DHS WORKING PAPERS

DHS Demographic and Health Surveys

Community Characteristics, Individual Attributes, and Child Survival in Brazil

Narayan Sastry

MACRO INTERNATIONAL INC.

DHS Working Papers
Number 14

Community Characteristics, Individual Attributes, and Child Survival in Brazil

Narayan Sastry

Macro International Inc.
Calverton, Maryland, USA

August 1994

Narayan Sastry is a Ph.D. candidate at the Woodrow Wilson School of Public and International Affairs and the Office of Population Research, Princeton University. This research was supported by grants from the Rockefeller Foundation, through the Demographic and Health Survey Program, and from the MacArthur Foundation, through the Center of International Studies at Princeton University. The author gratefully acknowledges guidance and advice from Noreen Goldman and Lorenzo Moreno.

The Demographic and Health Surveys Program is designed to collect data on fertility, family planning, and maternal and child health. DHS is funded by the United States Agency for International Development. DHS Working Papers are intended to disseminate early findings of in-depth analysis of DHS data. Comments about this working paper or requests for information about the DHS program should be sent to: DHS, Macro International Inc., 11785 Beltsville Drive, Calverton, MD 20705 USA (Telephone 301-572-0200; Fax 301-572-0999).

I. Introduction

This paper presents an analysis of the relationship among community attributes, individual and household characteristics, and child survival in Brazil. The principal objectives are to investigate how the social and environmental context in which a child is raised affects the chances of his or her survival, and to analyze how individual and household characteristics modify the effects of community characteristics. The ultimate goal of the study is to understand the role of community characteristics in shaping child mortality differentials in the context of a developing country.

The study of differential mortality has been an important focus of demographic research since the first systems for collecting vital statistics were developed. Apart from providing descriptive information on the pattern of mortality in a population, the analysis of mortality differentials forms the basis for policy interventions designed to improve the chances for individual survival. We expect that community characteristics play two important roles in determining mortality differentials. First, they influence mortality differentials between areas. Our analysis of community variables should, therefore, provide insights into the spatial pattern of mortality in Brazil. In particular, we should derive a more complete understanding of the factors responsible for the large regional variation in mortality in this country. Second, community characteristics may be playing an important role in exacerbating or mitigating mortality differentials based on household socio-economic attributes. This is because community services and infrastructure may complement or substitute for certain household attributes. We will examine this question by studying how community characteristics and household attributes interact. The results should be useful for designing effective policies to reduce both overall child mortality and child mortality differentials among population groups.

Few studies of child mortality differentials in the developing world have focussed on the role played by community- or municipality-level characteristics,[1] and little is known about the nature of substitutability or complementarity between household and community attributes—either in Brazil or in other parts of the less developed world. The closest most studies have come is to examine the effects of region or of rural-urban place of residence. The fact that many of these studies interpret significant regional or rural-urban differentials in mortality in terms of the possible effects of omitted community variables points to the interest of researchers and policy makers in the effects of these variables. Their potential importance is further highlighted by the fact that even in cases where differentials by place of residence are insignificant, community-level variables may *still* be significantly associated with child survival chances, as Sastry et al. (1993) have shown.

[1] It has been common for researchers to apply the term "community" to data collected at the municipality level, or to use the two terms interchangeably, as we do here.

The absence of an important number of empirical investigations on the relationship between community variables and child survival is principally due to the limited availability of relevant community data in the developing world, although the failure of researchers to successfully identify different sources of community data and combine them with more readily available household survey data is also a contributing factor. The individual-level data analyzed here come from a 1986 household survey conducted in Brazil as part of the Demographic and Health Surveys (DHS) Program. These data are linked with community variables obtained from Brazilian census bureau data and meteorological records. Standard hazard-model techniques are used to analyze the relationship between child mortality and individual, household and community characteristics.

The next section includes a review of research on the relationship between community characteristics and child health and survival and on child mortality differentials in Brazil. In Section III, we present the conceptual framework and discuss our modeling strategy. In Sections IV, V and VI we describe our data, the statistical methodology we employ, and the specific variables we include in our analysis. Our results are presented in Section VII.

II. Previous Research

Community Characteristics and Child Health and Survival

Of the small group of studies in which the association between community variables and child survival has been analyzed, the majority have focused on health service availability, which is widely believed to be the most important place-of-residence characteristic. Furthermore, most of these studies have examined the role these factors play in influencing survival differentials by maternal education, due to the importance of maternal education as a major socio-economic determinant of child mortality.[2]

Rosenzweig and Schultz's (1982) analysis of child mortality in Colombia included municipality-level data on the availability of medical services, family planning activities, education, transportation infrastructure, and climate. An important substitutive relationship between public health facilities and maternal education was uncovered in urban areas, but no significant interactions were found in rural areas. Rosenzweig and Schultz reported that controlling for average municipality education levels reduced the positive effect of municipality health services on child survival.

Al-Kabir (1984) incorporated community data on distances to the nearest health, family planning and educational facilities in a study of child mortality in Bangladesh. The distances to a family planning clinic and to a primary

[2] The relationship between maternal education and child mortality has been the topic of much recent research; for reviews see Cleland and van Ginneken (1988), Elo (1990) and Ware (1984).

school emerged as the strongest community-level correlates of mortality. Al-Kabir tested every possible interaction between individual and community factors but found few significant ones. However, he did find that maternal education and family planning clinics could substitute for each other and that maternal education complemented access to a trained birth attendant.

In a recent study, Frankenberg (1993) used fixed-effects logit models to study the effects of health service availability on child mortality in Indonesia. She discovered that child mortality levels were negatively associated with the number of maternity clinics and doctors in a community. Private toilets in the community and the presence of health centers did not have significant impacts, whereas an increase in the number of health workers was associated with higher mortality levels.

There has been more research on the relationship between community characteristics and child health—measured most commonly by anthropometric indicators, such as child height conditional on age and sex—in the field of development economics. A survey of this literature can be found in Behrman and Deolalikar (1988). Recent work includes papers by Barrera and by Strauss and collaborators. Strauss (1990) found that the quality of community health services was more important than their availability in determining child health outcomes in rural Côte d'Ivoire. Although indicators of major community health problems were important, he discovered no significant interactions between maternal education and community variables. Barrera (1990) found that, in the Philippines, environmental cleanliness, water connections, access to health care facilities, and toilet facilities were all significantly related to child health, with the first two variables serving as substitutes for maternal education and the latter two as complements. Thomas and Strauss (1990) found that local market prices and municipality infrastructure had large and significant impacts on child health in Brazil, in a study based on Brazilian child anthropometric data from the early 1970s. In a separate study using data on child height from the 1986 Brazil DHS survey, Thomas et al. (1991) discovered significant interaction effects between maternal education and the availability of municipality services, with health services serving as substitutes and sewerage services as complements.

Although the earliest study reviewed here is now over ten years old, much remains unknown about the relationship between community characteristics and child survival in many areas of the developing world, including Brazil. For instance, we know very little about the nature of substitutability or complementarity between household characteristics and community attributes for factors other than maternal education, such as household income. In addition, knowledge about the consistency of findings across countries, over different time periods, and for different indicators of child health is extremely limited. This type of information is important, however, for designing effective intervention strategies for reducing child mortality. It allows one to identify the segments of the population most likely to benefit from specific policies to improve the quality and availability of community infrastructure and services.

Child Mortality Differentials in Brazil

The study of child mortality differentials in Brazil has focussed primarily on geographic differences among regions and between rural and urban areas, and secondarily on differences by income and education. The tremendous spatial diversity within Brazil in the level and pace of social and economic development has been the principal reason for this focus. Differentials by income and education have tended to mirror the regional differentials, and hence have received somewhat less attention. Early studies, which applied indirect estimation techniques to census data, analyzed differentials at an aggregate level and were restricted methodologically to examining the effects of only one or two covariates.[3] More recently, individual-level analyses based on household survey data have studied the relationship between socio-economic, demographic and reproductive variables and child survival.[4] However, these studies have not, for the most part, tried to explain the well-known spatial and socio-economic differentials in mortality.

The Northeast region lags behind all other regions—particularly the more-developed South/Southeast, which includes highly industrialized areas in the states of São Paulo and Rio de Janeiro—in practically every measure of well-being. Documented differences between the Southeast and the Northeast in average literacy rates (1.7 times higher in the Southeast), percent enrolled in school (1.5 times higher), percent of households with piped water (2.2 times higher), percent of households with a septic tank (3.4 times higher), and percent of households with electricity (2.0 times higher) are reflected in differences in life expectancy and infant mortality.[5] These differences, which are among the largest in the world, have been confirmed by numerous studies. The most recently available published estimates are based on data from the 1980 census; at that time, life expectancy at birth was 14.2 years or 26 percent higher in the South than in the Northeast (Merrick, 1986).

While it has been widely known that the Northeast experiences substantially higher child mortality rates than the rest of Brazil, only a few previous studies (Curtis and McDonald, 1991; Wood and Lovell, 1992) have controlled for region, and only five have analyzed the covariates of child mortality separately for different regions. McCracken et al. (1991) separated observations in the North and Northeast regions from those in other areas of Brazil, in a study of the effects of fertility change on infant survival in Brazil based on 1986 Brazil DHS data.

---

[3] See, for example, Carvalho and Wood (1978), Daly (1985), Merrick and Graham (1979), Simões (1989), Simões and Oliveira (1986), Sawyer et al. (1987), and Wood and Carvalho (1988).

[4] Individual-level studies of child mortality in Brazil have focussed on the relationship between child mortality and access to piped water (Marcotte, 1988; Merrick, 1985); birth spacing (Curtis and McDonald, 1991); racial inequality (Wood and Lovell, 1992); water supply, sanitation and housing (Victora et al., 1988); familial mortality risk (Curtis et al., 1993; Sawyer and Beltrão, 1991); birth weight (Barros et al., 1987; Victora et al., 1992); fertility decline (McCracken et al., 1991); household socio-economic characteristics (McCracken, 1990; Sawyer and Soares, 1983; Thomas et al., 1990; Victora et al., 1986); breastfeeding (Goldberg et al., 1984); and place of residence (Sastry et al., 1993).

[5] The differentials in measures of well-being are for the year 1980 and are taken from Denslow and Tyler (1984).

Although their study did not focus on regional mortality differentials, the results indicate that reproductive patterns may be important in accounting for regional differences in child mortality rates.

Thomas et al. (1990) stratified their sample of Brazilian households from the early 1970s by mother's age and by location and region of residence. They note that although differences in urban and rural child mortality rates tend to be small for both the South and the Northeast, the impact of household-level variables varied substantially by location. Using data from the 1970 Census, Sawyer and Soares (1983) also analyzed the effects of socio-economic characteristics on child mortality separately for urban and rural areas in the Northeast and in the South. They found that household water and sewerage connections and mother's education accounted for part of the regional mortality differential, though much was left unexplained by the variables in their study. Sawyer and Soares speculated that unmeasured community characteristics might account for much of the residual variation and might also be important for explaining regional differences in relationships between household variables and mortality levels. In a study based on aggregate mortality rates calculated from the 1986 DHS survey, Barros and Sawyer (1991) found that differences in education levels between the Northeast and the rest of Brazil explained a negligible proportion of the regional differentials in infant mortality rates. Rather, it was differences in the relationship between education and child mortality that appeared to be a crucial factor. The results from these studies suggest that there are complex interactions between household characteristics and location attributes, and that detailed community-level data are essential for studying the regional mortality differential in Brazil correctly.

