COMMUNITY CHARACTERISTICS, INDIVIDUAL AND HOUSEHOLD ATTRIBUTES, AND CHILD SURVIVAL IN BRAZIL*

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This paper presents an analysis of the relationship between community characteristics, household attributes, and child survival in Brazil. The principal objectives are to investigate how the social and environmental context in which a child is raised affects his or her survival chances, and to analyze how household variables modify the effects of community characteristics. The interaction effects we examine help to explain the effects of community characteristics on child survival chances by illuminating the most likely pathways through which these covariates 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.

In this paper we present an analysis of the relationship between 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 his or her survival chances, and to analyze how individual and household characteristics modify the effects of community characteristics. The ultimate goal of this research is to understand the role of community characteristics in shaping child mortality differentials in a developing country.

Community characteristics play two potentially important roles in determining mortality differentials. First, they may influence mortality differentials between areas. Our analysis of community variables therefore should illuminate the spatial pattern of mortality in Brazil. In particular, this analysis should help to explain the factors responsible for the large regional variation in mortality in this country. Second, community characteristics may exacerbate or mitigate mortality differentials based on household socioeconomic attributes by complementing or substituting for certain household attributes. We will examine this issue by studying how community characteristics and household attributes interact.

By including a series of interaction terms in our models we can establish whether local services and infrastructure complement or substitute for household socioeconomic characteristics. This provides important public policy information on the health effects of improvements to local services and infrastructure. For example, if maternal education and the availability of medical facilities complement one another, then an increase in the number of health centers in an area, without a policy to improve women's education, will benefit more greatly the children of better-educated mothers, who have the means, ability, and knowledge to take advantage of the new facilities. If the association is substitutive, it is largely the children of less well-educated mothers who will be made better off; the apparent benefit of maternal education for children's health and survival will be reduced. This would be the case, for instance, if health facilities disseminated information on child care that was otherwise available only to better-educated women. Therefore, knowing the direction and magnitude of the interaction effects should be useful for designing effective policies both to reduce overall child mortality and to reduce child mortality differentials in population groups.

Few studies of child mortality differentials have focused on the role of 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 elsewhere. Most studies have come no closer than examining the effects of region or rural-urban place of residence. Many of these studies interpret significant regional or rural-urban differentials in mortality in terms of the possible effects of omitted community variables, which indicates researchers' and policy makers' interest in the effects of these variables. A further indication of their potential importance is that even in cases where differentials by place of residence are insignificant, community-level variables *still* may be associated significantly with child survival chances, as Sastry, Goldman, and Moreno (1993) have shown.

The scarcity of empirical investigations on the relationship between community variables and child survival is due principally to the limited availability of relevant community data; researchers' failure to identify sources of community data and to combine them with more readily available household survey data is also a contributing factor. The individual-level data analyzed in this study come from a 1986 household survey conducted in Brazil as part of the Demographic

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1. Researchers commonly apply the term community to data collected at the municipality or district level, or use the two terms interchangeably, as we do here.

and Health Surveys (DHS) Program. These data are linked with community variables obtained from Brazilian census bureau data and meteorological records.

PREVIOUS RESEARCH

Community Characteristics and Children's Health and Survival

Of the few studies that have analyzed the association between community variables and children's survival, the majority have focused on the effects of health service availability—widely believed to be the most important place-of-residence characteristic. Furthermore, most of these studies have examined the role of these factors in influencing survival differentials by maternal education. This attention is due to the importance of maternal education as a major socioeconomic determinant of child mortality.[2]

In an analysis of child mortality in Colombia, Rosenzweig and Schultz (1982) uncovered an important substitutive relationship between public health facilities and maternal education in urban areas, and reported that controlling for average education levels in the municipality reduced the positive effect of municipality health services on child survival. In a recent study of child mortality in West Africa conducted by Benefo and Schultz (1994), maternal education emerged as a complement to community water supply in Ghana; the provision of sanitation at the community level complemented maternal education in Côte d'Ivoire. Urban residence and proximity to a health clinic also complemented women's education in Ghana.

Several fairly recent studies have considered the relationship between community characteristics and child health, measured most commonly by anthropometric indicators such as child's height conditional on age and sex. Strauss (1990) found that although indicators of major community health problems were important in determining child health outcomes in rural Côte d'Ivoire, no significant interactions existed 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 related significantly to child health; the first two variables served as substitutes for maternal education and the latter two as complements. Using data on child height from the 1986 Brazil DHS survey, Thomas, Strauss, and Henriques (1991) discovered significant interaction effects between maternal education and the availability of municipality services; health services functioned as a substitute for maternal education, and sewage services served as a complement.

Although the earliest study reviewed here is now more than 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 substitutability or complementarity between household characteristics and community attributes for factors other than maternal education. Knowledge about the consistency of findings across countries, over different periods, and for different indicators of child health is extremely limited. This type of information is important, however, in designing effective intervention strategies for reducing child mortality.

In this study we examine interactions between community characteristics and both maternal education and household income. Although we consider only one country here, we stratify the sample by region of residence, which allows us to examine the consistency of results across two areas with substantially different household and community characteristics.

Child Mortality Differentials in Brazil

The study of child mortality differentials in Brazil has focused primarily on geographic differences between regions and between rural and urban areas, and secondarily on differences by income and education.[3] The principal reason for this focus has been the tremendous spatial diversity within Brazil in the level and pace of social and economic development. Differentials by income and education have tended to mirror the regional differentials, and hence have received somewhat less attention.

In practically every measure of well-being, the Northeast region of Brazil 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. Documented differences between the Southeast and the Northeast in average literacy rates (1.7 times higher in the Southeast), percentage enrolled in school (1.5 times higher), percentage of households with piped water (2.2 times higher), percentage of households with a septic tank (3.4 times higher), and percentage of households with electricity (2.0 times higher) are reflected in differences in life expectancy and infant mortality.[4] Numerous studies have confirmed these differences, which are among the largest in the world. 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% higher in the South than in the Northeast (Merrick 1986).

Although it is been widely known that child mortality rates are substantially higher in the Northeast than in the rest of Brazil, only a few previous studies (Curtis and McDonald 1991; Wood and Lovell 1992) have controlled for region, and almost none have analyzed the covariates of child mortality separately for different regions. 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 between urban and rural child mortality rates tended to be

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

3. See, for example, Carvalho and Wood (1978); Daly (1985); Sastry et al. (1993); Sawyer, Castilla, and Mor (1987); Sawyer and Soares (1983); Simões (1989); Simões and Oliveira (1986); Wood and Carvalho (1988); Wood and Lovell (1992).

4. The differentials in measures of well-being are those for 1980 and are taken from Denslow and Tyler (1984).

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 socioeconomic characteristics on child mortality separately for urban and for 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.

In a study based on aggregate mortality rates calculated from the 1986 DHS, Barros and Sawyer (1991) found that differences in education levels between the Northeast and the rest of Brazil explained only a negligible proportion of the regional differential in infant mortality rates. Rather, the crucial factor appeared to be differences in the relationship between education and child mortality. Sastry et al. (1993), in another study based on the 1986 Brazil DHS data set that included a limited set of municipality variables, uncovered important differences between the two regions in the relationship between community characteristics and child mortality risks.

