.14[c] (0.05)	0.01 (0.08)	EX	EX	0.02 (0.07)	-0.35 (13.9)	EX	R^2 = 0.76 R^2(C) = 0.70
						Females							
VII	25.10 (13.5)	-0.23[c] (0.08)	EX	-0.01 (0.32)	EX	0.17[c] (0.05)	-0.03 (0.09)	EX	EX	0.02 (0.07)	EX	EX	R^2 = 0.74 R^2(C) = 0.69
VIII	17.78 (13.4)	EX	-5.06[d] (2.26)	0.32 (0.31)	EX	0.18[c] (0.05)	-0.04 (0.09)	EX	EX	0.01 (0.08)	EX	EX	R^2 = 0.71 R^2(C) = 0.66
IX	18.82 (16.9)	-0.25[d] (0.09)	EX	0.10 (0.32)	EX	0.16[d] (0.06)	0.01 (0.10)	EX	15.05 (21.83)	0.02 (0.07)	EX	EX	R^2 = 0.86 R^2(C) = 0.68
X	16.45 (18.2)	-0.28[c] (0.09)	EX	0.04 (0.35)	0.11 (0.06)	EX	-0.01 (0.11)	EX	23.84 (23.04)	0.05 (0.08)	EX	EX	R^2 = 0.83 R^2(C) = 0.63

Number of Observations = 32

State Means = Male Preschool Child Death Rate = 13.9
Female Preschool Child Death Rate = 14.2

60.1	2.0	13.8	32.1	23.7	72.4	0.18	0.32	67.4	254.2	70.1	

EX means the variable does not enter the equation.

[a]The numbers in parentheses are standard errors of the coefficients.

[b]R^2(C) is R^2 corrected for degrees of freedom.

[c]Significant at the 1 percent level (one-tail test).

[d]Significant at the 5 percent level (one-tail test).

in 1963. In 1950 (but not 1960), the literacy parameter estimates are slightly higher in the female than in the male regressions.

The coefficient of mean educational attainment is significant at the 5 percent level in the two variants in Table 13 in which it enters; the associated elasticity evaluated at the means of the observations is somewhat lower (0.99 for female literacy vs. 0.68 for female educational attainment).[1] Mean female educational attainment was only 2.0 years in 1960. A large number of women who were classified as literate in 1960 must have possessed only very fundamental reading and writing skills.

Although the sign of the female labor force participation parameter is positive as expected in almost all variants, it is significantly different from zero in only one. Better results might be expected with a more direct measure of maternal time allocation.

The nutrition parameters are far more encouraging. Parameter estimates are plausible, and many are significantly different from zero at the 5 percent level or better. "No animal products," the more appropria nutritional measure, outperforms "no wheat bread." On the basis of the significant parameters, a decrease of 1 percentage point in the population not eating animal products at least once daily leads to an expected decrease of from 6 to 7.3 infant deaths per 10,000 births and 1.3 to 1.8 preschool child deaths per 10,000 in this age category. The corresponding elasticities are 0.15 to 0.18 for infants and 0.22 and 0.31 for the preschool children.

Although the parameter estimates indicate that nutrition has a smaller effect than literacy, it is quite possible that government programs promoting a better diet have a greater short-run impact on child mortality than investments in schooling of female children. The latter involve considerable lags between the time schooling is received and the time the female child becomes a mother.

As in Costa Rica, the analysis does not support a causal effect of housing on infant and preschool child mortality. Unlike the case of

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[1]The calculations are based on Variants I and II of Table 12.

Costa Rica, a summary housing quality measure is not available for Mexico. The "no water" and housing density variables are not significant; nor are their signs in the expected direction.

The parameter of the measure of access to medical services, "no doctor available," though positive as expected is always smaller than its standard error. These coefficients imply an elasticity of 0.10 at the highest. Measurement error may be responsible for a downward bias in the "no doctor available" coefficient. Even though the "no doctor" variable is an improvement over ratios of medical resources to population, it is still less adequate than a measure of the consumption of medical services. Arriaga's measure of the costs associated with registering a vital event explains none of the variance in the preschool child death rate. Although a negative sign was expected, a positive infant mortality coefficient is obtained in child death rate equations. The infant mortality variable picks up state-associated effects that account for relatively high mortality in all age groups in some states.

It is possible that the parameter estimates of such variables as female literacy also incorporate influences omitted from the equation. In the case of female literacy, one such variable may be wealth. But this is doubtful since housing variables also correlated with wealth are included, and female literacy clearly outperforms these.

The following test is designed to detect the presence of omitted variables that vary geographically, but are constants in a temporal sense. These variables represent <u>state effects</u>. They may be eliminated from the equation in the following manner:

Specify,

(1) $Y_{it} = a + b_1X_{1it} + b_2X_{2it} - - - - - - - + b_n \text{ state effect}_i$

and (2) $Y_{it-1} = a + b_1X_{1it-1} + b_2X_{2it-1} - - - - - - b_n \text{ state effect}_i$;

cross-sections for two time periods.[1] The omission of the time subscript from the state effect variable reflects its intertemporal constancy.

[1] i stands for state; t for time.

Subtracting (2) from (1),

$$(3)\quad Y_{it} - Y_{it-1} = b_1(X_{1it} - X_{1it-1}) + b_2(X_{2it} - X_{2it-1})$$

$$- - - - - + b_n\ (\text{state effect}_i - \text{state effect}_i)\ .$$

The state effect term in (3) equals zero. Equation (3) relates current changes in the dependent variable -- in this case preschool child mortality -- to current changes in the levels of the explanatory variables.

If mortality rates respond with a rather lengthy lag, the equation may fit differenced data poorly, even though it performed well in an analysis of levels and the included independent variables are uncorrelated with the unspecified state effects. In the case under study, one does have an a priori notion of these lags. Although schooling may have an almost immediate impact on the pupil, several years are required before the educational investment pays off in terms of reduced child mortality; a girl receives basic reading and writing skills at age six or seven, but is likely to have her first child in her teens. Nonetheless, this severe test is useful, for good results with temporal differences in variables should improve confidence in the analysis of variable levels.