Sastry et al. (1993), in another study based on the 1986 Brazil DHS data, found differences in childbearing patterns to be important in explaining mortality differentials between the Northeast and the rest of Brazil. Their results indicated that in both regions, women who were socio-economically disadvantaged contributed a disproportionately large share of high-risk births. However, in the Northeast, not only were children generally worse off socio-economically, but the negative consequences of inferior living conditions and disadvantaged household circumstances seem to have been more severe. Using a limited set of municipality variables, Sastry and colleagues also uncovered important differences between the two regions in the relationship between community characteristics and child mortality risks. Knowledge of the determinants of the observed regional mortality differentials in Brazil thus appears to be improving, but is still incomplete.

III. Conceptual Framework

The relationships among reproductive, demographic, socio-economic, and environmental variables as they affect child mortality have been organized into a number of conceptual frameworks (Pool, 1982; Venkatacharya, 1985; Mosley and Chen, 1984; Mahadevan, 1986). The framework proposed by Mosley and Chen is generally considered to be the most comprehensive and systematic (Ruzicka, 1989) and has formed a powerful organizing structure for mortality studies by demographers and epidemiologists.

The Mosley-Chen framework identifies five proximate determinants of child health and survival: (1) maternal factors, (2) environmental contamination, (3) nutrient deficiency, (4) injury, and (5) personal illness control. Individual, household, and community-level socio-economic characteristics influence child health and survival through each of these sets of intervening variables. Though not based explicitly on a theoretical model of household behavior, the framework specifies the following variables to be causally prior to the proximate determinants: individual factors, such as maternal education; household factors, such as income and family composition; institutional factors, including community infrastructure and health programs; ecological factors, such as rainfall, temperature, seasonality and altitude; and cultural factors, such as traditions, norms and values.

Models of household behavior generally are useful for guiding the choice of variables in analyses and generating predictions that can be tested (Behrman and Deolalikar, 1988); in particular, they can be used to separate endogenous variables from exogenous ones and to select appropriate explanatory variables. Although the Mosley-Chen framework lacks an explicit behavioral model, it specifies exogenous and endogenous variables that are consistent with the economic model of the household. In the basic microeconomic model of the family, households maximize a utility function subject to several constraints.[6] Utility depends on the consumption of goods, services and leisure, and on the health of family members. The constraints consist of a time constraint for each household member, an income constraint for the entire household, and a health production function. The model can be solved to yield a series of reduced-form demand equations. These functions relate the demand for child survival to the exogenous variables in the system of equations, including prices and income, and characteristics of the child, parents and community. Using the reduced-form equations, one can examine the relationship between child survival and exogenous variables that are generally open to policy intervention.

The exogenous variables in the microeconomic model are the same as the exogenous variables in the Mosley-Chen framework, and the choice variables that appear as explanatory variables in the health production are the Mosley-Chen proximate determinants. By nature, the proximate determinants—such as breastfeeding, birth spacing, household sanitation and water supply—are endogenously determined and should not appear in the reduced-form equation for child survival. Rather, they belong in the health production function—including them in the reduced-form equation yields hybrid production-function/reduced-form estimates, which are difficult to interpret (Rosenzweig and Schultz, 1983).

In this paper, we estimate reduced-form equations of household demand for child survival to analyze the relationship between child mortality and individual, household and community attributes. Our conceptualization of this relationship builds on the Mosley-Chen framework and the economic model of the family to focus on the effects of three sets of exogenous factors: (1) individual and household socio-economic and demographic characteristics;

---

[6] See Becker (1981) for a description of the economic model of the family or Behrman and Deolalikar (1988) for an outline of the economic model of the household-farm, which is more commonly used in the development field.

(2) service levels, infrastructure, ecological setting, and other community-level attributes; and (3) the interactive or joint effects of individual and household characteristics and community-level attributes.

For each community factor that measures service levels or infrastructure, we include two types of variables in our models. The first is an indicator of quantity, availability or accessibility of the service. The second is an indicator of the quality of the community service. For example, the number of schools per person provides a measure of the availability of education services in a community, while student-teacher ratios provide a measure of quality. We expect higher quantity and better quality of local services and infrastructure to be directly associated with lower mortality.

While the availability of health, sanitation and other social services is clearly important for reducing child mortality, its interaction with individual and household characteristics determines the actual outcomes (Mosley, 1984). The direction of the interaction effects will depend on the type of community service being provided and on the household-level variable with which it is interacted. Our study focusses on interactions with maternal education and with household income. Given that education supplies women with knowledge and skills necessary for raising healthy children (Caldwell, 1979; Rosenzweig and Schultz, 1982), maternal education will be a substitute for services that *provide* knowledge, skills and a healthy environment for raising healthy children. On the other hand, maternal education is likely to complement local services that *require* knowledge and skills.[7] We expect household income to complement community services and infrastructure that require investments in goods and services in order to produce improvements in child survival chances and to substitute for community infrastructure and services that are directed to the poor or that are provided free or at very low cost. We anticipate that higher quality and more specialized services will complement income and education, whereas basic and non-specialized services are more likely to serve as substitutes for income and maternal education.

By including a series of interaction terms in our models we will, therefore, be able to establish whether local services and infrastructure complement or substitute for household socio-economic characteristics. This provides important public policy information on the health effects of improvements to local services and infrastructure. For example, consider the relationship between maternal education and the availability of medical facilities. If the

---

[7] Education may also (1) provide women with the financial means to take advantage of local services and infrastructure, through higher earnings or selective mating; (2) change the value of time; and (3) alter preferences (Rosenzweig and Schultz, 1982). However, there is a growing body of evidence to suggest that the most important role of maternal education in improving child survival is to provide women with the knowledge and skills to raise healthy children. There is considerable evidence from numerous studies—beginning with Caldwell's (1979) study of Nigeria—that the positive effect of maternal education on child health is not simply due to higher family income. A recent review of maternal education and child survival in developing countries notes that most studies have failed to find effects of maternal employment and the increased value of mothers' time (Cleland and van Ginneken, 1988). Barrera (1990) and Rosenzweig and Schultz (1982) provide evidence consistent with the hypothesis that the primary channels through which maternal education operates are augmenting the productivity of inputs and reducing the cost of information. Thomas et al. (1991) find that "almost all of the impact of mother's education [on child health] can be explained by indicators of her access to information."

association is complementary, then an increase in the number of health centers within an area, without a policy to improve women's education, will benefit to a greater extent the children of more educated mothers, who have the means, ability, and knowledge to take advantage of the new facilities. Otherwise, if the association is substitutive, it will mostly be the children of less educated mothers who are made better off, reducing the apparent benefit of maternal education for child health and survival. This would occur, for instance, if health facilities disseminated information on child care that was otherwise available only to more educated women.

In many cases we are unable to predict the direction of the interaction effect. This is because the broad measures of availability and quality of community infrastructure and services with which we are working provide little insight into their primary community effect. In the above example, medical facilities can provide information on child care to women who would benefit from adopting the practices or they can provide specific services that require potential users to be knowledgeable and sophisticated consumers. If the interaction effects indicate that maternal education and medical services are substitutes, this suggests that the most important role of medical services in reducing child mortality is the dissemination of information. A finding of complementarity, on the other hand, would imply that the actual treatment of patients was the primary function of local medical services. The interaction effects thus offer insights for each community variable into which of its several roles are likely to be primary in this particular setting.

Our discussion of the anticipated relationships among variables would not be complete without cautioning about the possibility that community levels of services and infrastructure are not distributed randomly. As Rosenzweig and Wolpin (1986) argue, community characteristics—especially the concentration of health facilities in a location—may be endogenously determined. For instance, it may be government policy to locate these facilities in areas of especially high (or especially low) mortality. Even if the distribution of community levels of services and infrastructure is not systematic, individuals may choose to migrate to communities based on their demand for a particular mix of community services and amenities. In particular, disadvantaged households may be attracted in large numbers to areas with good infrastructure and community services, since these areas may also provide the best employment opportunities. We, however, treat all community variables in this study as exogenous since we lack the necessary data to apply appropriate correction procedures.[8]

IV. Data

Information on individual and household variables comes from the *Pesquisa Nacional sobre Saúde Materno-Infantil e Planejamento Familiar—Brasil* (Arruda et al., 1987), a household survey of Brazil that was conducted as part of Phase I of the Demographic and Health Survey (DHS) program. Retrospective maternity histories from 5,892

[8] To treat community variables as endogenous in the present context would require a set of instrumental variables. Unfortunately, these are not available. In addition, instrumental variable estimation techniques for hazard models have yet to be developed. An alternative is to use fixed-effects estimates. In the absence of community data for several points in time, however, the differencing that is required to compute the fixed-effects estimates would eliminate the community variables.

women age 15 to 44 were collected over a three-month period in mid-1986. The survey was based on a multistage, clustered sampling scheme that selected primary sampling units and households from Brazilian census files.

A total of 12,356 births was captured in the survey, of which 3,573 occurred within five years of the survey. It is the mortality experience of these children that we analyze in this study. We restrict our attention to these observations for two reasons: first, misreporting due to recall error of key variables, such as age at death, is diminished. Second, the household socio-economic covariates are a record of the household's situation at the time of the interview. Given the rapid pace of change in Brazilian living standards during the 1970s, it is likely that a child born in the more distant past was exposed to the risk of death under a different set of socio-economic conditions than those recorded in the survey.

During the five-year period preceding the survey, there were 153 deaths among the 1,435 births in the Northeast region and 80 deaths among 2,042 births in the rest of Brazil. Infant mortality probabilities (${}_{12}q_0 \times 1000$) are estimated to be 105.2 and 122.9 for urban and rural areas of the Northeast, respectively (see Table 1). Compared to the rest of Brazil, these probabilities are roughly twice as high for rural areas (122.9 versus 69.6) and nearly three times as high for urban areas (105.2 versus 36.6). Under-five mortality probabilities (${}_{60}q_0 \times 1000$) for the rest of Brazil are 75.1 for rural areas and 41.9 for urban areas; in the Northeast, the probabilities are 145.8 for rural areas and 114.8 for urban areas.

Community data were obtained from two sources. The primary source is the *Informações Básicas Municipais*, an occasional data series assembled by Fundação Instituto Brasileiro de Geografia e Estatística (IBGE), the Brazilian state statistical agency. This data set includes information on population, employment, infrastructure, agriculture, industry, commerce, services, communications, government, education, transportation, and health care for each municipality in Brazil. The data are assembled from data bases of government ministries and a variety of censuses, including the 1980 population census. We linked data from the 1984 *Informações Básicas Municipais* with individual observations using a listing obtained from DHS personnel that provided the municipality name for each primary sampling unit number. Ninety municipalities in the Northeast region and 175 in the rest of Brazil are included in the DHS sample. Note that our community data are actually collected at the municipality level. Municipalities in Brazil can be fairly large, in terms of both population and area.[9] While notions of what constitutes a community are open to discussion, the average municipality in Brazil is likely to be somewhat larger than what most analysts have in mind when they talk about communities.

Climate data for Brazil were extracted from the World Monthly Surface Station Climatology (Spangler and Jenne, 1988), an international data set assembled by the U.S. National Center for Atmospheric Research. Monthly

[9] There are 4,088 municipalities in Brazil, with an average population of 29,800 and an average area of 2,118 km^2. Municipalities in the Northeast are slightly smaller in size and population than those in other parts of the country.

Table 1. Mortality by region and location of residence 1981-86

	Rest of Brazil		Northeast	
	Rural	Urban	Rural	Urban
Infant Mortality ($_{12}q_0$)	69.58 (11.88)	36.62 (4.47)	122.89 (11.85)	105.18 (10.95)
Under-Five Mortality ($_{60}q_0$)	75.14 (12.44)	41.85 (5.15)	145.81 (13.36)	114.79 (11.51)

Note: Standard errors in parentheses; all entries * 1000.

temperature and precipitation data are collected regularly from 60 weather stations in Brazil, some of which have been reporting continuously for over 100 years. Households were assigned climate data from the nearest weather station based on its coordinates and those of the municipality.

