Inter-American Development Bank
Banco Interamericano de Desarrollo
Latin American Research Network
Red de Centros de Investigación
Research Network Working paper #R-386

Health, Climate and Development in Brazil: A Cross-Section Analysis

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August 2000

Cataloging-in-Publication data provided by the
Inter-American Development Bank
Felipe Herrera Library

Health, climate and development in Brazil : a cross-section analysis / by Elca Rosenberg … [et al.].

p. cm. (Research Network Working papers ; R-386)
Includes bibliographical references.

1. Health--Brazil--Effect of Climatic changes on--Econometric models. 2. Infant--Mortality--Brazil--Effect of Climatic changes on--Econometric models. 3. Environmental health--Brazil.
I. Rosenberg, Elca, 1946-. II. Inter-American Development Bank. Research Dept. III. Latin American Research Network. IV. Series.

306.461 H385--dc21

Inter-American Development Bank
1300 New York Avenue, N.W.
Washington, D.C. 20577

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Abstract[*]

This study uses a cross-section of Brazilian municipal data in an attempt to estimate the impact of climate changes on the pattern of disease morbidity and infant mortality. Brazil is a country with climate conditions that range from tropical rain forest to temperate savanna regions in the southern part of the country. When one travels from north to south and west to east, and from sea level to altitudes of 1,300 meters, it is possible to examine the results of a stochastic process and a range of global warming experiences. Therefore looking at the relationship between health and climate in Brazil could help to explain the impact of climate change on the health of the population. The objective of this study is to understand the relationship between health and climate after taking into account the interaction between man and nature represented by the level of economic development and the effects of policies to create a more (or less) adequate life environment.

The model is estimated for each morbidity group using a Tobit estimation procedure due to data censoring. For infant mortality the estimation procedure utilized is Ordinary Least Square because data censoring was not a problem. The impact of climate variables is analyzed using confidence intervals generated by bootstrapping the marginal effect due to changes in climate variables. The same procedure is carried out for other explanatory variables such as level of education and population density. All these confidence bounds are estimated at the regional level.

Key words: health, data censoring, marginal effects

[*] This study was supported by the Inter-American Development Bank and by the Pronex Program of the Ministerio de Ciência e Tecnologia under the Nemesis Project. This paper is part of a larger project with the participation of Sandra Utsumi, Natalia Batista, Claudia Monteiro and Ignez M. Tristão. Rita Barradas was part of the main project team's work, and without her valuable advice on the medical interpretation of the data this study could not have been made. The authors thank them for their valuable contributions and comments in several parts of this paper but as usual the authors are responsible for the remaining errors.

1. Introduction

If, as many scientists predict, average global temperatures and rainfall increase over the next century, the welfare of Brazilians could be adversely affected. Coastal development, agriculture,[1] water supplies, health and other societal systems are at risk. Ecosystems will be exposed to temperatures higher than any seen in the last 125,000 years.[2] There is a growing consensus that, over the last hundred years, the increase in greenhouse gases has contributed to a warming of the earth's surface by between 0.3^{o} and 0.6^{o} C, with a measurable rise in average sea level of about 10 to 25 cm. Depending on how emissions of greenhouse gases continue to evolve in the future, it is predicted that over the next century the global mean temperature may increase by 1^{o} to 4^{o} C and sea level might rise by another 15 to 90 cm, with a consequent increase in average evaporation and precipitation (allowing for regional variations in all measurements).[3] It is not ruled out that temperate zones might present, in the near future, patterns similar to the tropical regions, both worldwide as well as within Brazil. As mentioned by Fagan[4] in his climatic history of human civilization, climatic anomalies–droughts, floods, temperature extremes–affect people's lives and the institutions and societies they build.

A look at existing world poverty maps indicates a greater concentration of the world's poor in tropical areas where temperatures are higher and the environment is more humid. In a country the size of Brazil, with its geographical and climatic diversity, one would expect a similar distribution of poverty, with a higher prevalence of selected diseases–and higher mortality and morbidity rates–in the warmest areas and in areas with certain rainfall or geographic patterns.

There is a growing concern among physicians and climatologists that significant climate changes could create even greater health problems in areas already affected, while introducing new problems in other areas which at present are relatively immune to certain diseases. A direct consequence of such a change might be a sharp rise in heat-related mortality, as thermal stress is associated with cardiovascular and respiratory morbidity and mortality. Indirect effects would encompass the range and activity of vector-borne and infectious parasitic diseases (including malaria, dengue, schistosomiasis, leishmaniasis) and water and food-borne diseases (including cholera), as well as other diseases. Other impacts of climate change on health may be due to changes in food productivity or related to stratospheric ozone depletion, which might be responsible for increases in skin cancers, cataracts and possibly immune suppression.[5] In most cases, indirect effects can only be perceived after a long delay.

[1] See Evenson and Alves (1999) and Sanghi *et al.* (1997) for a discussion of possible global change impacts on Brazilian agriculture and possible policy actions foreseen to mitigate some of the eventual damages.

[2] See Smith *et al.* (1995) for a discussion of the possible consequences of global warming, which presents six studies, commissioned by the U.S. Environmental Protection Agency, on potential climate change's impacts on coastal resources, agriculture, rivers, health and vegetation in developing countries. Also see Houghton *et al.* (1992).

[3] See Phelps (1996).

[4] See Fagan (1999) for an analysis of El Niño and the fate of civilizations.

[5] See Kalkstein and Guanri (1995) for evidence of the impact of heat waves on mortality rates for the U.S. and China. A relevant discussion about direct and indirect effects of climate changes on health status can also be found in Martens (1998) and in McMichael *et al.* (1996).

How can public health scientists predict and monitor the population health impact of this new challenge? Not surprisingly, the World Health Organization considers the health consequences of global warming to be among the major pressing problems of the twenty-first century.[6] It is necessary to detect and predict these effects early on so that countermeasures and coping mechanisms can be developed and introduced.

This paper aims to contribute to the discussion through the development of a model to predict the impact of selected climatic variables on morbidity patterns for selected groups of diseases. More specifically, the paper proposes to analyze the direct effects of increases in temperature and rainfall, as well as indirect effects of other geographic/climatic variables such as altitude and distance from the sea. The paper is based on data at the level of the *municipio* (a government unit consisting of a city or town and the surrounding area) for all Brazilian states. The data is reported at the municipio level by three government agencies (see below). This report is organized as follows: Part 2 discuses diseases patterns in Brazil. In Part 3, the econometric specifications are discussed. Part 4 reports estimates of climate effects on morbidity and infant mortality based on the municipio-level database. Part 5 concludes.

2. Morbidity for Selected Diseases and Infant Mortality in Brazil by Regions

2. A. Morbidity

Five disease groups and three individual diseases were selected for the paper. The selection took into account a number of criteria: i) the extent to which a disease is expected to be associated with climate; ii) the magnitude of the problem (including the assessment of the risk of becoming ill or of dying as a result of the disease); iii) the relevance or transcendence of the problem (i.e., the qualitative measurement related to its economic, social, and political impact and the epidemic potential); iv) the vulnerability of the problem (i.e., the existence of appropriate, accepted and economically effective technology for the prevention and treatment of the conditions resulting from the problem); and v) the availability of relevant data sources. Based on these criteria, the following diseases were included in the paper: cardiovascular diseases, respiratory diseases, vector-transmitted diseases, water-borne diseases, cholera, malaria, and meningitis. The group of diseases classified under tumors was also included to serve as a control group, since neoplasms were not expected to be directly related to climatic variables.

Table 1 presents the rates of hospitalization per 10,000 inhabitants for the selected groups of diseases, in each state of the Brazilian Federation.

Cardiovascular diseases (*Cardiac*): This group represents the principal cause of death in Brazil, accounting for 30% of total registered deaths. The mortality rate is 160.72 deaths per 100,000 inhabitants, with the south and southeastern regions of the country presenting the highest rates. These diseases also account for 16.2% percent of total expenditures for all treatment by the public health system in Brazil. This group of diseases comprehends three major diseases: coronary diseases, ischemia and cardiac insufficiency. Rates of hospitalization for cardiovascular diseases have varied from 18.13 cases per 10,000 inhabitants in the state of

[6] See WHO (1990).

Amazonas to 125.51 cases per 10,000 inhabitants in Distrito Federal. The distribution of cardiovascular diseases is associated with two types of determining factors: greater occurrence in the past of chronic cases of Chagas disease in areas of epidemic transmission, and the process of urbanization and industrialization.

Respiratory diseases (*Respiratory*): This group constitutes one of the major causes of death among young children and the elderly, and it represents around 11% of the total mortality rate. These diseases account for 52.35 deaths per 100,000 inhabitants, representing 15.2% of federal health system expenditures in Brazil. The major respiratory diseases are pneumonia and bronco-pneumonia, influenza and obstructive diseases such as asthma, emphysema, and chronic bronchitis. While respiratory diseases strike more often in the south and southeast regions of Brazil, hospitalization for respiratory diseases does not differ much among the states, with the least number observed in Amazonas and the greatest in Distrito Federal. In respiratory diseases, as in water-borne diseases, the majority of the cases do not require hospitalization. Therefore, the data presented here serve as indicative of the real occurrence of the problem. It is necessary to take into account that the proportion of actual cases to cases that required hospitalization can vary among regions according to the population's access to basic health services.

Table 1

Rates of Hospitalization (10,000 inhabitants) per Disease and State, 1996

State	Cardiovascular*	Water-borne**	Neoplasm *	Respiratory *	Vector ***
Rondônia	51.42	65.33	7.34	201.18	37.34
Acre	21.45	55.68	9.93	141.48	43.02
Amazonas	18.13	32.92	7.83	96.25	17.39
Roraima	19.03	24.17	3.26	105.48	27.81
Pará	39.93	98.64	22.13	184.92	17.88
Amapá	35.37	39.43	2.05	112.84	35.90
Tocantins	73.72	70.88	7.98	246.99	8.39
Maranhão	54.48	69.33	18.66	241.19	2.92
Piauí	61.15	72.70	19.05	199.27	0.66
Ceará	52.11	78.56	19.43	193.52	0.45
Rio Grande Norte	40.76	69.46	23.15	166.70	1.26
Paraíba	89.20	65.16	21.16	215.71	0.42
Pernambuco	60.84	61.91	16.85	173.22	0.53
Alagoas	41.89	92.67	17.22	195.11	0.44
Sergipe	39.23	34.36	15.04	141.59	0.84
Bahia	58.93	66.19	23.86	188.91	1.21
Minas Gerais	106.45	37.71	43.17	195.53	0.23
Espírito Santo	70.64	33.26	20.83	164.51	0.10
Rio de Janeiro	82.03	26.38	21.13	143.08	0.08
São Paulo	68.03	16.73	27.84	126.57	0.11
Paraná	88.06	34.74	21.27	208.85	0.10
Santa Catarina	94.79	49.79	23.99	227.52	0.04
Rio Grande Sul	97.72	40.88	33.50	250.17	0.03
Mato Grosso Sul	55.44	50.29	6.32	165.86	0.03
Mato Grosso	75.48	46.60	13.23	228.97	3.50
Distrito Federal	125.51	18.89	5.40	334.68	0.00
Goiás	79.81	27.75	14.64	163.88	0.32

* groups according to the International Classification of Diseases (ICD 10)
** cholera, typhoid fever and diarrhea
***malaria, leishmaniasis and dengue

Table 2
Rates of Hospitalization for Cholera, Malaria and Meningococcal Meningitis by State, 1996

State	Cholera*	Malaria**	Meningitis*
Rondônia	0.00	41.59	0.00
Acre	6.20	22.96	0.00
Amazonas	2.50	32.32	0.00
Roraima	0.00	163,02	0.00
Pará	0.00	21.89	0.00
Amapá	0.00	52.06	0.00
Tocantins	0.00	16.98	0.00
Maranhão	0.60	3.81	0.00
Piauí	0.00	0.05	0.00
Ceará	0.10	0.01	4.20
Rio Grande Norte	1.20	0.01	0.00
Paraíba	3.30	0.00	0.00
Pernambuco	3.30	0.00	4.10
Alagoas	14.80	0.00	0.20
Sergipe	1.60	0.00	0.00
Bahia	1.20	0.00	0.00
Minas Gerais	0.00	0.01	0.00
Espírito Santo	0.00	0.06	0.00
Rio de Janeiro	0.00	0.00	0.00
São Paulo	0.00	0.01	5.50
Paraná	0.00	0.02	3.10
Santa Catarina	0.00	0.01	8.80
Rio Grande Sul	0.00	0.00	3.20
Mato Grosso Sul	0.00	0.03	0.20
Mato Grosso	0.00	10.39	0.00
Distrito Federal	0.00	0.00	0.00
Goiás	0.00	0.08	1.30

* rates per 100,000 inhabitants ** rates per 1,000 inhabitants

Vector transmitted diseases (*Vector*): This group includes malaria, dengue and leishmaniasis. The mortality rate is not very high for these diseases, but they strongly disable the people stricken by them, causing physical as well as economic hardship, usually to the poorest people in developing countries like Brazil. Of these diseases, malaria is one of the most important health problems in Brazil. In the 1950s the number of malaria cases was as high as eight million, and at present it is close to 600,000. The incidence rate ranges from around one case per 1,000 inhabitants in the southern parts of Brazil to close to 50 cases per 1,000 inhabitants in the northwestern areas of Brazil. Leishmaniasis occurs mainly in the north, northeast and center western regions of Brazil. It used to be believed that leishmaniasis would decline as deforestation increased. This was not the case, however, in Brazil. Beginning in the 1980s, the incidence of this disease was on the rise, striking even in the metropolitan areas of the southeast. It is also a disabling rather than lethal disease. The rate of incidence of leishmaniasis is around 30 cases per 100,000 inhabitants in Brazil. Dengue has been on the rise in Brazil in the last decades. It had disappeared as a disease in Brazil and came back starting in the northern state of Roraima in 1982. In 1986 it reached Rio de Janeiro, Ceará and Alagoas. From there on it spread to all states of Brazil, reaching the present level of 150,000 cases. The risk associated with the spreading of dengue is the increasing probability of a dangerous as well as less dangerous variety of the disease. Hemorrhagic dengue, a particularly dangerous variety, has been noticed in some parts of the country in recent years.

Hospitalizations for vector transmitted diseases range from 0.03 cases per 10,000 inhabitants in Rio Grande do Sul to 43.02 cases per 10,000 inhabitants in Acre. These hospitalizations appear to exist in accordance with the presence of the vectors in the territory; they also seem to follow the pattern of the predominant endemic diseases, since the need for hospitalization is different for each of the diseases selected for the paper. The pattern observed from the available information indicates that hospitalization is mostly related to the more serious cases of malaria, and possibly to a few cases of visceral leishmaniasis. As for cutaneous leishmaniasis and dengue, hospitalization is very seldom required. Unfortunately, it was impossible to obtain information on the notified cases of cutaneous leishmaniasis or of dengue, which would have allowed a more appropriate analysis of these health problems.

Water transmitted diseases (*Hydric*): This disease group includes diarrheas, typhoid fever and cholera. Cholera has been on the rise in Brazil. It entered Latin America through Peru in 1991, also reaching Brazil in 1991, and spread throughout the Amazon's rivers and the northeastern seacoast. Although cholera presents a low lethality rate, it has a high potential for epidemics. Rates of hospitalization for water-borne diseases have ranged from 16.73 cases per 10,000 inhabitants in the state of São Paulo to 98.63 cases per 10,000 inhabitants in Para, a distribution strongly associated with the sanitary conditions prevailing in each state. Information on rates of hospitalization reflects only the occurrence of the more severe cases of cholera, typhoid fever and diarrhea, thus indicating only the approximate distribution of these diseases. Nevertheless, since there are no data on medical consultations for this group of diseases, hospital morbidity is the only available information.

Tumors (*Control*): Tumors constitute the second most important cause of mortality, accounting for 12% of deaths in Brazil, and they have been steadily climbing in recent years, following a pattern similar to that displayed by cardiac diseases. The mortality rate associated with tumors or neoplasm in Brazil is around 61.27 deaths per 100,000 inhabitants. Rates of

hospitalization due to neoplasm are associated with the technological capacity for diagnosis available as well as the proportion of the population that is elderly in each state. In view of the large variety of determining factors associated with neoplasm, it is not possible to establish a relationship between the frequency of hospitalization for this condition and the presence of risk factors among the population. However, as the majority of neoplasms are somewhat associated with products and processes derived from industrialization, it is expected that regions with higher levels of urbanization and industrialization will present a greater concentration of cases.

The cases of **cholera** registered in 1996 occurred in no more than ten states, with the incidence varying between 0.10 cases per 100,000 inhabitants in Ceara and 14.80 cases per 100,000 inhabitants in Alagoas. The distribution of the cases of cholera is directly related to sanitation conditions and to the presence of sources of infection.

The incidence for **malaria** varied between 0.01 cases per 1,000 inhabitants in Santa Catarina and 163.02 cases per 1,000 inhabitants in Roraima. The regional distribution of malaria cases depends on the presence of the vectors and on the existence of sources of infection.

Cases of **meningococcal disease** (*meningitis*) in 1996 have occurred in only nine states. The disease's distribution depends on the circulation of the etiologic agent, which is favored by the reduction of the relative humidity of the air. The incidence ranged from 0.20 cases per 100,000 inhabitants in Alagoas and Mato Grosso do Sul to 8.80 cases per 100,000 inhabitants in Santa Catarina.

2. B. Infant Mortality

Given the importance of infant mortality both as a health indicator and as an indicator of the socioeconomic conditions of the population, the analysis of the factors explaining the dispersion of infant mortality across Brazilian municipios has been prepared with regression analysis by the ordinary least square estimation method due to the absence of data censoring for infant mortality.

3. Modeling Climate Effects

3. A. The Model

Studies of climate change can be broadly grouped into two classes: (1) meteorological models predicting changes in climate and (2) empirical estimates of climate impacts on economic variables. This is a study of the second type and, as such, it makes no claims for predicting climate change. Studies of the second type can be further classified into (i) studies relying on wage and income "hedonics" to infer climate values and (ii) studies that directly estimate the relationship between economic outcomes and cross-section climate variation. This is a study of the second sub-type in which we attempt to identify climate effects on morbidity and

mortality from cross-section data. We then draw inferences for climate change impacts from these estimates.

The model to be estimated proposes that both morbidity and mortality associated with the group of diseases selected for the study would be related to three main groups of variables: climatic variables, development variables, and policy variables.

The climatic variables considered were average temperatures and rainfall, altitude and distance from the sea. Each of these variables had been observed or estimated for each of the 4,073 municipios in Brazil. Temperatures and rainfall were reported four times a year (months of March, June, September, and December), each month proxying for one season of the year.[7] Altitude and distance from the sea are variables that attempt to measure the possible effects of geographical factors on disease patterns, as well as controlling for certain determinants of economic development.

Development variables reflect the level of development of the municipio and encompass variables such as income levels and distribution, education, population density, rate of urbanization, and age structure of the population.

Policy variables indicate some of the investment in infrastructure at the municipio level. They include use of running water, sewage collection (both controlled by the municipal government) and availability of hospital beds. These variables might be connected to development, but the implementation of policies to cope with these issues is the responsibility of the local government. Other policy variables would be desirable but systematic data were unavailable.

Finally, in order to capture major regional differences, four dummy variables were included, with the omitted regional dummy variable referring to municipios in the state of São Paulo.

3. B. The Equation

MODj, INFM = f(DNEAST, DNORTH, DSOUTH, DCENTER, ALTM, ALTM2, DSEAM, DSEAM2, TNt, TNt2 RNt, RNt2, TNtxRNt, POPDENS91, PYOUNG,POLD, EDUC, EDUC2, PCFI91, HHWAT91, HHSAN91, BEDPOP, IDHM_R91)

MODj is the morbidity rate of disease j = 1,..., 8,

INFM is the infant mortality rate,

DNEAST = dummy assuming value of 1 for municipios located in the Northeast,

DNORTH = dummy assuming value of 1 for municipios located in the northern region,

DSOUTH = dummy assuming value of 1 for municipios located in the southern region,

DCENTER = dummy assuming value of 1 for municipios located in the center region.

[7] The average corresponds to a 30-year average of normal rainfall. See Sanghi *et al*. (1997) for a discussion of the methodology used to estimate the monthly average rainfall at the municipio level.

ALTM = altitude of the municipio measured in meters.

ALTM2 = square of the altitude of the municipio.

DSEAN = the distance from the sea, measured in Km.