With t equal to 1960 and t-1 to 1950, the resulting regression equation is as shown in Table 14. The coefficient of the literacy rate is significant at the 5 percent level but is larger in absolute value than the parameter estimates derived from cross-sectional analysis of levels.[1] The nutrition and housing coefficients are unreasonable. The changes in the size of the literacy coefficient and the poor

[1]The increase in absolute values is surprising since misspecification of the dynamic structure should have led to a decrease in absolute value in the literacy parameter estimate unless the state effects are negatively correlated with literacy. There is less than a 0.12 probability that the value -1.27 would have been calculated if the true value were below -0.52, the most negative parameter value obtained from the analysis of levels. An equation expressing the variables as differences between the logarithms of the variables has also been estimated; the results were implausible and are not reported here.

Table 14

EMPIRICAL RESULTS -- 1950-1960 CHANGES IN PRESCHOOL CHILD DEATH RATES, MEXICO[a]

Intercept	Female Literacy (percent)	Female Labor Force Participation (percent)	No Wheat Bread (percent)	Rooms Per Person	
Dependent Variable = Change in Male Preschool Child Death Rate 1950-1960.					
Independent Variables = 1950-1960 Changes in					
-0.68	-1.27[c]	-0.93	-0.25	72.88	$R^2 = 0.20$
(8.88)	(0.53)	(1.15)	(0.19)	(68.7)	$R^2(C) = 0.08$
Number of Observations = 64					

[a]The numbers in parentheses are standard errors of the coefficients.

[b]$R^2(C)$ is R^2 corrected for degrees of freedom.

[c]Significant at the 5 percent level (one-tail test).

performance of nutrition in the intertemporal change analysis are cause for some concern; nevertheless, statements based on the variable level analysis regarding their potential for affecting death rate reductions in the under 5 age group may be accepted tentatively; further regression analysis on Mexican data will be worthwhile when 1970 census data become available.

EAST PAKISTAN

Results of regression analysis of East Pakistan infant and crude death rates are presented in Table 15. Probably because the quality of the data is poor, the results are inconclusive. Female literacy and labor force participation parameters have implausible signs. The percentage of population with protein intake below an "acceptable" level is a more direct nutrition measure than in the Costa Rican and Mexican analysis; nevertheless, the standard errors are large relative to the parameter estimates. Hospital beds per 1,000 population and the urban dummy variables account for a substantial portion of the variation in both infant and crude death rates. Medical care appears to have a much stronger impact on mortality in the East Pakistan regressions than in the regressions for other countries.

PUERTO RICO

Table 16 contains empirical results for Puerto Rico. In contrast to somewhat pessimistic expectations concerning the quality of the results of the East Pakistan analysis, the Puerto Rican analysis appeared promising at the outset. Other demographic studies with Puerto Rican data from published sources have proved to be worthwhile.[1] After implausible results were obtained in initial trials, infant mortality series for both 1950 and 1960 were inspected for possible errors. Positive associations between infant mortality and the medical care facilities in the municipality are clear. One may infer from this that infant deaths occurring in families living in rural municipalities are

[1] See, for example, Friedlander [1966], Schultz [1969], and Nerlove and Schultz [1970].

Table 15

EMPIRICAL RESULTS -- INFANT AND CRUDE DEATH RATES, EAST PAKISTAN, 1961[a]

Variant	Intercept	Female Literacy (percent)	Female Labor Force Partici-pation (percent)	Population Below "Acceptable" Protein (percent)	Rooms Per Person	Poor Housing Quality (percent)	Hospital Beds-Population (1000)	Urban Dummy	R^2 [b]
				Infant Mortality Rate					
I	205.0	EX	EX	0.52	-168.68	0.37	-128.02[c]	-31.39[d]	$R^2 = 0.33$
	(58.4)			(0.46)	(123.5)	(0.31)	(46.88)	(14.28)	$R^2(C) = 0.23$
II	122.3	5.71	-0.49	0.36	3.73	0.10	-145.50[c]	-25.49	$R^2 = 0.42$
	(67.0)	(2.67)	(0.34)	(0.45)	(141.9)	(0.34)	(45.61)	(13.98)	$R^2(C) = 0.30$
III	250.7	EX	EX	0.00	-205.18	0.21	-115.29[d]	EX	$R^2 = 0.24$
	(57.3)			(0.41)	(128.6)	(0.32)	(47.97)		$R^2(C) = 0.15$
IV	250.7	EX	-0.48	-0.10	-104.72	0.19	-168.75[d]	EX	$R^2 = 0.32$
	(84.1)		(0.50)	(0.60)	(202.4)	(0.50)	(69.7)		$R^2(C) = 0.10$
				Crude Death Rate					
V	3.98	0.03	EX	EX	1.73	0.01	-8.20	-10.58[c]	$R^2 = 0.89$
	(4.34)	(0.04)			(1.23)	(0.03)	(4.19)	(1.28)	$R^2(C) = 0.85$
VI[e]	2.70	-0.01	EX	EX	3.12	0.01	-7.97[d]	-9.73[c]	$R^2 = 0.92$
	(4.28)	(0.04)			(1.11)	(0.03)	(3.28)	(1.16)	$R^2(C) = 0.98$

Number of Observations = 21

District Means: Infant Mortality Rate = 171.4; Crude Mortality Rate = 8.5

9.4	15.3	64.5	0.32	68.7	0.14	0.24	

EX means the variable is excluded from the equation.

[a]The numbers in parentheses are standard errors of the coefficients.

[b]$R^2(C)$ is R^2 corrected for degrees of freedom.

[c]Significant at the 1 percent level (one-tail test).

[d]Significant at the 5 percent level (one-tail test).

[e]Weighted by population.

Table 16

EMPIRICAL RESULTS — INFANT MORTALITY RATE, PUERTO RICO, 1950 AND 1960[a]

Variant	Intercept	Female Literacy (percent)	Female Labor Force Participation (percent)	Water Supply Below Public Health Standards (percent)	No Water (percent)	No Toilet (percent)	Births Not Attended By M.D. (percent)	M.D. Population	Legitimacy (percent)	Sex Ratio	Import Dummy	R^2 [b]
						1950						
I	27.05	0.26	0.29	-0.17	-0.61	0.26	EX	-2.03	0.29	0.26	1.72	$R^2 = 0.29$
	(59.3)	(0.61)	(0.30)	(0.13)	(0.29)	(0.61)		(2.20)	(0.22)	(0.25)	(4.70)	$R^2(C) = 0.19$
Municipality Means = Infant Mortality Rate = 66.8												
		69.6	18.6	17.4	53.7	25.0	EX	1.1	67.6	103.1	0.20	
						1960						
II	-3.00	0.54	-0.21	EX	0.25	EX	0.06	EX	EX	EX	6.11	$R^2 = 0.07$
	(3.03)	(0.36)	(0.32)		(0.34)		(0.05)				(4.12)	$R^2(C) = 0.00$
III[c]	48.69	-0.36	2.07	EX	2.33	EX	-0.04	EX	EX	EX	EX	$R^2 = 0.05$
	(139.)	(1.67)	(1.21)		(1.52)		(0.22)					$R^2(C) = 0.00$
IV[d]	-8.90	0.34	-0.01	EX	0.28	EX	0.10[f]	EX	EX	EX	0.66	$R^2 = 0.10$
	(23.5)	(0.28)	(0.25)		(0.26)		(0.04)				(3.25)	$R^2(C) = 0.03$
Number of Observations = 75												
Municipality Means = Infant Mortality Rate = 4.21[e]												
		78.7	16.1	EX	42.3	EX	41.8	EX	EX	EX	0.12	

EX means the variable is excluded from the equation.