V. Statistical Methods

We used hazard models to analyze the association between individual-, household- and municipality-level variables and a child's risk of death. This class of models was developed initially by Cox (1972) and has the principal advantage of being able to accommodate censored observations and time-varying covariates. We have adopted a variant of the original model that considers events in discrete time. Although the hazard function, i.e., the age-specific risk of mortality, is continuous by nature, the events of death and censoring are reported for discrete ages. The risk of death is therefore considered constant within the reported age intervals—which may be combined if there are insufficient numbers of deaths in finer age ranges—and the hazard is represented by a step function. This feature of the model is responsible for it being known as the piecewise exponential model. A finding by Holford (1980) and Laird and Olivier (1981) that the log-likelihood function for the piecewise exponential model is equivalent to a certain Poisson regression model implies that the model can be estimated using standard statistical software.

Formally, we model the hazard rate at age a for individual k, $\lambda_k(a)$, as a function of a vector of possibly time-varying individual and community covariates, $\mathbf{x}_k(a)$. The covariates may be either continuous or discrete. The model takes the form

$$\lambda_k(a) = \lambda_0(a) \exp[\ \beta' \mathrm{x}_k(a)\ ]$$

where $\lambda_0(a)$ represents the baseline hazard. Exponentiated parameter estimates measure the multiplicative effect on the risk of death from a unit increase in the covariate for a continuous variable or from a one-category increment for a factor. If there are no interactions with age, then the hazard rates in the model are proportional for any two individuals. That is, the effect of a covariate on the risk of death does not change with the age of the child—it has a constant, multiplicative effect at each age.

The standard hazard model assumes that all observations in the sample are independent. However, our data set is based on a clustered sampling scheme. In addition, since women provide retrospective reproductive histories, each woman may contribute more than one observation to the sample of children. We therefore have clustering of observations at the community level and at the family level. Since we ignore this correlation when estimating parameters and standard errors, the standard errors will tend to be *understated* and the coefficients themselves may be biased.

VI. Individual, Household and Community Covariates

Individual and Household Covariates

Table 2 provides a listing of the individual- and household-level variables in our analysis, together with their means and standard deviations or percentage in each category, as appropriate. Individual- and household-level covariates in our analysis consist of the child's age and sex, maternal age (mother's age at the birth of the child), mother's education, household income, and current and childhood place of residence of the mother. The most fundamental determinant of the hazard of death is the child's age. In our models we consider survival through the following age intervals: 0 months, 1-5 months, 6-11 months, 12-23 months, and 24-59 months. This grouping ensures a reasonable number of deaths in each age interval and maintains a parsimonious description of the baseline hazard.

Male children experience higher mortality than female children in the absence of discriminatory allocation of resources and care (Waldron, 1987); hence sex is included as a covariate in our models. There is no indication of sex discrimination in Latin America[10] though there is evidence of under-reporting of male births in the rural Northeast during the period 1981-86.[11] Including sex as a covariate ensures that the existence of correlation between under-reporting of male births and other covariates does not result in biased parameter estimates.

---

[10] See Rutstein (1984) or United Nations (1986) for estimates of sex differentials in mortality, none of which provide any indication of discrimination.

[11] The sex ratio at birth for the rural Northeast during the period 1981-86 was (391/434) = 0.90. The difference between this estimate and the expected value of 1.05 is statistically significant.

Table 2. Summary statistics for individual variables used in statistical analysis

Variable	Rest of Brazil: Mean or percentage in category	Rest of Brazil: Standard deviation	Northeast: Mean or percentage in category	Northeast: Standard deviation
Sex				
Female	47.45 %		49.59 %	
Male	52.55		50.41	
Maternal age	25.59	(5.91)	26.44	(6.48)
Mother's years of education	5.44	(4.50)	3.79	(7.48)
Total household income	Cr$ 3252.65	(5749.54)	Cr$ 1240.49	(2491.43)
Place of residence				
Lifetime urban	66.21 %		38.53 %	
Rural-to-urban migrant	13.42		11.50	
Rural	20.37		49.97	
Number of births	2042		1435	
Number of deaths	80		153	

There is considerable evidence on the deleterious consequences for child survival of childbearing at younger and older maternal ages.[12] To account for the non-linear relationship between a maternal age and child survival chances, we include maternal age and age-squared as covariates in our models.

We incorporate income in our analysis to control for the socio-economic status of the household. This covariate also captures the household's financial ability to secure goods and services that promote better health, assist in maintaining a more hygienic environment, and ensure adequate nutrition levels. A negative relationship between income and child mortality has been established in a number of household-level studies in developing country settings (Casterline et al., 1989). Three studies focussing on Brazil have found higher levels of household income to be significantly associated with improved child survival chances (Merrick, 1985; Thomas et al., 1990; Victora et al., 1986). Interactions between income and community characteristics will provide information on how a family's ability to pay for goods and services allows it to take advantage of beneficial community attributes yet shield itself from others that may have deleterious consequences for child survival.

[12] See, for example, Hobcraft et al. (1985), Miller et al. (1992), Palloni and Millman (1986) and Pebley and Stupp (1987).

There are several problems connected with studying the relationship between income and child survival. First, income frequently is unreported; when information is available, income received in kind and imputed earnings from home production (especially agricultural output) might be omitted and are likely, in any case, to be reported with error.[13] Second, annual income is subject to transitory variation, due, for instance, to yearly fluctuations in employment status, weather, and household composition. If households are able to smooth consumption, by borrowing during bad times and saving during good times, total expenditure or wealth, rather than income, would provide a more appropriate indicator of household resources. Unfortunately, neither of these two variables was measured in the Brazil DHS survey. Finally, household income—particularly the mother's earnings component—may be endogenously determined: women who work will bring in additional household income, but might have less time available to care for their children. Since estimation techniques for hazard models with endogenous variables are not available, we experiment with an alternative way to skirt this problem: we remove the earnings of mothers from total household income and assume that the remaining portion of income is exogenous to the demand for child survival.

To control for community characteristics that differ between urban and rural areas, but are not included as covariates in our models, we include place of residence as a covariate. We realize that a woman's place of residence may be a choice variable, but without better data on her background characteristics this treatment provides the best way to account for omitted individual and community variables that reflect the important differences in the rural and urban environment. To investigate the effects of the mother's childhood place of residence, we subclassify children residing in urban areas by their mother's childhood place of residence. This specification allows us to explore the effects of a mother's move from a rural area to an urban one. Previous studies have shown that a woman's migration experience has a strong connection with her children's risk of death (Brockerhoff, 1990; Farah and Preston, 1985; Mensch et al., 1985). These authors have suggested four factors that may explain this relationship: (1) the positive selection of migrants from the population at the origin according to a number of traits, (2) differences in community characteristics and the disease environment between origin and destination areas, (3) difficulties migrants face in adapting to their new surroundings, and (4) disruption caused by the move itself.

Community Covariates

In Table 3 we list our community-level covariates, together with their means and standard deviations or percentage in each category, as appropriate. The covariates include measures of health care availability and specialization; the prevalence of water, sewage and electrical connections; the existence of garbage disposal services; indicators of the

---

[13] We investigated measurement error and the incidence of non-response for household income and its components in a previous study that used the same data set (Sastry et al., 1993). The set of correction procedures that we proposed are implemented in this study.

Table 3. Summary statistics for community variables used in statistical analysis

Variable	Rest of Brazil: Mean or percentage in category	Rest of Brazil: Standard deviation	Northeast: Mean or percentage in category	Northeast: Standard deviation
Total population (1,000's)	216.06	(772.97)	117.99	(250.79)
Population density (persons per km²)	505.70	(1427.39)	407.37	(1352.39)
Percent urban	67.29 %	(26.13)	46.75 %	(29.06)
Population growth (1970-80)	43.59	(58.08)	29.75	(31.01)
Altitude (meters)	471.70	(328.95)	251.78	(237.80)
Monthly temperature (Celsius)				
Mean	21.09	(2.42)	25.82	(1.11)
Standard deviation	2.25	(8.74)	1.03	(2.41)
Monthly precipitation (mm)				
Mean	123.89	(23.25)	120.68	(39.11)
Standard deviation	69.36	(34.41)	88.12	(28.93)
Household water supply				
Regular network water	51.28 %	(27.28)	30.14 %	(24.52)
Well water	40.88	(25.54)	26.90	(19.51)
Household electrical connection	67.25 %	(25.96)	38.55	(26.80)
Household sewage connection				
Regular network sanitation	25.41 %	(27.55)	4.23 %	(10.38)
No sanitation	19.81	(17.84)	57.22	(26.94)
Trash collection/public cleaning service?				
Neither	13.14 %		7.78 %	
Both	86.86		92.22	
Education				
Preschools per 100,000 persons	18.52	(14.97)	23.13	(31.63)
Preschool teachers per student	.04	(0.05)	0.04	(0.02)
Primary schools per 100,000 persons	159.17	(118.14)	234.80	(157.64)
Primary school teachers per student	.04	(0.01)	0.04	(0.01)
Number of television stations	3.16	(1.60)	1.66	(0.98)
Health facilities (per 100,000 persons)				
General facilities	14.26	(8.98)	14.70	(13.63)
Specialized facilities	2.20	(2.87)	1.29	(2.01)
Beds per inpatient health facility	84.54	(62.72)	46.08	(42.53)
Hospital beds				
Any	93.71 %		84.44 %	
None	6.29		15.56	
Hospital beds for specialized care	77.43 %	(36.51)	72.11 %	(41.72)
Specialized health-care facilities (per person × 100,000)				
Specialized pediatric facilities	.26	(0.60)	.21	(0.44)
Facilities providing pediatric services	12.00	(7.07)	10.87	(11.06)
Specialized obstetric/gynecologic facilities	.08	(0.23)	.22	(1.19)
Facilities providing obstetric services	10.88	(7.42)	10.55	(9.34)
Facilities providing gynecologic services	10.21	(6.53)	7.55	(6.10)
Number of municipalities	175		90	

availability and quality of education services; and such environmental covariates as altitude and several climate measures.

A number of indicators of the availability of different types of formal health-care facilities exist for each municipality. We include several measures as covariates that reflect the general availability of medical facilities, the degree to which the local health system emphasizes specialized health-care, and the presence of specific medical services that promote maternal and child health. Our indicators of general availability are the number of general and specialized health-care facilities per person. We expect higher availability to be associated with greater accessibility to health-care services and lower average costs. Both of these covariates should, therefore, be associated with lower overall mortality. However, there are a couple of reasons why we might not find this result. Mentioned previously was the possibility of reverse causation—the targeting of facilities to areas of especially high mortality and/or the attraction of disadvantaged households to areas with good health-care facilities. Another possibility is that resources may be allocated to specialized, curative facilities and treatments to the detriment of preventive and promotional measures that may benefit the more disadvantaged segments of the population to a greater extent.[14] The degree of specialization is one—albeit crude—measure of the orientation of the local health system. Since a lower number of facilities per person may be due to the larger average size of facilities, we control for the average number of beds per inpatient facility in our models. Smaller facilities may be associated with lower mortality if they provide more personalized care. However, larger facilities may be better equipped and may provide a wider range of services (Thomas et al., 1991). Several municipalities lack any inpatient facilities and we include a dummy indicator variable to distinguish these localities. The availability of three types of specialized medical facilities—pediatric, gynecologic and obstetric care—may be directly associated with lower child mortality levels. Unfortunately, we have no information on the availability of family planning services, which we would expect to be associated with lower mortality based on results from other developing countries (Frankenberg, 1993; Rosenzweig and Schultz, 1982).