The results from these studies suggest complex interactions between household characteristics and location attributes, and indicate that detailed community-level data are essential for studying correctly the regional mortality differential in Brazil. Knowledge of the determinants of the observed regional mortality differentials in Brazil thus appears to be improving, but is still incomplete.

CONCEPTUAL FRAMEWORK

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 (1984) framework and the economic model of the family to focus on the effects of three sets of exogenous factors: (1) individual and household socioeconomic and demographic characteristics; (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.

Although the availability of health, sanitation, and other social services is 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 provided and on the household-level variable with which it is interacted. Our study focuses 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 should be a substitute for services that *provide* knowledge, skills, and an environment conducive to raising healthy children. On the other hand, maternal education is likely to complement local services that *require* knowledge and skills.[5] We expect household income to complement community services and infrastructure that require investments in goods and services in order to produce improvements in children's survival chances, and to substitute for community infrastructure and services that are directed to the poor or are provided free or at subsidized prices. We anticipate that higher- quality and more specialized services will complement income and education, whereas basic and nonspecialized services are more likely to serve as substitutes.

In many cases we cannot predict the direction of the interaction effect because the broad measures of availability and quality of community infrastructure and services that are available for this study provide little insight into the primary community effect of these variables. For example, medical facilities can provide information on child care to women who would benefit from adopting the practices in question, 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 for one another, this finding suggests that dissemination of information is the most important role of local medical services in reducing child mortality. A finding of complementarity, on the other hand, would imply that the actual treatment of patients is their primary function. The interaction effects thus clarify, for each community variable, which of its several roles are likely to be primary in this particular setting.

This discussion would not be complete without a warning that community levels of services and infrastructure may not be distributed randomly. As Rosenzweig and Wolpin (1986) argue, community characteristics—especially the concentration of health facilities in a location—may be determined endogenously. 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 services and infrastructure across communities is not systematic, individuals may choose to migrate to communities on the basis of their demand for a particular mix of community services and amenities. In this study, however, we treat all community variables as exogenous because we

5. Education also may (1) provide women with the financial means to take advantage of local services and infrastructure, through higher earnings or selective mating; (2) increase the value of their time; and (3) alter their preferences (Rosenzweig and Schultz 1982). A growing body of evidence, however, suggests that the most important role of maternal education in improving child survival is providing women with the knowledge and skills to raise healthy children. Considerable evidence from numerous studies—beginning with Caldwell's (1979) study of Nigeria—shows that the positive effect of maternal education on child health is not due simply to higher family income. In a recent review of maternal education and child survival in developing countries, the authors note 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: 209) find that "almost all of the impact of mother's education [on child health] can be explained by indicators of her access to information."

lack the necessary data to apply appropriate correction procedures.[6]

DATA AND STATISTICAL METHODS

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 Program. Retrospective maternity histories were collected from 5,892 women age 15 to 44 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 reported in the survey. In this paper we restrict our attention to the mortality experience of the 3,573 singleton births that occurred within five years of the survey.[7] Because the household and community socioeconomic covariates are available only for the time of the interview and because Brazilian living standards changed fairly rapidly 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 socioeconomic conditions than those recorded in the survey, and, especially, in the community data sets. Thus, to ensure that the household and community covariates provide an accurate picture of actual living conditions, we restrict the sample to births in the last five years.

Preliminary analysis for the entire country (not shown) revealed that the relationships between the covariates and child mortality for the Northeast were different from the corresponding relationships for the rest of Brazil. Consequently we stratified the sample, separating the Northeast from the rest of Brazil. For the rest of Brazil we subsequently combined all observations in the South and Southeast regions and dropped those in the North and Central West. We combined all observations for the South and the Southeast for two reasons. First, regional dummy variables were generally insignificant when these data were pooled. Second, when analyzed separately, the relationships between child mortality risks and each of the important covariates were similar for the two regions. Covariate effects were distinct in the North and the Central West, but observations from these areas did not constitute large enough samples to permit separate analyses.

During the five-year period preceding the survey, 153 deaths occurred among the 1,435 births in the Northeast region and 1,651 births and 75 deaths occurred in the South/Southeast region. Infant mortality rates (${}_1q_0 \times 1{,}000$) are estimated to be 105.2 and 122.9 respectively for urban and rural areas of the Northeast (see Table 1). These rates are roughly twice as high as in the South/Southeast for rural areas (122.9 versus 64.5) and nearly three times as high for urban areas (105.2 versus 37.4). Under-five mortality rates (${}_5q_0 \times 1{,}000$) for the South/Southeast are 74.8 for rural areas and 43.8 for urban areas; in the Northeast, the corresponding rates are 145.8 and 114.8.

TABLE 1. INFANT AND UNDER-FIVE MORTALITY BY REGION AND LOCATION OF RESIDENCE 1981–1986

	South/Southeast		Northeast	
	Rural	Urban	Rural	Urban
${}_1q_0$	64.52	37.38	122.89	105.18
	(11.88)	(4.47)	(11.85)	(10.95)
${}_5q_0$	74.14	43.84	145.81	114.79
	(12.44)	(5.15)	(13.36)	(11.51)

Note: Standard errors in parentheses; all entries × 1,000.

We obtained community data from two sources. The primary source is the *Informações Básicas Municipais*, an occasional data series assembled by Fundação Instituto Brasileiro de Geografia e Estatística, the Brazilian federal 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 databases 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 that provided the municipality name for each primary sampling unit. Ninety municipalities in the Northeast region and 145 in the South/Southeast are included in the DHS sample.

Our community data actually were collected at the municipality level. Municipalities in Brazil can be fairly large, both in population and in area.[8] Although definitions of 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 speak of communities.

We extracted climate data for Brazil from the *World Monthly Surface Station Climatology* (Spangler and Jenne 1984), an international data set assembled by the U.S. National Center for Atmospheric Research. Monthly temperature and precipitation are collected regularly from 60 weather stations in Brazil, some of which have been reporting continuously for more than 100 years. Households were assigned climate data from the nearest weather station, based on its coordinates and those of the municipality in which the household is located.

6. To treat community variables as endogenous in the present context would require a set of instrumental variables. Unfortunately, a useful set is not available. In addition, instrumental-variable estimation procedures for hazard models have not been developed to the point where they are easy to apply to models with a large number of observations and covariates. 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 such estimates would eliminate the community variables.

7. We exclude multiple births from our analysis because these children experience substantially higher mortality, which is associated principally with their multiplicity.

8. Brazil contains 4,088 municipalities, with an average population of 29,800 and an average area of 2,118 km^2.

We employ 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); its principal advantage is the ability to accommodate censored observations and time-varying covariates. We adopt a variant of the original model that considers events in discrete time. Although the hazard function, or the age-specific death rate, is continuous, the events of death and censoring are reported for discrete ages. The risk of death therefore is considered constant within the reported age intervals, which we combine if there are insufficient events in finer age ranges, and the baseline hazard is represented by a step function. This feature of the model has made it known as the piecewise exponential model. Holford's (1980) and Laird and Olivier's (1981) finding 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 with conventional statistical software.