DSEAN2 = square of the distance from the sea.

TNt = monthly average temperature, measured in degree °C.

RNt = monthly average rainfall, measured in mm.

TNt2= square of temperature,

RNt2 = square of rainfall.

t = March, June, September and December.

TN x RN = variable measuring possible interaction effects between temperature and rainfall.

POPDENS91= population density, population per square km.

PYOUNG = percentage of the population below 15 years of age,

POLD = percentage of the population above 64 years of age.

EDUC = education of the population measured by the average numbers of years of schooling among adults 25 years or older.

EDUC2 = square of the average education.

PCFI= percentage of people with insufficient income in 1991.

BEDPOP = number of hospital beds per person in each municipio.

IDHM_91= the average household per capita income, measured by the UN Index of Human Development – income component.

HHWAT91 = percentage of the municipal population receiving running water at their homes in 1991.

HHSAN91 = percentage of the municipal population living in house connected to sewage system.

MODj and INFM are the dependent variables of the model.

3. C. Variables and Data

In this paper, health–or ill health–was measured by one or more of three complementary indicators, depending on what information was available for the different disease groups: infant mortality rate, hospital morbidity and incidence rate.

Infant Mortality Rate translates the risk of death for a child less than 5 years, calculated for the population of each Brazilian municipio in 1996. Infant mortality rate is often used as a "proxy" for the social development of a country. In addition to reflecting development, infant mortality rate is also indicative of the existing technological capacity of the health system to provide adequate health care to the infant.

Hospital Morbidity translates the risk of being hospitalized as result of each of the selected diseases or disease groups, calculated for the population of each Brazilian municipio in a given period of time. The rates of hospitalization are also used as "proxies" for prevalence, better reflecting the actual occurrence of certain diseases, especially those that require hospitalization for the majority of its cases. For most of the diseases in this paper, hospitalization is the only information on morbidity for which there are regular records available on a country-wide basis.

Population is the total for each municipio in 1996. It was used as denominator for all rates calculated for this paper, as well as for weights to deal with heteroskedasticity problems in the regression analysis. The data on population were obtained from Fundação IBGE, the Brazilian Institute of Geography and Statistics, a federal government agency in charge of the demographic census and special surveys.

Infant Mortality per 1000: The information on the number of deaths of children less than five years old and place of residence of the deceased was obtained directly from the Sistema de Informações de Mortalidade (SIM), a system on mortality information managed by the Ministry of Health. Deaths are registered regularly in special civil notaries' offices with records sent regularly to State Secretaries of Health, which in turn forward the information to the National Epidemiological Center. The mortality data used in this paper are from 1996, the latest year for which data is available.

Hospitalization: The data regarding hospitalization has been obtained directly from the Hospital Information System of DATASUS, the agency responsible for the recording of all the hospitalizations taking place within SUS, the Unified Health System. The system was created in 1987 and covers about 70% of all hospitalizations in the country. Information is collected through the Authorization for Hospitalization, a document identifying the patient and recording the main diagnosis and information about all clinical and hospital procedures and other services provided by the health institution where hospitalization took place.

This system, used to manage the payment for these procedures and services, is subject to systematic consistency checks. Research conducted in São Paulo and Rio de Janeiro reinforces the reliability of this source of information in terms of diagnostic information.

For some of the diseases selected for this paper, this source of information covers only a small part of the existing cases, given that their treatment is provided at clinics without requiring hospitalization. This is the case for diseases transmitted by vectors, diarrhea and cholera. For meningococcal meningitis, leptospirosis and typhoid fever, hospitalization is a better indicator, given that these diseases usually require hospital treatment. The same is true for neoplasm, cardiovascular and respiratory diseases, which in most cases require hospitalization.

To ensure compatibility with the data on population and deaths, the data on hospitalization also refers 1996, although more recent information is available.

4. Estimate Based on Aggregate (municipio) Level Data

4. A. Morbidity Estimates

In this section, the effect of climate on morbidity is deduced from the cross-sectional variation in aggregate data describing the incidence of disease at the level of the municipio. Regressions exploit the observed correlation between these measures of morbidity and municipio-level seasonal measures of rainfall and temperature over the course of a year, while controlling for other exogenous municipio characteristics that might influence health. The idea behind this approach is that reported morbidity data can be "decomposed" into the distinct effects of exogenous locational characteristics on disease incidence. The effect on morbidity of marginal increases in a number of climate measures can then be used to simulate the disease consequences of global climate change.

The diseases that are modeled according to this aggregate strategy can be grouped under reported sicknesses ascribed to one of the following categories: cardiovascular, respiratory, neoplasm, hydric, vector, meningitis, cholera, and malaria. Some of these disease categories are obviously broader than others; this, in part, explains the pattern of censoring described (see below). Table 3 reports summary statistics for morbidity from each of these disease categories over municipios where data were available. Morbidity is calculated as the number of reported cases of the disease category, measured in 1996, divided by municipio population, measured in 1996 census.

In order to extract the effect of climate on morbidity, it is useful to have information on as many other municipio-related determinants of disease incidence as possible. In the specifications, the following variables are used:

1. Average education of individuals over age 25, which proxies for both income and occupation of residents, and which measures an individual's ability to undertake behaviors to avoid the onset of disease, such as eating a healthy diet, or boiling unsanitary water.

2. Age structures, measured by the percentage of individuals in a municipio under age 15 (young) and over age 64 (old). These variables control for the fact that certain diseases tend to afflict individuals of certain ages, such as circulatory disease in the old and cholera in the young

3. Altitude and distance from sea, which proxy for access to ports and economic markets, and quality of land for agricultural purposes

4. Population density, measured as a municipio's population in the 1991 census (in 1,000's) divided by the municipio's land-area (in Km^2). This variable should control for the effect of urbanization on disease; high population density may increase the rate of disease transmission when individuals live in close proximity to one another, and it may result in the creation of "public bads," such as smog or excess solid waste, which can lead to disease.

5. Regional fixed effects. A vector of fixed effects, which place each municipio in one of six regions of Brazil, are included to control for the effect on morbidity of anything that does not appear in our data set, but which is particular to the region in question. It is hoped that the inclusion of these dummies might help to minimize the impact of reporting error by limiting the impact of unobservables that may be correlated with regressors to things that only vary *within a region*.

6. Climate variables. The variables of primary interest in this paper measure rainfall and temperature in each of four months (i.e., December, March, June, September) in each municipio in Brazil. These data allow for the measurement of the effect of global warming on morbidity to exploit the information in detailed climate simulation models that report varying climate change by season and location in Brazil. Table 3 reports summary statistics for each of the variables used in the decomposition of morbidity data.

Table 3
Summary Statistics: Municipio Characteristics

	Mean	Standard Deviation	Minimum	Maximum
December Rainfall (cm)	17.39	9.69	0.113	49.58
March Rainfall (cm)	17.41	7.24	1.409	59.63
June Rainfall (cm)	7.28	6.24	0.006	42.69
September Rainfall (cm)	6.37	4.48	0.004	26.19
December Temperature (°C)	24.36	2.22	15.92	33.41
March Temperature (°C)	24.26	1.96	15.48	34.85
June Temperature (°C)	19.99	4.02	7.2	32.75
September Temperature (°C)	22.23	3.56	10.13	31.62
Education (years)	3.17	1.26	0.30	8.80

Altitude (meters)	429.78	298.69	1.00	1628.00
Distance From Sea (Km)	228.95	204.23	5.00	1339.37
Population Density (1,000 per Km^2)	0.43	3.58	0.00023	130.21
% Population < Age 15	0.37	0.056	0.23121	0.56
% Population > Age 64	0.05	0.015	0.00492	0.12
Bedpop	0.009	0.046	0.000	1.386
IDHM_R91	0.492	0.267	0.070	0.974
Region Indicator: North	0.062	0.24	0.00	1.00
Region Indicator: North-East	0.357	0.48	0.00	1.00
Region Indicator: South	0.174	0.38	0.00	1.00
Region Indicator: Center	0.057	0.23	0.00	1.00

4.B. Data Censoring Problems

For certain diseases, censoring is prevalent; i.e., certain diseases do not appear in certain municipios, and morbidity is therefore reported at the lower bound of 0.0%. Table 5 describes the percentage of censored observations, by disease, in the full data sample. Given these percentages, a Type-I Tobit specification was chosen for all (non-infant mortality) diseases, following Greene, (1993, p. 694) and Johnston and DiNardo (1997, pp. 436-7):

$$m^*_{i,j} = X_j \_b + e_j$$

$$m_{i,j} = m^*_{i,j} \quad if \ m^*_{i,j} > 0 \qquad (1)$$

$$m_{i,j} = 0 \quad if \ m^*_{i,j} \le 0$$

where $m_{i,j}^*$ represents "latent" morbidity for disease i in munipio j, which can be either positive or negative, and $m_{i,j}$ represents observed morbidity. X_j includes all the variables described in Table 3, as well as a number of higher-order terms and interactions. e_j measures unobserved determinants of morbidity in municipio j, and is assumed to be distributed i.i.d. normal with variance s^2 and mean zero.[8] For infant mortality, the fact that no muncipio

[8] Note that heteroskedasticity was not found to be a serious problem in these regressions. Weighted-least-squares regression results for a number of diseases that do not exhibit much censoring are reported in Appendix 2. These results confirm that our predicted marginal climate effects on morbidity are not sensitive to alternative assumptions about the form of heteroskedastisity present in the error term.

reported a censored value allowed for a simple least-squares estimation procedure to be used instead of a Tobit. In particular, a linear OLS specification fit the data well.

The results of these estimation procedures are found in Appendix 2. The results pertain to Tobit specifications; estimated coefficient magnitudes cannot therefore be simply interpreted as marginal effects. Instead, the marginal effects of a number of key variables on morbidity are summarized in the following subsection.

Table 4
Percentage of Censored Observation by Disease

Disease	Censoring Percentage	Disease	Censoring Percentage	Disease	Censoring Percentage
Circulatory	0.5%	Hydric	1.22%	Meningitis	86.10%
Respiratory	0.25%	Vector	69.65%	Malaria	82.84%
Tumor	2.63%	Cholera	96.85%	Infant Mortality	0.0%

4.C. Marginal Effects

A goal of this analysis is to determine the effect of a marginal increase in various measures of climate and other relevant variables on each of eight morbidity categories and on infant mortality. The regression results described in Appendix 2 allow for the measurement of such marginal effects, as well as the marginal effects of other policy-relevant variables like education and population density. In order to summarize these marginal effects in a concise manner that still features the important differences that arise as one moves around Brazil, average marginal effects are found for each variable by region (i.e., defined in the same manner as for the regional dummies described before), and standard errors for those marginal effects are bootstrapped from the variance-covariance matrices of the estimated parameters.

In particular, for each Tobit specification, the marginal effect of $x_{k,j}$ on the conditional expectation of $m_{i,j}$ is found by taking:

$$\frac{\partial E[m_{i,j} \mid X_j]}{\partial x_{k,j}} = \Phi\left(\frac{X_j \_ b}{s}\right)\frac{\partial X_j \_ b}{\partial x_{k,j}} \qquad (2)$$

where X_j refers to the vector of all regressors for municipio j, and $x_{k,j}$ refers only to regressor k for municipio j. For each disease, this expression is evaluated at the sample mean of X_j, taken over all municipios j in region m = {North, North-East, São Paulo, SEast CWest}. The

standard error of that marginal effect is then found by (i) taking 10,000 pseudo-random draws of the parameter vector b from that vector's estimated variance-covariance matrix, (ii) simulating marginal effects evaluated at regional sample means, and (iii) calculating the variance of that set of simulated effects.

Appendix 1 presents the 90% confidence intervals for the marginal effect of a number of seasonal and annual climate measures, education, and population density on morbidity.[9] These intervals highlight the important fact that, for many variables and many diseases, while point estimates of marginal effects are different from zero, this result is often not statistically significant. Still, a number of economically and statistically significant results are evident when the confidence intervals are calculated.

4.D. Discussion of Results: Morbidity

Looking first at cardiac diseases (Figure 1 of Appendix 1), a marginal increase in annual rainfall (i.e., a 1 cm increase in every month) has a beneficial effect (i.e., it reduces cardiac disease incidence). This effect is quite pronounced in the South and in the states of Rio de Janeiro and São Paulo. Looking at the seasonal effects that comprise this annual effect, increased summer (i.e., December) rainfall is clearly harmful (possibly suggesting that increased humidity in combination with high heat will impose undue stress on the body's cardiovascular system), while spring (i.e., September) rainfall has a beneficial effect in Rio de Janeiro and the South. Increases in annual temperature are also beneficial in every region of Brazil; this effect arises primarily from the beneficial impact of increasing summer temperature. Increasing education has a detrimental effect on cardiac morbidity in the North and North-East (possibly reflecting the effects of increased economic development to a level similar to that seen in the southern states where cardiovascular morbidity is higher in the data). Increasing population density, on the other hand, is universally beneficial.

Turning next to hydric diseases (Figure 2 of Appendix 1), increasing annual rainfall has a clear beneficial effect, particularly in the North and North-East. That beneficial effect tends to be present throughout the year (especially in the summer), suggesting that increased precipitation may augment available water supplies, allowing possibly contaminated sources to be avoided. Annual increases in temperature are also generally beneficial, but this measure obscures very important differences in seasonal temperature changes. In particular, very strong harmful effects are associated with increasing summer temperatures (particularly in the North and North-East) suggesting that such conditions may facilitate the growth of harmful parasites. The same is true in the North, North-East, and Center regions in the winter, and in Minas Gerais, Rio de Janeiro, São Paulo, and the South in the spring. Increasing fall temperatures, conversely, are universally beneficial. Finally, increasing population density is beneficial in every region, suggesting that with increased density may come the provision of a public infrastructure that facilitates the provision of clean water.

Considering respiratory diseases (Figure 3 of Appendix 1), rainfall appears not to have a statistically significant impact on morbidity, except in the North and North-East, where

[9] 90% confidence intervals were estimated for all eight morbidity groups and all of them supported the hypothesis of meaningful results for the marginal effects.

increased fall and winter precipitation have beneficial impacts. The more pronounced effects on respiratory morbidity come from increased temperatures. While the effect of a marginal increase in annual temperature tends to be insignificantly different from zero, changes in seasonal temperatures can be quite important. Increases in spring and summer temperature, for example, tend to increase respiratory disease incidence in every region of Brazil (especially in Minas Gerais and the South). This effect may reflect the aggravation of breathing problems that can arise from ozone and smog when accompanied by high temperatures. Increases in fall and winter temperatures, on the other hand, tend to be beneficial in every region, with the most pronounced effects coming again in the southern states. This could reflect a reduction in respiratory infections accompanying milder winters.

Rainfall exhibits strong effects on vector diseases (Figure 5a). In particular, increased annual rainfall tends to raise the likelihood of contracting an insect-carried disease in the North and Center regions, with this result arising primarily from large harmful effects of increased rain in the spring and summer. Increased winter rain, on the other hand, reduces vector morbidity in the North, while increasing it in other regions. Increasing temperature in the winter, spring, and summer also increases the likelihood of vector diseases in the North and North-East; along with the estimated effects of rainfall, these effects seem to correspond closely to the life-cycle of the mosquito. Increasing fall temperatures, on the other hand, seem to be universally beneficial (particularly in the North).

Meningitis and cholera (Figures 6 and 7 of Appendix 1) are diseases that exhibit tremendous censoring in the full data sample (i.e., 86.10% and 96.85%, respectively). Consequently, predicted marginal effects for regions where the disease is not already present are quite small, but large relative to the current morbidity levels, which are typically zero. In regions where significant marginal effects are identified (i.e., Rio de Janeiro, São Paulo, and the South), increased annual rainfall tends to increase meningitis. This effect comes from a large beneficial effect of increased summer rainfall, which is offset by harmful effects of increasing rain in the fall, winter and spring. The effects of increased temperature on meningitis tend to be beneficial in the fall and winter and harmful in the spring, and increased education and population density were found to be associated with higher incidences of the disease. The effects of temperature on cholera are imprecisely estimated but tend to indicate a harmful effect of warmer weather; rainfall does not appear to have a statistically significant impact on cholera.

Finally, as expected for a control variable, rainfall and temperature tend to exhibit statistically insignificant effects on morbidity from diseases related to tumors (Figure 8 of Appendix 1), both at the seasonal and annual levels. The only notable effects found in the estimations are from increased education, which significantly reduces tumors in Minas Gerais, Rio de Janeiro, and São Paulo.

The results described in Figures 1-8 describe a diverse set of marginal effects of climate on morbidity. Indeed, one clear fact emerges from this discussion: the impact on morbidity of global climate change cannot be simply described as either “beneficial” or “harmful”. Instead, these effects differ by location and depend on complicated interactions between seasonal climate changes as well as interactions between rainfall and temperature, and even between climate, population settlement patterns, and education. Moreover, the effects of a

given change in climate can be very different for different diseases. These conclusions suggest that valuable insights might be gained by incorporating these estimation results with the results of elaborate climate-change simulation models (e.g., GISS, GFDL, UKMO), which describe these complicated interactions in great detail.

Appendix 2 reports OLS estimates and discuses the use of weights to address possible heteroskedasticy. It also reports estimates showing the role of clean water in reducing the incidence of hydric disease, tumors and vector diseases.

4.E. New Disease Versus Marginal Increases in Morbidity

Especially for diseases where censoring is a prevalent feature of reported morbidity, it is interesting to ask to what extent the increases or decreases in a region's average morbidity, observed in Figures 1-8 of Appendix 1, result from marginal changes in morbidity in municipios that had previously reported positive numbers of cases of disease, and to what extent those changes come from municipios that had hitherto been censored suddenly exhibiting non-censored morbidities (or previously uncensored municipios suddenly becoming censored). This is an important policy question, as it suggests to what extent disease will "spread" to previously unaffected areas as climate changes with global warming. This is likely to have an impact on the approach taken by public health officials to control global warming-induced changes in disease in different regions.

McDonald and Moffitt (1980) describe a method for decomposing the marginal effect of a regressor in a Tobit specification into a percentage attributable to previously positive realizations changing their magnitudes, and a percentage attributable to previously censored realizations becoming positive (or vice-versa). The first part of the right hand side of equation (3) represents the change in the mean of $\boldsymbol{m}$ by changing the conditional mean of $\boldsymbol{m}$ and the second part by changing the probability that an observation will be positive.[10]

$$\frac{\partial E[m_{i,j}|X_j]}{\partial x_{k,j}} = \mathbf{prob}(m^*_{i,j} > 0).\frac{\partial E[m_{i,j}|X_j, m^*_{i,j}>0]}{\partial x_{k,j}} + \frac{\partial \mathbf{prob}(m^*_{i,j}>0)}{\partial x_{k,j}} E[m_{i,j}|X_j, m^*_{i,j} > 0] \quad (3)$$

Table 5 lists the percentage of the marginal effect on morbidity due to an increase in December temperature, calculated according to this method, that is attributable to previously disease-free municipios reporting positive morbidity or previously uncensored municipios becoming censored. For circulatory and respiratory diseases, which exhibit very little censoring in the majority of regions, most of the change in expected morbidity comes from changing disease incidence in municipios where the disease has already been present. For diseases where significant censoring is present in the data, however, the situation is quite different. Consider malaria, which exhibits an unconditional censoring probability of 82.84%

[10] See McDonald and Moffitt (1980) p. 319 and Johnston and DiNardo (1997) p. 438 for a discussion of this decomposition.

in the full data set. The effect of a marginal increase in December temperature on the probability of contracting malaria in Rio and São Paulo is to increase that probability by 0.0003836. 89% of that increase (i.e., 0.0003414) is attributable to the new incidence of malaria in municipios that had previously not reported malaria cases. In comparison, only 43.5% of the effect is attributable to the disease spreading to new municipios of a marginal increase in December temperature in the north (i.e., 0.0119).