[a]The numbers in parentheses are standard errors of the coefficients.

[b]$R^2(C)$ is R^2 corrected for degrees of freedom.

[c]The dependent variable is constructed from U.S. Census data. See the text for description. The mean of this series is 74.7.

[d]Deaths occurring during the first 28 days are excluded. The mean of this series is 24.7.

[e]This mean value is an unadjusted infant mortality rate.

[f]Significant at the 1 percent level (one-tail test).

registered as urban deaths or that infant deaths in rural municipalities are less likely to be reported.

To by-pass this deficiency in the data, two alternative dependent variables have been constructed. The first variable is designed to measure preschool child deaths. The numerator is the difference in the number of children under one minus one-fourth the number of children under five in the municipality. Municipalities with large numbers of preschool child deaths are expected to show a large difference. To adjust for municipality size differences the denominator is the number of children under one divided by one thousand. The second dependent variable is the number of infant deaths minus the number of deaths of children under twenty-eight days divided by total births, expressed in thousands. It is plausible that deaths occurring in the first twenty-eight days of life are more poorly reported than other infant deaths. If the death occurs soon after the birth, both events may go unreported. With the exception of one medical care variable, respecifying the dependent variable does not alter the results.

Unlike most variants in the Costa Rican and Mexican analysis, several female literacy parameters generally assume a positive sign. The sign and magnitude of the labor force participation rate parameters are quite sensitive to model specification. Housing parameters follow the same pattern as the analysis for the other three countries. With one exception (Variant III), the medical care parameters are plausible. The parameter of "births not attended by an M.D." is significant at the 1 percent level; the 0.10 parameter implies a 0.17 elasticity (evaluated at the means of the observations).

Two variables not present in the analysis of the other three countries are introduced. "Water supply below public health standards" is the number of months of those in which tests were conducted that the bacterial count in the public water supply exceeded public health standards. The negative sign of the public water supply quality variables runs counter to expectations. The parameter of "legitimacy," expected to be negative, is positive. It is quite likely that the counterintuitive sign reflects measurement error in the dependent variable.

Regressions of a legitimacy variable on "births not attended by an M.D." yields a positive parameter significant at the 5 percent level or better. Parent marital status influences medical care consumption in Puerto Rico, even when other likely determinants of utilization, such as income, are held constant.[1]

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[1]See Appendix D for further evidence on consensual unions and medical care consumption.

VI. IMPLICATIONS OF THE EMPIRICAL FINDINGS

This analysis has identified several determinants of variation in the mortality in the under five age group in less-developed countries. The most clearly evident relationships are the effects of female literacy and nutrition on mortality of infants and preschool children. The roles of female labor force activity and medical care emerge less clearly. Sanitation and housing variables provide no explanation of variation in the mortality series. In view of the ambiguous results of previous studies, future investigations of a linkage of sanitation and housing with infant and preschool child mortality should be given a low priority.

On the whole, literacy parameters suggest that investments in public education will generate substantial reductions in preschool child mortality. Only moderate amounts of schooling per child may be required to bring about these reductions. However, the mechanism through which education operates is not fully understood. Possible explanations include:

(1) Increased awareness of personal hygiene;

(2) The propensity of the literate to seek medical care from scientific rather than from folk sources;

(3) Cognitive development enabling the consequences of particular acts to be anticipated, particularly those associated with child care, and

(4) Greater efficiency in consumption. That is, the literate pay lower prices for the goods and services they purchase and thus secure more goods and services from a fixed amount of income.

Definitive answers to these questions require detailed data on households that are unavailable at the present time.

Literacy undoubtedly has an effect on some of the other independent variables. Several indirect effects, some having a positive influence on mortality, are not captured by the literacy parameter in the

mortality equation. For example, as mentioned above, literate women are more likely to enter the labor force. Maternal allocation of time to job-related pursuits is likely to result in less time spent with children. Acting through labor force activity, literacy has a positive indirect effect on infant and preschool child mortality.

The Mexican analysis supports a causal relationship between nutrition and death among children in the under five age group. Although the East Pakistan nutrition data are probably better in some respects, they are less appropriately matched to the district than the Mexican, and the mortality data are considerably worse; the East Pakistan results are thus not reliable. Although birth weight is believed to be influenced by maternal nutrition and the Costa Rican results indicate a relationship between birth weight and mortality in the under five age group, the statistical evidence provided by the Costa Rican analysis is weak when viewed in isolation. However, it lends support to the Mexican analysis, which demonstrates quite clearly the causal influence of nutrition among infants and preschool children.

The relationship between female labor force activity and mortality emerges less distinctly. Labor force participation parameters are often plausible, but only once is a labor force participation parameter estimate significantly different from zero at the 5 percent level or better. It is likely that lack of statistical significance reflects the crude measure of maternal time allocation used in the analysis. Increased female labor force participation may increase the probability of fatal household accidents and spread of infectious diseases among young children, and it may lead to weaning at an earlier age, which may not be compensated for by other food sources.

Costa Rican, Pakistani, and Puerto Rican analyses suggest a causal relationship between medical care consumption and infant and preschool child mortality. Significant parameters are often obtained when a services measure of medical care is used. The hospital beds per 1,000 population variable in the Pakistani analysis, a less appropriate measure, is significantly different from zero at the 5 percent level or better in all but one variant. Since the data available for the

analysis of mortality in East Pakistan are poor, these results should be interpreted cautiously.