Our community infrastructure covariates include indicators of the prevalence and quality of municipality water, electricity and sanitation services. For water supply, we include two measures: (1) the proportion of households in the municipality that receive water through the regular network and (2) that obtain it from a well. Municipal sanitation services also has two measures: (1) the proportion of households with a network sewage connection and (2) the proportion with no sewage disposal facilities. The proportion of households with electricity provides an indicator of the extent of electrification at the municipal level. Finally, a dummy variable marks municipalities in which there are both trash collection and a public cleaning service.

[14] Curative health care services were allocated about 85 percent of the national health budget in Brazil during the early 1980s (PAHO, 1990). Although funding comes primarily from the public sector, the health delivery system is largely private and the emphasis is on specialized, high-technology, curative health care (Banta, 1986). One result is that levels of waste and duplication are high: it has been estimated that between 10 and 30 percent of medical procedures at the secondary and tertiary levels are unnecessary (Macedo, 1984; cited in Banta, 1986).

Most studies of the relationship between child mortality and sanitation or water connections have focussed on variables at the household level (Esrey and Habicht, 1986). Measured at the municipality level, these variables capture several possible effects. First, they may reflect the public health environment in which households interact with each other. Norms of behavior regarding food preparation and storage, personal hygiene and household cleanliness are likely to be established at the community level, and will be influenced by the general availability of water and sanitation facilities. Second, these variables, along with the presence of trash collection and municipal cleaning service, also determine children's exposure to contamination from garbage and raw sewage outside the house. Third, the source of water, the type of sewage disposal, and a household electrical connection are likely to be highly correlated with availability at the municipal level. This is because the wider availability of these utilities means that it is easier and cheaper for a household to obtain a connection. For electricity, we would expect this to be the principal effect, since a household connection is likely to be crucial for electricity to have any effect on mortality.

We are interested in the relationship between community education levels and child mortality, which we would expect to be relatively important. Unfortunately, the only measures available from our community data set are the number of preschools and primary schools in each municipality. Teacher-student ratios in pre- and primary schools provide our indicators of education quality. Although the availability of schooling is likely to be correlated with general levels of education, these measures may be quite sensitive to our assumptions that facilities are randomly placed and migration is relatively unimportant. One way that community education levels may affect child mortality is by influencing norms and attitudes regarding child care and reproductive behavior. In Brazil, there is considerable evidence that television has played a similar role, particularly regarding contraceptive use (Rios-Neto et al., 1991). We include as a covariate in our models the number of television stations received in the municipality as an indicator of exposure to mass media messages.

The final set of community covariates describes the ecological and environmental setting and includes measures of altitude, precipitation and rainfall. We test for quadratic effects of altitude and of mean annual temperature and precipitation. Greater seasonality in precipitation and temperature may be associated with higher mortality levels. In the Northeast, where diarrhea is estimated to be responsible for 30 to 40 percent of child deaths (Barros and Victora, 1990; Rodrigues, 1992), there is a seasonal pattern in the incidence of the disease (Schorling et al., 1990).

VII. Results

Preliminary analysis for the entire country (not shown) revealed that the relationships between the covariates and child mortality for the Northeast differed from the corresponding relationships for the rest of Brazil. As a consequence, we stratified the sample, separating the Northeast from the rest of Brazil. This has the added advantage of allowing us to focus on the factors responsible for the mortality differential between these two regions without including interactions between region of residence and other covariates. We combined all observations for the rest of Brazil for two reasons. First, regional dummy variables were generally insignificant when the data were pooled. Second, when analyzed separately, the relationships between child mortality risks and each of the important covariates were similar for each region.

The results of our hazard model analysis for the Northeast and for the rest of Brazil are shown in Tables 4 and 5, respectively. Three different models were estimated for each region. The first model provides estimates of the direct effects of individual, household and community variables on a child's mortality risk. The second model adds interactions between maternal education and the community variables, while the third adds interactions between household income and community variables to the first model. The coefficients in the tables are interpreted as relative risks; they show the multiplicative effect on the risk of death associated with a unit increase in the covariate for a continuous variable or in relation to the omitted category for a factor. The z-statistics are presented in parentheses to the right of the coefficient estimates.

Individual and Household Variables

Our results indicate that the standard relationships between child mortality risks and individual and household covariates hold in both the Northeast and the rest of Brazil. The hazard rate declines steadily with child age and is slightly lower for female children. Childbearing at younger and older maternal ages is associated with higher mortality, though the relationship is not strong.

We have included mother's years of education as a continuous variable in the rest of Brazil since its effect was found to be linear. Our results indicate that a one-year increase in mother's education is associated with an 8 percent decline in the risk of death. This value is in close agreement with results from elsewhere in the developing world (Cleland and van Ginneken, 1988). Since the linear effect of mother's education does not hold in the Northeast, we include it as a factor in this region. We distinguish uneducated or poorly educated mothers (less than three years of schooling) from mothers with three or more years of education. When we control for all other covariates, the children of more educated mothers have approximately 26 percent lower mortality, though the effect is not statistically significant.

An increase in household income is associated with lower mortality in the Northeast region but its effect is insignificant in the rest of Brazil. As noted earlier, one potential problem with including household income in our models is that mothers' earnings may be endogenously determined. We experimented with removing mother's earnings from household income, but found only small changes in the coefficient in both regions. Therefore, it has been included in our measure of total household income.

Table 4. Results for hazard model analysis of child survival for the Northeast of Brazil

Variable	MODEL 1 Direct Effect		MODEL 2 Direct Effect		MODEL 2 Interaction with Mother's Education		MODEL 3 Direct Effect		MODEL 3 Interaction with Income	
Main effect	-14.084	(2.374)[1]	-9.974	(1.641)	.	.	-13.778	(2.291)	.	.
Age										
0 months[2]	.	.	.	.	.	.	.	.	.	.
1-5 months	-1.278	(6.746)	-1.268	(6.691)	.	.	-1.276	(6.737)	.	.
6-11 months	-1.817	(8.370)	-1.788	(8.232)	. .	.	-1.805	(8.311)	.	.
12-23 months	-3.828	(10.048)	-3.793	(9.952)	.	.	-3.816	(10.015)	.	.
24-59 months	-4.760	(9.156)	-4.729	(9.094)	.	.	-4.745	(9.125	.	.
Sex										
Female[2]	.	.	.	.	.	.	.	.	.	.
Male	0.181	(1.125)	0.178	(1.079)	.	.	0.186	(1.141)	.	.
Maternal age										
Linear effect	-0.117	(1.167)	-0.126	(1.229)	.	.	-0.129	(1.265)	.	.
Squared effect	0.002	(1.309)	0.002	(1.369)	.	.	0.003	(1.410)	.	.
Mother's education										
Less than three years[2]	.	.	.	.	.	.	.	.	.	.
Three years or more	-0.302	(1.596)	0.552	(0.212)	.	.	-0.266	(1.376)	.	.
Total household income[3]	-1.580	(2.346)	-1.524	(2.221)	.	.	7.410	(0.413)	.	.
Place of residence										
Rural resident[2]	.	.	.	.	.	.	.	.	.	.
Lifetime urban resident	0.365	(1.580)	0.244	(0.949)	.	.	0.345	(1.416)	.	.
Rural-to-urban migrant	0.379	(1.316)	0.009	(0.028)	.	.	0.326	(1.071)	.	.
Water supply										
Regular network water[4]	-1.008	(1.058)	-4.130	(3.205)	7.486	(3.423)	-1.264	(1.104)	1.886	(0.180)
Well water[4]	-0.976	(1.801)	-1.224	(1.692)	0.149	(0.123)	-1.233	(2.014)	10.106	(1.439)
Electricity										
Electrical connection[4]	-1.550	(0.956)	3.824	(1.678)	-10.261	(2.963)	-1.142	(0.600)	-1.309	(0.079)
Sanitation										
Regular network sanitation[4]	-2.501	(1.662)	-19.015	(2.430)	17.977	(2.215)	-4.581	(2.110)	19.293	(1.654)
No sanitation[4]	-1.272	(1.271)	1.225	(0.988)	0.289	(0.128)	-0.972	(0.825)	-13.534	(0.864)
Trash collection/public cleaning										
Neither[2]	.	.	.	.	.	.	.	.	.	.
Both	-1.051	(1.940)	-1.050	(1.727)	0.679	(0.453)	-0.850	(1.439)	-10.626	(1.188)
Preschools										
Per 1,000 persons	0.021	(0.044)	-0.774	(1.077)	1.586	(1.480)	0.460	(0.792)	-12.492	(1.476)
Teacher/student ratio	-4.421	(0.730)	-9.854	(1.413)	22.981	(1.469)	-5.738	(0.821)	0.129	(0.001)
Primary schools										
Per 1,000 persons	0.076	(0.572)	0.196	(1.179)	-0.433	(1.670)	0.132	(0.850)	-0.202	(0.122)
Teacher/student ratio	-2.714	(0.293)	4.643	(0.424)	-36.653	(1.797)	-3.633	(0.339)	-43.057	(0.301)
Number of television stations	-0.093	(0.706)	-0.218	(1.213)	0.230	(0.887)	-0.124	(0.817)	-0.439	(0.409)

Table 4. (continued)

	MODEL 1		MODEL 2				MODEL 3			
Variable	Direct Effect		Direct Effect		Interaction with Mother's Education		Direct Effect		Interaction with Income	
Health facilities										
General facilities[5]	0.361	(0.381)	-2.385	(1.696)	4.432	(2.058)	1.102	(0.959)	-16.061	(0.929)
Specialized facilities[5]	4.965	(0.703)	-15.623	(1.550)	38.261	(2.669)	7.777	(0.905)	-54.540	(0.916)
Beds/inpatient health facility	0.009	(2.247)	0.016	(2.729)	-0.015	(1.728)	0.011	(2.321)	0.002	(0.067)
Hospital beds										
Any[2]	.	.	.	.	.	.	.	.	.	.
None	-0.536	(1.172)	-0.277	(0.551)	-0.531	(0.423)	-0.915	(1.721)	7.839	(0.904)
Proportion of hospital beds for specialized care	0.206	(0.506)	-0.537	(1.212)	1.902	(1.604)	-0.068	(0.147)	8.433	(1.052)
Specialized health-care										
Pediatric services[5]	-0.635	(0.486)	2.186	(1.247)	-6.175	(2.060)	-3.506	(1.847)	55.970	(2.578)
Obstetric/gynecologic facilities[5]	-4.204	(0.395)	28.490	(2.059)	-68.880	(2.544)	-11.790	(0.884)	239.436	(1.028)
Population growth rate[6]	-1.062	(2.014)	-0.530	(0.832)	-2.121	(1.715)	-0.716	(1.271)	-12.357	(1.917)
Altitude (km)										
Linear effect	3.910	(2.317)	2.504	(1.421)	.	.	3.642	(2.149)	.	.
Squared effect	-4.559	(1.987)	-2.897	(1.204)	.	.	-3.864	(1.711)	.	.
Monthly temperature (Celsius/10)										
Mean	4.827	(2.498)	3.880	(1.938)	.	.	4.844	(2.463)	.	.
Variance	83.327	(1.993)	47.536	(1.030)	.	.	70.156	(1.618)	.	.
Monthly precipitation (meters)										
Mean	5.813	(2.898)	3.891	(1.808)	.	.	5.638	(2.681)	.	.
Mean squared	-2.403	(2.605)	-1.623	(1.651)	.	.	-2.271	(2.353)	.	.
Variance	0.444	(0.924)	0.073	(0.139)	.	.	0.303	(0.601)	.	.
Number of observations	1435		1435				1435			
Model χ^2 (d.f.)	393.703 (37)		448.135 (56)				416.957 (56)			

[1] ( ) contains the z-statistic which is the absolute value of the estimate divided by its standard error. It has an asymptotically normal distribution, with critical values of 1.960 at the five-percent significance level and 1.645 at the ten-percent significance level.