We employed two additional modeling approaches in this paper. First, to examine the effects of individual-level unobserved heterogeneity, we estimated hazard models with child-specific frailty.[9] Second, to assess the consequences of correlation among observations due to the hierarchical clustering of the data, we used a multilevel hazard model with family- and community-level random effects.[10] The presence of individual-level unobserved heterogeneity is always a concern in demographic research; the hierarchical clustering of child survival data by family and community arises from the sample design of the Brazil DHS-1 survey.

INDIVIDUAL, HOUSEHOLD, AND COMMUNITY COVARIATES

Individual and Household Covariates

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 mother's current and childhood place of residence. Table 2 provides a list of these variables, together with their means and standard deviations or the percentage in category, as appropriate.

The child's age is the most fundamental determinant of the hazard of death. 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. These categories ensure a reasonable number of deaths in each age interval and maintain a parsimonious description of the baseline hazard. Preliminary explorations revealed that the overall results were robust to the age categories selected, in agreement with Curtis and McDonald's (1991) experience with the same data set.

In the absence of discriminatory allocation of resources and care, male children experience higher mortality than female children (Waldron 1987); hence sex is included as a covariate in our models. We find no indication of sex discrimination in Latin America,[11] though there is evidence that male births were underreported in rural Northeast Brazil during the period 1981–1986 (Sastry 1995b). Including sex as a covariate ensures that the existence of correlation between underreporting of male births and other covariates will not result in biased parameter estimates.

Considerable evidence indicates the harmful consequences for child survival of childbearing at younger and older maternal ages.[12] To account for the nonlinear relationship between a mother's age at her child's birth and the child's survival chances, we include maternal age and age squared as covariates in the model.

We incorporate an income covariate to control for the socioeconomic status of the household. This covariate also captures the household's financial ability to secure goods and services that promote better health, help to maintain a more hygienic environment, and ensure adequate nutrition levels. A negative relationship between income and child mortality has been established in several household-level studies in developing countries (Casterline, Cooksey, and Ismail 1989). Three studies focusing on Brazil have found higher levels of household income to be associated significantly with improved chances of child survival (Merrick 1985; Thomas et al. 1990; Victora, Smith, and Vaughan 1986). Interactions between income and community characteristics will demonstrate how a family's ability to pay for goods and services allows it to take advantage of beneficial community attributes and to shield itself from other attributes that have deleterious consequences for child survival.

Total household income includes earnings of the mother and father as well as other household income. The mother's earnings component of this variable may be determined endogenously: women who work bring in additional household income, but may have less time available to care for their children. We experimented with removing mother's earnings from household income, but found only small changes in the coefficient in both regions.

To control for community characteristics that differ between urban and rural areas but are not available in our data set, we include place of residence as a covariate. We realize

9. Specifically, we estimate a piecewise exponential hazard model with gamma distributed individual-level unobserved heterogeneity. We specified gamma-frailty because of growing evidence that results are likely to be insensitive to the choice of frailty distribution (Guo and Rodríguez 1992; Rodríguez 1994). Under these circumstances, the gamma distribution has the advantages of a flexible shape and analytical tractability. Previous research has made wide use of this distribution (Clayton 1978; Oakes 1982; Vaupel, Manton, and Stallard 1979). Although results may be more sensitive to the functional form of the baseline hazard, the piecewise exponential specification is an appropriate choice because it provides great flexibility. Furthermore, preliminary analysis revealed that some simpler hazard functions, such as the Weibull, did not fit the data well.

10. The multilevel hazard model for hierarchically clustered data (Sastry 1995a) specifies the baseline hazard as piecewise exponential, and both the family- and the community-specific random effects as following the gamma distribution.

11. See Rutstein (1984) or United Nations (1986) for estimates of sex differentials in mortality, none of which provide any indication of discrimination either in Brazil or elsewhere in Latin America.

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

TABLE 2. SUMMARY STATISTICS FOR INDIVIDUAL VARIABLES USED IN STATISTICAL ANALYSIS OF CHILD SURVIVAL

Variable	South/Southeast Mean or Percentage in Category	South/Southeast SD	Northeast Mean or Percentage in Category	Northeast SD
Sex				
Female (%)	47.30		49.59	
Male (%)	52.70		50.41	
Maternal Age	25.82	5.89	26.44	6.48
Mother's Years of Education	5.47	3.98	3.79	7.48
Total Household Income (Cr$)	3,273.24	5,807.06	1,240.49	2,491.43
Place of Residence				
Lifetime urban (%)	63.66		38.53	
Rural-to-urban migrant (%)	10.78		11.50	
Rural (%)	25.56		49.97	
Number of Births	1,651		1,435	
Number of Deaths	75		153	

that a woman's place of residence may be a choice variable, but without fuller data on her background characteristics this treatment is the most effective way to account for omitted individual and community variables that reflect the important differences between the rural and the urban environment. To investigate the effects of the mother's childhood place of residence, we subclassify children living 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 to an urban area. Previous studies have shown that a woman's migration has a strong negative association with her children's risk of death. Brockerhoff (1990) Farah and Preston (1985), and Mensch, Lentzner, and Preston (1985) suggest 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 faced by migrants in adapting to their new surroundings; and (4) disruption caused by the move itself.

Community Covariates

The community-level covariates in our study include measures of health care availability and specialization, of the prevalence of water, electric, and sewage connections, and of the existence of garbage disposal services, as well as indicators of the availability and quality of education services. Environmental covariates consist of several climate measures. Table 3 contains a list of these covariates with their means and standard deviations or the percentage in category, as appropriate.

Several indicators of the availability of different types of formal health care facilities exist for each municipality. We include as covariates a number of measures 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 mothers' and children's health. Our indicators of general availability are the numbers of general and specialized health care facilities per person. We expect higher availability to be associated with greater accessibility to health care services and with lower average costs. Both of these covariates therefore should be associated with lower overall mortality. For two reasons, however, we may not find this result. First, as mentioned previously, is the possibility of reverse causation: the targeting of facilities to areas of especially high mortality and/or the attraction of a select group of households to areas with good health care facilities. Second, resources may be allocated to specialized, curative facilities and treatments to the detriment of preventive and promotional measures that may bring greater benefits to the less advantaged segments of the population.[13] The degree of specialization in the municipality provides us with one measure—albeit crude—of the orientation of the local health system.

13. Curative health care services were allocated about 85% 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 emphasizes specialized, high-technology, curative health care (Banta 1986). The magnitude of this effect was such that in 1981 the total health expenditure on 12,000 high-cost patients was greater than the amount spent to provide basic health care and disease control for 41 million people (Barnum and Kutzin 1993). Another result is a high level of waste and duplication: it has been estimated that 10 to 30% of medical procedures at the secondary and tertiary levels are unnecessary (Banta 1986).