Environment and housing parameters are quite sensitive to the mortality equation's specification. The signs of the parameters are often counterintuitive, and the standard errors of the parameter estimates are high. Measurement of such variables as the existence of water inside or near the dwelling or structure is relatively easy. Housing data may be expected to be more accurate than such attributes of the population as educational attainment and food consumption data, collected by census enumerators. Therefore, it is difficult to attribute the unstable and implausible parameters to poor measurement. The results probably reflect a weak or nonexistent relationship between housing variables and infant and preschool child mortality.

VII. EXTENSIONS OF THIS RESEARCH

The exploratory analysis with published data has revealed several sources of variation in infant and preschool child mortality rates. Extensions using a more precisely formulated theory and better data in the empirical phases will permit more satisfactory judgments of the relative importance of these sources. These judgments are required for rational choice among governmental policy alternatives that have reductions in fertility and infant and preschool mortality as primary objectives. The evidence presented above suggests an important causal relationship between female literacy and nutrition and mortality in the under five age group. Further study of these relationships merits high priority. Analysis of maternal time allocation and medical care consumption is also likely to be worthwhile.

THE ROLE OF A THEORY OF CONSUMER CHOICE

An extension of this analysis should exploit recent developments in the theory of household decisionmaking.[1] Parents invest in the health of their children by devoting part of their income as well as part of their time to this end. If informed choices among policy alternatives are to be made, it is important to understand both the contribution of these resource commitments to child health and factors that govern resource commitments on the part of parents.

Most decisions relevant to health are made at the household level with government playing a role in influencing this decision. Through a variety of public health measures, governments may relieve families of certain costs. If government-sponsored programs do not control mosquitoes by drainage, households may lower the probability of contracting malaria by using mosquito netting and chemical repellents, or by choosing another place to live. In areas where water supplies have high bacterial counts, families may reduce the probability of

[1] Becker [1965, 1968], De Vany [1970], Grossman [1970], Lancaster [1966], and Muth [1966].

infectious disease by boiling water. Public medical programs lower the monetary price by direct subsidization and the price measured in patient time by ensuring the public's access to medical facilities. A non-medical program such as public schooling influences health through its impact on lifetime earnings and on knowledge of personal hygiene, nutrition, and alternative sources of medical care.[1] Such distributional policies as land reform may contribute to the health of the poor by enabling them to purchase goods and services that contribute to good health.

Many, if not most, government programs rely on incentives rather than compulsion to secure citizen participation. For example, the price of certain foods, believed to contribute to nutrition, may be reduced by government subsidy as an inducement to increased consumption. Clinics may be made more accessible to the public. In these cases, analysis of household decisionmaking is essential for a full evaluation of government programs because consumer decisions are prerequisites for program effectiveness. A clinic cannot be effective if it is not used. Nor can female literacy rates be raised unless parents are willing to sacrifice services that daughters not in school render in the household. The results of this study suggest that empirical application of this theory may be confined to a few areas -- schooling, nutrition, labor force activity and medical care consumption.

FURTHER USE OF DATA FROM EXISTING SOURCES

Extensions of this study will require better data. Some data that have been collected for other purposes could be used. In conducting this research, I learned of three types of surveys that could serve as the basis for future research in the area. The observational unit in these surveys is the household.

1. An On-Going Health Survey by the Puerto Rican Department of Public Health has been conducted since 1963. The Department collects detailed data on the health and consumption of medical service by each

[1] This and related issues are developed in Welch [1970].

household member. Education, employment, and income data are also secured from the households in the survey. Occasionally, questions dealing with food consumption and insurance coverage have been added. The survey is designed to accommodate special "add-ons" requesting information of interest to researchers and policymakers.

2. Budget Studies have been conducted in a large number of developing countries. These generally provide data on family characteristics as well as detailed accounts of household budget allocation. Data on individual households are needed. Published budget studies do not provide adequate information since data are typically reduced to two-way contingency tables. Household decisionmaking involves a large number of interactions that are lost in aggregated data. Budget studies are useful for an analysis of the demand for goods and services contributing to good health. They allow study of the effects of education on labor force activity and on consumer purchases. They do not contain information on health of family members.

3. Special Surveys are cross-sectional surveys conducted at one point in time. Particularly relevant to future research are nutrition surveys. Data from a nutrition survey conducted in East Pakistan have been used in this study. The survey findings have been examined from a biomedical vantage point and merit study with tools of economic analysis.

DATA COLLECTION

Although some further progress can undoubtedly be made with material from existing sources, new surveys also merit attention. The importance of and the interrelationships among several decisions made by households are becoming increasingly apparent. For example, opportunities open to women in the marketplace are likely to impinge on child-bearing decisions as well as child health. Since the breadwinner may obtain first priority on food available to the family, child nutrition may depend on the type of work the head of the household performs as well as the family income level.

A study of these interrelationships requires detailed information on the household: vital events; morbidity record of family members; consumption of goods and services relevant to health; income, occupation, and educational attainment; time budget data indicating how family members (particularly the mother) divide their total time among different activities, especially among income-producing and child-rearing activities.[1] Some time-budget data have been collected from American households.[2] To my knowledge, no one has collected such information from households in developing countries.

An effort should be made to study households intensively. A comprehensive survey of this type need not involve a large number of families. Considerable advances in knowledge about health in developing countries could be made by an analysis of 300 households.

QUESTIONS OF HEALTH AND POPULATION POLICY

Very little is known at the present time about health and health sector planning in developing countries. Poor data are both cause and effect of the present state of knowledge. By contrast the policy questions are pressing. One book reviewer recently remarked,

> "the popular demand to allocate to the health industry vitally scarce economic resources in impoverished lands grows each quinquennium.... Public resources invested in people, although very profitable in the long haul, detract from consumption and investment in plant in the short haul....Is a direct attack via the health industry the most efficient (least cost-same results or some cost-better results) way to improve the health of the nation? Or, to put the matter explicitly, does a nation do better to purify air, water, food, and the environment generally rather than to try to create a corps of physicians at great public expense (with many emigrating and thereby repudiating any notion of personal indebtedness to the government and taxpayers who paid the bill for their education)? Is there more and better health in a general education or literacy program than in the

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[1] Time budget studies would have other uses, such as in national income accounting. See Ruggles and Ruggles [1970], p. 40.

[2] See Morgan et al. [1966] and Sirageldin [1969].

construction of great hospitals which are more often ill equipped and understaffed?[1]

These are the broad policy questions that health sector planners and policymakers are beginning to ask. They require detailed analysis -- much of it at the household level.

The link between child health and fertility was stressed at the outset. Mortality reductions are a principal factor in reducing fertility. Public policies that promote good child health are thus important to officials charged with population policy. Answers to queries about effective population policies are in part answers to queries about child health.