Table 5
Percentage of Marginal Effect of an Increase in December Temperature on Morbidity Owing to New Disease

Disease / Region	North	North-East	Minas Gerais	São Paulo	South	Cwest
Circulatory	0.512	0.416	0.199	0.173	0.195	0.221
Respiratory	0.388	0.315	0.301	0.265	0.153	0.197
Tumors	0.661	0.595	0.000	0.544	0.567	0.621
Hydric	0.343	0.273	0.462	0.469	0.391	0.421
Vector	0.489	0.745	0.829	0.821	0.846	0.749
Cholera	0.893	0.896	0.973	0.991	0.981	0.958
Meningitis	0.979	0.898	0.907	0.770	0.740	0.922
Malaria	0.435	0.850	0.879	0.890	0.879	0.759

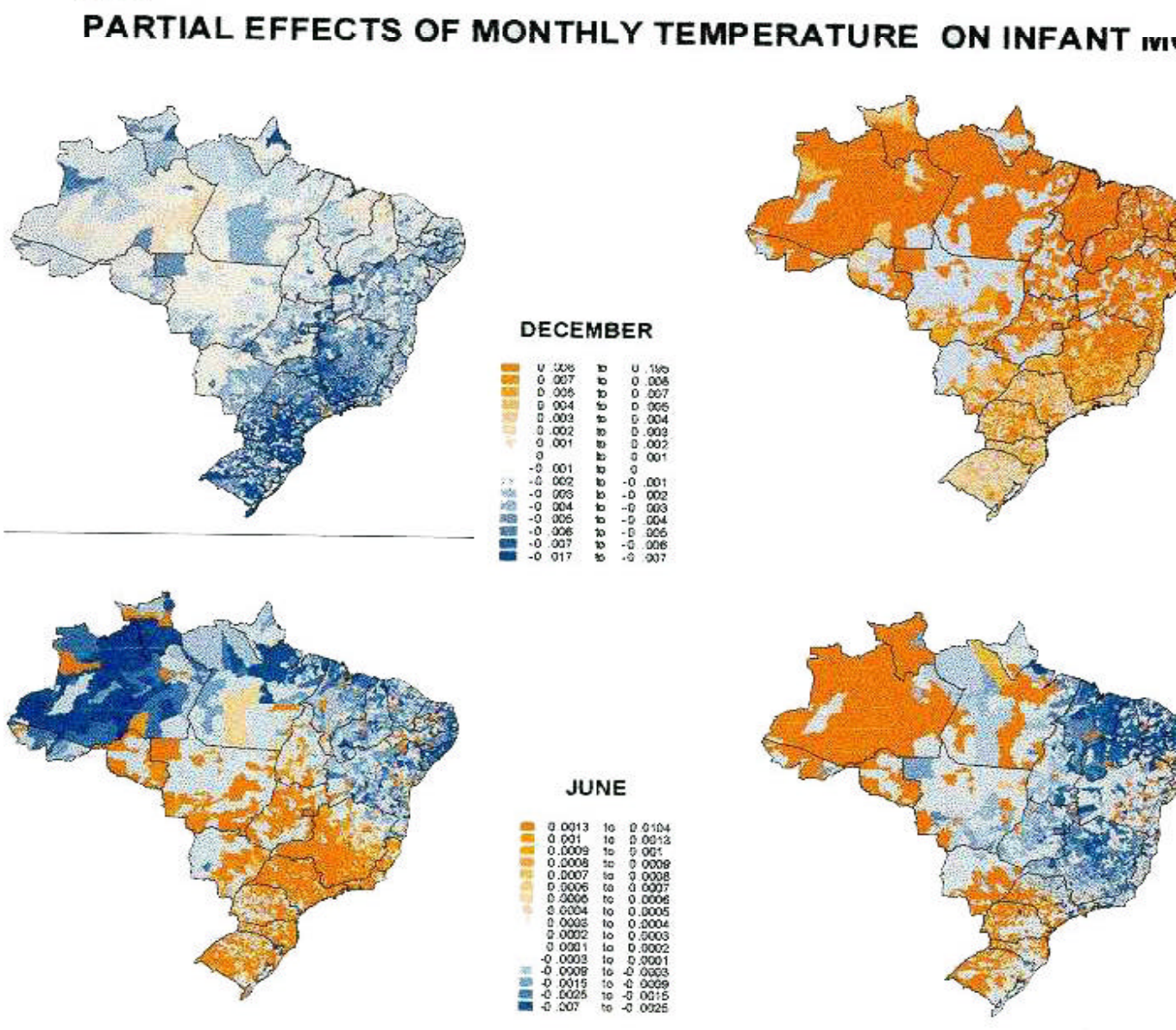
4.F. Reporting Bias

A valid concern with the results of the specifications reported in this section is that the mechanism by which Brazilian morbidity data is collected is imperfect (i.e., cases of each disease go unreported), and the degree of imperfection may be correlated with the locational characteristics that are being used to decompose morbidity. To the extent that this is true, the estimated marginal effects may be biased. Consider a simple example. Suppose that reporting a disease requires that individuals have easy access to hospitals, clinics, or health-care providers. In the preceding specifications, that access appears in the error term. To the extent that, *within a region*,[11] access to hospitals, clinics, or healthcare providers is correlated with temperature, climate, education, population density, or other variables, the estimated effects of any of these variables on morbidity can be biased. Additional specifications have been estimated (see Appendix 2) that check to what extent reporting error may be biasing the parameter estimates reported in this section. In particular, additional variables that may

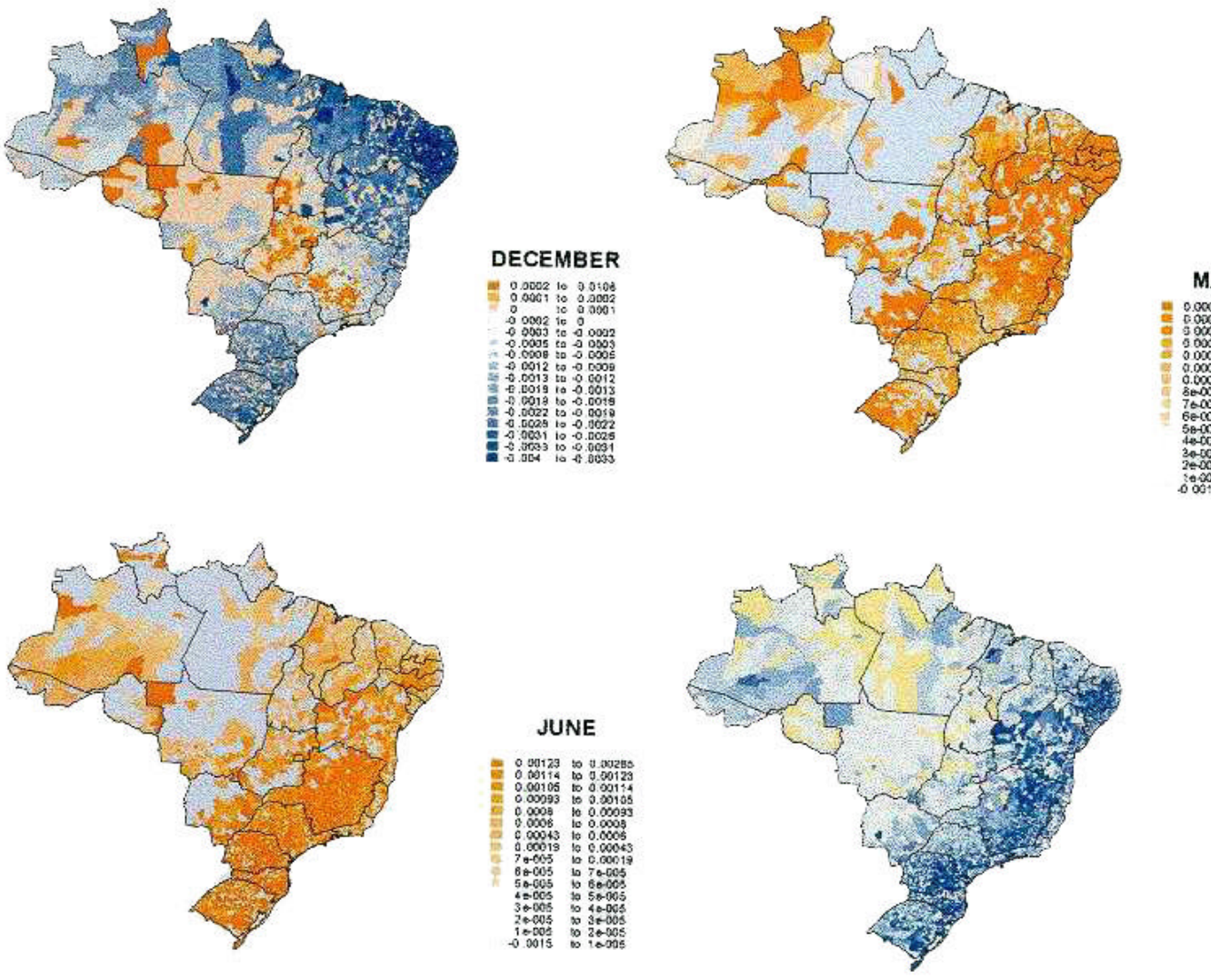
[11] Regional dummy variables were included in all specifications where available data identified them (i.e., for all diseases except cholera and meningitis) in order to reduce possible biases from systematic reporting bias. The inclusion of these variables means that the unobserved determinant of morbidity reporting must be correlated with a regressor *within a region* in order for the parameter estimates to be biased (i.e., access to healthcare would have to be correlated with temperature within the North; the fact that such access may be more limited in the warmer North region than in the cooler southern regions is of no consequence for the parameter estimates.

influence reporting, such as the number of hospital beds per 1,000 people in a municipio and a number of income measures, are included in OLS regression specifications for disease categories that do not exhibit much censoring.

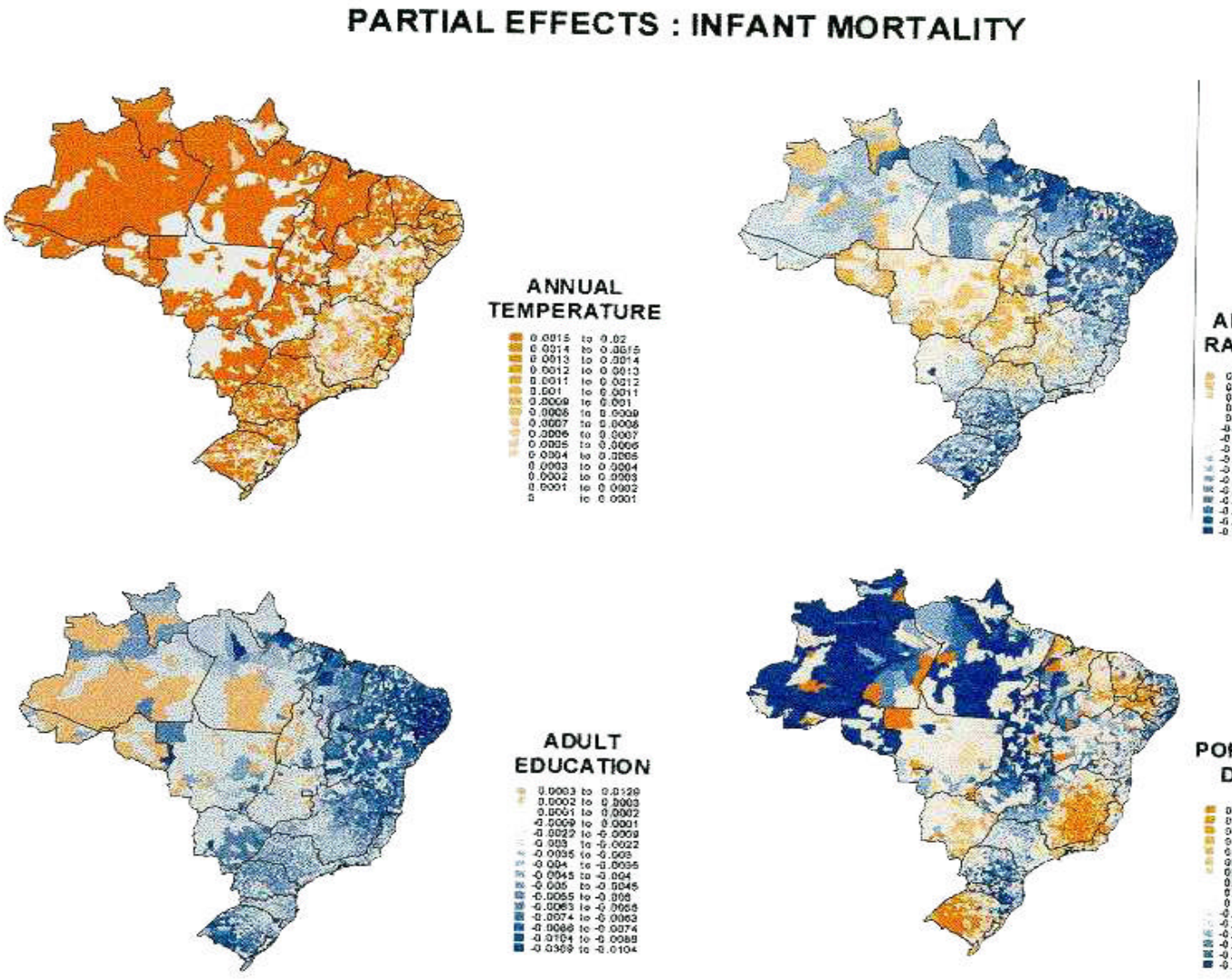
MAP 1


PARTIAL EFFECTS OF MONTHLY TEMPERATURE ON INFANT
DECEMBER
JUNE

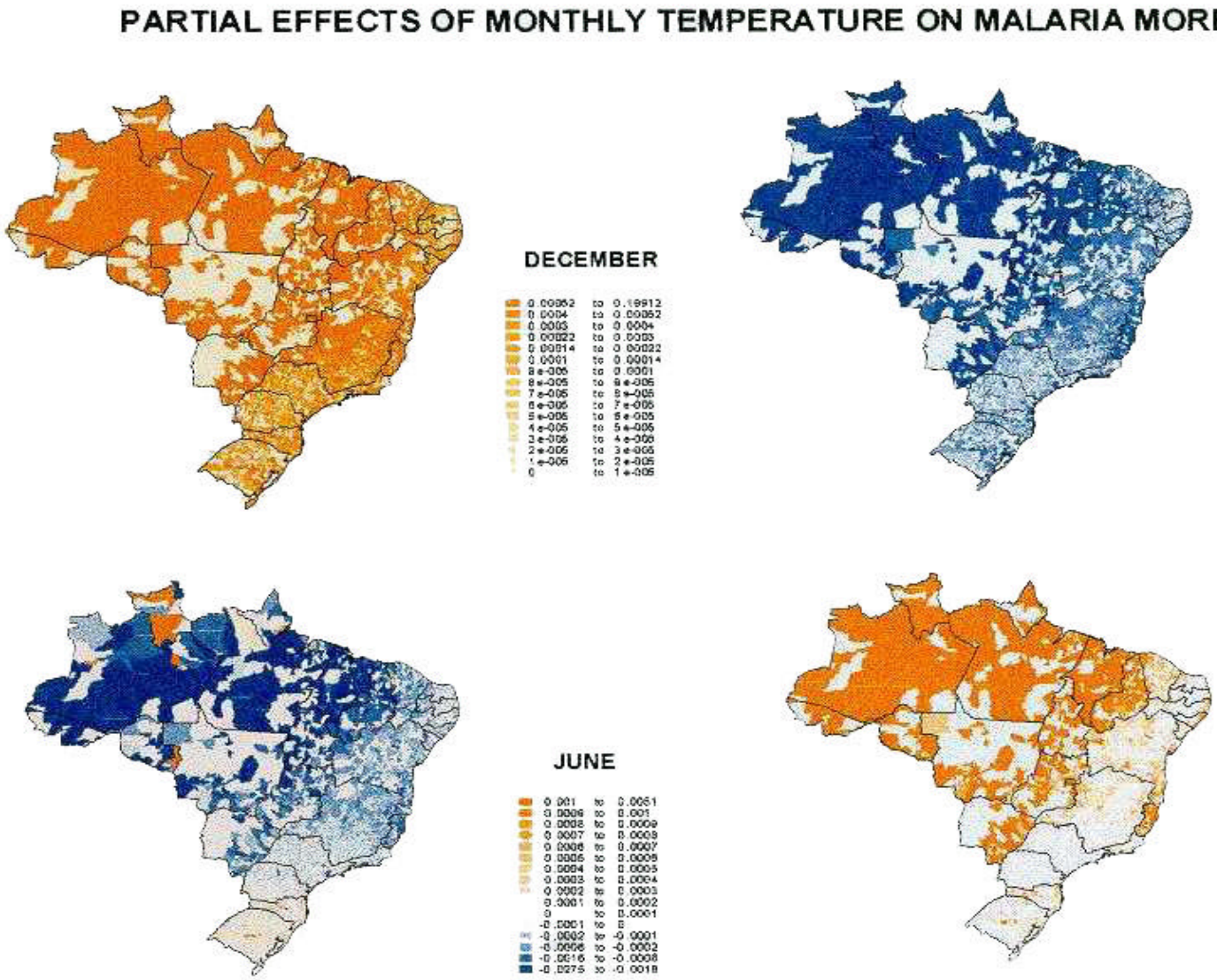
MAP 2


PARTIAL EFFECTS OF MONTHLY RAINFALL ON INFANT MORTALIT
DECEMBER
0.0002 to 0.0106
0.0001 to 0.0002
0 to 0.0001
-0.0002 to 0
-0.0003 to -0.0002
-0.0005 to -0.0003
-0.0008 to -0.0005
-0.0012 to -0.0009
-0.0013 to -0.0012
-0.0019 to -0.0013
-0.0018 to -0.0019
-0.0022 to -0.0019
-0.0025 to -0.0022
-0.0031 to -0.0025
-0.0033 to -0.0031
-0.004 to -0.0033
JUNE
0.00123 to 0.00285
0.00114 to 0.00123
0.00105 to 0.00114
0.00093 to 0.00105
0.0008 to 0.00093
0.0006 to 0.0008
0.00043 to 0.0006
0.00019 to 0.00043
7e-005 to 0.00019
6e-005 to 7e-005
5e-005 to 6e-005
4e-005 to 5e-005
3e-005 to 4e-005
2e-005 to 3e-005
1e-005 to 2e-005
-0.0015 to 1e-005

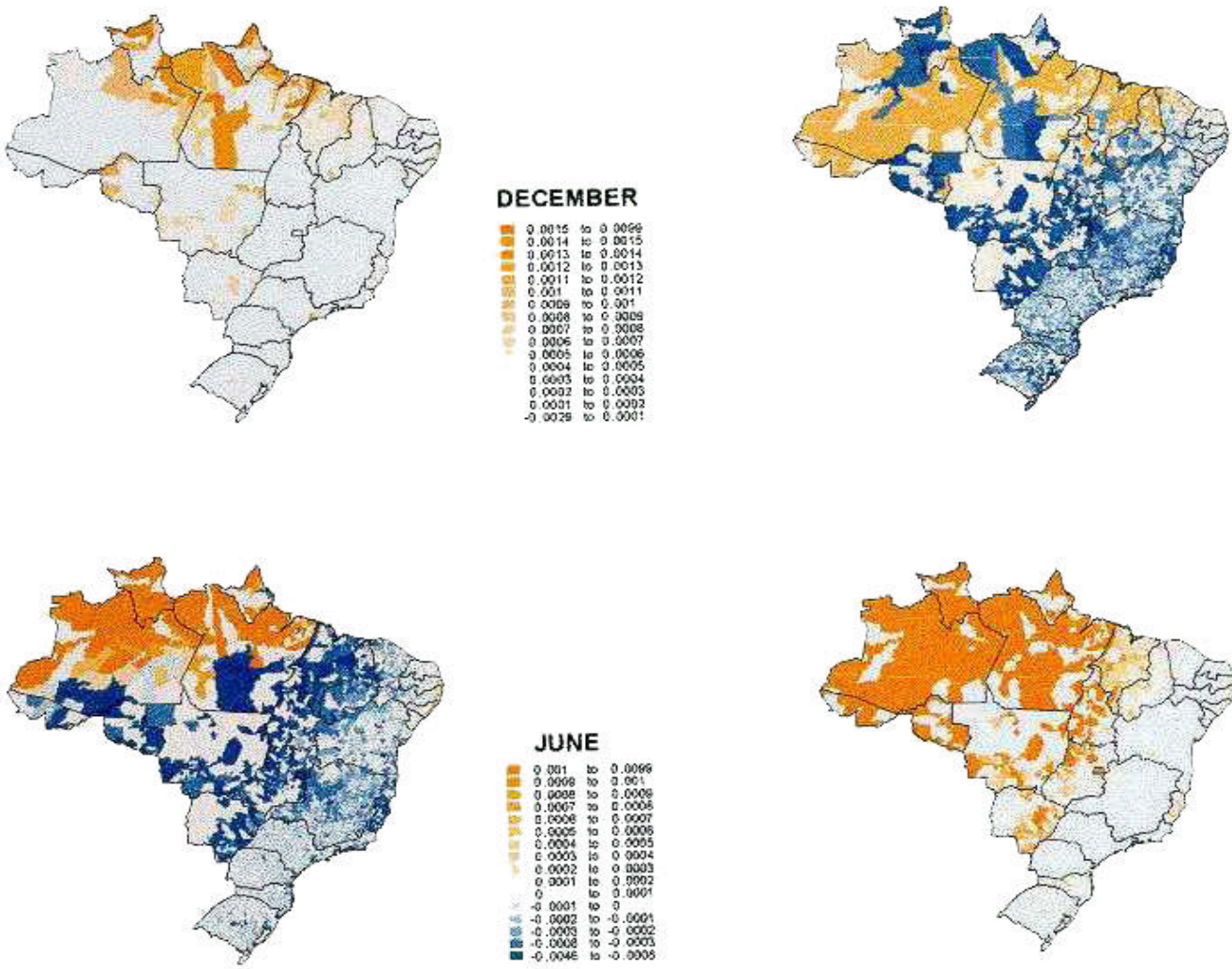
MAP 3


PARTIAL EFFECTS : INFANT MORTALITY
ANNUAL TEMPERATURE
ADULT EDUCATION

MAP 4


PARTIAL EFFECTS OF MONTHLY TEMPERATURE ON MALARIA MORI
DECEMBER
JUNE

MAP 5


PARTIAL EFFECTS OF MONTHLY RAINFALL ON MALARIA MORBID
DECEMBER
0.0015 to 0.0099
0.0014 to 0.0015
0.0013 to 0.0014
0.0012 to 0.0013
0.0011 to 0.0012
0.001 to 0.0011
0.0009 to 0.001
0.0008 to 0.0009
0.0007 to 0.0008
0.0006 to 0.0007
0.0005 to 0.0006
0.0004 to 0.0005
0.0003 to 0.0004
0.0002 to 0.0003
0.0001 to 0.0002
-0.0029 to 0.0001
JUNE
0.001 to 0.0099
0.0009 to 0.001
0.0008 to 0.0009
0.0007 to 0.0008
0.0006 to 0.0007
0.0005 to 0.0006
0.0004 to 0.0005
0.0003 to 0.0004
0.0002 to 0.0003
0.0001 to 0.0002
0 to 0.0001
-0.0001 to 0
-0.0002 to -0.0001
-0.0003 to -0.0002
-0.0008 to -0.0003
-0.0046 to -0.0008