TABLE 3. SUMMARY STATISTICS FOR COMMUNITY VARIABLES USED IN STATISTICAL ANALYSIS OF CHILD SURVIVAL

Variable	South/Southeast Mean or Percentage in Category	South/Southeast SD	Northeast Mean or Percentage in Category	Northeast SD
Household Water Supply				
Percent with regular network water	54.50	26.67	30.14	24.52
Percent with well water	38.34	25.24	26.90	19.51
Percent of Households with Electric Connection	57.99	20.41	38.55	26.80
Household Sewage Connection				
Percent with regular network sanitation	29.27	28.22	4.23	10.38
Percent with no sanitation	17.21	17.29	57.22	26.94
Trash Collection/Public Cleaning Service				
Neither or one (%)	12.41		7.78	
Both (%)	87.59		92.22	
Education				
Preschools per 100,000 persons	18.65	15.25	23.13	31.63
Preschool teachers per student	.06	0.06	0.04	0.02
Primary schools per 100,000 persons	157.37	120.30	234.80	157.64
Primary school teachers per student	.05	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	14.18	9.25	14.70	13.63
Specialized facilities	2.45	3.01	1.29	2.01
Beds Per Inpatient Health Facility	89.21	65.76	46.08	42.53
Hospital Beds				
Any (%)	92.41		84.44	
None (%)	7.59		15.56	
Percent of Hospital Beds for Specialized Care	88.31	25.96	72.11	41.72
Specialized Health Care Facilities (per Person × 100,000)				
Specialized pediatric facilities	.28	0.62	.21	0.44
Facilities providing pediatric services	12.10	7.50	10.87	11.06
Specialized obstetric/gynecologic facilities	.09	0.25	.22	1.19
Facilities providing obstetric services	10.98	7.90	10.55	9.34
Facilities providing gynecologic services	10.21	6.76	7.55	6.10
Total Population (× 1,000)	234.12	842.37	117.99	250.79
Population Density (Persons per km²)	591.72	1,550.64	407.37	1,352.39
Percent Urban	67.97	26.80	46.75	29.06
Percent Growth of Population (1970–1980)	33.15	54.88	29.75	31.01
Monthly Temperature (Celsius)				
Mean	20.47	2.00	25.82	1.11
Standard deviation	2.44	8.14	1.03	2.41
Monthly Precipitation (mm)				
Mean	119.58	15.35	120.68	39.11
Standard deviation	63.70	33.29	88.12	28.93
Number of Municipalities	145		90	

Because a smaller number of facilities per person may be due to the larger average size of facilities, we control in our models for the average number of beds per inpatient facility. Smaller facilities may be associated with lower mortality if they provide more personalized care. Larger facilities, however, may be better equipped and may provide a wider range of services (Thomas et al. 1991). Several municipalities lack any inpatient facilities; we include a dummy indicator variable to distinguish these localities. The availability of three types of specialized medical facilities—for pediatric, gynecologic, and obstetric care—may be associated directly with lower child mortality levels.

Our community infrastructure covariates include indicators of the prevalence and quality of municipality water, electricity, and sanitation services. Residential water supply is tabulated by both source and type of connection (external or internal plumbing). Preliminary analysis revealed that water source is related more strongly to mortality levels than is the type of water connection. Therefore we consider as covariates the proportion of households in the municipality that receive water through the regular network and the proportion that obtain water from a well. The proportion of households with electricity indicates the extent of electrification at the municipal level. The proportions of households (1) with a network sewage connection and (2) with no sewage disposal facilities are our two measures of municipal sanitation services. Finally, a dummy variable marks municipalities offering both trash collection and a public cleaning service.

Most studies of the relationship between child mortality and sanitation or water connections have considered indicators at the household level (Esrey and Habicht 1986). Measured at the municipality level, these variables capture three 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 the presence of an electrical connection at the household level are likely to be correlated highly with availability at the municipal level because the wider availability of these utilities makes it easier and cheaper for a household to obtain a connection. For electricity, we would expect this to be the principal effect because a household connection is likely to be crucial if the availability of electricity is to have a positive effect on child survival.

We are interested in the relationship between community education levels and child mortality; we would expect this to be relatively consequential because this covariate is important at the individual level. Unfortunately the only measures available from our community data set are the numbers of preschools and primary schools in each municipality. Teacher-student ratios in pre- and primary schools indicate the quality of education.

Our municipality schooling indicators are partly intended to capture the effect of education levels in the adult population in the community. These measures, however, are likely to be quite sensitive to our assumptions that facilities are placed randomly and that migration is relatively unimportant (Thomas et al. 1991). Nevertheless, schools may be important for reducing child mortality in their own right; they may disseminate information to mothers in the community on nutrition, child care, and prevention and treatment of illness. In Brazil, schools are at the center of government programs to improve children's health and nutrition, such as the National School Lunch Program (PNAE) and the National Milk Program for Needy Children (PNLCC). More than half of the federal government expenditure on nutrition programs in Brazil is allocated through school-based programs (World Bank 1991).

Community education levels may affect child mortality 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, McCracken, and Rodrigues 1991). As an indicator of exposure to mass media messages, we include as a covariate in our models the number of television stations received in the municipality.

The final set of community covariates describes the ecological and environmental setting and includes measures of precipitation and rainfall. Following Rosenzweig and Schultz (1982), we test for quadratic effects of mean annual temperature and precipitation. Greater seasonality in precipitation and temperature may be associated with higher mortality levels, where seasonality is measured by the variance of average monthly precipitation and temperature. In the Northeast, where diarrhea is estimated to be responsible for 30 to 40% of child deaths (Barros and Victora 1990; Rodrigues 1992), the incidence of the disease follows a seasonal pattern (Schorling et al. 1990).

RESULTS

In Tables 4 and 5 we present the results of our hazard model analysis for the Northeast and for the South/Southeast. For each region we estimated three different models. The first model provides estimates of the additive effects of individual, household, and community variables on a child's mortality risk. The second adds interactions between maternal education and the community variables. We also estimated a third model that adds interactions between household income and community variables; the results from this model are discussed briefly in the text but are not presented in the tables. We examined duration-dependent effects in the three models by including interactions between child age and the measured covariates. We found some significant coefficients but no consistent set of results, and consequently do not discuss these results.

Only results based on the standard hazard model are presented in this paper.[14] We found that under the full model

14. The results from estimating the individual-level frailty model and the multilevel model for hierarchically clustered data are available to interested readers on request.

specifications, the effects of individual-level unobserved heterogeneity were negligible in the Northeast. Although the individual-level frailty effect was statistically significant in the South/Southeast, the results were not altered so far as to change any of the basic findings or conclusions presented here. Family- and community-level frailty effects were individually insignificant in both the Northeast and the South/Southeast, and the effects of the clustered sampling scheme on parameter estimates and standard errors were found to be small and unimportant in both regions.

Individual and Household Covariates

Our results show that the standard relationships between child mortality risks and individual and household covariates hold in both the Northeast and the South/Southeast. The hazard rate declines steadily with child age and is slightly lower for girls. Childbearing at younger and older maternal ages is associated with higher mortality, though the relationship is not strong.