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[1]Perlman [1971], pp. 493-494.

Appendix A

MEASUREMENT ERROR

Some of the weaknesses in the demographic data used in this study and likely consequences of analysis of data that are subject to measurement error were reviewed in Section II. This appendix, like Section II, concentrates on demographic data. Most of Costa Rican, Mexican, and Puerto Rican demographic data used in this study are based on published registration materials. East Pakistan data are from its 1960-61 census; errors in the Pakistan data are largely based on errors of recall and usual census enumeration shortcomings. Registration-based data may contain errors because an individual may incur costs in registering a vital event that outweigh benefits obtained from doing so. Errors in the Pakistan data base have been reviewed in the text. The present discussion focuses on errors in registration-based data.

Inaccuracies in registration-based data reflect social and cultural characteristics of the society and costs and benefits to citizens who have vital events to report, as well as recording errors. Many recording errors can be detected by a careful examination of the data.

Social and cultural characteristics of the area influence the proportion of vital events that are reported. A lower ratio of reported to actual vital events may be expected in areas where individuals have less schooling or where an indigenous language is spoken (as in some parts of Mexico). Puerto Rican data indicate quite strongly that when a physician is not in attendance at death, males are far more likely to notify authorities than are females.[1] The Latin culture assigns extra-household contacts to the male. Thus, if neither a physician nor a male relative or friend is present at the death of an individual, the death is likely to go unreported. Since medical services have been available to virtually all Puerto Ricans in recent years,

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[1] See Department of Health of Puerto Rico [1942], p. 42. The lower propensity of females to report may, of course, reflect on educational attainment rather than social custom.

this cultural factor is not an important source of error in Puerto Rican mortality data. It is likely to be a far more important factor in the case of a Latin American country such as Mexico. Since a greater proportion of births than infant deaths are attended by health professionals, underreporting of deaths is expected to exceed underreporting of births;[1] estimates of infant death rates may be biased downward.

As noted above, examination of Puerto Rican mortality data indicates considerable misregistration of infant deaths.[2] Some adjustments were attempted in the above analysis to correct for this "border crossing" phenomenon, but the adjustments were not successful. Caution must be exercised in analysis of mortality data from countries with regionalized health delivery systems.

There is evidence in both Costa Rica and Mexico of substantial lags in birth registration. In Costa Rica, a country reputed to have relatively accurate demographic data, only 80 percent of births are registered in the year they occur. Costa Rican sources distinguish births by year of occurrence; Mexican data do not, but births are grouped into three categories on the basis of the length of time between birth and registration -- up to 30 days, 30 days to one year, and over a year. From this information, one may judge that large numbers of births are registered over a year after occurrence, but it is, of course, not possible to determine what the mean of the "over the year" category is. Reporting lags in both countries have been relatively stable over time, but both exhibit substantial geographic variation. If there is temporal stability, the lags effectively smooth movements in the birth time series. In other words, if births rise markedly in a given year, only part of the increase is reported in

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[1]Based on a comparison of data on professional attendance at birth and death in Costa Rica; see Ministerio de Economia y Hacienda [1958]. Similar data are available for Puerto Rico, but data on attendance at birth and at death are not published for the same year. See Puerto Rico Department of Health [1959, 1961].

[2]Data on patient residence and where medical care is received are contained in School of Public Health and Administrative Medicine, Columbia University, and Department of Health of Puerto Rico [1960]. Mortality data are available in the aforementioned sources.

that year. The rest is recorded in subsequent years. Similarly, a decline will be spread over several years. The cross-sectional variation in reporting lags is far more serious and may lead to biases in the parameter estimates, especially because the lags may signify variations in reporting rates. Costa Rican provinces and Mexican states containing large metropolitan areas consistently show greater registration lags than others.[1] Many late registrations occur in urban areas because information on birth is required for such activities as travel to foreign countries and for certain occupations.

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[1]A Costa Rican province is a combination of several cantons.

Appendix B

NUTRITION ANALYSIS

Direct measures of food intake are available for Mexico and East Pakistan. This appendix reports the results of statistical analysis of these data. The analysis of Mexican food consumption presents estimates of the impact of family income and other variables on the percentage of families eating animal and wheat-based bread products. Planning effective government programs requires knowledge of the important determinants of consumption of goods and services that contribute to good health. The East Pakistan analysis determines the relationship between other diet deficiencies and protein deficiencies. Do protein deficiencies occur in isolation or in combination with others?

MEXICAN ANIMAL PRODUCT AND WHEAT-BASED BREAD CONSUMPTION

A description of the variables used and statistical findings of the Mexican food consumption analysis are found in Tables B-1 and B-2, respectively. Elasticities associated with the income parameters are 0.57 and 0.60 for the animal product and 0.38 and 0.40 for the wheat-based bread regressions. As expected, female literacy is negatively associated with both dependent variables. A one percentage point increase in female literacy is associated with an approximately one-half percentage point reduction in the families not consuming animal products at least once daily. The effect of literacy on wheat-based bread consumption is somewhat smaller. With one exception, all parameters of variables representing minority population groups are smaller than their standard errors. Consumption of these food groups therefore does not differ on ethnic or linguistic lines. In areas with poor transportation systems, the prices of commodities produced and sold by the household are substantially below those available to it in the marketplace. The price of corn-based bread, which can be produced at home, is far lower in these areas than wheat-based bread, which must be purchased. Thus, one expects corn-based

Table B-1

VARIABLES USED IN THE ANALYSIS OF MEXICAN FOOD CONSUMPTION

Variable	Definition
Percentage of population not eating animal products at least once daily.	See Table 8.
Percentage of population not eating wheat-based bread at least once daily.	See Table 8.
Monthly income	Mean income per month in pesos, 1956. Incomes are for six regions. States are assigned regional means.
Female literacy	See Table 8.
Indigenous language only; Spanish and indigenous language, persons speaking a foreign mother tongue, and combined category.	Percentage of the population who speak an indigenous language exclusively; percentage of population who speak both Spanish and an indigenous language; percentage of population who speak a foreign mother tongue; combined category is the sum of these three groups.
Agriculture, mining, fishing	Percentage of persons employed in agriculture, mining, and fishing of the total labor force.