4.G. Discussion of Results: Infant Mortality

The effects of climate on infant mortality are described in Figure 9. The most notable results are that increases in annual temperature tend to be harmful, especially in the North and Center regions, while increases in annual rainfall tend to be beneficial (except in the Center), with the largest advantageous effects coming in the North-East and Center regions. These annual effects, however, obscure some interesting and statistically significant seasonal differences in the impacts of climate. For example, increasing summer temperatures are universally beneficial, especially in the southern states, while increasing fall temperatures are universally detrimental (especially in the North). Increased winter temperatures tend to be beneficial in the northern half of the country and detrimental in the southern half, while increased spring temperatures appear to be particularly harmful in the South. The beneficial effects of an increase in annual rainfall tend to be driven by the effects of summer rainfall, although increased spring rainfall also tends to reduce infant mortality (particularly in the southern states). Increased rainfall in the fall and winter, on the other hand, tends to increase infant mortality. Increased education has clear beneficial effects, especially in the southern half of the country.

These effects are displayed with more geographic detail for infant mortality in Maps 1, 2 and 3. (We also include Maps 4, 5 and 6 for morbidity from malaria.)

Map 1 displays monthly temperature effects on infant mortality. These results clearly show that higher December temperatures are favorable (i.e., reduce infant mortality) and that higher March temperatures are unfavorable to infant mortality. Higher June temperatures are favorable in the North and Northeast, but unfavorable in the Center and South. Higher September temperatures are favorable in the Center-East and Northeast. Reference to Map 4 shows, however, that for all seasons combined higher temperatures are unfavorable to infant mortality, especially in the North. Rainfall effects are shown in Map 2. Here we see that higher rainfall in December and September is favorable to infant mortality while the reverse is true for higher rainfall in March and June. Map 4 shows that higher annual rainfall is generally favorable to infant mortality except in the Center and Center-West.

Map 4 also shows that higher education lends are favorable to infant mortality and especially so in the Northeast. Population density is unfavorable to infant mortality in some highly populated regions.

Maps 4, 5 and 6 show climate effects on morbidity for malaria. The relevant point in this case is that the unfavorable effects of both rainfall and temperature are concentrated in the areas of high malaria incidence.

5. Conclusions

Designed to explore the effects of global warming on health, this paper has successfully demonstrated the importance of climate changes on morbidity and mortality patterns for certain diseases. The findings in this paper reflect the results obtained in the first stage of the study, which are not yet enough to lead to specific recommendations to policymakers. Nevertheless, the findings were sufficient to suggest at least three areas for further investigation. The first would be to incorporate in the analysis the results of elaborated climate-change simulation models which would enable the prediction of specific changes in rain and temperature patterns for each micro-region and the resulting impact in the morbidity and mortality for each disease in each region. The second relates to more in-depth studies for certain regions and states in the country for which more information is available (e.g., the state of São Paulo) in order to further confirm the validity of some of the results obtained in this first stage. Finally, given that the data is available on a municipal level, it would be enlightening to pursue this study further and try to capture the effects of special programs financed by national or international agencies, which are being implemented in selected municipios. It is expected that going through a second round of more detailed analysis, as suggested above, would lead to more informed conclusions and allow more clear recommendations to policy makers at national, state and municipal levels.

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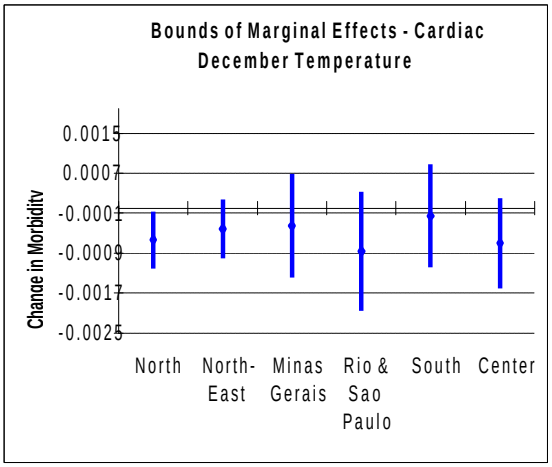
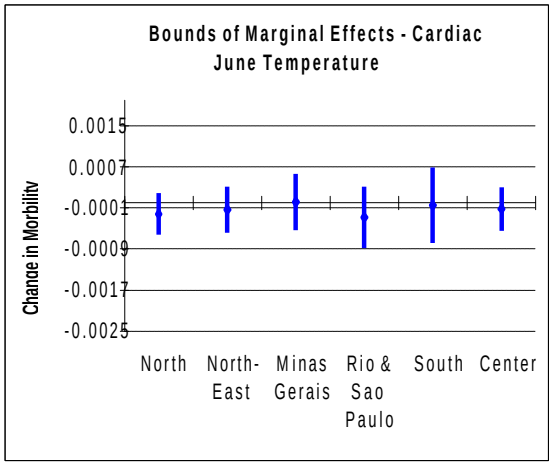
APPENDIX 1: 90% Confidence Interval for the Marginal Effects

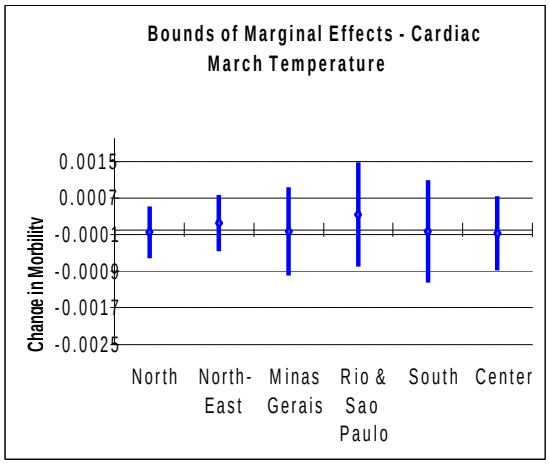
Figure 1a: Cardiovascular Partial Effects - Temperature and Education



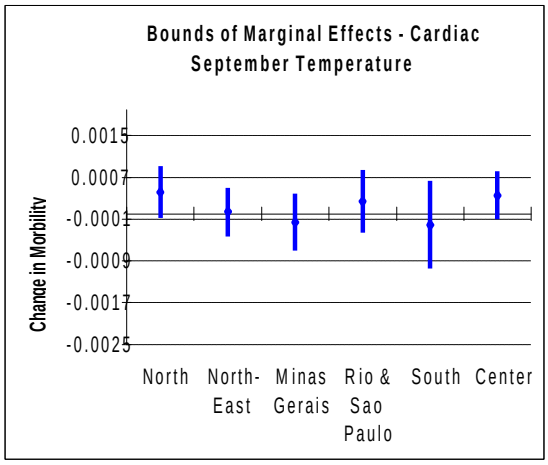
December Temperature



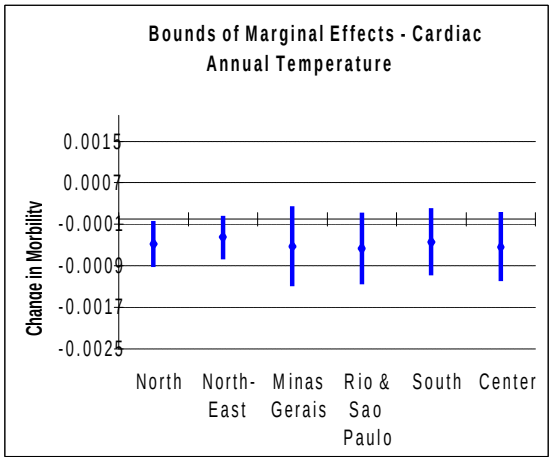
June Temperature



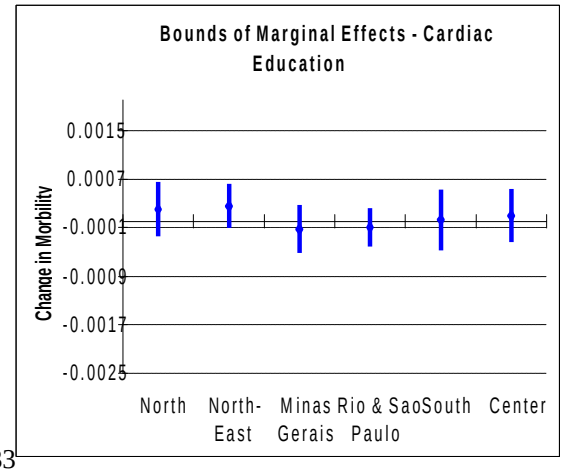
March Temperature



September Temperature

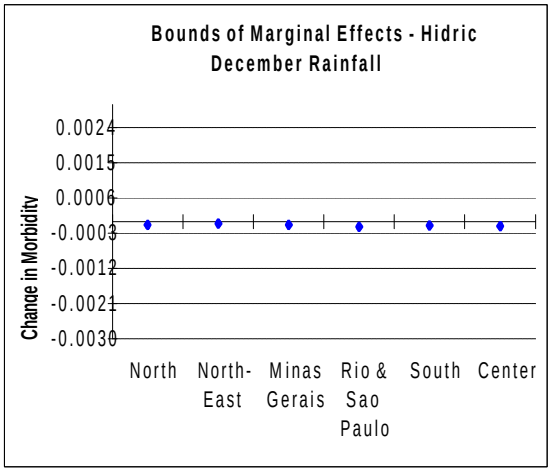


Annual Temperature

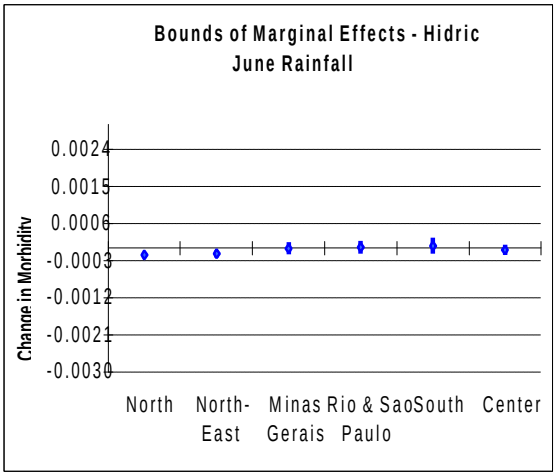


Education

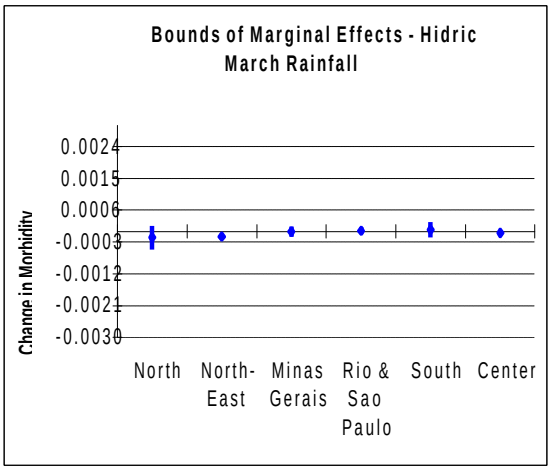
Figure 1b: Cardiac Partial Effects - Rainfall and Populational Density



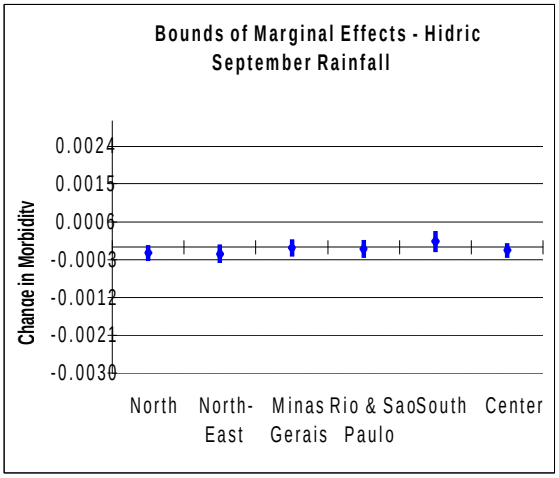
December Rainfall



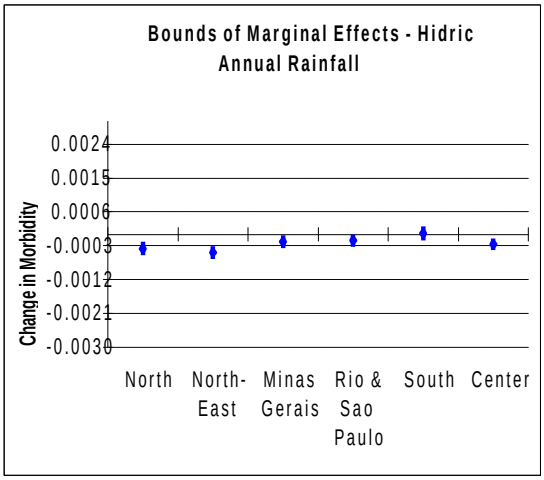
June Rainfall



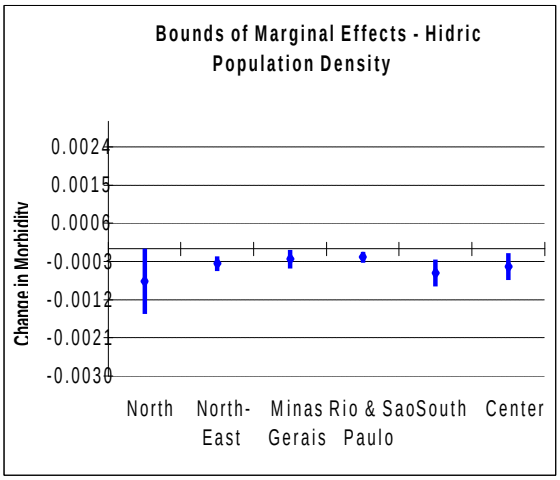
March Rainfall



September Rainfall

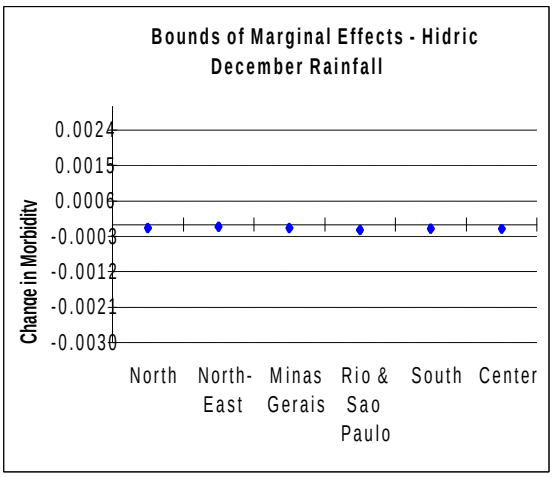


Annual Rainfall

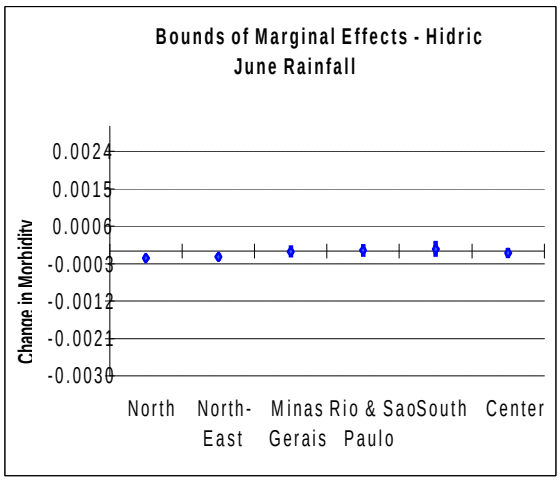


Population Density

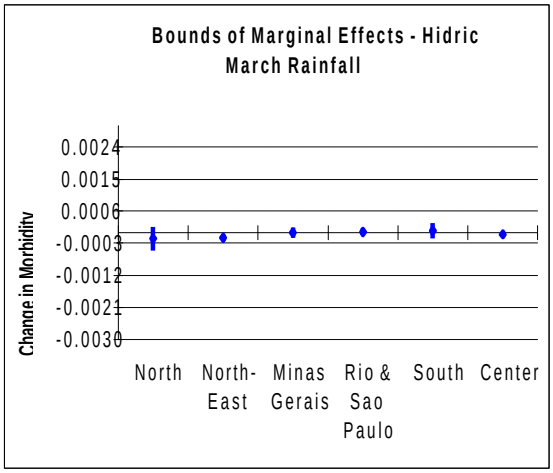
Figure 2a: Hydric Partial Effects - Rainfall and Population Density