The estimated effects of maternal education on child mortality in Brazil correspond closely to results from elsewhere in the developing world (Cleland and van Ginneken 1988): a one-year increase in mother's education is associated with an 8% decline in the risk of death in the South/Southeast region (see Model 1 in Table 5).[15] We find a strong nonlinear effect of maternal education in the Northeast in contrast to results for the South/Southeast. To avoid the need to include a quadratic term for mother's years of education in the Northeast—which would complicate the analysis of interaction effects—we model this variable as a factor in this region. We distinguish uneducated or poorly educated mothers (with fewer than three years of schooling) from mothers with three or more years of education. Because of differences between the two regions in relationships and in the levels of educational attainment, this breakpoint is not meaningful in the South/Southeast; in fact, no single breakpoint in the South/Southeast reveals the important association between maternal education and child survival. In the Northeast, when we control for all other covariates, mortality among the children of better-educated mothers is 28% lower (see Model 1 in Table 4). The effects of maternal education are statistically significant at the .10 level in both regions.

An increase in household income is associated with significantly lower mortality in the Northeast region, but its effect is insignificant in the South/Southeast. Although mortality is higher in urban areas than in rural areas of the Northeast, this effect is not statistically significant; thus previous findings for this region are confirmed (Goldberg et al. 1984). In the South/Southeast, however, residence in an urban area is associated with substantially lower mortality. The survival advantage for children of rural-urban migrants in the South/Southeast is especially notable: we estimate the risk of death to be 92% lower for rural-urban migrants than for rural residents. In comparison, mortality among lifetime urban residents is 73% lower than among rural residents.[16]

What explains the survival advantage for children of migrants to urban areas in the South/Southeast? The direction of the effect eliminates the disruption and adaptation hypotheses, which may be either unimportant or offset by stronger effects in the opposite direction. Two possible explanations are left. First, the process of selection from the rural population at risk of moving may yield a group of migrants with characteristics that compare favorably with those of lifetime urban residents. Second, community characteristics in urban destination areas may be more beneficial for child survival than in rural sending areas. They may be far worse, however, in neighborhoods in which recent urban migrants reside. Because municipalities in Brazil are typically part urban and part rural, we have no direct way to compare community characteristics for urban and for rural areas. Nevertheless, 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 of rural residents becomes statistically insignificant. This finding suggests that community characteristics may be unfavorable for child survival in some urban areas or for certain segments of the urban population. Therefore we conclude that the positive selectivity of in-migrants 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 South/Southeast may be attracting the most select rural-urban migrants from the Northeast, while cities in the Northeast are left with the remainder. The nature of rural-urban migration also may differ in the two regions: rural push factors may dominate in the Northeast, and urban attraction may operate in the South/Southeast. 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 South/Southeast. The relationship between community variables and child mortality risks is as expected, although some notable exceptions exist. The community covariates are jointly significant in the Northeast ($\chi^2_{24}=50.2$, $p = .001$) and in the South/Southeast ($\chi^2_{25} = 42.0$, $p = .018$).

15. The coefficients in the tables are interpreted as relative risks, or multiplicative effects 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. Thus we interpret the exponentiated coefficient for mother's years of education in Model 1 of Table 5 as a multiplicative effect on the risk of death of exp(−0.079) = 0.924; this value indicates that the child's relative risk of death decreases approximately 8% for each additional year of mother's education.

16. In-migration of families from high-mortality areas, such as the Northeast region, has been thought to be partly responsible for high urban mortality and for the small rural-urban difference in Brazil (Sawyer and Soares 1983). Our results suggest that this characterization is no longer true, at least not in the South/Southeast region.

TABLE 4. RESULTS FOR HAZARD MODEL ANALYSIS OF CHILD SURVIVAL, NORTHEAST OF BRAZIL

Variable	Model 1 Additive Effect		Model 2 Additive Effect		Model 2 Interaction with Mother's Education	
Main Effect	−13.518**	(2.34)	−9.617	(1.62)		
Age						
0 months[a]	—	—	—	—	—	—
1–5 months	−1.279**	(6.75)	−1.267**	(6.69)	—	—
6–11 months	−1.821**	(8.39)	−1.789**	(8.24)	—	—
12–23 months	−3.828**	(10.05)	−3.788**	(9.94)	—	—
24–59 months	−4.766**	(9.17)	−4.729**	(9.09)	—	—
Sex						
Female[a]	—	—	—	—	—	—
Male	0.197	(1.23)	0.198	(1.21)	—	—
Maternal Age						
Linear effect	−0.103	(1.03)	−0.121	(1.18)	—	—
Squared effect	0.002	(1.17)	0.002	(1.33)	—	—
Mother's Education						
Less than three years[a]	—	—	—	—	—	—
Three years or more	−0.333*	(1.77)	0.331	(0.13)	—	—
Total Household Income[b]	−1.458**	(2.16)	−1.482**	(2.16)	—	—
Place of Residence						
Rural resident[a]	—	—	—	—	—	—
Lifetime urban resident	0.318	(1.39)	0.201	(0.79)	—	—
Rural-to-urban migrant	0.303	(1.06)	−0.055	(0.17)	—	—
Water Supply						
Regular network water[c]	−1.199	(1.29)	−4.254**	(3.35)	7.367**	(3.38)
Well water[c]	−1.089**	(2.06)	−1.294*	(1.82)	0.151	(0.13)
Electricity						
Electrical connection[c]	−1.218	(0.78)	4.142*	(1.87)	−10.030**	(2.93)
Sanitation						
Regular network sanitation[c]	−2.560	(1.58)	−20.806**	(2.62)	20.000**	(2.43)
No sanitation[c]	−1.238	(1.35)	−1.270	(1.10)	0.553	(0.25)
Trash Collection/Public Cleaning						
Neither[a]	—	—	—	—	—	—
Both	−0.897*	(1.68)	−1.031*	(1.77)	0.791	(0.53)
Preschools						
Per person	−0.044	(0.10)	−0.923	(1.29)	1.766*	(1.66)
Teacher/student ratio	−2.706	(0.48)	−8.756	(1.30)	21.744	(1.43)
Primary Schools						
Per person	0.061	(0.46)	0.206	(1.23)	−0.444*	(1.71)
Teacher/student ratio	0.761	(0.08)	5.908	(0.54)	−36.482*	(1.77)
Number of Television Stations	−0.135	(1.05)	−0.215	(1.24)	0.175	(0.68)
Health Facilities						
General facilities[d]	0.297	(0.32)	−2.418*	(1.74)	4.201**	(1.97)
Specialized facilities[d]	3.137	(0.45)	−17.176*	(1.73)	39.113**	(2.74)
Beds/Inpatient Health Facility	0.008**	(1.96)	0.015**	(2.64)	−0.016*	(1.78)

(continued on next page)

(Table 4 continued from previous page)

Variable	Model 1 Additive Effect		Model 2 Additive Effect		Model 2 Interaction with Mother's Education	
Hospital Beds						
Any[a]	—	—	—	—	—	—
None	−0.336	(0.73)	−0.191	(0.38)	−0.440	(0.35)
Proportion of Hospital Beds for Specialized Care	0.261	(0.62)	−0.536	(1.20)	1.999*	(1.66)
Specialized Health Care						
Pediatric services[d]	−0.990	(0.74)	1.993	(1.12)	−6.217**	(2.02)
Obstetric/gynecologic facilities[d]	−2.801	(0.26)	29.652**	(2.17)	−70.281**	(2.49)
Population Growth Rate[e]	−1.174**	(2.20)	−0.555	(0.88)	−2.243*	(1.79)
Monthly Temperature (Celsius/10)						
Mean	0.485**	(2.63)	0.393**	(2.05)	—	—
Variance	10.011**	(2.50)	5.747	(1.28)	—	—
Monthly Precipitation (Meters)						
Mean	4.646**	(2.34)	3.261	(1.54)	—	—
Mean squared	−1.932**	(2.11)	−1.372	(1.43)	—	—
Variance	0.362	(0.78)	0.006	(0.01)	—	—
Number of Observations	1,435		1,435			
Model Chi-Square (df)	387.66 (35)		445.79 (54)			

$^{*}p < .10$; $^{**}p < .05$

Note: z-statistics in parentheses.