[2] Omitted category.

[3] Household income is measured in Cr$ 10,000.

[4] Water supply, electricity and sanitation variables measure proportion of households with particular type of service.

[5] Number of facilities per 1,000 persons.

[6] Population growth rate during the period 1970-80.

Table 5. Results for hazard model analysis of child survival for the rest of Brazil

	MODEL 1		MODEL 2				MODEL 3			
Variable	Direct Effect		Direct Effect		Interaction with Mother's Education		Direct Effect		Interaction with Income	
Main effect	15.821	(1.689)[1]	23.853	(2.218)	.	.	20.445	(1.978)	.	.
Age										
0 months[2]	.	.	.	.	.	.	.	.	.	.
1-5 months	-2.308	(8.963)	-2.299	(8.925)	.	.	-2.301	(8.935)	.	.
6-11 months	-2.871	(9.179)	-2.854	(9.118)	.	.	-2.858	(9.136)	.	.
12-23 months	-4.561	(8.762)	-4.534	(8.705)	.	.	-4.545	(8.729)	.	.
24-59 months	-5.119	(8.596)	-5.060	(8.488)	.	.	-5.108	(8.574)	.	.
Sex										
Female[2]	.	.	.	.	.	.	.	.	.	.
Male	-0.084	(0.393)	-0.079	(0.361)	.	.	-0.057	(0.264)	.	.
Maternal age										
Linear effect	-0.136	(1.008)	-0.136	(0.957)	.	.	-0.144	(1.051)	.	.
Squared effect	0.002	(0.831)	0.002	(0.693)	.	.	0.002	(0.848)	.	.
Mother's years of education	-0.087	(2.393)	-1.150	(1.410)	.	.	-0.113	(2.799)	.	.
Total household income[3]	0.090	(0.412)	0.138	(0.648)	.	.	-16.196	(1.277)	.	.
Place of residence										
Rural resident[2]	.	.	.	.	.	.	.	.	.	.
Lifetime urban resident	-0.964	(2.482)	-0.979	(2.272)	.	.	-1.047	(2.514)	.	.
Rural-to-urban migrant	-2.441	(3.672)	-2.628	(3.747)	.	.	-2.638	(3.785)	.	.
Water supply										
Regular network water[4]	3.081	(1.543)	0.357	(0.124)	1.178	(1.575)	0.346	(0.136)	16.193	(1.300)
Well water[4]	1.740	(0.997)	1.166	(0.454)	0.566	(0.756)	0.499	(0.232)	10.392	(0.819)
Electricity										
Electrical connection[4]	-0.832	(0.595)	-1.541	(0.748)	0.265	(0.533)	-1.229	(0.664)	4.008	(0.551)
Sanitation										
Regular network sanitation[4]	-0.078	(0.117)	2.983	(2.497)	-0.728	(3.628)	0.716	(0.784)	-4.631	(1.852)
No sanitation[4]	-0.065	(0.037)	-2.045	(0.751)	0.633	(0.941)	-1.336	(0.600)	3.306	(0.334)
Trash collection/public cleaning										
Neither[2]	.	.	.	.	.	.	.	.	.	.
Both	-0.707	(1.384)	-1.091	(1.358)	0.071	(0.471)	-0.638	(0.978)	0.332	(0.138)
Preschools										
Per 1,000 persons	-0.618	(0.445)	-1.090	(0.495)	0.357	(0.924)	-1.298	(0.753)	2.830	(0.518)
Teacher/student ratio	-7.165	(1.664)	-13.129	(2.280)	1.010	(1.426)	-8.021	(1.621)	-5.195	(0.576)
Primary schools										
Per 1,000 persons	-0.025	(0.114)	-0.451	(1.470)	0.148	(2.045)	-0.225	(0.860)	0.671	(0.668)
Teacher/student ratio	-2.752	(0.133)	10.106	(0.336)	-3.030	(0.487)	18.438	(0.677)	-36.708	(0.383)
Number of television stations	0.208	(1.808)	-0.280	(1.554)	0.145	(3.905)	0.027	(0.183)	0.880	(1.851)

Table 5. (continued)

Variable	MODEL 1 Direct Effect		MODEL 2 Direct Effect		MODEL 2 Interaction with Mother's Education		MODEL 3 Direct Effect		MODEL 3 Interaction with Income	
Health facilities										
General facilities[5]	-0.039	(0.019)	-0.0825	(0.024)	0.289	(0.378)	-1.163	(0.397)	12.266	(0.980)
Specialized facility[5]	9.893	(1.665)	-9.064	(0.922)	3.925	(2.806)	7.168	(0.909)	20.064	(1.089)
Beds/inpatient health facility	-0.001	(0.291)	0.008	(1.634)	-0.002	(1.943)	0.002	(0.526)	-0.128	(0.759)
Hospital beds										
Any[2]	.	.	.	.	.	.	.	.	.	.
None	2.751	(3.123)	4.272	(3.091)	-0.442	(1.819)	2.328	(2.074)	2.252	(0.594)
Proportion of hospital beds for specialized care	1.490	(2.176)	2.408	(2.212)	-0.261	(1.127)	1.056	(1.349)	2.043	(0.610)
Specialized health-care										
Pediatric facilities[5]	-21.142	(0.648)	96.362	(2.078)	-26.581	(2.401)	24.884	(0.639)	-149.315	(1.455)
Obstetric services[5]	5.395	(2.203)	9.798	(2.613)	-1.286	(1.279)	6.634	(1.926)	-3.944	(0.256)
Gynecologic services[5]	-1.767	(0.685)	6.964	(1.778)	-2.757	(2.449)	4.935	(1.322)	-41.661	(2.384)
Population growth rate[6]	-0.214	(0.751)	-0.001	(0.002)	-0.095	(1.032)	0.235	(0.637)	-3.046	(2.162)
Altitude (km)										
Linear effect	-0.801	(0.520)	-1.064	(0.635)	.	.	-1.293	(0.785)	.	.
Squared effect	0.905	(0.573)	1.176	(0.689)	.	.	1.428	(0.837)	.	.
Monthly temperature (Celsius/10)										
Mean	-16.812	(1.863)	-22.730	(2.265)	.	.	-19.140	(1.944)	.	.
Mean squared	4.101	(1.855)	5.541	(2.252)	.	.	4.636	(1.927)	.	.
Variance	-9.728	(1.269)	-9.322	(1.104)	.	.	-0.013	(1.601)		
Monthly precipitation (meters)										
Mean	0.625	(0.747)	0.249	(0.261)	.	.	0.794	(0.893)	.	.
Variance	-0.618	(1.123)	-0.435	(0.705)	.	.	-0.001	(1.359)	.	.
Number of observations	2042		2042				2042			
Model χ^2 (d.f.)	341.086 (38)		386.940 (58)				365.585 (58)			

1 ( ) contains the z-statistic which is the absolute value of the estimate divided by its standard error. It has an asymptotically normal distribution, with critical values of 1.960 at the five-percent significance level and 1.645 at the ten-percent significance level.

2 Omitted category.

3 Household income is measured in Cr$ 10,000.

4 Water supply, electricity and sanitation variables measure proportion of households with particular type of service.

5 Number of facilities per 1,000 persons.

6 Population growth rate during the period 1970-80.

Although mortality is higher in urban areas than in rural areas of the Northeast, the effect is not statistically significant, confirming previous findings for this region (Goldberg et al., 1984). In the rest of Brazil, however, residence in an urban area is associated with substantially lower mortality, with the survival advantage for children of rural-urban migrants being especially notable, i.e., 91 percent lower than rural residents. In comparison, lifetime urban residents have mortality 62 percent lower than rural residents.[15] What explains the survival advantage of migrants to urban areas in the rest of Brazil? The direction of the effect eliminates the disruption and adaptation hypotheses, and leaves two possible explanations. First, the process of selection from the rural population at risk of moving may yield a group of migrants with characteristics that compare favorably to lifetime urban residents. Second, community characteristics in urban destination areas may be more beneficial for child survival than in rural sending areas. Because municipalities in Brazil are typically part urban and part rural we have no direct way to compare community characteristics for urban and rural areas. Community characteristics are probably better for survival in urban areas than in rural areas, but they may be far worse in neighborhoods in which recent rural migrants reside.[16] If we omit the community variables from Model 1, the urban migrant effect is reduced and the difference in survival chances between children of lifetime urban residents and rural residents becomes statistically insignificant. This suggests that community characteristics may be unfavorable for child survival in some urban areas or for certain segments of the urban population. We therefore conclude that the positive selectivity of in-migrants to urban areas is responsible for the dramatic effect of rural-urban migration that we observe.

The absence of a similar effect for rural-urban migration in the Northeast suggests that the rest of Brazil may be attracting the most select rural-urban migrants from the Northeast with cities in the Northeast being left with the remainder. The nature of rural-urban migration may also be different in the two regions, with rural push-factors dominating in the Northeast and urban attraction operating in the rest of Brazil. Unfortunately, our data are not appropriate for examining these issues.

Community Covariates

In the Northeast, environmental factors emerge as the most significant group of community variables, although local infrastructure also appears to be important. Fewer of the environmental variables but more of the health service variables are significant in the rest of Brazil. The relationship between community variables and child mortality risks is as expected, although some notable exceptions exist.

---

[15] In-migration of households from high mortality areas, such as the Northeast region, has been thought to be partly responsible for high urban mortality and the small rural-urban differential in Brazil (Sawyer and Soares, 1983). Our results suggest that this characterization is no longer true, at least not in the rest of Brazil.

[16] For a vivid description of living conditions in a typical *favela*—a squatter community of urban migrants—see Scheper-Hughes (1991).

Our municipality data set contains information on residential water supply tabulated by both source and type of connection (external/internal plumbing). Preliminary analysis revealed that water source was more strongly related to mortality levels than type of water connection. We therefore consider as covariates the proportion of households receiving network water and the proportion of households receiving well water. Our results indicate that in the Northeast region, an increase of 10 percent in the proportion of households receiving water from a well is associated with a 9 percent reduction in mortality. An increase of the same magnitude in the proportion of households receiving regular network water is associated with a 10 percent decline in mortality. Thus, water quality apparently is quite unimportant compared to availability in the Northeast region. In the rest of Brazil the infrastructure variables are jointly and individually insignificant. Of the many studies that have examined the relationship between child mortality and water supply at the household level,[17] only a few have considered the effects of both quality and quantity of water. These have uncovered findings, not inconsistent with our results, that water quantity has a greater impact than water quality on heath and mortality (Bourne, 1984; Esrey and Habicht, 1988; Victora et al., 1988).

We measure quantity and quality of municipality sanitation services by the proportion of households having a network sewage connection and the proportion of households having no sanitation facilities. The only significant effect occurs in the Northeast a 10 percent increase in households with network sanitation is associated with a 22 percent decline in child mortality. The absence of significant results is consistent with findings from Brazil that have revealed that household toilet facilities are very weakly related to child mortality risks (Victora et al., 1986, 1988). In other parts of the developing world, however, sanitation facilities have been found to be more important than water supply in reducing mortality levels (Habicht et al., 1988).

The presence of a trash collection and public cleaning service in a municipality is associated with 65 percent lower mortality in the Northeast, but although approximately 90 percent of municipalities in both regions have a trash collection and public cleaning service, there is not a statistically significant relationship between this variable and child mortality in the rest of Brazil. Our measures of community infrastructure—water supply, sanitation, electricity and the presence of a trash collection and public cleaning service—are significantly related to child mortality risks, only in the Northeast region. In the rest of Brazil, these effects are individually and jointly insignificant.