Table B-2

ANALYSIS OF THE PERCENTAGES OF POPULATION NOT EATING ANIMAL PRODUCTS, NOT EATING WHEAT-BASED BREAD AT LEAST ONCE DAILY, MEXICO, 1960[a]

Variant	Intercept	Monthly Income 1956 (pesos)	Female Literacy (percent)	Indigenous Language Only (percent)	Spanish and Indigenous Language (percent)	Aliens Speaking Indigenous Language and/or Spanish (percent)	Agriculture, Mining, Fishing (percent)	R^2[b]
Dependent Variable = Percentage of Population Not Eating Animal Products at Least Once Daily								
I	70.94	-0.20	-0.58	-1.39	-0.14	-1.70	0.12	$R^2 = 0.54$
	(26.3)	(0.11)	(0.32)	(1.25)	(0.50)	(4.63)	(0.21)	$R^2(C) = 0.43$
II	63.25	-0.21[c]	-0.47		-0.49		0.14	$R^2 = 0.52$
	(23.3)	(0.10)	(0.24)		(0.18)		(0.19)	$R^2(C) = 0.46$
Dependent Variable = Percentage of Population Not Eating Wheat-Based Bread at Least Once Daily								
III	42.21	-0.18	-0.34	-0.82	-0.44	2.45	0.48[c]	$R^2 = 0.63$
	(25.3)	(0.10)	(0.31)	(1.22)	(0.48)	(4.47)	(0.20)	$R^2(C) = 0.54$
IV	40.03	-0.19	EX		-0.56		0.51[c]	$R^2 = 0.63$
	(22.3)	(0.10)			(0.17)		(0.19)	$R^2(C) = 0.57$

Number of Observations = 32

State Means = Percentage of Population Not Eating Animal Products = 23.7
Percentage of Population Not Eating Wheat-Based Bread = 32.0

	676.	60.1	3.2	7.1	0.4	60.5	
				10.7			

EX means the variable does not enter the equation.

[a]The numbers in parentheses are standard errors of the coefficients.

[b]$R^2(C)$ is R^2 corrected for degrees of freedom.

[c]Significant at the 5 percent level (one-tail test).

bread consumption to be higher in areas that are predominantly agricultural.[1] The percentage of the labor force employed in agriculture, mining, and fishing is included to capture this effect. The variable has a positive effect on the percentage of the population not eating wheat-based bread. Corresponding parameters in the animal products regressions are positive, but not significantly different from zero.

DEFICIENCIES IN THE EAST PAKISTAN DIETS

The percentage of the population whose protein intake was found to be "inadequate" by nutritional standards was included as an explanatory variable in the East Pakistan regressions. Data on several other nutritional deficiencies are available from the same survey. It is likely that other nutritional deficiencies are prevalent in populations that are deficient in protein.

Data on nutritional differences are analyzed by means of factor analysis, a statistical procedure that reduces a large number of variables to a much smaller number of entities termed factors. Each factor can then be characterized by examining the loading, or contribution of each of the original variables to it. Rotation facilities factor interpretation; two alternative rotations, varimax and quartimax, are performed.[2]

The results of the factor analysis of these nutrition data are presented in Figures 1 and 2. Two factors account for more than 80 percent of the variance in the data. Vitamin A and Vitamin C deficiencies load heavily on factor 1. All three are dependent in part on green vegetable consumption. Calorie, protein, thiamine, and niacin deficiencies load heavily on factor 2; these are related to meat, eggs, pulse, corn, and rice consumption. Protein deficiency in the East Pakistan regression most likely picks up the effects of

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[1] This point is discussed in greater detail in Massell [1967].

[2] For a discussion of varimax and quartimax rotations, see Harman [1967].