[a]Omitted category.

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

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

[d]Measured in number of units per 1,000 persons.

[e]Population growth rate during the period 1970–1980.

Water quality is much less important than availability in the Northeast region, according to our results. A 10% increase in the proportion of households receiving water from a well is associated with a 10% reduction in mortality (see Table 4); an increase of the same magnitude in the proportion of households receiving regular network water is associated with an 11% decline in mortality. In the South/Southeast 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 both the quality and the quantity of water. These have found, somewhat in keeping with our results, that water quantity has a greater impact than water quality on health and mortality (Bourne 1984; Esrey and Habicht 1988; Victora et al. 1988).

We found no significant effects on child mortality of improvements in community sanitation, either in the Northeast or in the South/Southeast. This absence of significant results is consistent with findings from Brazil revealing that household toilet facilities are related very weakly to child mortality risks (Victora et al. 1986; Victora et al. 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, DaVanzo, and Butz 1988).

The presence of both trash collection and a public cleaning service in a municipality is associated with 59% lower mortality in the Northeast and 61% lower mortality in the South/Southeast. In both regions the effect is statistically significant at .10 level. Approximately 90% of municipalities in both regions have trash collection and public cleaning services (see Table 3). Overall our measures of community infrastructure—water supply, sanitation, electricity, and the presence of a trash collection and public cleaning service—are related significantly to child mortality risks almost exclusively in the Northeast region.

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

TABLE 5. RESULTS FOR HAZARD MODEL ANALYSIS OF CHILD SURVIVAL, SOUTH/SOUTHEAST OF BRAZIL

	Model 1		Model 2			
Variable	Additive Effect		Additive Effect		Interaction with Mother's Education	
Main Effect	3.582	(0.85)	6.361	(1.18)	—	—
Age						
0 months[a]	—	—	—	—	—	—
1–5 months	–2.652**	(8.92)	–2.238**	(8.87)	—	—
6–11 months	–3.207**	(8.79)	–3.182**	(8.72)	—	—
12–23 months	–5.227**	(7.24)	–5.184**	(7.17)	—	—
24–59 months	–5.088**	(8.52)	–5.012**	(8.39)	—	—
Sex						
Female[a]	—	—	—	—	—	—
Male	–0.100	(0.43)	–0.104	(0.43)	—	—
Maternal Age						
Linear effect	–0.154	(1.07)	–0.177	(1.15)	—	—
Squared effect	0.003	(0.96)	0.003	(0.98)	—	—
Mother's Years of Education	–0.079*	(1.91)	–0.961	(0.74)	—	—
Total Household Income[b]	0.076	(0.29)	0.071	(0.24)	—	—
Place of Residence						
Rural resident[a]	—	—	—	—	—	—
Lifetime urban resident	–1.296**	(2.88)	–1.322**	(2.64)	—	—
Rural to urban migrant	–2.519**	(3.58)	–2.785**	(3.76)	—	—
Water Supply						
Regular network water[c]	3.432	(1.62)	2.528	(0.84)	1.142	(1.22)
Well water[c]	1.514	(0.78)	2.349	(0.83)	0.646	(0.65)
Electricity						
Electrical connection[c]	1.245	(0.68)	0.755	(0.26)	0.097	(0.13)
Sanitation						
Regular network sanitation[c]	–0.401	(0.57)	2.832**	(2.19)	–0.778**	(3.62)
No sanitation[c]	–1.107	(0.44)	–2.020	(0.55)	–0.168	(0.18)
Trash Collection/Public Cleaning						
Neither[a]	—	—	—	—	—	—
Both	–0.938*	(1.68)	–2.011**	(2.15)	0.236	(1.38)
Preschools						
Per person	–1.015	(0.72)	–1.690	(0.73)	0.179	(0.41)
Teacher/student ratio	–8.395*	(1.79)	–16.148**	(2.27)	1.419	(0.84)
Primary Schools						
Per person	–0.089	(0.37)	–0.476	(1.31)	0.151*	(1.75)
Teacher/student ratio	–14.174	(0.60)	–7.777	(0.23)	0.884	(0.13)
Number of Television Stations	0.122	(0.98)	–0.461**	(2.37)	0.166**	(3.77)
Health Facilities						
General facilities[d]	–0.122	(0.05)	–1.463	(0.33)	0.384	(0.40)
Specialized facility[d]	10.365*	(1.83)	–7.498	(0.73)	3.440**	(2.24)
Beds/Inpatient Health Facility	–0.001	(0.27)	0.009*	(1.80)	–0.003**	(2.37)
Hospital Beds						
Any[a]	—	—	—	—	—	—
None	2.018**	(2.16)	3.557**	(2.46)	–0.735**	(2.60)

(continued on next page)

(Table 5 Continued from previous page)

Variable	Model 1 Additive Effect		Model 2 Additive Effect		Model 2 Interaction with Mother's Education	
Proportion of Hospital Beds for Specialized Care	0.548	(0.72)	1.540	(1.29)	−0.510*	(1.72)
Specialized Health Care						
Pediatric facilities[d]	−17.119	(0.52)	94.893**	(2.46)	−25.883**	(2.13)
Obstetric services[d]	6.197**	(2.10)	10.215**	(2.47)	−0.857	(0.81)
Gynecologic services[d]	−3.492	(1.25)	7.969*	(1.79)	−3.710**	(2.76)
Population Growth Rate[e]	−0.575	(1.40)	−0.454	(0.67)	−0.038	(0.35)
Monthly Temperature (Celsius)						
Mean	−0.143	(1.59)	−0.185*	(1.82)	—	—
Variance	−1.922**	(2.50)	−2.115**	(2.48)	—	—
Monthly Precipitation (meters)						
Mean	0.056	(0.04)	−0.789	(0.45)	—	—
Variance	−1.258**	(2.16)	−1.251*	(1.82)	—	—
Number of Observations	1,651		1,651			
Model Chi-Square (df)	313.02 (35)		357.15 (55)			

*$p < .10$; **$p < .05$

Note: z-statistics in parentheses.

[a]Omitted category.

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

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

[d]Measured in number of units per 1,000 persons.

[e]Population growth rate during the period 1970–1980.

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 schools, as measured by higher teacher-student ratios, though the coefficient is statistically significant only for preschools in the South/Southeast.