The wider availability of education services in preschools and primary schools is not associated with child mortality levels in either region. Mortality is lower in communities with better quality schools, as measured by higher teacher-student ratios. However, the coefficient is statistically significant only for primary schools in the rest of Brazil. Our municipality schooling indicators are intended to capture the effect of education levels among the adult

[17] See Brockerhoff (1990), Butz et al. (1984), Casterline et al. (1989), DaVanzo (1988), DaVanzo and Habicht (1986), Das Gupta (1990), and Mensch et al. (1985). Three studies focussing on Brazil are Merrick (1985), Victora et al. (1986) and Victora et al. (1988).

population in the community. We suspect that these variables are a poor proxy for the education effects we would like to measure. The school situation today may differ from that of the mothers' time either because the relative quality or quantity of schooling across municipalities has changed or because migration is relatively important (Thomas et al., 1991).

Perhaps the most interesting finding regarding our community health service variables is that relatively few of them are significant. For instance, in both the Northeast and the rest of Brazil there are no statistically significant associations between child mortality and the availability of either general or specialized health facilities. Nevertheless, several important results do emerge from our analysis. Allocating a larger proportion of hospital beds to specialized health-care is associated with significantly higher mortality. This evidence is consistent with our hypothesis that areas with health systems oriented more towards specialized, curative services may provide this type of care at the expense of preventive and promotional measures. Our results indicate that in the rest of Brazil, the absence of inpatient facilities in a municipality is associated with a 15-fold increase in the risk of death. This points to the great importance of establishing a basic level of health services in a community. In the Northeast, we find that larger inpatient health facilities are associated with higher child mortality. Thomas and Strauss (1990) discovered similar results in their analysis of child anthropometric outcomes in Brazil. Rather than providing more comprehensive health-care and better facilities, there may instead be dis-economies of scale associated with larger health-care facilities. Furthermore, large facilities may be inappropriate for providing the kind of care that is likely to improve the survival chances of children from disadvantaged households, who constitute the largest number of deaths.

Relatively few of our community education, infrastructure and health-care covariates are statistically significant. There are several possible explanations for this finding. First, sample sizes might be too small to obtain a large set of significant coefficients, particularly since we have a sizeable number of covariates. Second, our modeling approach, which is based upon the assumption that the placement of health facilities and the prevalence of services are exogenously determined, may be incorrect. Finally, the relationship between health service availability and child mortality could be fundamentally different for distinct segments of the population. By ignoring this, we mask the true effects. We shall explore this issue in detail in the following section.

The final set of community variables includes measures of the ecological setting and the physical environment. Taken together, this set of variables is highly significant in the Northeast, but not in the rest of Brazil. In the Northeast, altitude, precipitation and temperature are associated with child mortality levels, whereas in the rest of Brazil, only the positive relationship between temperature and mortality is statistically significant.

There is a quadratic relationship between child mortality and altitude in the Northeast. Almost all the children in this region live at altitudes between 0 and around 600 meters. Within this range, mortality increases rapidly with altitude, reaching a peak at 500 meters before declining slightly. A positive association between altitude and child mortality has been documented elsewhere in Latin America (Edmonston and Andes, 1983) and the adverse physiological and disease effects of high altitude are well known (de Meer, 1993). However, these effects are apparent only at altitudes above 3,000 meters (Edmonston and Andes, 1983; Haas et al., 1982). The significant effects we find in the Northeast are therefore likely to be caused either by omitted socio-economic variables or by ecological factors that are correlated with altitude in this environment.

Higher temperature is associated with higher mortality in the Northeast. In the rest of Brazil there is a quadratic relationship between temperature and mortality, with a trough near the mean of 21 degrees Celsius. This pattern is the exact opposite of that found by Rosenzweig and Schultz (1982) in another study that analyzed the relationship between temperature and child mortality. Note, however, that they did not control for altitude in their study, which uses data from Colombia, and hence they may be picking up the important effect of altitude noted above.

There is a quadratic relationship between precipitation and child mortality in the Northeast. Relative risks are highest in areas with average rainfall that is close to the sample mean of 120 mm per month. Seasonality of rainfall does not appear to have a separate effect in the Northeast; large seasonal variation in temperature is, however, associated with higher mortality.

There is a complicated relationship between climate and child mortality in Northeastern Brazil. Although it may be the case that the climate variables are picking up the effects of omitted variables, this set of variables is more strongly associated with child mortality risks than any of the other sets of community factors. Removing the controls for the municipality socio-economic covariates does not alter these results greatly. However, adding interaction terms (Models 2 and 3) does diminish somewhat the size and significance of the climate effects. This suggests that the climate variables are serving partly as proxies for omitted socio-economic variables that are correlated with climate.

Interactions Between Mother's Education and Community Variables

Model 2 includes interaction effects between maternal education and community socio-economic variables for the Northeast and the rest of Brazil (see Tables 4 and 5, respectively). In both areas the interaction effects are jointly significant for the entire set of community characteristics. Recall that mother's years of education is modeled as a continuous covariate in the rest of Brazil and as a dummy variable distinguishing women with three or more years of schooling from less educated mothers in the Northeast. Although this makes direct comparison of the coefficient values between the two regions somewhat difficult, the results with maternal education modeled as a dummy variable in the rest of Brazil do not differ substantially from those reported here. However, goodness-of-fit is much better with the model specifications that we present here.

Adding interaction effects between maternal education and community infrastructure variables alters our earlier results considerably. The changes are much more important in the Northeast, however, and our discussion focusses on this region. With the exception of household electricity connections, community infrastructure variables emerge as substitutes for maternal education. Consequently, improvements to community sanitation and water supply and the introduction of a public cleaning service are more beneficial for children of less educated mothers, at least in this region of Brazil.

The direct effects of the water variables indicate that for children of less educated mothers, quality of water services is far more important than availability. An increase of 10 percent in the proportion of households receiving network water is associated with 44 percent lower mortality for the children of less educated mothers, while upgrading a similar proportion of households to well water is associated with a reduction in mortality of only 12 percent. The benefits associated with improving the quality of sanitation services appear to be even larger. The net effects of improved community water supply and sanitation for the children of more educated mothers (obtained as the sum of the direct and interaction effects) are small and statistically insignificant. We find similar effects for the presence of a trash collection and a public cleaning service in the community. The presence of these services is associated with 65 percent lower mortality for the children of less educated mothers but with insignificantly lower mortality for the children of more educated mothers.

If the most important effect of an increase in the prevalence of water and sanitation connections at the municipality level were to increase the likelihood of a household having that particular connection, then we would expect a complementary relationship with maternal education. Since we have uncovered a substitutive relationship, we can infer that an increase in high quality water and sanitation connections probably benefits children by changing norms of behavior regarding hygienic practices in the household and/or by improving the general healthiness of the community environment. In the absence of these services, more educated mothers are able to use their knowledge and skills to protect their children from a contaminated environment outside the home and promote hygiene and cleanliness within the home (Cleland and van Ginneken, 1988; Lindenbaum et al., 1989).

The community infrastructure variables for the rest of Brazil remain insignificant in Model 2, except for the measure of high quality sanitation and its interaction with maternal education. The proportion of households connected to the sewerage network emerges as a strong complement to maternal education, however, in contrast to our results for the Northeast. In the rest of Brazil, an increase in network sanitation connections apparently does less to improve the cleanliness of the community or to change norms regarding hygienic practices. The different results in these two regions may be explained by the fact that 25 percent of households in the rest of Brazil are connected to the sewerage network, compared to only 4 percent in the Northeast. This suggests that substitutability between maternal education and community services may change to complementarity as the prevalence of these services increases. We suspect this may be especially true for infrastructure services—beyond some threshold, the public health consequences of improving water supply and sanitation facilities may only accrue to households that actually receive a hookup.

Maternal education serves as a complement to municipality electrical connections in the Northeast. A greater prevalence of household electricity is associated with higher mortality for children of less educated mothers, though the effect is only just significant at the 10 percent level. Although the direct effect is unexpected, the direction of the interaction effect was anticipated. The prevalence of electricity in the municipality is likely to be highly correlated with the presence of an electrical connection in the household, since it reduces the cost of obtaining a hookup. We should note that many households in Brazil receive electricity without payment—a practice that is permitted as a social subsidy for the poor. Our municipality data indicate that in the Northeast (as in the rest of Brazil) over 16 percent of households have an electrical connection without a meter. Since converting the availability of electricity in the household into a survival advantage *requires* knowledge and skills (and investments in electric appliances), maternal education should be a complement, as it in fact is.

Our preschool and primary school interactions seem to offer little insight into the relationship between community education levels and child mortality risks. The only statistically significant finding is that the number of primary schools is a substitute for maternal education in the rest of Brazil. A more interesting result is the substitutive relationship in this region between maternal education and the number of television stations. For the least educated, television is apparently a useful source of information on raising healthy children, though this effect is not estimated with much precision. We suspect that much of this benefit may operate through contraceptive use, which is encouraged by family planning messages and soap operas. The highly significant, positive interaction effect suggests that television is not a source of information for promoting child health for more educated women.

The final set of interactions is between maternal education and community health service covariates. The wider availability of health services generally serves as a substitute for maternal education, whereas greater specialization tends to be complementary. These are consistent findings for both the Northeast and the rest of Brazil.

The direct and interaction effects of the availability of general and specialized health facilities are jointly significant in the Northeast; the insignificant relationships in Model 1 between availability of health facilities and child mortality risks are, therefore, misleading. Greater availability is associated with lower mortality, though only for the children of less educated mothers. Omitting the interaction effects masks this relationship. For children of more educated mothers, the positive coefficient on the interaction effect offsets the negative direct effect, and the net effect of availability is insignificant. A similar pattern emerges in the rest of Brazil, although only for the availability of specialized services is the interaction effect significant. The substitutive relationship between maternal education and availability of both general and specialized health services indicates that these facilities probably improve survival chances of children through the dissemination of information.

Our results indicate that larger health facilities and maternal education are complementary in both regions. Smaller health facilities benefit the children of less educated mothers more than larger health facilities. Smaller facilities are perhaps more likely to be located in rural areas and in residential areas close to more disadvantaged households and apparently are more oriented towards providing health information and teaching women child-care skills.

Having no local health facilities with inpatient care is associated with much higher mortality for children of less educated women in the rest of Brazil. Maternal education complements the absence of inpatient facilities, though our results indicate that the negative impact on child survival is nullified only for children of highly educated mothers (six years or more of education). The disadvantage of having no formal inpatient health facilities in a community is apparently substantial for all but the most educated women.

Women's education complements the availability of specialized services and facilities directly related to maternal and child health. This suggests that these facilities do not play an especially important role in disseminating health-care information. In the Northeast, a higher concentration of facilities providing obstetric and gynecologic services is associated with higher mortality for children of less educated women. In the rest of Brazil, all three measures of specialized maternal and child health-care services are associated with higher mortality for children of uneducated women. This reverse relationship may be caused by the targeting of these facilities to areas with high child mortality. However, knowledge and skills of the type that are provided by formal education are required of mothers to convert the availability of these services into a survival advantage for their children.

Interactions Between Household Income and Community Variables

The interaction effects between household income and our three sets of municipality variables are jointly insignificant for the Northeast region and for the rest of Brazil. Testing the infrastructure, education and health-care interactions separately reveals that each of these three sets of variables is insignificant, again for both regions. Several of the individual interactions are significant. There are, however, few consistent patterns within or across regions. Our lack of statistically significant results is probably the consequence of household income being measured with considerable error in the survey and annual income being a poor indicator of a household's command over resources.