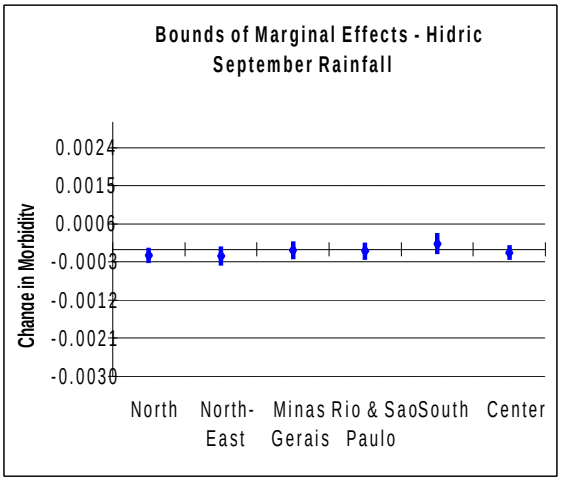
December Rainfall



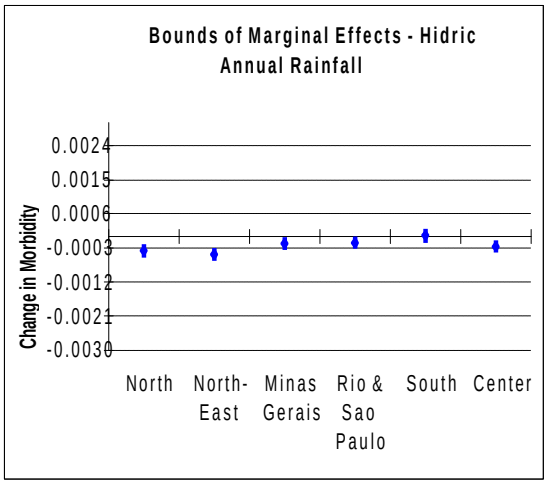
June Rainfall



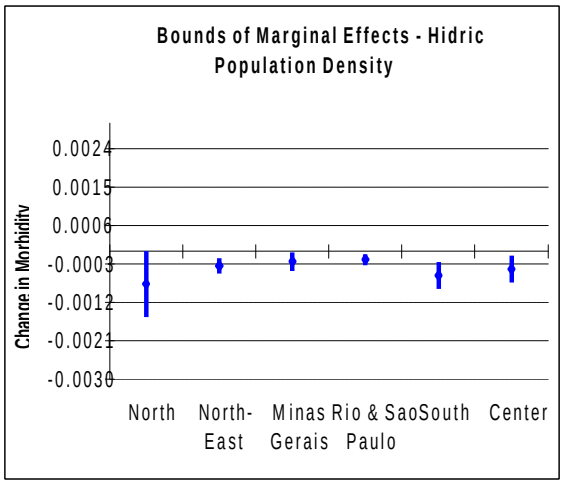
March Rainfall



September Rainfall

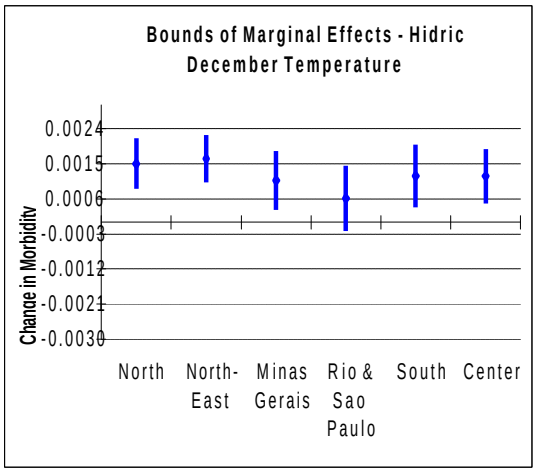


Annual Rainfall

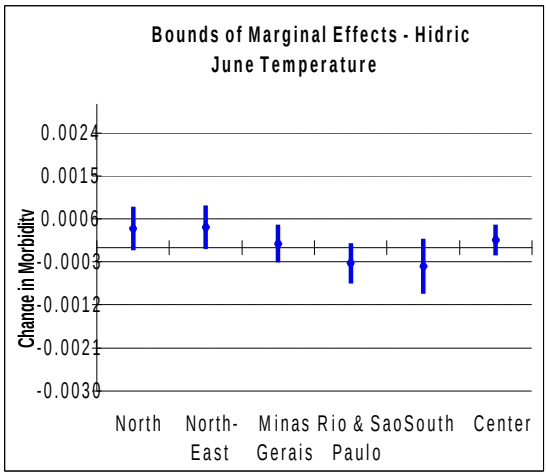


Population Density

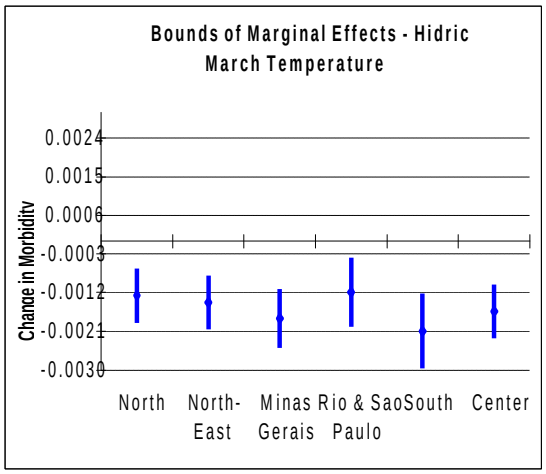
Figure 2b: Hydric Partial Effects - Temperature and Eeducation



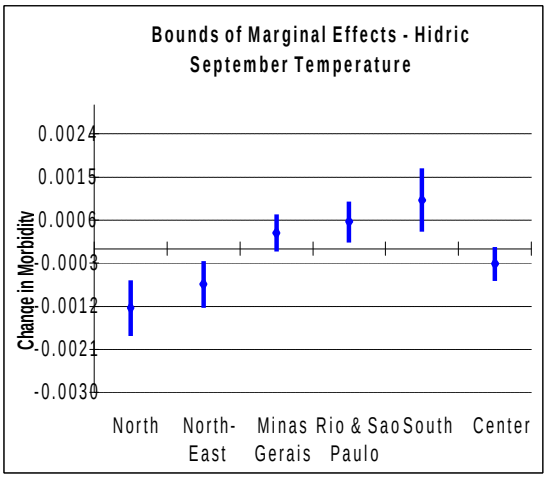
December Temperature



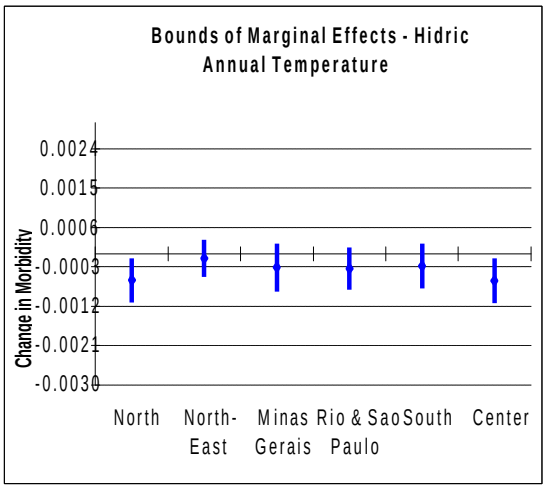
June Temperature



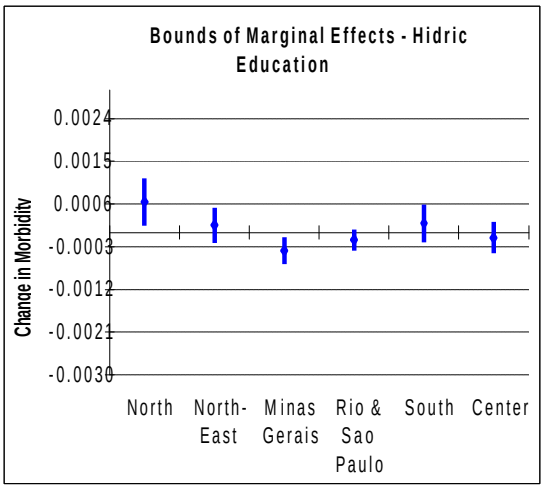
March Temperature



September Temperature

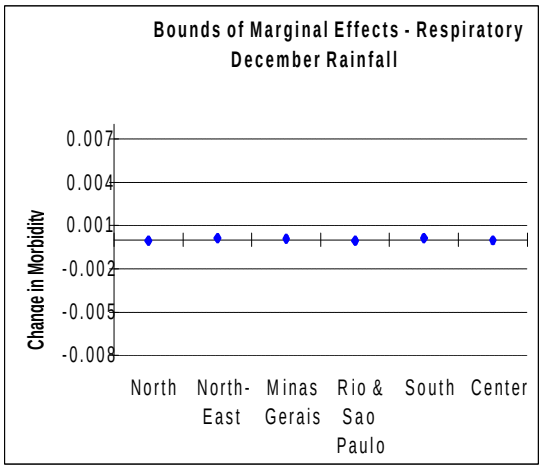


Annual Temperature

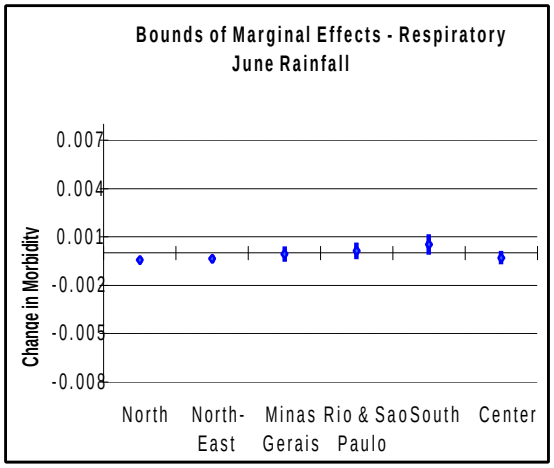


Education

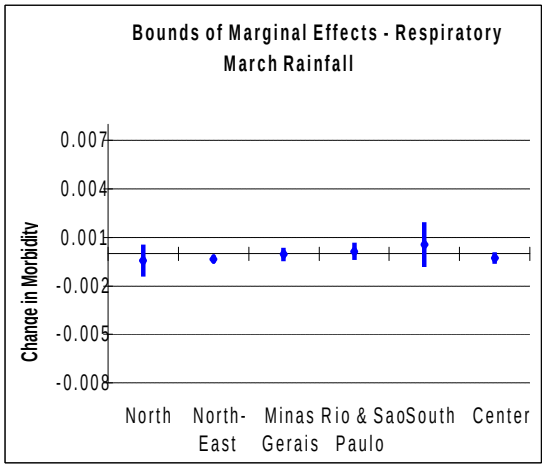
Figure 3a: Repiratory Partial Effects - Rainfall and Population Density



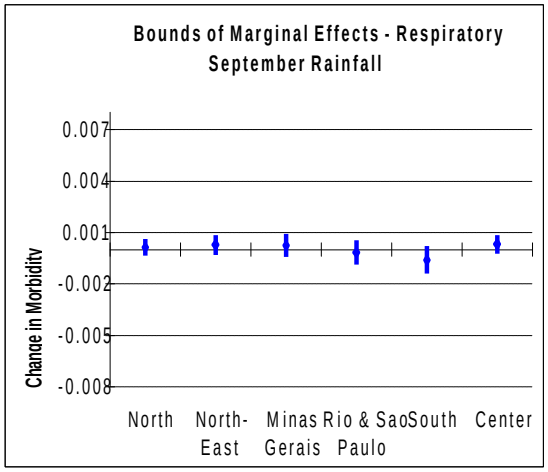
December Rainfall



June Rainfall



March Rainfall



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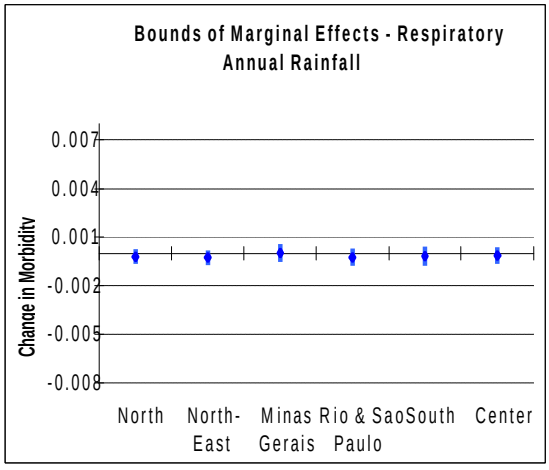
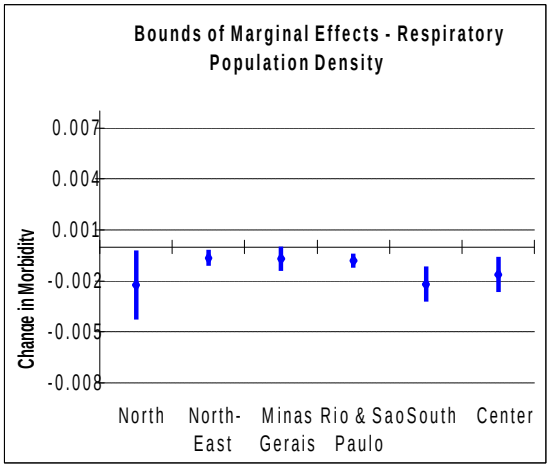
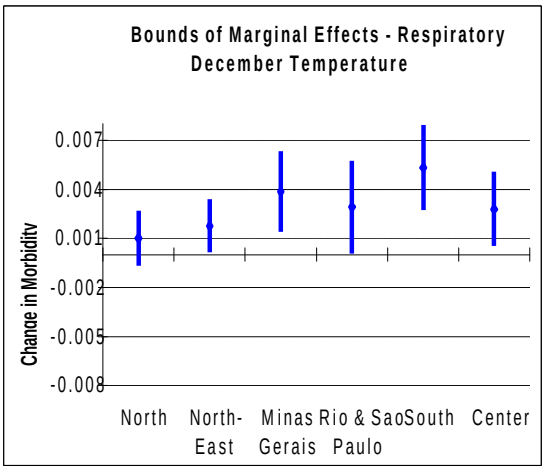


Annual Rainfall

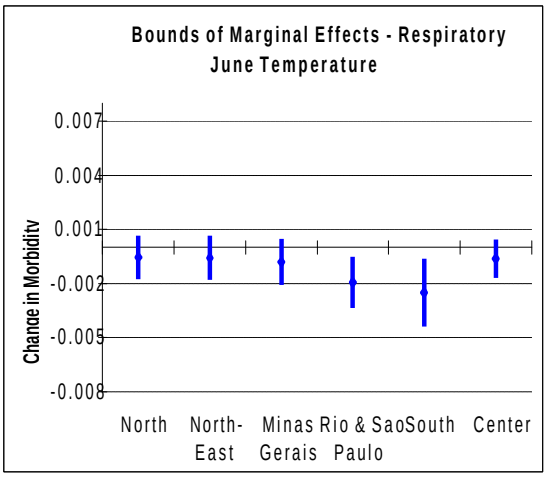


Population Density

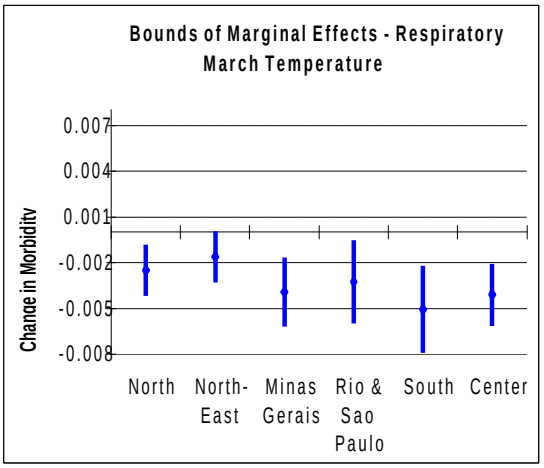
Figure 3b Respiratory Partial Effects – Temperature and Education



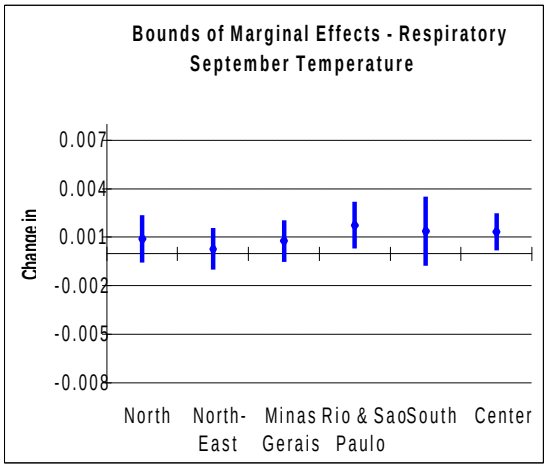
December Temperature



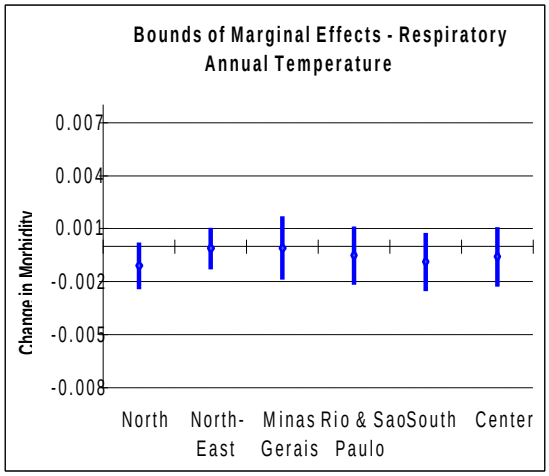
June Temperature



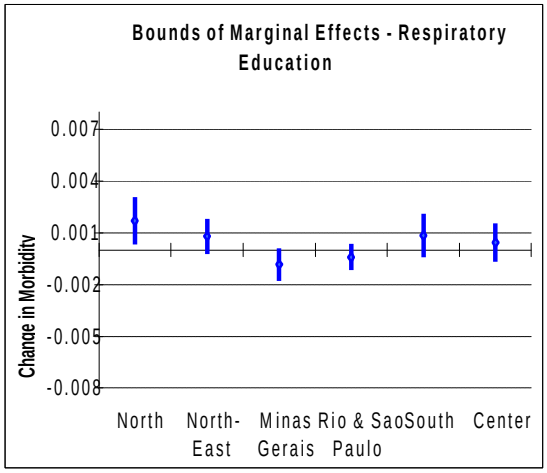
March Temperature



September Temperature

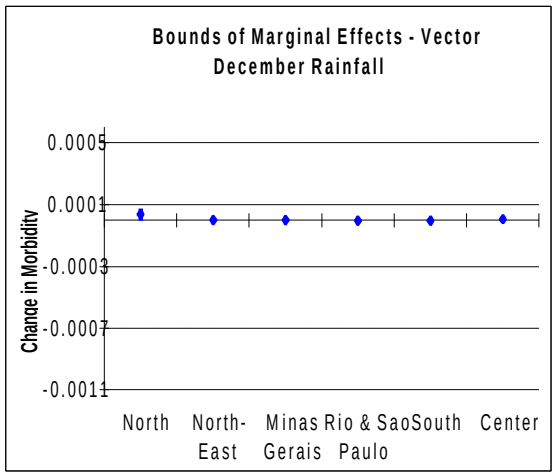


Annual Temperature

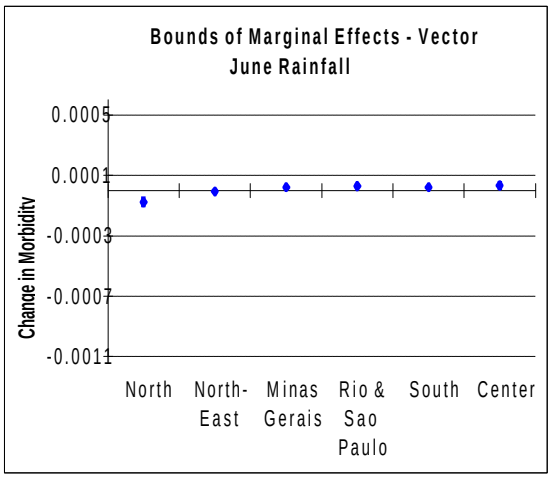


Education

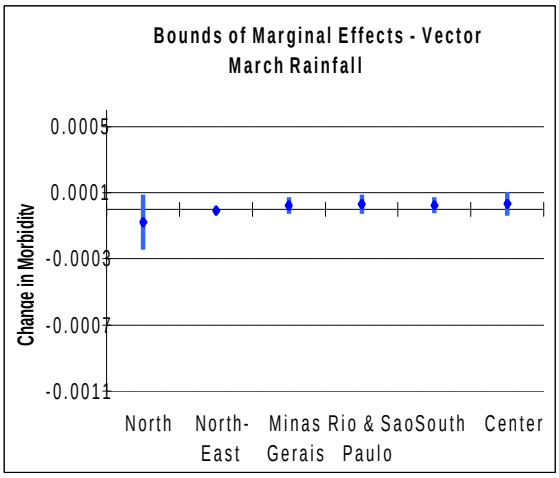
Figure 4a: Vectors Partial Effects – Rainfall and Population Density