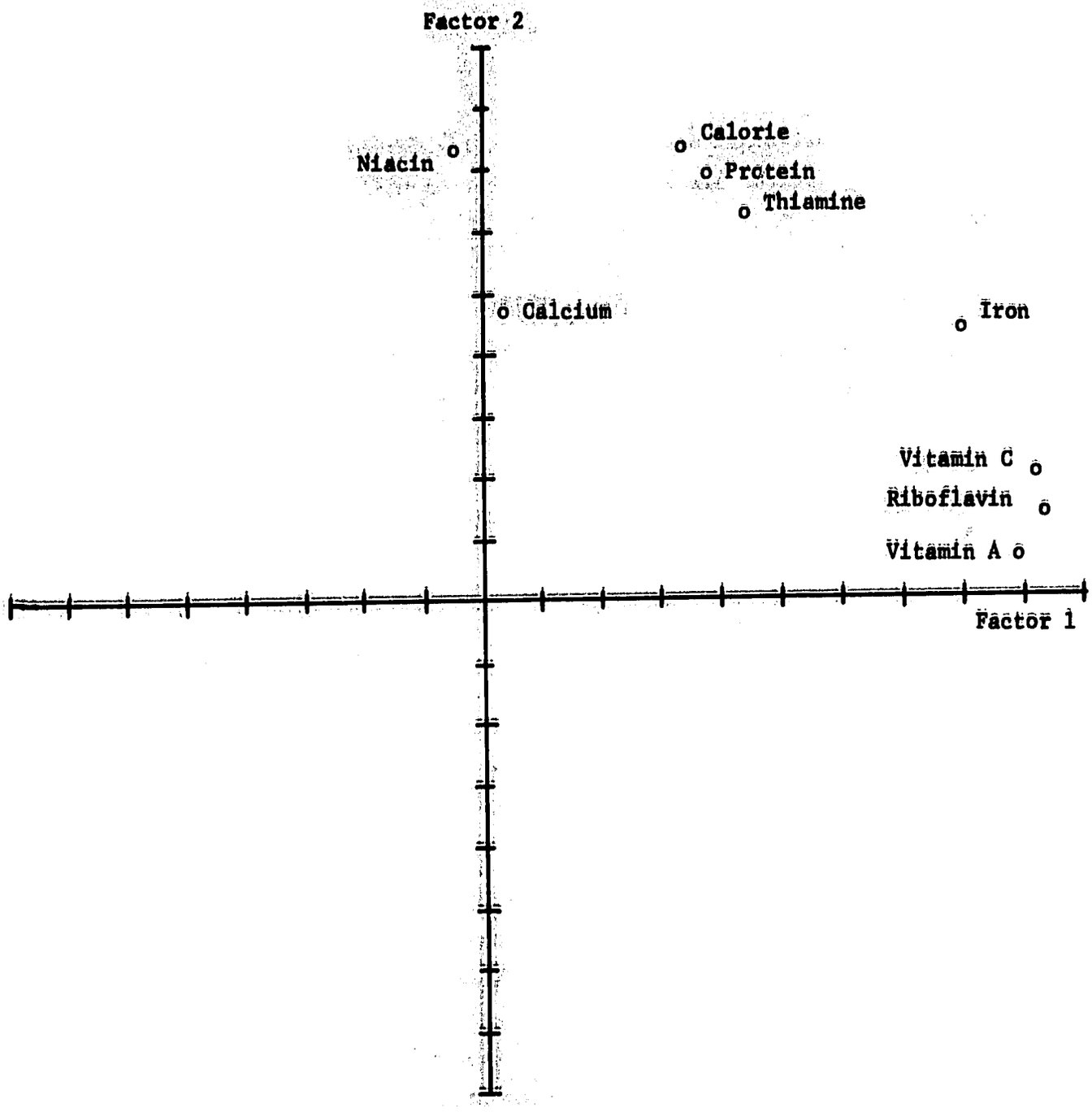

Fig. 1 -- Analysis of diet deficiencies--East Pakistan--Varimax rotation

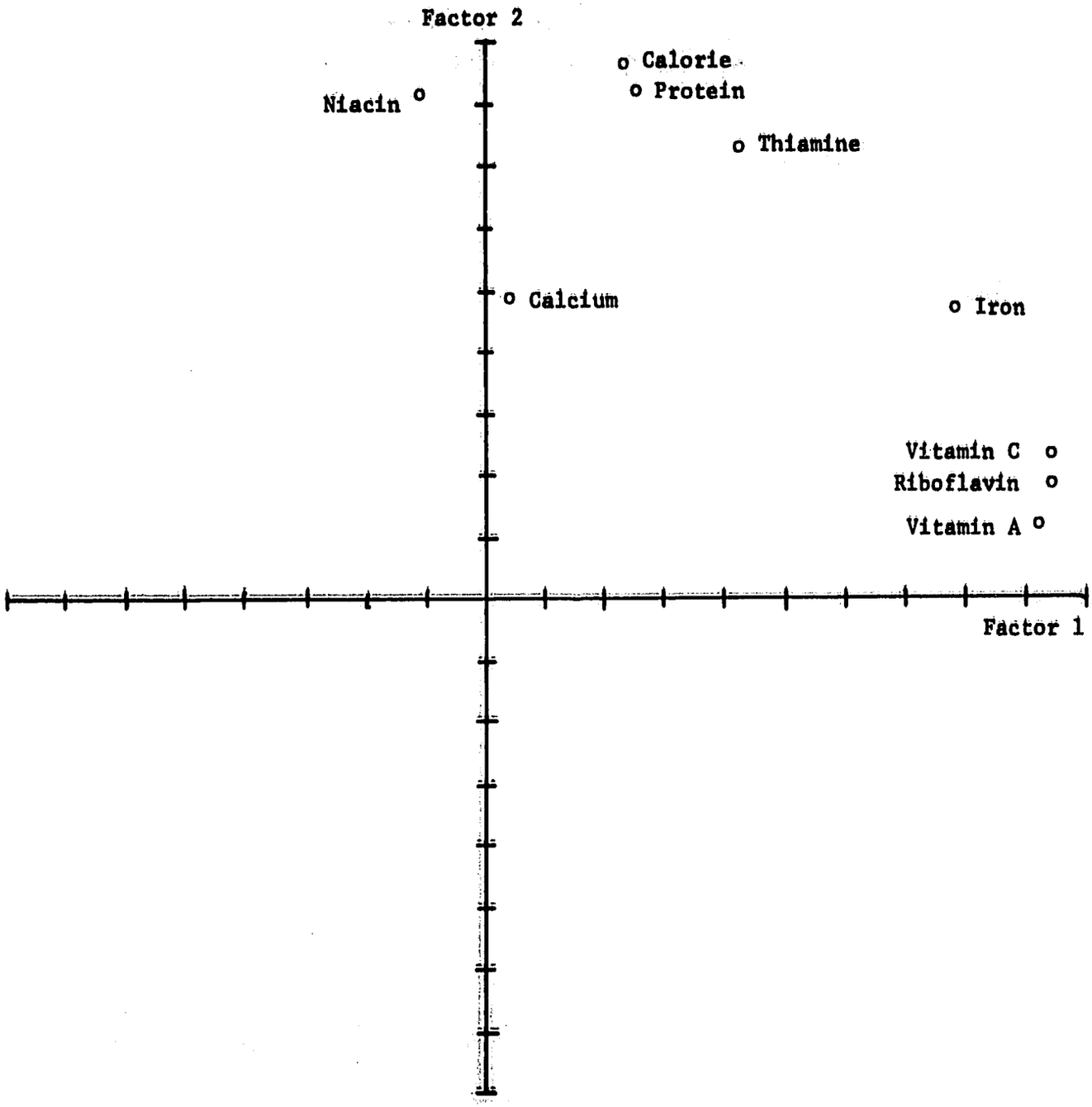

Fig. 2 -- Analysis of diet deficiencies--East Pakistan--Quartimax rotation

other deficiencies loading on factor 2 as well as protein deficiency. Riboflavin occurs in milk, muscle, liver, kidney, eggs, grass, and various algae. One would thus expect it to be more closely related to factor 2 than to factor 1. Its association with factor 1 is surprising.

The above analysis supports previous research in finding no clear relationship between housing and health. The regressions in Table C-1 are therefore likely to be of greatest interest to officials charged directly with housing policy. They are based on a Mexican national housing survey, conducted in 1960-61.[1] Unlike other regressions in this study, the unit of observation is the family group; families are classified by region, by whether the family resides in an urban or rural setting, and by income class. All dependent and explanatory variables except the urban dummy variable are expressed in natural logarithms; the urban variable is not transformed. The parameters of the transformed variables are constant elasticity estimates.

In all cases, the monthly income elasticities are less than unity in absolute value. These are far less than income by mean elasticities computed in an analysis of substandard housing in Chicago (Muth [1969]) and in an earlier study by Reid[2] but are roughly the same as income elasticities in a housing study based on grouped data for the United States (David [1962]). David finds that family size has a positive effect on dwelling size.

The number of persons parameter in Variant I is negative. Although large families in Mexico probably desire larger quarters, actual living space is smaller because family incomes do not keep pace with growth in family size. That is, income per capita is lower in larger families.[3]

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[1] Instituto Nacional de la Vivienda [1963].

[2] Reid [1962].

[3] A review of the demand for housing literature is contained in deLeeuw [1971].