VIII. Conclusions

In this paper we have demonstrated the important relationships between community characteristics and child mortality risks for Brazil. We examined four sets of municipality variables describing infrastructure levels, education services, health-care facilities and ecological setting. Our focus was on estimating and interpreting interaction effects between maternal education and the community variables. The interaction effects provide us with a deeper understanding of the effect of community characteristics on child survival chances by illuminating the most likely pathways through which these variables operate. This information is also useful for predicting who is most likely to benefit from public policies to improve community infrastructure, education, and health-care.

Based on Model 1, which included only the direct effects of community variables, we would conclude that basic infrastructure and ecological setting were the most important community-level covariates of child mortality in the Northeast region. For the rest of Brazil, the results from Model 1 suggested that health facilities played an important role, although the influence of community factors was generally weak in this part of the country. Our results from Model 2 showed that including interaction effects between maternal education and the community variables substantially altered the nature of the relationships between child mortality risks and many of the community characteristics from Model 1. For instance, quality of water supply appears to be far more important than quantity based on our results from Model 2, which is not the conclusion suggested by Model 1. Omitting interaction effects when studying the effects of community variables on child health outcomes may lead to results and policy prescriptions that are misleading. The problem is one of averaging effects for several groups if these work in opposite directions the total effect can be very close to zero although the group-specific effects may all be statistically significant.

One interesting finding from our study is that the nature of complementarity between maternal education and community variables may be altered by changes in community characteristics. We found that maternal education and network sanitation were substitutes in the Northeast region but were complements in the rest of Brazil. Municipalities in the rest of Brazil have a much larger proportion of households with network connections, so the benefits to the community from improving sanitation—such as a cleaner environment and improved awareness of appropriate hygienic practices in the home—are less apparent. Improvements to the sanitation network affect child survival primarily by reducing the cost for a household to obtain a connection.

An important implication is that results may not be generalizable across regions or countries, or for different time periods, since relationships among the same variables may be complementary in some situations but substitutive in others. For instance there is inconsistent evidence on the direction of the interaction effect between maternal education and community water connections in studies of child anthropometry. Barrera (1990) reports the variables to be substitutes in the Philippines, whereas Thomas and Strauss (1990) report complementary effects using Brazilian data. Thomas et al. (1991) and Strauss (1990) find insignificant interaction effects. Although this may be due to these studies using different measures of these variables and statistical techniques, it could be due to different levels of development of the infrastructure in the study areas. Presumably there is a threshold at which the nature of the relationship changes. Knowing the location of this threshold would be very useful information for policy makers in developing countries and a promising area for future research.

In the rest of Brazil, we found a large urban-rural mortality differential that was conspicuously absent in the Northeast region. Mortality was especially low for children of rural-urban migrants in the rest of Brazil; lower, in fact, than for children of lifetime urban residents. Our results suggest that it is the positive selectivity of urban migrants rather than improved living conditions in urban areas that is responsible for this finding. The absence of a similar effect in the Northeast may be a consequence of the rural-urban migration processes being quite different in the two regions. Unfortunately, the data set we worked with is unsuitable for studying these issues further. We encourage researchers interested in this issue to seek out and analyze other available data sets.

Our study examined in detail the relationship between child mortality and community ecological factors. Although environmental variables appear in most conceptual frameworks of child mortality, they seldom appeared in empirical analyses. We uncovered significant relationships in both regions of Brazil, but especially in the Northeast, where altitude, mean temperature and mean precipitation were significantly related to child mortality risks. Part of the altitude and climate effect is presumably due to socio-economic characteristics, since the magnitude of the coefficients and their statistical significance are diminished in models with interaction effects. We suspect that only part of the remaining effect of ecological variables may be due to unmeasured, or perhaps unmeasurable, socio-economic characteristics at the household or community level. Although climate is not a variable open to policy influences, it is possible to design interventions to reduce its harmful effects. Understanding the relationship between climate and health, particularly in the Northeast, appears to us to be a useful topic for future research.

Community characteristics appear to play some role in explaining the large mortality differential between the Northeast and the rest of Brazil. There are large differences between these regions in climate and in the levels and quality of infrastructure, education and health-care. There are also substantial differences in the relationships between these variables and child mortality risks, particularly for infrastructure and climate. Our results for health-care, while not quite consistent for the two regions, suggest that the relatively poor quantity and quality of medical facilities in the Northeast may explain part of the regional mortality differential. For community water supply and sanitation, however, differences in the relationships with mortality indicate that the nature of demand and supply of these facilities at the community level is quite distinct in the two regions. Nevertheless, part of the reason the Northeast has higher mortality is that it has much less basic infrastructure. Finally, interregional migration patterns appear to play a role in increasing the regional mortality differential.

Household-level differences in socio-economic characteristics influence the regional mortality differential, but are also of separate interest. Many of the community services in the Northeast appear to favor the children of less educated mothers, suggesting that improvements in these facilities will not only reduce regional mortality differentials, but will reduce differentials in mortality by education both within the Northeast and for the country as a whole. In particular, connecting households to water and sewerage networks, implementing community trash collection services, and improving the availability of health-care facilities and reducing their average size should result in large reductions in mortality for disadvantaged households in the Northeast. A similar outcome could be achieved for the rest of Brazil by increasing the exposure to messages on child care and family planning in the mass media, establishing a basic level of inpatient care in all communities, and reducing the emphasis on providing specialized care in hospitals.

References

Al-Kabir, A. 1984. Effects of Community Factors on Infant and Child Mortality in Rural Bangladesh. WFS Scientific Reports No. 56. Voorburg, Netherlands ISI.

Arruda, J.M., N. Rutenberg, L. Morris, and E. Anhel Ferraz. 1987. *Pesquisa Nacional Sobre Saúde Materno-Infantil e Planejamento Familiar Brasil—1986.* Rio de Janeiro BEMFAM/IRD.

Banta, H.D. 1986. Medical Technology and Developing Countries The Case of Brazil. *International Journal of Health Services* 16 363-373.

Barrera, A. 1990. The Role of Maternal Schooling and Its Interaction with Public Health Programs in Child Health Production. *Journal of Development Economics* 32 69-91.

Barros, R. and D.O. Sawyer. 1991. Unequal Opportunities to Survive, Education and Regional Disparities in Brazil (Mimeographed). Rio de Janeiro, Brazil IPEA.

Barros, F.C. and C.G. Victora. 1990. Breastfeeding and Diarrhea in Brazilian Children. Demographic and Health Surveys Further Analysis Series, Number 3. Columbia, MD Macro International Inc.

Barros, F.C., C.G. Victora, J.P. Vaughan, and H.J. Estanislau. 1987. Perinatal Mortality in Southern Brazil A Population-Based Study of 7392 Births. *Bulletin of the World Health Organization* 65 95-104.

Becker, G. 1981. *A Treatise on the Family.* Cambridge, MA Harvard University Press.

Behrman, J.R. and A.B. Deolalikar. 1988. Health and Nutrition. Chapter 14 in *Handbook of Development Economics, Vol. I,* ed. H. Chenery and T.N. Srinivasan. Amsterdam Elsevier Science Publishers.

Bourne, P., 1984. Water and Sanitation for All. In *Water and Sanitation Economic and Sociological Perspectives,* ed. P. Bourne, Orlando, FL Academic Press.

Brockerhoff, M. 1990. Rural-to-Urban Migration and Child Survival in Senegal. *Demography* 27 601-616.

Butz, W.P., J-P. Habicht, and J. DaVanzo. 1984. Environmental Factors in the Relationship between Breastfeeding and Infant Mortality The Role of Sanitation and Water in Malaysia. *American Journal of Epidemiology* 119 516-525.

Caldwell, J.C. 1979. Education as a Factor in Mortality Decline An Examination of Nigerian Data. *Population Studies* 33 395-413.

Carvalho, J.A.M. and C.H. Wood. 1978. Mortality, Income Distribution and Rural-Urban Residence in Brazil. *Population and Development Review* 4405-420.

Casterline, J.B., E.C. Cooksey and A.F.E. Ismail. 1989. Household Income and Child Survival in Egypt. *Demography* 26 15-35.

Cleland, J.G. and J.K. van Ginneken. 1988. Maternal Education and Child Survival in Developing Countries The Search for Pathways of Influence. *Social Science and Medicine* 27 1357-1368.

Cox, D.R. 1972. Regression Models and Life Tables (with discussion). *Journal of the Royal Statistical Society* 34 187-220.

Curtis, S.L. and J.W. McDonald. 1991. Birth Spacing and Infant Mortality in Brazil. *Journal of Biosocial Science* 23 343-52.

Curtis, S.L., I. Diamond and J.W. McDonald. 1993. Birth Interval and Family Effects on Postneonatal Mortality in Brazil. *Demography* 30 33-43.

Daly, H.E. 1985. Marx and Malthus in Northeast Brazil A Note on the World's Largest Class Difference in Fertility and Its Recent Trends. *Population Studies* 39 329-338.

Das Gupta, M. 1990. Death Clustering, Mothers' Education and the Determinants of Child Mortality in Rural Punjab, India. *Population Studies* 44 489-505.

DaVanzo, J. 1988. Infant Mortality and Socioeconomic Development Evidence from Malaysian Household Data. *Demography* 25 581-595.

DaVanzo, J. and J-P. Habicht. 1986. Infant Mortality Decline in Malaysia, 1946-1975 The Roles of Changes in Variables and Changes in the Structure of Relationships. *Demography* 23 143-160.

de Meer, K. 1993. *Agriculture and Child Health at High Altitudes.* Thesis. Netherlands Gronigen University.

Denslow, D. and W. Tyler. 1984. Perspectives on Poverty and Income Inequality in Brazil. *World Development* 12 1019-1028.

Edmonston, B. and N. Andes. 1983. Community Variations in Infant and Child Mortality in Peru. *Journal of Epidemiology and Community Health* 37 121-126.

Elo, I.T. 1990. Female Education and the Use of Maternal and Child Health Care Services in Peru. Unpublished Ph.D. dissertation. Princeton University.

Esrey, S.A. and J-P. Habicht. 1986. Epidemiologic Evidence for Health Benefits from Improved Water Supply and Sanitation in Developing Countries. *Epidemiology Review* 8117-28.

Esrey, S.A. and J-P. Habicht. 1988. Maternal Literacy Modifies the Effect of Toilets and Piped Water on Infant Survival in Malaysia. *American Journal of Epidemiology* 127 1079-1087.

Farah, A.A. and S.H. Preston. 1985. Child Mortality Differentials in Sudan. *Population and Development Review* 8 365-383.

Frankenberg, E. 1993. The Effect of Access to Health Care on Mortality An Analysis of Infant Mortality in Indonesia 1980-1987. Paper presented at the 1993 Annual Meeting of the Population Association of America, Cincinnati, OH.

Goldberg, H.I., W. Rodrigues, A.M. Thome, B.S. Janowitz, and L. Morris. 1984. Infant Mortality and Breastfeeding in Northeastern Brazil. *Population Studies* 38(1) 105-115.

Haas, J.D., G. Moreno-Black, E.A. Frongillo Jr., J. Pabon, G. Pareja, J. Ybarnegaray, and L. Hurtado. 1982. Altitude and Infant Growth in Bolivia A Longitudinal Study. *American Journal of Physical Anthropology* 59 251-262.

Habicht, J-P., J. DaVanzo and W.P. Butz. 1988. Mother's Milk and Sewage Their Interactive Effects on Infant Mortality. *Pediatrics* 81 456-461.

Hobcraft, J.N., J.W. McDonald and S.O. Rutstein. 1985. Demographic Determinants of Infant and Early Child Mortality A Comparative Analysis. *Population Studies* 39 363-385.

Holford, T.R. 1980. The Analysis of Rates and Survivorship Using Log-Linear Models. *Biometrics* 36 299-306.