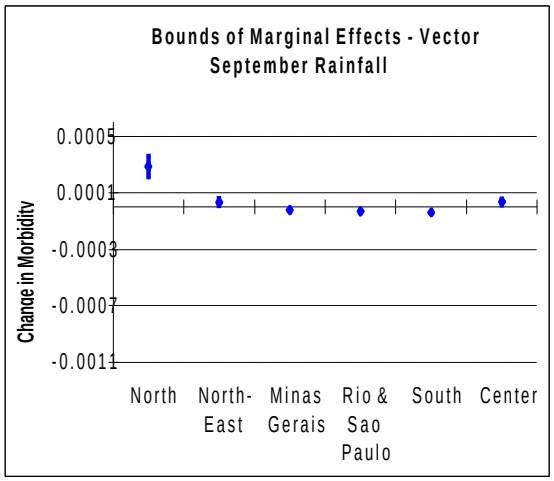
December Rainfall



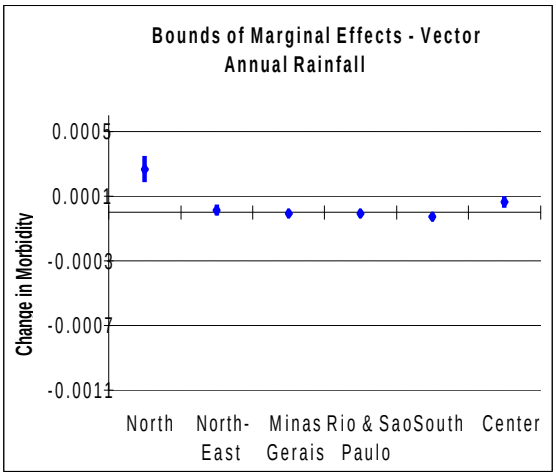
June Rainfall



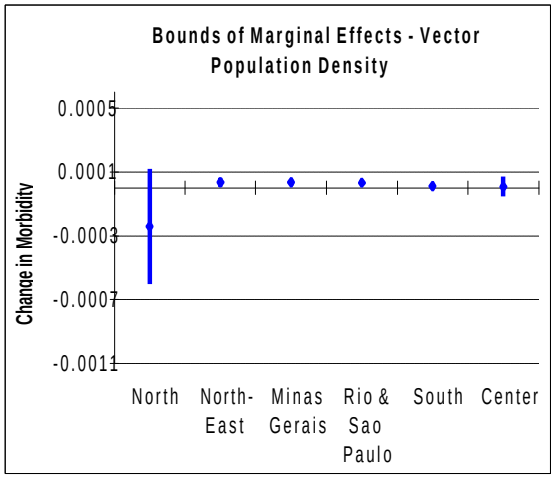
March Rainfall



September Rainfall

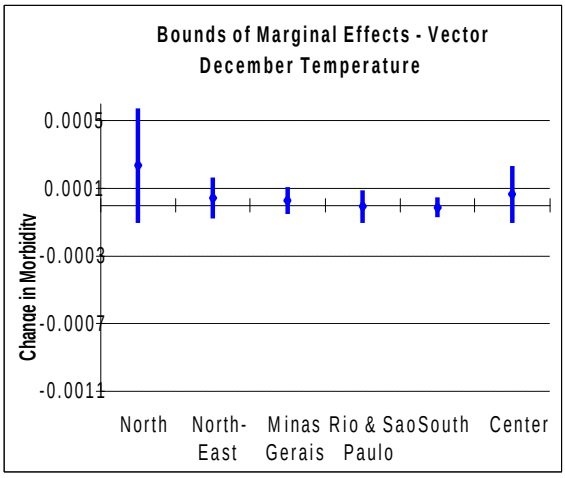


Annual Rainfall

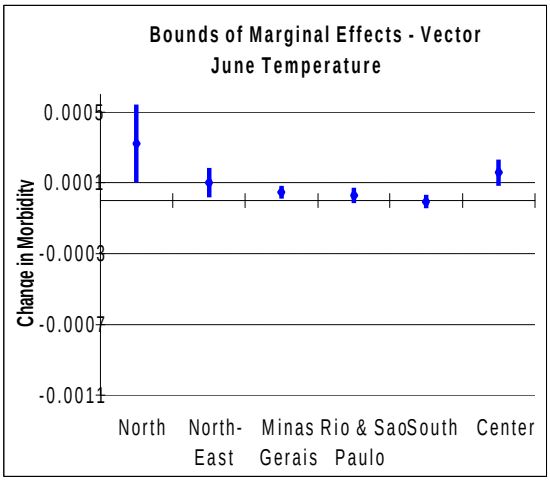


Population Density

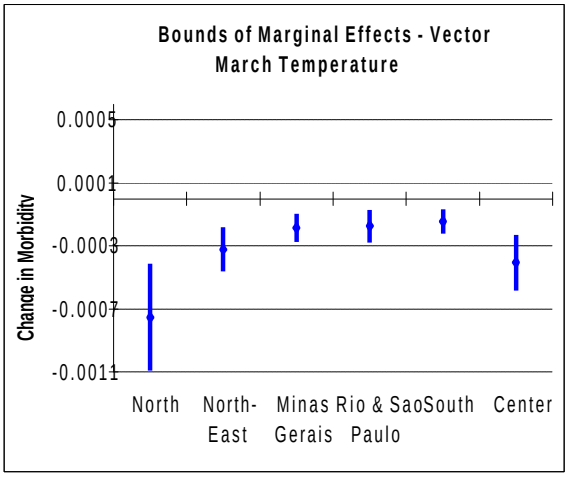
Figure 4b: Vectors Partial Effects – Temperature and Education



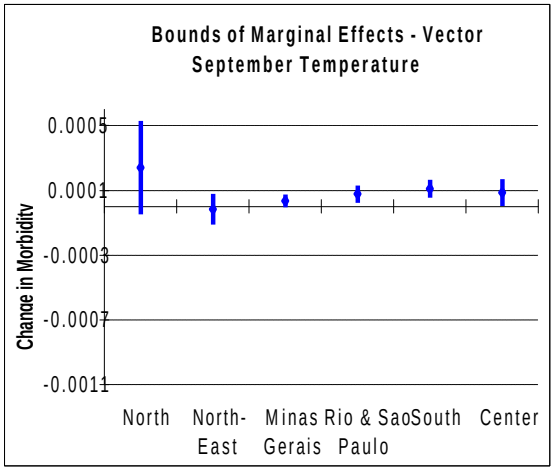
December Temperature



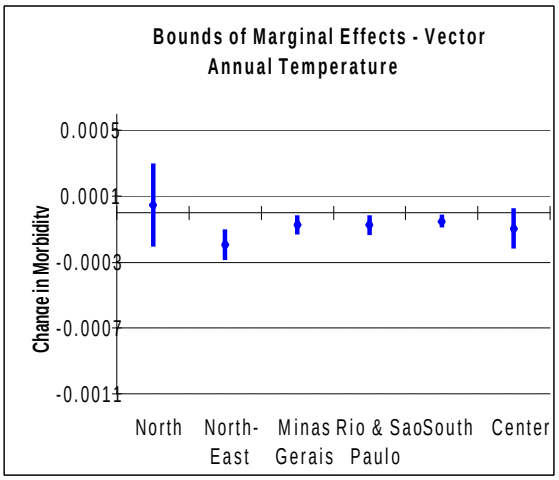
June Temperature



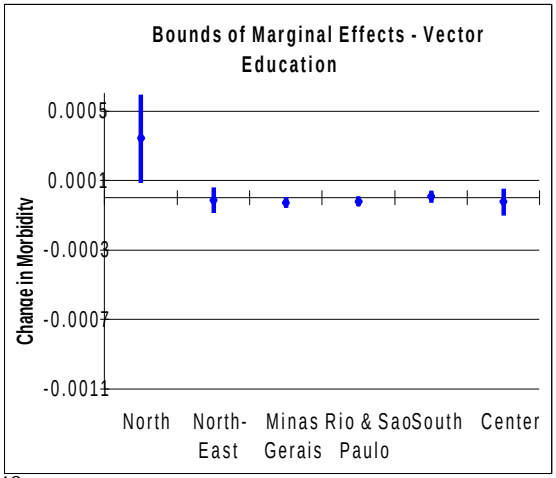
March Temperature



September Temperature

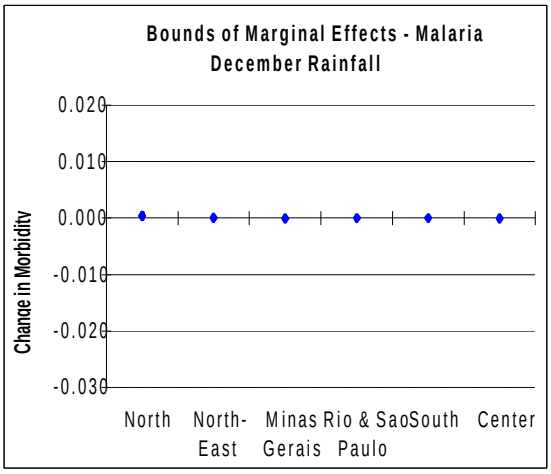


Annual Temperature

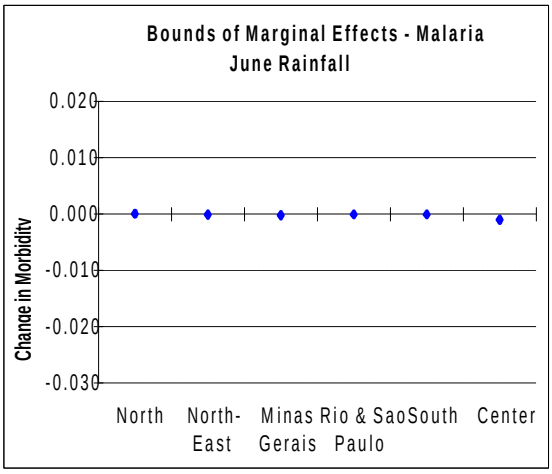


Education

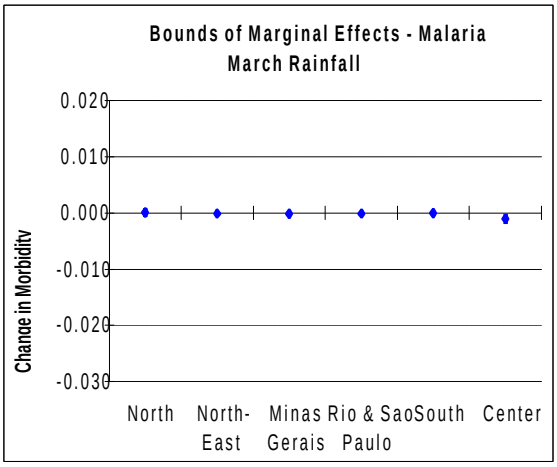
Figure 5a: Malaria Partial Effects – Rainfall and Population Densit



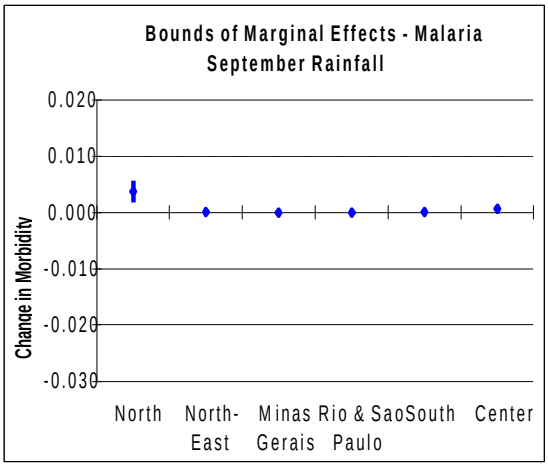
December Rainfall



June Rainfall



March Rainfall



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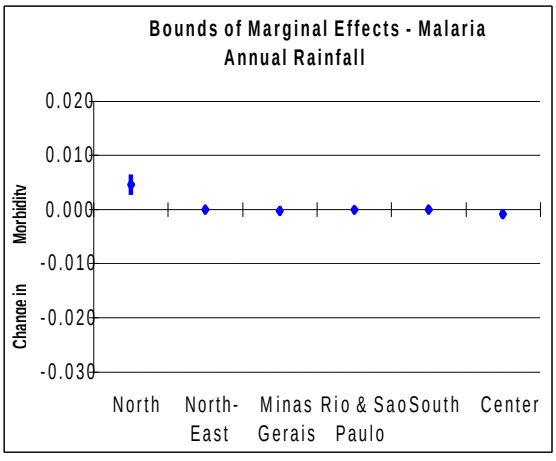
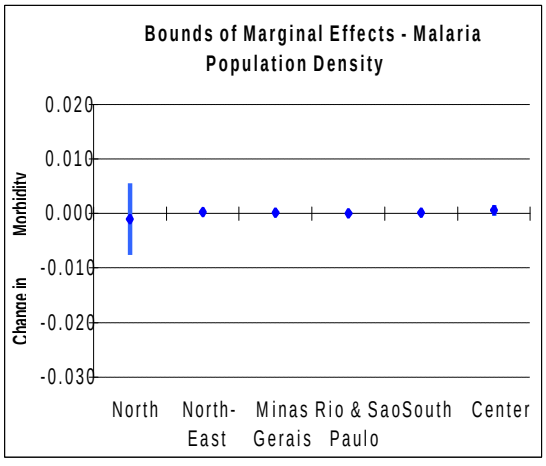
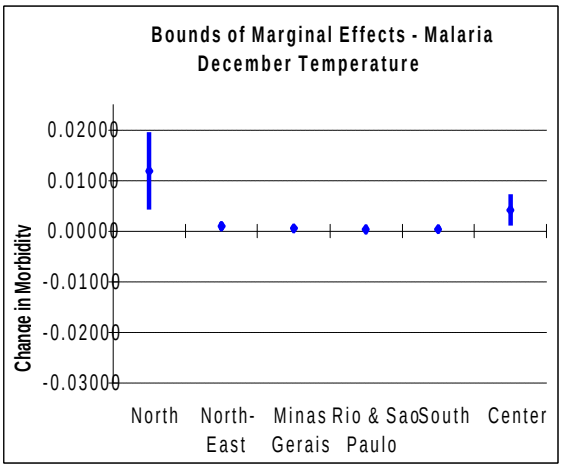


Annual Rainfall

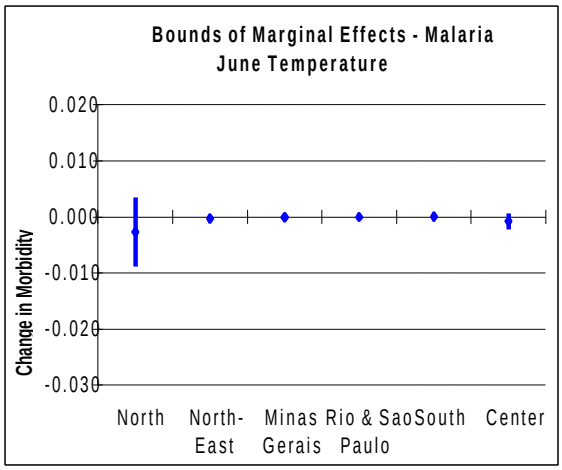


Population Density

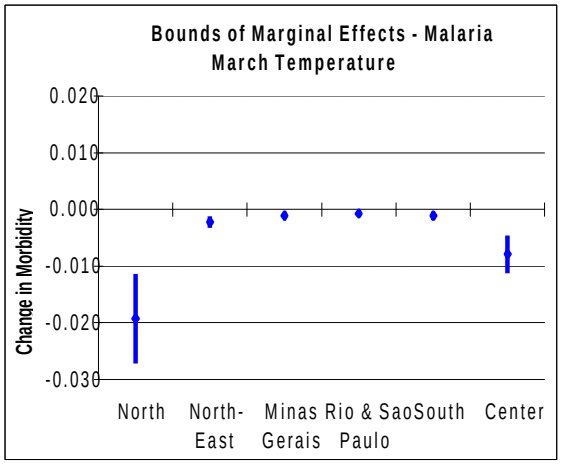
Figure 5b: Malaria Partial Effects – Temperature and Education



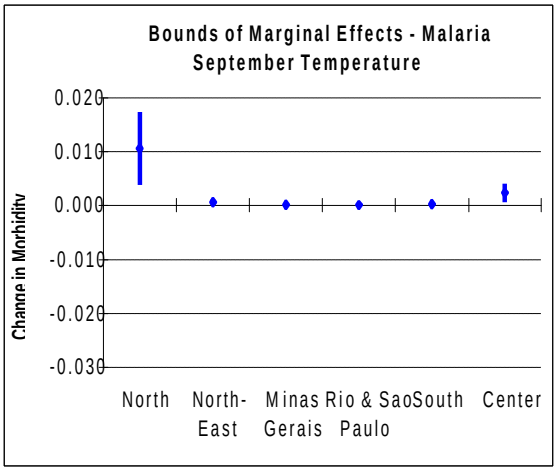
December Temperature



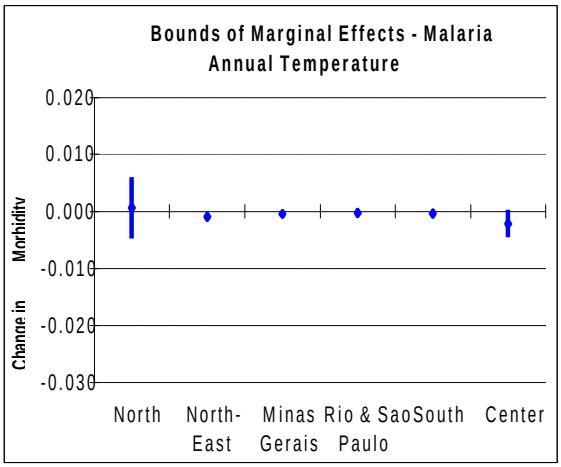
June Temperature



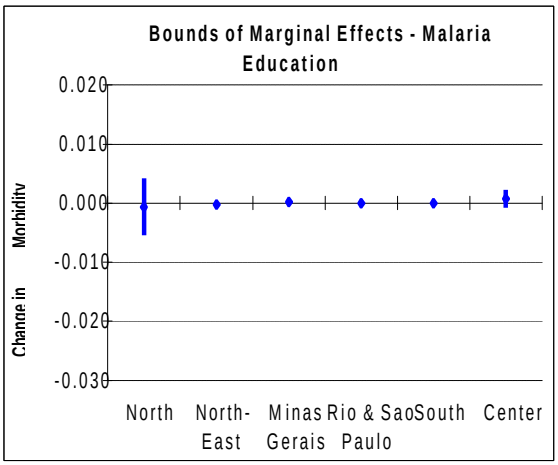
March Temperature



September Temperature

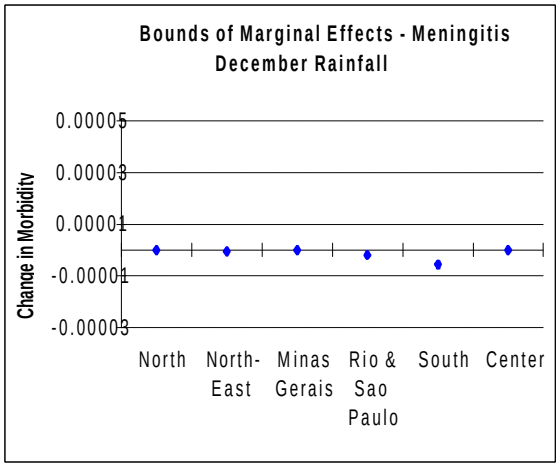


Annual Temperature

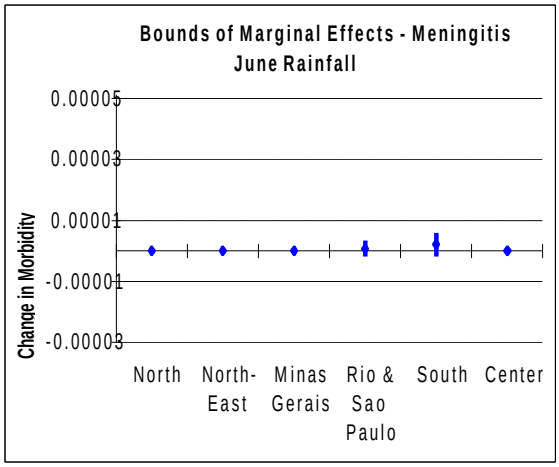


Education

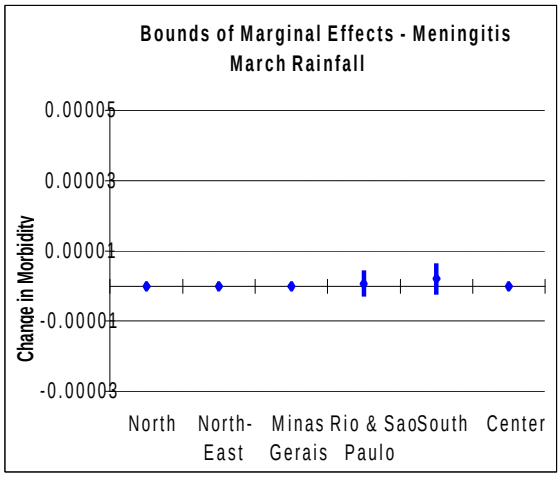
Figure 6a: Meningitis Partial Effects – Rainfall and Population Den