A larger concentration of medical facilities that provide only specialized health care is associated with significantly higher mortality in the South/Southeast. A similar finding emerges for specialized obstetric care. In neither region is greater specialization of health facilities or greater availability of specialized health facilities associated with significantly lower mortality. This evidence is consistent with our hypothesis that areas with health systems oriented toward specialized, curative services may provide this type of care at the expense of preventive and promotional measures. Overall, relatively few of our community health service variables are statistically significant. In both the Northeast and the South/Southeast, for instance, we found no significant associations between child mortality and the availability of general health facilities.

The results in Table 5 show that in the South/Southeast, the absence of inpatient facilities in a municipality is associated with a sevenfold increase in the risk of death. This finding indicates 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 (1992) discovered similar results in their analysis of child anthropometric outcomes in Brazil. Rather than providing more comprehensive health care and better facilities, larger installations may imply diseconomies of scale. 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. We suggest three possible explanations for this finding. First, sample sizes may be too small to produce a large set of significant coefficients, particularly because we have a sizable number of covariates that tend to be correlated fairly highly. Second, our modeling approach, which is based on the assumption that the placement of health facilities and the prevalence of community services are determined exogenously, may be incorrect. Finally, it may be that the relationship between availability of health service and child mortality differs fundamentally among distinct segments of the population, and that we mask the true effects by ignoring this difference. In the following section we explore this last issue in detail.

The final set of community covariates consists of measures of climate and precipitation that indicate the ecological setting of the community. Taken together, these variables are highly significant in the Northeast, and are significant at the .10 level in the South/Southeast.

In the Northeast, higher average temperature is associated with higher mortality, and a quadratic relationship exists between precipitation and child mortality. Relative risks are greatest in areas with average rainfall that is close to the sample mean of 120mm per month. Seasonality of rainfall does not appear to have a separate effect in the Northeast; large seasonal variation in temperature, however, is associated with significantly higher mortality. In the South/Southeast, levels of precipitation are not associated with child mortality risks. There is weak evidence that lower average temperature is associated with lower mortality, the opposite of the finding for the Northeast region. Greater seasonality in both temperature and precipitation is related to significantly lower levels of child mortality in the South/Southeast.

In Brazil a complicated relationship exists between climate and child mortality. Although it may be that the climate variables are picking up the effects of omitted variables, this set of variables is associated strongly with child mortality risks, especially in the Northeast. Our results are not altered greatly by removing the controls for the municipality socioeconomic covariates. The addition of interaction terms (Model 2), however, diminishes both the size and the significance of the climate effects, but only in the Northeast. This suggests that the climate variables are serving partly as proxies for omitted socioeconomic covariates which are correlated with climate in this region. In the South/Southeast, however, the effects of climate become more important in the models with interactions. We suspect that the effect of ecological variables may be due only partially to unmeasured, or perhaps unmeasurable, socioeconomic characteristics at the household or community level in this part of Brazil. 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 South and Southeast regions, appears to us to be a useful topic for future research.

Interactions between Mother's Education and Community Covariates

To investigate the nature of complementarity and substitutability between community characteristics and maternal education, we include interactions between these covariates in Model 2 of Tables 4 and 5. The addition of interactions alters our earlier results considerably, although the changes are much more important in the Northeast. Consequently our discussion focuses more heavily on this region. In both the Northeast and the South/Southeast, however, the interaction effects are jointly significant for the entire set of community characteristics. Recall that mother's education is modeled as a continuous covariate in the South/Southeast and as a dummy variable—distinguishing women with three or more years of education from less highly educated women—in the Northeast. This difference makes it somewhat difficult to draw direct contrasts between the two regions based on the magnitudes of the coefficient values. However, it does not affect comparisons between models with and without interactions or comparisons based on the direction of the additive and the interactive effects, which we discuss in this section.

With the exception of household electricity connections, community infrastructure variables emerge as substitutes for maternal education in the Northeast. Improvements to community sanitation and water supply and the introduction of a public cleaning service are consequently more beneficial for children of less well-educated mothers, at least in this region of Brazil.

The additive effects of the community water supply variables show that for children of less highly educated mothers, the quality of water is far more important than availability. A 10% increase in the proportion of households receiving network water is associated with 35% lower mortality for the children of less well-educated mothers, while upgrading an equal proportion of households to well water is associated with only a 12% reduction in mortality. The benefits associated with improving the quality of sanitation services appear to be more important: reducing the proportion of households with no sanitation service has no significant effect, but a 10% increase in the proportion of households with network sanitation connections reduces mortality by 88%, a remarkably large effect. The net effects of improved community water supply and sanitation for the children of better-educated mothers (obtained as the sum of the additive and the interactive effects) are small and statistically insignificant. We find similar effects for trash collection and public cleaning services. The presence of these services in the community is associated with 64% lower mortality for the children of less well-educated mothers but with insignificantly lower mortality for the children of better-educated mothers.

If the most important effect of an increase in the prevalence of water and sanitation connections at the municipality level were an increase in the likelihood that a household would have that particular connection, we would expect a complementary relationship with maternal education. Yet because 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. When water supply and sanitation services at the community level are limited, better-educated mothers apparently can use their knowledge and skills to protect their children from a contaminated environment outside the home and to promote hygiene and cleanliness within the home (Cleland and van Ginneken 1988; Lindenbaum, Chakraborty, and Elias 1989).

The community infrastructure variables for the South/Southeast 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 sewage network emerges as a strong complement to maternal education, however, in contrast to our results for the Northeast. In the South/Southeast, an increase in network sanitation connections apparently does less to improve the cleanliness of the community or to change norms regarding hygienic practices. Rather, it indicates that improvements in the provision of infrastructure at the community level simply increase the likelihood that a household will obtain a sanitation connection.[18] The differences in results for these two regions may be explained by the fact that 25% of households in the South/Southeast are connected to the sewage network, compared with only 4% in the Northeast. These figures suggest that substitutability between maternal education and community services may change to complementarity as these services become more prevalent. We suspect that this may be especially true for infrastructure services: beyond some threshold, the public health consequences of improving water supply and sanitation facilities may accrue only to households that receive a hookup.

Maternal education complements municipality electrical connections in the Northeast. Greater prevalence of household electricity is associated with higher mortality for children of less well-educated mothers. Although the additive effect is unexpected, the direction of the interactive effect was anticipated. The prevalence of electricity in the municipality is likely to be correlated highly with the presence of an electrical connection in the household because it reduces the cost of obtaining a hookup. Many households in Brazil receive electricity without charge—a practice that is permitted as a social subsidy for the poor. Our municipality data show that in the Northeast (as in the South/Southeast) more than 16% of households have an electrical connection without a meter. Because converting the availability of electricity in the household into a survival advantage *requires* knowledge and skills (as well as investments in electric appliances), maternal education should be a complement, and in fact it is.

Our preschool and primary school interactions seem to offer little insight into the relationship between community education levels and child mortality risks. A more interesting result is the substitutive relationship between maternal education and the number of television stations in the South/Southeast. For the least educated, television is apparently quite a useful source of information on raising healthy children. We suspect that much of this benefit may operate through contraceptive use, which is encouraged by family-planning messages and soap operas. Increased contraceptive use should promote child survival by increasing birth spacing and reducing high-risk births among teenagers and among women near the end of the childbearing years. The highly significant, positive interaction effect suggests that television is not a source of information for promoting child health among better-educated women.