Laird, N. and D. Olivier. 1981. Covariate Analysis of Censored Survival Data Using Log-Linear Analysis Techniques. *Journal of the American Statistical Association* 76 231-240.

Lindenbaum, S., M. Chakraborty and M. Elias. 1989. The Influence of Maternal Education on Infant and Child Survival in Bangladesh. In *Selected Readings in the Cultural, Social and Behavioral Determinants of Health,* ed. J.C. Caldwell and G. Santow. Canberra The Australian National University.

Macedo, C. Director of the Pan-American Health Organization. Comments at a Special Meeting with the Former Minister of Health of Colombia, June, 1984. Cited in Banta. 1986.

McCracken, S.D. 1990. A Multilevel Socio-Demographic Analysis of Early Childhood Mortality in Brazil. Unpublished Ph.D. dissertation. Austin University of Texas.

McCracken, S.D., R.N. Rodrigues and D.O. Sawyer. 1991. Fertility Change and Infant Survival in Brazil, 1970-75 and 1980-85. In *Proceedings of the Demographic and Health Surveys World Conference* Vol. II, pp. 1021-1043. Columbia, MD Macro International Inc.

Mahadevan, K. 1986. Mortality, Biology and Society Analytical Framework and Conceptual Model. In *Fertility and Mortality Theory, Methodology and Empirical Issues,* ed. K. Mahadevan. New Delhi Sage Publications.

Marcotte, J.E. 1988. The Impact of Piped Water on Child Mortality and Breastfeeding in Ecuador and Brazil. Unpublished Ph.D. dissertation. Madison University of Wisconsin.

Mensch, B., H. Lentzner and S.H. Preston. 1985. *Socioeconomic Differentials in Child Mortality in Developing Countries.* Population Study No. 97. New York United Nations.

Merrick, T.W. 1985. The Effect of Piped Water on Early Childhood Mortality in Urban Brazil, 1970 to 1976, *Demography* 22 1-23.

Merrick, T.W. 1986. A População Brasileira a Partir de 1945. In *A Transição Incompleta*, ed. E. Bacha and H.S. Klein. Rio de Janeiro Paz e Terra.

Merrick, T.W. and D.H. Graham. 1979. *Population and Economic Development in Brazil.* Baltimore, MD The Johns Hopkins University Press.

Miller, J.E., J. Trussell, A.R. Pebley and B. Vaughan. 1992. Birth Spacing and Child Mortality in Bangladesh and the Philippines How Much Is Explained by Gestation? *Demography* 29 305-318.

Mosley, W.H. 1984. Child Survival Research and Policy. In *Child Survival Strategies for Research*, ed. W.H. Mosley and L.C. Chen. A supplement to Vol. 10 of *Population and Development Review.*

Mosley, W.H. and L.C. Chen, 1984. An Analytical Framework for the Study of Child Survival in Developing Countries. In *Child Survival Strategies for Research*, ed. W.H. Mosley and L.C. Chen. A supplement to Vol. 10 of *Population and Development Review.*

PAHO. 1990. *Health Conditions in the Americas.* Scientific Publication No. 524, Vol. II. Washington, DC PAHO.

Palloni, A. and S. Millman. 1986. Effects of Inter-Birth Intervals and Breastfeeding on Infant and Early Childhood Mortality. *Population Studies* 40 215-236.

Pebley, A.R. and P.W. Stupp. 1987. Reproductive Patterns and Child Mortality in Guatemala. *Demography* 24 43-60.

Pool, I. 1982. Is New Zealand a Healthy Country? *New Zealand Population Review* 8 2-27.

Rios-Neto, E.L.G, S.D. McCracken and R.N. Rodrigues. 1991. Contraceptive Use and Fertility in Brazil. In *Proceedings of the Demographic and Health Surveys World Conference* Vol. I, pp. 113-134. Columbia, MD Macro International Inc.

Rodrigues, R.N. 1992. Levels and Differentials in Mortality by Diarrhea in Brazil. Paper presented at the 1992 Annual Meeting of the Population Association of America Annual Meeting, Denver, CO.

Rosenzweig, M.R. and T.P. Schultz. 1982. Child Mortality in Colombia Individual and Community Effects. *Health Policy and Education* 2 305-348.

Rosenzweig, M.R. and T.P. Schultz. 1983. Estimating a Household Production Function: Heterogeneity, the Demand for Health Inputs, and their Effects on Birth Weight. *Journal of Political Economy* 91: 723-746.

Rosenzweig, M.R. and K.I. Wolpin. 1986. Evaluating the Effects of Optimally Distributed Public Programs Child Health and Family Planning Interventions. *American Economic Review* 76 470-482.

Rutstein, S.O. 1984. *Socioeconomic Differentials in Infant and Child Mortality.* WFS Comparative Studies (Cross-National Summaries) Preliminary tables. Voorburg, Netherlands ISI.

Ruzicka, L. 1989. Problems and Issues in the Study of Mortality Differentials. In *Differential Mortality Methodological Issues and Biosocial Factors*, ed. L. Ruzicka, G. Wunsch and P. Kane. Oxford Clarendon Press.

Sastry, N., N. Goldman and L. Moreno. 1993. The Relationship between Place of Residence and Child Survival in Brazil. *International Population Conference* Vol. 3, pp. 293-322. Liège IUSSP.

Sawyer, D.O. and K.I. Beltrão. 1991. Healthy Household and Child Survival in Brazil. In *Proceedings of the Demographic and Health Surveys World Conference* Vol. I, pp. 205-222. Columbia, MD Macro International Inc.

Sawyer, D.O. and E.S. Soares. 1983. Child Mortality in Different Contexts in Brazil Variation in the Effects of Socio-Economic Variables. In *Infant and Child Mortality in the Third World.* ParisWHO.

Sawyer, D.O., R. Fernández-Castilla and R.M. Monte-Mor. 1987. The Impact of Urbanization and Industrialization on Mortality in Brazil. *World Health Statistics Quarterly* 40 84-95.

Scheper-Hughes, N. 1992. *Death without Weeping The Violence of Everyday Life in Brazil.* Berkeley, CA: University of California Press.

Schorling, J.B., C.A. Wanke, S.K. Schorling, J.F. McAuliffe, M. Auxiliadora de Souza, and R.L. Guerrant. 1990. A Prospective Study of Persistent Diarrhea among Children in an Urban Brazilian Slum. *American Journal of Epidemiology* 132 144-156.

Simões, C.C. 1989. Novas Estimativas da Mortalidade Infantil 1980-87. In *Perfil Estatístico de Crianças e Mães no Brasil Mortalidade Infantil e Saúde na Década de 80.* Rio de Janeiro IBGE.

Simões, C.C. and L.A.P. de Oliveira. 1986. Evolução da Mortalidade Infantil. In *Perfil Estatístico de Crianças e Mães no Brasil Aspectos Socio-Economicos da Motalidade Infantil em Areas Urbanas.* Rio de Janeiro IBGE.

Spangler, W.M.L. and R.L. Jenne. 1988. World Monthly Surface Station Climatology (mimeographed). National Center for Atmospheric Research. Available as *World Weather Disc Climate Data for the Planet Earth*, on CD-ROM from Weather Disc Associates, Inc.

Strauss, J. 1990. Households, Communities, and Preschool Children's Nutrition Outcomes Evidence from Rural Côte d'Ivoire. *Economic Development and Cultural Change* 38 231-262.

Thomas, D. and J. Strauss. 1990. Prices, Infrastructure, Household Characteristics and Child Height (mimeographed). New Haven Department of Economics, Yale University.

Thomas, D., J. Strauss and M-H. Henriques. 1990. Child Survival, Height for Age and Household Characteristics in Brazil. *Journal of Development Economics* 33 197-234

Thomas, D., J. Strauss and M-H. Henriques. 1991. How Does Mother's Education Affect Child Height? *Journal of Human Resources* 26 183-211.

United Nations. 1986. *Age Structure of Mortality in Developing Countries.* New York United Nations.

Venkatacharya, K. 1985. An Approach to the Study of Socio-Biological Determinants of Infant and Child Morbidity and Mortality. *International Population Conference* Vol. 2. Liège IUSSP.

Victora, C.G., P.G. Smith and J.P. Vaughan. 1986. Social and Environmental Influences on Child Mortality in Brazil Logistic Regression Analysis from Census Files. *Journal of Biosocial Science* 18 87-101.

Victora, C.G., P.G. Smith, J.P. Vaughan, L.C. Nobre, C. Lombardi, A.M. Texeira, S.C. Fuchs, L.B. Moreira, L.P. Gigante, and F.C. Barros. 1988. Water Supply, Sanitation and Housing in Relation to the Risk of Infant Mortality and Diarrhea. *International Journal of Epidemiology* 17 651-654.

Victora, C.G., F.C. Barros, S. Rittuttley, A.M. Texeira, and J.P. Vaughan. 1992. Early Childhood Mortality in a Brazilian Cohort The Roles of Birthweight and Socioeconomic Status. *International Journal of Epidemiology* 21 911-915.

Waldron, I. 1987. Patterns and Causes of Excess Female Mortality among Children in Developing Countries, *World Health Statistics Report* 40 194-210.

Ware, H. 1984. Effects of Maternal Education, Women's Roles, and Child Care on Child Mortality. In *Child Survival Strategies for Research*, ed. W.H. Mosley and L.C. Chen. A supplement to Vol. 10 of *Population and Development Review.*

Wood, C.H. and J.A.M. Carvalho. 1988. *The Demography of Inequality in Brazil.* New York, NY Cambridge University Press.

Wood, C.H. and P.A. Lovell. 1992. Racial Inequality and Child Mortality in Brazil. *Social Forces* 70 703-724.

Demographic and Health Surveys Working Papers Series

---

1 Bicego, George T. and J. Ties Boerma. *Maternal Education, Use of Health Services, and Child Survival: An Analysis of Data from the Bolivia DHS Survey*, December 1990.

2 Pullum, Thomas W. *The Relationship of Service Availability to Contraceptive Use in Rural Guatemala*, October 1991.

3 Chayovan, Napaporn and John Knodel. *Age and Birth Data Reporting in Thailand: Evidence from the 1987 Demographic and Health Survey*, August 1993.

4 Westoff, Charles F. and Germán Rodríguez. *The Mass Media and Family Planning in Kenya*, August 1993.

5 Meekers, Dominique. *Sexual Initiation and Premarital Childbearing in Sub-Saharan Africa*, August 1993.

6 McKinney, Barbara J. *Impact of Rural-Urban Migration on Migrant Fertility in Senegal*, December 1993.

7 Olaleye, David O. *Ideal Family Size: A Comparative Study of Numerical and Non-numerical Fertility Desires of Women in Two sub-Saharan African Countries*, December 1993.

8 Tam, Luis. *Rural-to-Urban Migration in Bolivia and Peru: Association with Child Mortality, Breastfeeding Cessation, Maternal Care, and Contraception*, March 1994.

9 Moreno, Lorenzo. *Residential Mobility and Contraceptive Use in Northeastern Brazil*, February 1994.

10 Martín, Teresa Castro and Fátima Juárez. *Women's Education and Fertility in Latin America: Exploring the Significance of Education for Women's Lives*, May 1994.

11 Bankole, Akinrinola. *The Role of Mass Media in Family Planning Promotion in Nigeria*, April 1994.

12 Vidal-Zeballos, David. *Social Strata and its Influence on the Determinants of Reproductive Behavior in Bolivia*, May 1994.

13 Tórrez Pinto, Hugo. *Características Socioeconomicas y Culturales de Mujeres con Necesidad Insatisfecha en Anticoncepción y su Relación con los Diferenciales de la Fecundidad*, 1994.