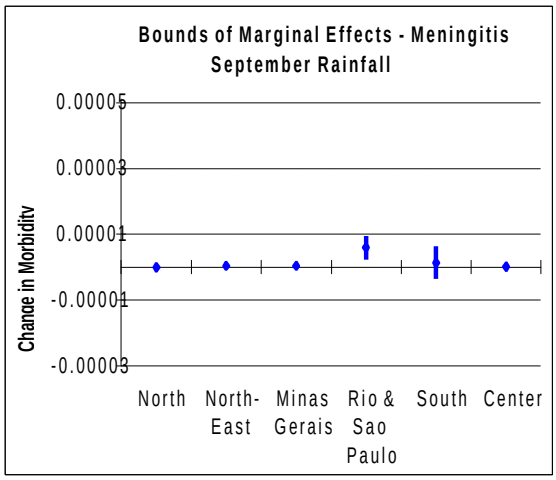
December Rainfall



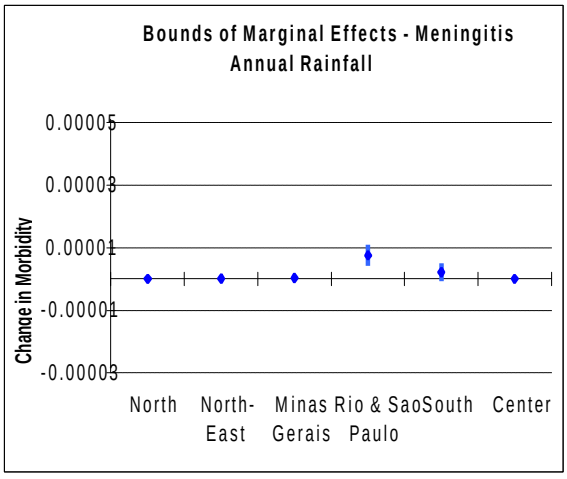
June Rainfall



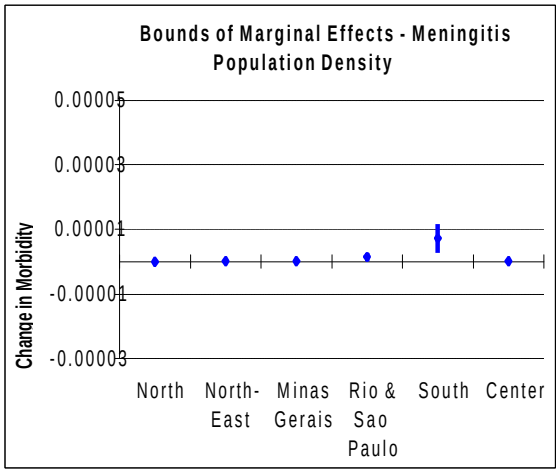
March Rainfall



September Rainfall

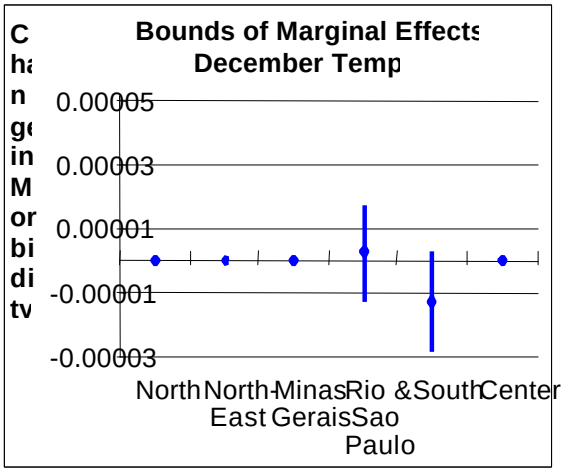


Annual Rainfall

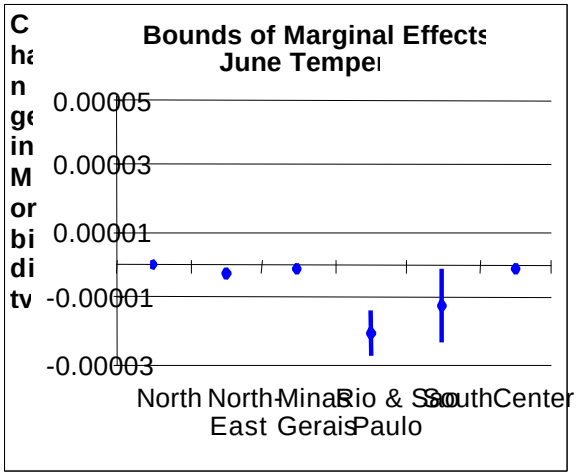


Population Density

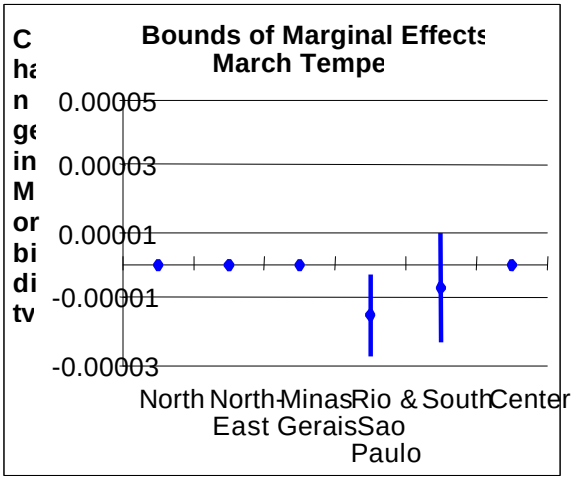
Figure 6b: Meningitis Partial Effects – Temperature and Education



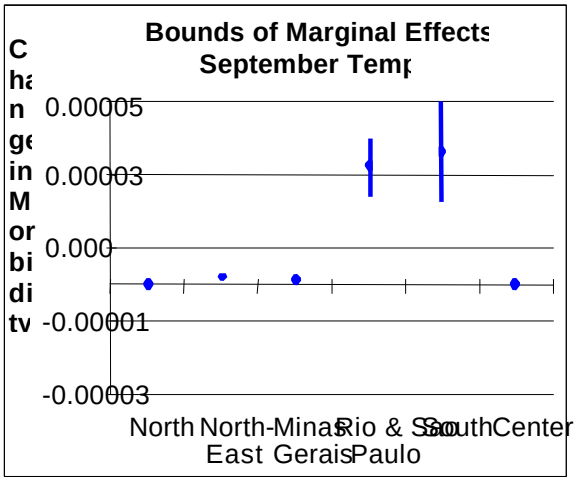
December Temperature



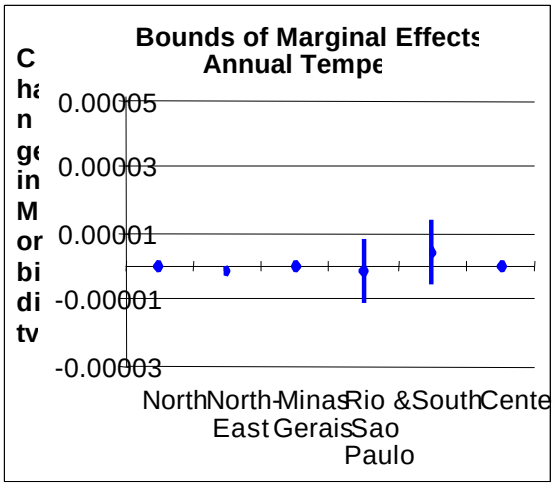
June Temperature



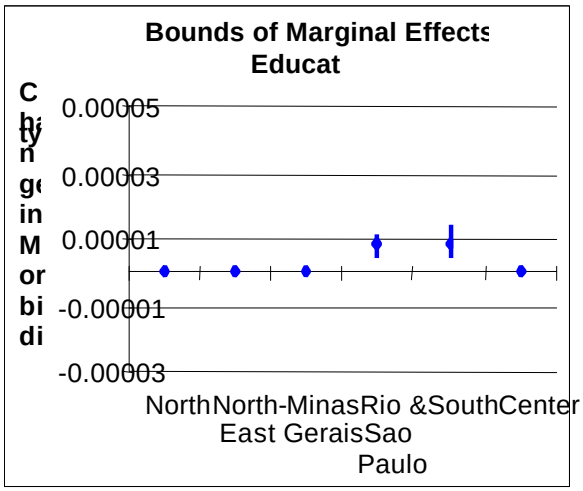
March Temperature



September Temperature

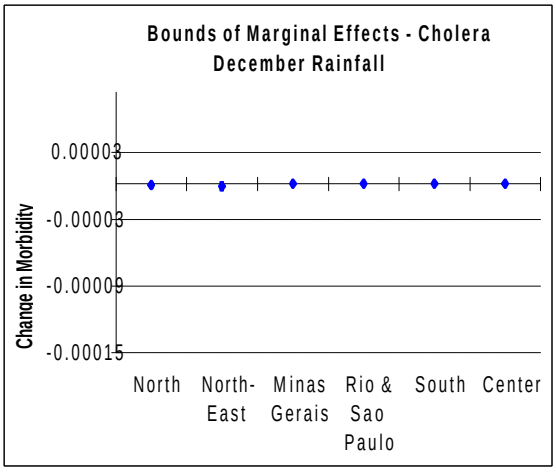


Annual Temperature

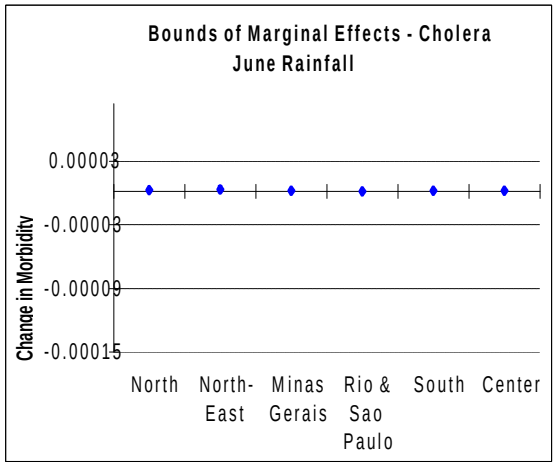


Education

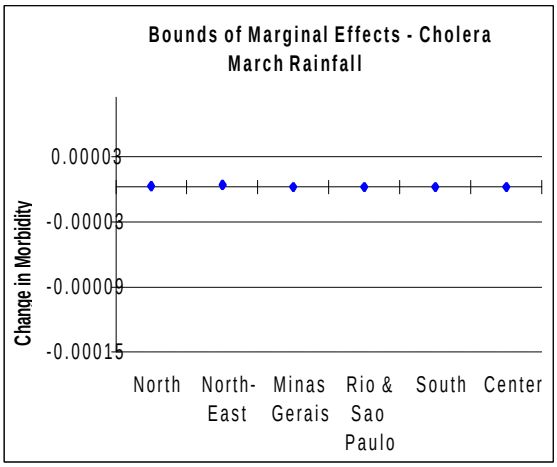
Figure 7a: Cholera Partial Effects – Rainfall and Population Density



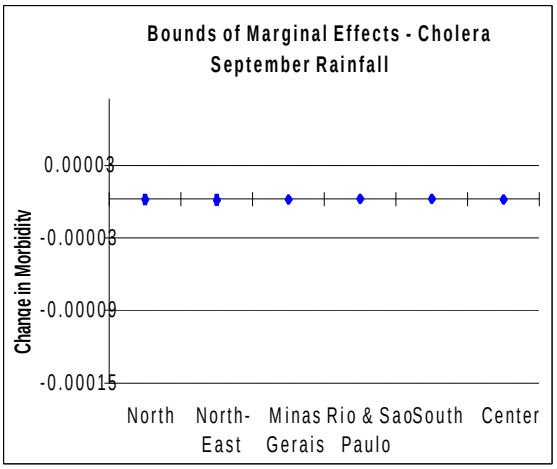
December Rainfall



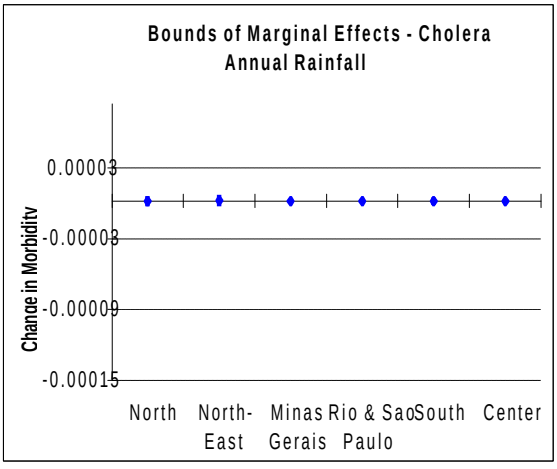
June Rainfall



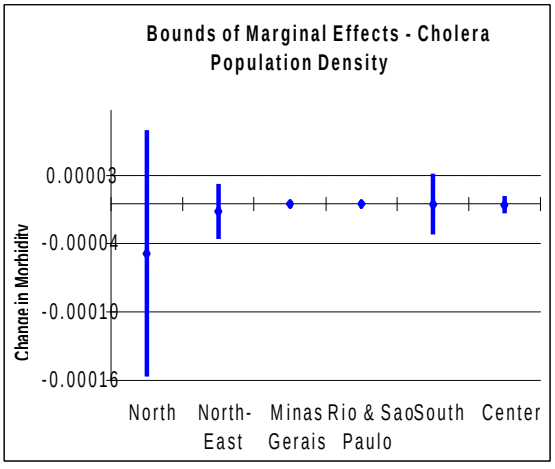
March Rainfall



September Rainfall

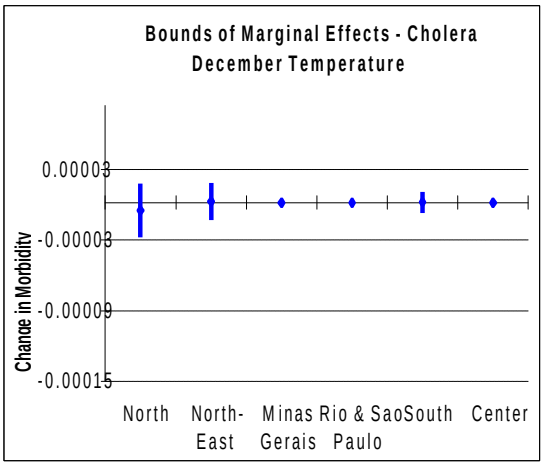


Annual Rainfall

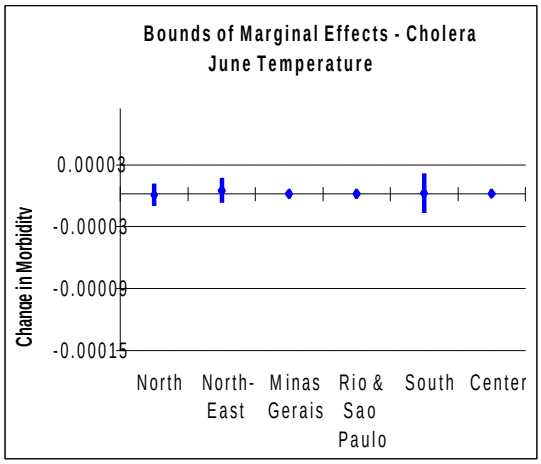


Population Density

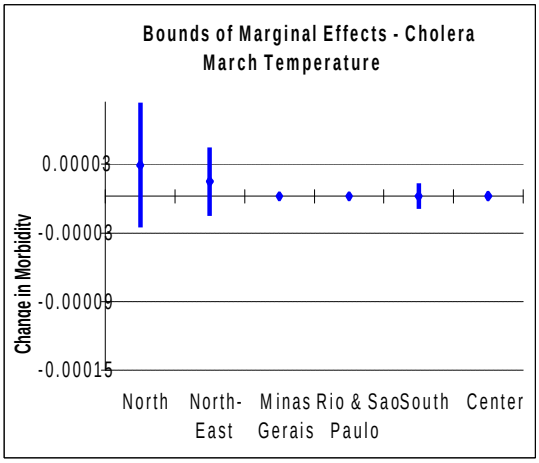
Figure 7b: Cholera Partial Effects – Temperature and Education



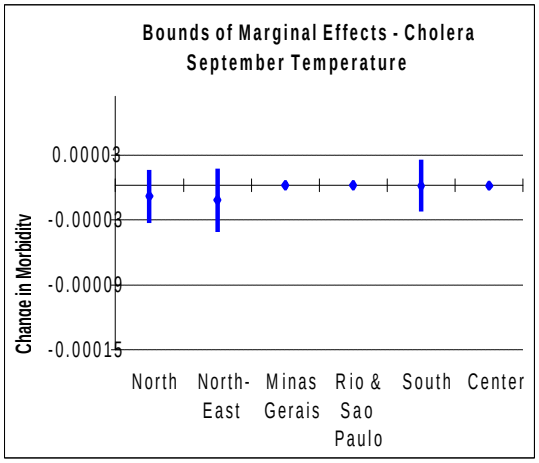
December Temperature



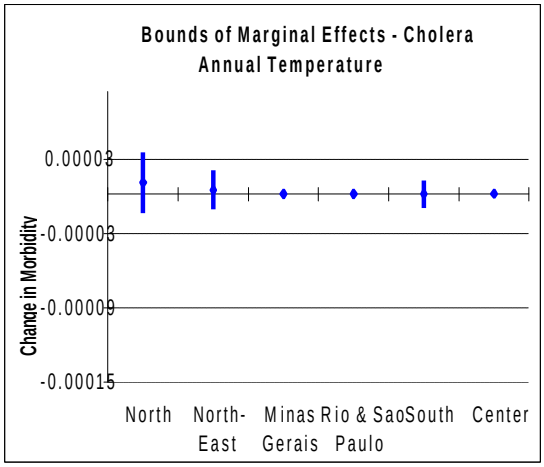
June Temperature



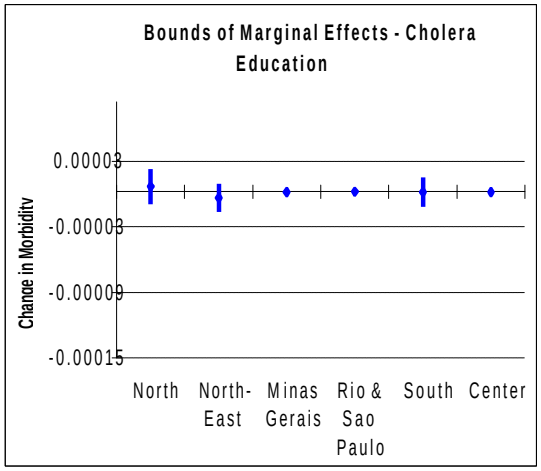
March Temperature



September Temperature

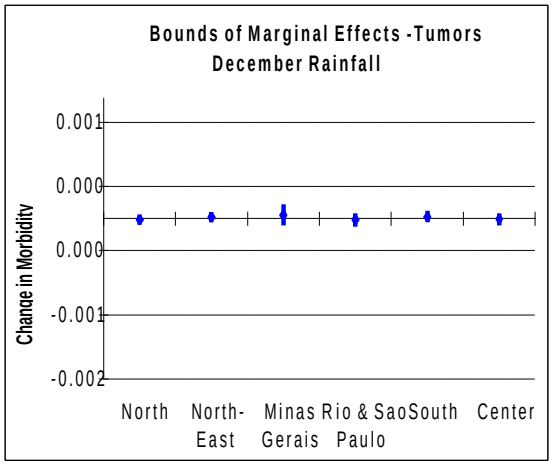


Annual Temperature

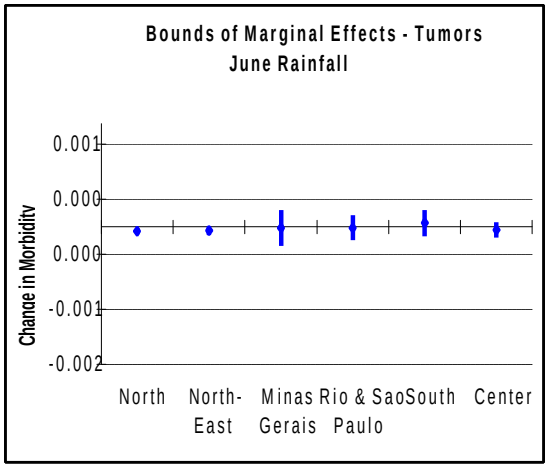


Education

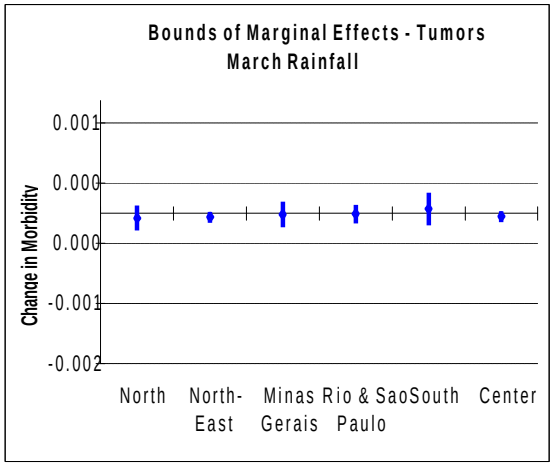
Figure 8a: Tumors Partial Effects – Rainfall and Population Density