Table C-1

MEXICAN HOUSING REGRESSIONS[a]

Dependent Variable	Intercept	Monthly Income (pesos)	Number of Persons in Dwelling	Urban Area (Urban = 1)	R^2[b]
	Explanatory Variables				
I. Floorspace (square meters)	3.40 (0.36)	0.23[c] (0.06)	-0.32 (0.25)	0.19 (0.11)	$R^2 = 0.37$ $R^2(C) = 0.33$
II. Dwelling has own or communal water supply (percent)	3.70[c] (0.14)	0.12[c] (0.02)	-0.11 (0.10)	0.22[c] (0.04)	$R^2 = 0.64$ $R^2(C) = 0.62$
III. Dwelling has private or communal bath (percent)	-2.30[c] (0.66)	0.90[c] (0.10)	-0.93 (0.45)	1.50[c] (0.20)	$R^2 = 0.80$ $R^2(C) = 0.79$
IV. Dwelling has windows (percent)	2.67[c] (0.28)	0.36[c] (0.45)	-0.55[c] (0.19)	EX	$R^2 = 0.58$ $R^2(C) = 0.56$
V. Dwelling has separate kitchen (percent)	3.69[c] (0.12)	0.09[c] (0.02)	0.07 (0.08)	EX	$R^2 = 0.47$ $R^2(C) = 0.45$
VI. Animals live within dwelling (percent)	2.06 (1.03)	-0.41 (0.19)	1.54 (0.90)	EX	$R^2 = 0.10$ $R^2(C) = 0.06$
VII. Dwelling has private or communal latrine (percent)	3.10[c] (1.04)	0.42 (0.19)	-1.88 (0.89)	EX	$R^2 = 0.10$ $R^2(C) = 0.06$
VIII. Dwelling has private or communal toilet (percent)	2.06[c] (0.32)	0.34[c] (0.05)	-0.39 (0.23)	0.55[c] (0.10)	$R^2 = 0.70$ $R^2(C) = 0.68$

Number of Observations = 54

Means

Variables	Mean
Floorspace (square meters)	98.9
Private or communal water (percent)	84.3
Private or communal bath (percent)	37.4
Windows (percent)	69.9
Separate kitchens (percent)	82.9
Animals within dwelling (percent)	8.5
Private or communal latrine (percent)	21.9
Private or communal toilet (percent)	59.9
Income (pesos)	1,423.1
Number of persons in dwelling	5.6

EX means the variable does not enter the equation.

[a]All dependent and explanatory variables with the exception of the urban variables are expressed in natural logarithms of the original variable. The urban dummy variable is not transformed.

[b]$R^2(C)$ is R^2 corrected for degrees of freedom.

[c]Significant at the 1 percent level (one-tail test).

Appendix D

ANALYSIS OF BIRTHS NOT ATTENDED BY A PHYSICIAN

Births not attended by a physician is a measure of medical services to infants in the Puerto Rican infant mortality analysis. In 1960, as Table D-2 indicates, a substantial number of births were not attended by physicians. Regressions of this variable on several explanatory variables reveal two important factors accounting for inter-municipality differences in these percentages. The parameter of personal per capita income is significant at the 1 percent level. The elasticities corresponding to these parameters range from 0.09 to 0.12. The ratio of legal to consensual marriages has a negative impact on the physician nonattendance percentage. This result confirms the hypothesis developed in the text predicting that parents in common-law marriage make smaller investments in their children. Evidence presented in Nerlove and Schultz [1970] indicates that personal income has a strong effect on the percentage of Puerto Rican women over age 14 that are legally married. If personal income were excluded from the Table D-2 regressions, one could argue that the legal consensual marriage parameter merely reflected the effect of income on nonattendance. However, since income is included in the regression as a separate explanatory variable and is significant, it is likely that the marriage parameter measures the direct contribution of marriage form to the quantity of medical care received by children at birth. The parameters of variables expressing variations in medical resources per 1,000 population are not significant. The spatial distribution of medical resources does not explain differences in medical service consumption in Puerto Rico, a small country with a well-developed transportation system.

Table D-1

VARIABLES USED IN THE ANALYSIS OF BIRTHS NOT ATTENDED BY A PHYSICIAN, PUERTO RICO, 1960

Variable	Definition
Percentage of births not attended by a physician	See Table 8.
Personal per capita income	Personal per capita income.
Female literacy	See Table 8.
Legal marriages/consensual marriages	Number of legal marriages divided by the number of consensual marriages.
Urban	Percentage of population living in an urban area.
Adjacent to hospital	Municipality borders on a municipality containing a regional hospital.
M.D.-Population	See Table 8.
Government hospital beds-population	Hospital beds operated by governments per 1,000 population.
Nongovernment hospital beds-population	Nongovernment hospital beds per 1,000 population.

Table D-2

BIRTHS WITHOUT A PHYSICIAN PRESENT, PUERTO RICO, 1960[a]

Variant	Intercept	Personal per Capita Income ($)	Female Literacy (percent)	Legal Marriage/ Consensual Marriages	Urban	Adjacent to Hospital	M.D.-Population	Government Hospital Beds-Population	Non-Government Hospital Beds-Population	R^2[b]
I	106.4	-0.029[c]	-0.36	-1.81[d]	0.32	1.96	-0.68	-0.75	0.63	$R^2 = 0.29$
	(62.4)	(0.011)	(0.86)	(0.69)	(0.16)	(5.53)	(1.68)	(1.32)	(2.74)	$R^2(C) = 0.21$
II	126.2[d]	-0.022[d]	-0.63	-2.08[c]	EX	EX	0.54	EX	EX	$R^2 = 0.24$
	(60.5)	(0.009)	(0.82)	(0.67)			(0.24)			$R^2(C) = 0.20$
III	111.7	-0.028[c]	-0.43	-1.84[c]	0.32	EX	-0.93	EX	EX	$R^2 = 0.29$
	(59.6)	(0.009)	(0.81)	(0.66)	(0.15)		(0.41)			$R^2(C) = 0.24$

Number of Observations = 75

Municipality Means = Percengage Births Without a Physician Present = 41.8

1015.	78.7	6.8	22.3	0.40	2.1	1.6	0.66	

EX means the variable does not enter the equation.

[a]The numbers in parentheses are standard errors of the coefficients.

[b]$R^2(C)$ is R^2 corrected for degrees of freedom.

[c]Significant at the 1 percent level (one-tail test).

[d]Significant at the 5 percent level (one-tail test).

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