The final set of interactions is between maternal education and community health service covariates. Wider availability of health services generally serves as a substitute for maternal education; greater specialization tends to be complementary. These findings are consistent for both the Northeast and the South/Southeast.

The additive and interactive effects of the availability of general and specialized health facilities are jointly significant in the Northeast; therefore the insignificant relationships, in Model 1, between availability of health facilities and child mortality risks are somewhat misleading. Greater availability is associated with lower mortality, though only for the children of less well-educated mothers. Omission of the interaction effects masks this relationship. For children of better-educated mothers, the positive coefficient on the interactive effect offsets the negative additive effect, and the net effect of greater availability of health services is essentially zero. A similar pattern emerges in the South/Southeast, although the interactive effect is significant only for the availability of specialized services. The substitutive relationship between maternal education and availability of both general and specialized health services suggests that these facilities probably improve children's survival chances through the dissemination of information.[19]

Our results show that larger health facilities complement maternal education in both regions. Smaller health facilities apparently provide greater benefits to the children of less well-educated mothers than do larger facilities. Smaller facilities perhaps are more likely to be located in rural areas and in residential areas close to less advantaged households. Evidently they are more oriented toward providing health information and teaching women child care skills—that is, providing primary health care.

Absence of local health facilities with inpatient care is associated with much higher mortality for children of less well-educated women in the South/Southeast while maternal education complements the absence of inpatient facilities in both regions. Our results show that in the South/Southeast the negative effect on child survival is nullified only for children of highly educated mothers (six or more years of education). The disadvantage of having no formal inpatient health facilities in a community seems to be substantial for all but the best-educated women.

Women's education complements the availability of specialized services and facilities directly related to mater-

18. The direction, magnitude, and significance of the interaction effect between maternal education and the prevalence of community sanitation services are quite robust to the inclusion of household indicators of both sanitation and water supply (including interactions of these variables with maternal education). Moreover, the household-level indicators are statistically insignificant, both individually and jointly. This finding suggests that community indicators of availability actually may be providing a more accurate measure of household variables than direct reports from the survey. Recall that the household-level covariates measure conditions *at the time of the interview*. The situation in the past—even in the recent past—may have been quite different. This may be especially true for Brazil in the early 1980s because during that period the proportion of households receiving sewage connections and piped water increased rapidly as a result of PLANASA, a national program to improve sanitation infrastructure begun in the 1970s (see Merrick 1985). Because our community indicators describe conditions in the early 1980s rather than in 1986, they may reflect more accurately the household circumstances under which children were exposed to the risk of death.

19. It could be the case, however, that when health care facilities are not available locally, better-educated women are able to access them elsewhere when they need them.

nal and child health. This suggests that these facilities do not play an especially important role in disseminating information on health care. In the Northeast, a higher concentration of facilities providing obstetric and gynecologic services is associated with higher mortality for children of less well-educated women. In the South/Southeast, all three measures of specialized maternal and child health care services are associated with significantly higher mortality for children of uneducated women. This reverse relationship may be caused by targeting these facilities to areas with high child mortality or by allocating resources to these facilities rather than to primary or preventive health care facilities. Yet mothers require knowledge and skills of the type provided by formal education in order to convert the availability of these services into a survival advantage for their children.

Interactions between Household Income and Community Characteristics

Interactions between household income and community characteristics provide information on how family financial resources can complement or substitute for community services and infrastructure. For both the Northeast region and the South/Southeast these interaction effects are jointly insignificant (results not shown). Separate tests of the infrastructure, education, and health care interactions reveal that each of these three sets of variables is insignificant, again for both regions. Although several of the individual interactions are significant, we find few consistent patterns within or across regions. Probably we lack statistically significant results because household income is measured with considerable error in the survey and because annual income is a poor indicator of a household's command over resources.

DISCUSSION

The relationships between child mortality risks and many of the community characteristics considered here vary substantially by the level of maternal education. For instance, the quality of water supply is important for promoting child survival, but only for the children of less well-educated mothers; the net effect for children of better-educated mothers is negligible. The problem with models that omit interactions is that they average effects over different groups: the total effect can be very close to zero if these effects work in opposite directions, although all of the group-specific effects may be statistically significant and sizable.

These results suggest that policies to increase child survival by improving living conditions can be more effective if interventions are targeted to specific population subgroups. Information on the direction of interaction effects is also useful for predicting who is most likely to benefit from public policies to improve community infrastructure, education, and health care. Finally, the interaction effects demonstrate more clearly the effect of community characteristics on children's survival chances by illuminating the most likely pathways through which these variables operate.

The relationship between maternal education and community variables may be altered by changes in the prevalence of community services. We found that maternal education and network sanitation were substitutes in the Northeast region but were complements in the South/Southeast. Municipalities in the South/Southeast have a much larger proportion of households with network connections, so the benefits to the community due to improving sanitation—such as a cleaner environment and greater awareness of appropriate hygienic practices in the home—are less apparent.[20] Improvements to the sanitation network in this region affect child survival primarily by reducing a household's cost of obtaining a connection.

An important implication is that results may not be generalizable across regions or countries, or for different periods, because relationships between given variables may be complementary in some situations but substitutive in others. For instance, the evidence is inconsistent on the direction of the interaction effect between maternal education and community water connections in studies of child anthropometry. Barrera (1990) reports that these variables are substitutes in the Philippines; Thomas and Strauss (1992) report complementary effects in Brazilian data from the mid-1970s. Thomas et al. (1991) and Strauss (1990) find insignificant interaction effects in Northeast Brazil and in Côte d'Ivoire respectively. Although this difference may be due to the use of different measures of these variables as well as different statistical techniques, it also could be due to differences in 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 for policy makers in developing countries, and a promising area for future research.

Community characteristics play some role in explaining the large difference in mortality between the Northeast and the South/Southeast. These regions differ greatly in climate and in the level and quality of infrastructure, education, and health care. Substantial differences also exist in the relationships between these variables and child mortality risks, particularly for infrastructure and climate. Our results for health care, although 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 difference in mortality. For community water supply and sanitation, however, differences in the relationships with child mortality suggest 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 why mortality is higher in the Northeast is that the region has much less basic infrastructure.

Household-level differences in socioeconomic characteristics influence the regional mortality differential, but also are of separate interest. Many of the community services in the Northeast appear to favor the children of less

20. Differences in education between the two regions also may play a role here. Women in the South/Southeast may be schooled about the benefits of a cleaner environment and specific hygienic practices. Alternatively, public information messages that educate mothers about the importance of hygiene may be correlated with the availability of sanitation.

well-educated mothers; this suggests that improvements in these facilities will reduce not only regional mortality differentials, but also differentials in mortality by education, both in the Northeast and for the country as a whole. In particular, connecting households to water and sewage networks, implementing community trash collection services, 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 South/Southeast 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 health system's emphasis on providing specialized care.

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