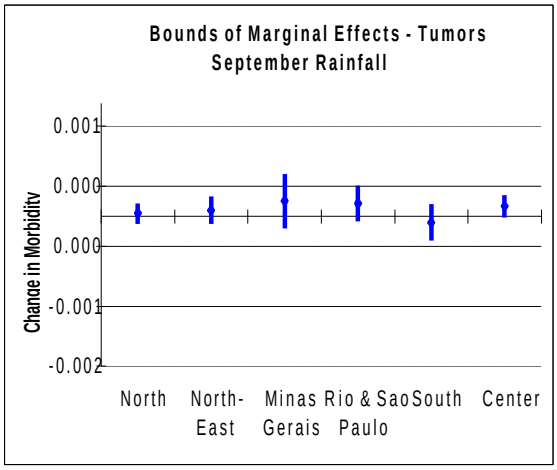
December Rainfall



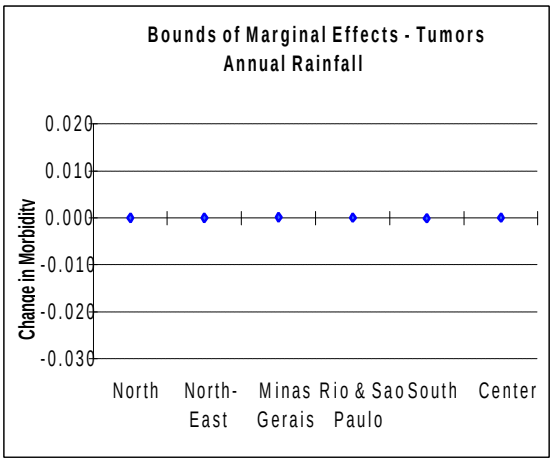
June Rainfall



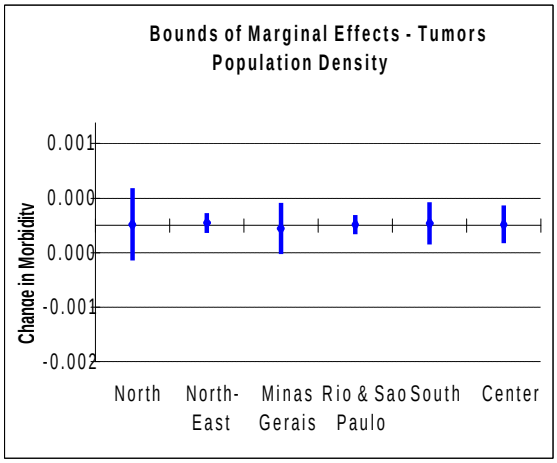
March Rainfall



September Rainfall

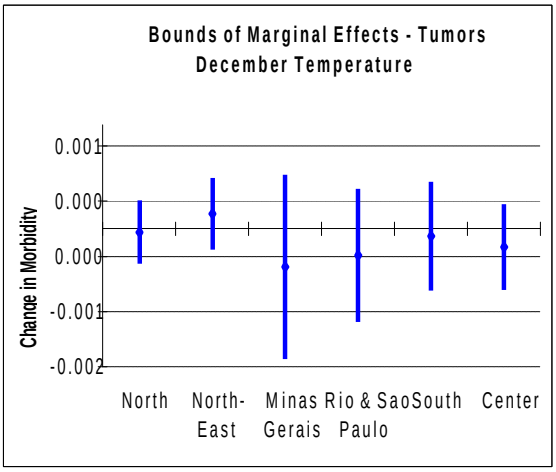


Annual Rainfall

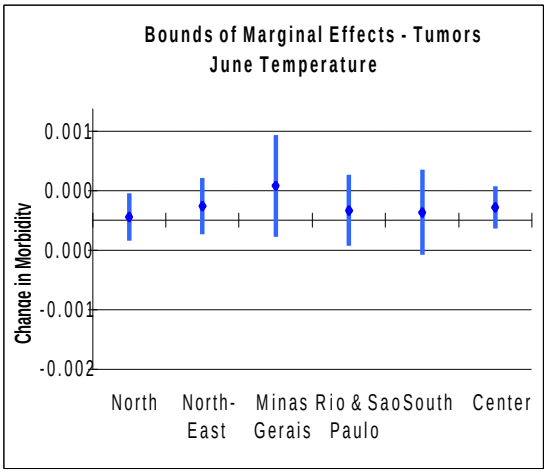


Population Density

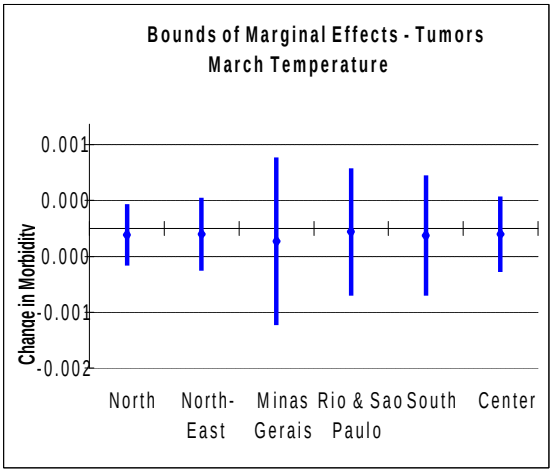
Figure 8b: Tumors Partial Effects – Temperature and Education



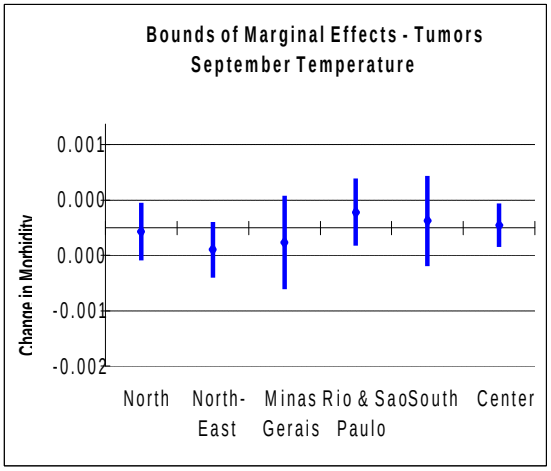
December Temperature



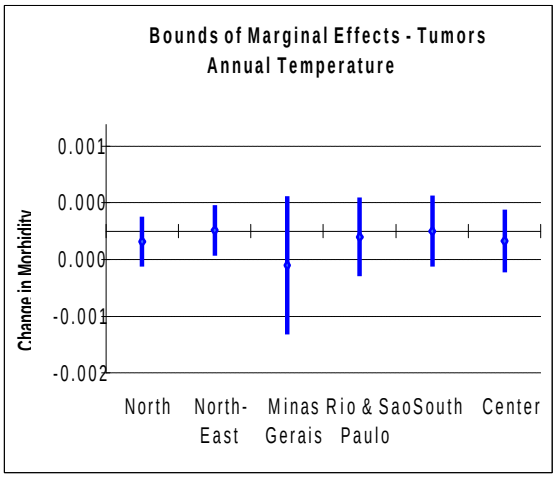
June Temperature



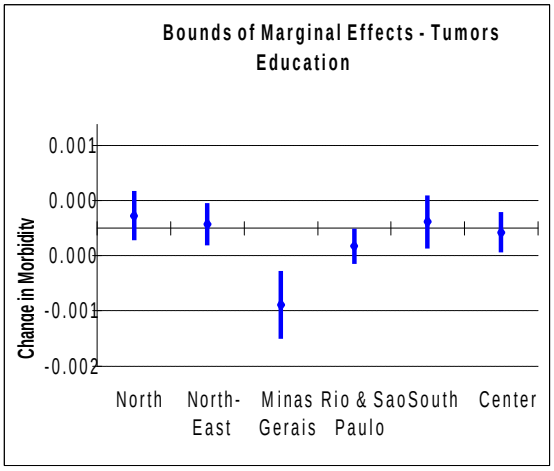
March Temperature



September Temperature

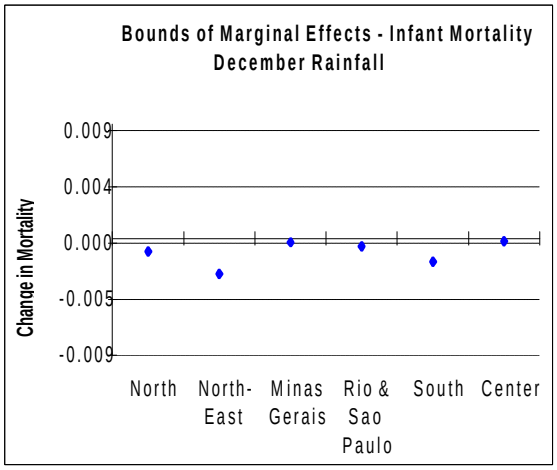


Annual Temperature

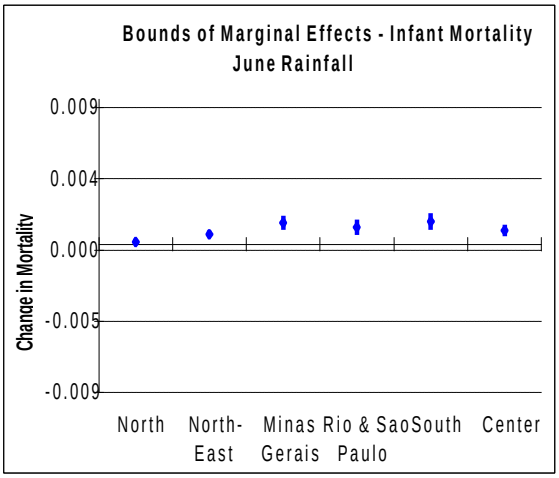


Education

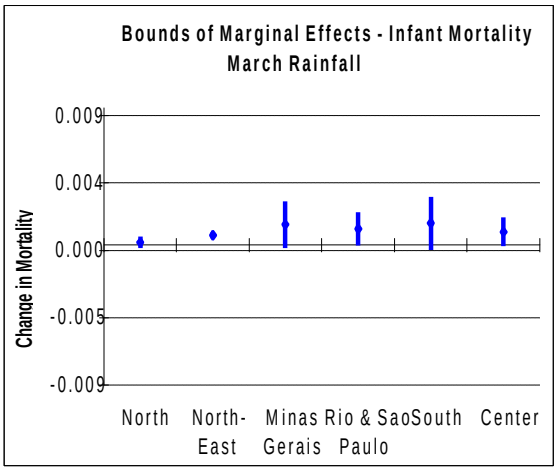
Figure 9a: Infant Mortality Partial Effects – Rainfall and Population Density



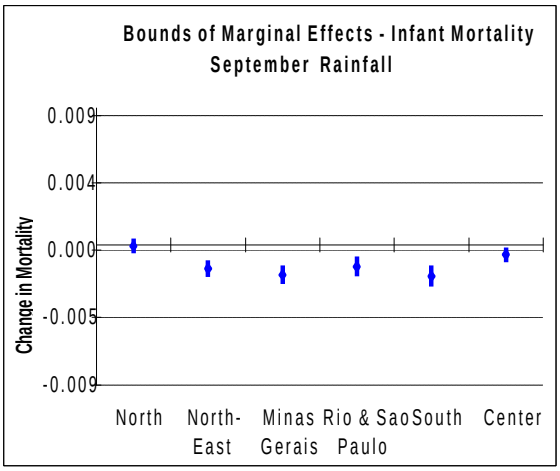
December Rainfall



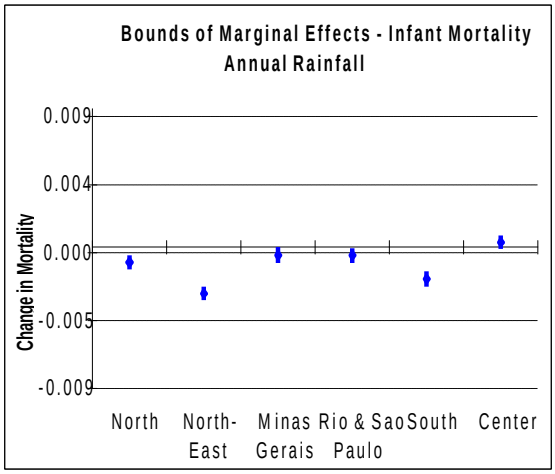
June Rainfall



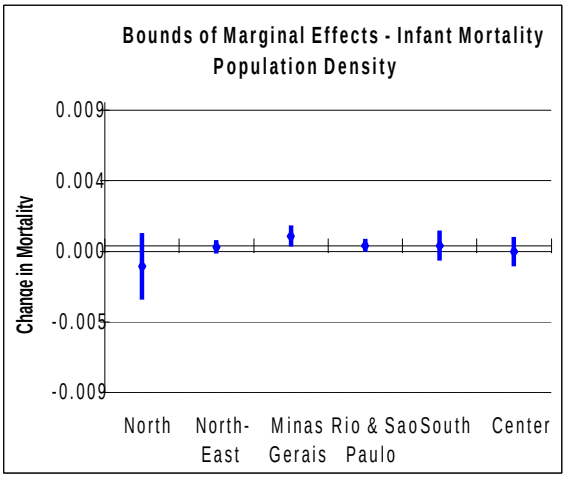
March Rainfall



September Rainfall

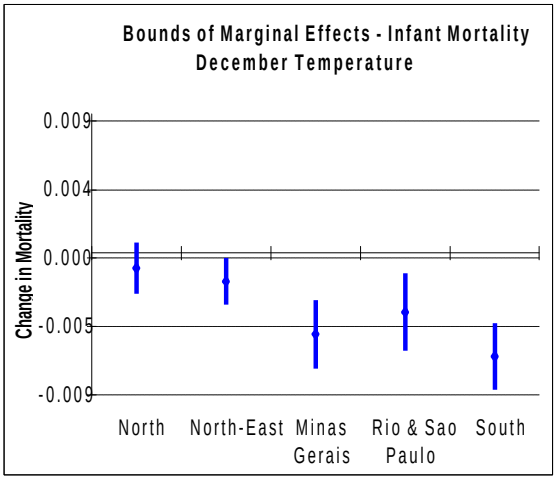


Annual Rainfall

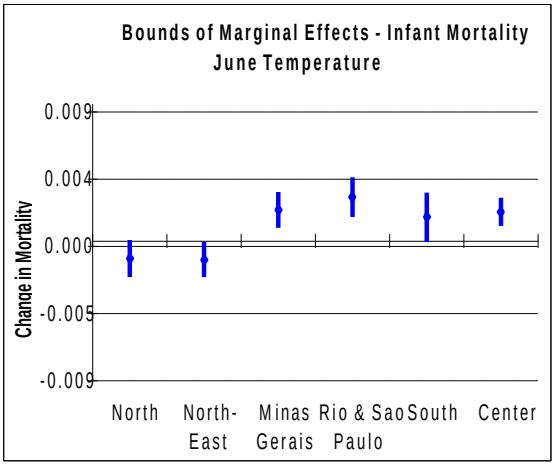


Population Density

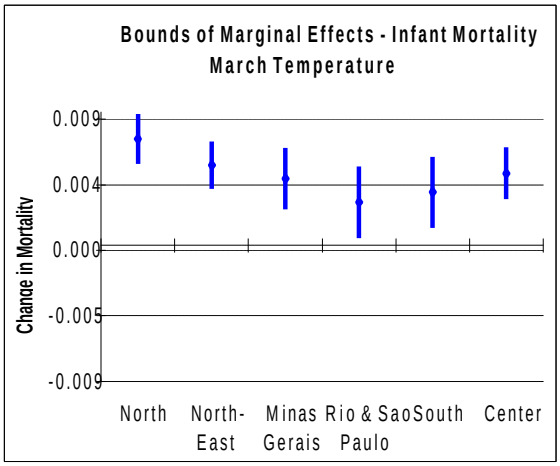
Figure 9b: Infant Mortality Partial Effects – Temperature and Education



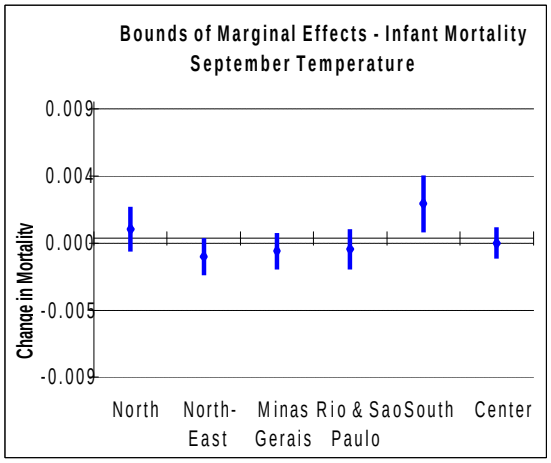
December Temperature



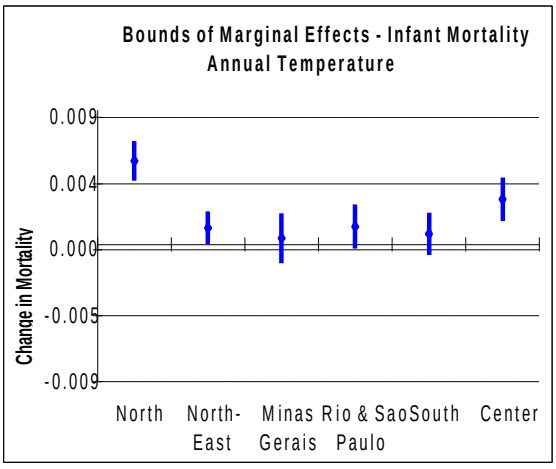
June Temperature



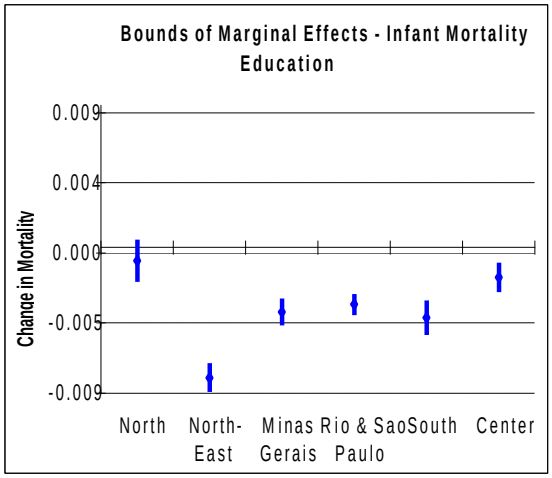
March Temperature



September Temperature



Annual Temperature



Education

Appendix 2: Tobit Estimates for Morbidity and Ordinary Least Square Results for Infant Mortality

This appendix reports the Tobit estimates underlying figures 1-8 of Appendix I. Mean, marginal effects, percentage effects, 90 confidence bounds and the proportion of the marginal effect due to changes from zero to non-zero incidence are reported.

The variables present in the regressions are:

Variable	Description
RNDEC	Average rainfall in December
RNDEC2	Square of average rainfall in December
RNMAR	Average rainfall in December
RNMAR2	Square of average rainfall in March
RNJUN	Average rainfall in June
RNJUN2	Square of average rainfall in June
RNSEP	Average rainfall in September
RNSEP2	Square of average rainfall in September
TNDEC	Average temperature in December
TNDEC2	Square of average temperature in December
TNMAR	Average temperature in December
TNMAR2	Square of average temperature in March
TNJUN	Average temperature in June
TNJUN2	Square of average temperature in June
TNSEP	Average temperature in September
TNSEP2	Square of average temperature in September
TRNDEC	Interaction between temperature and rainfall in December
TRNMAR	Interaction between temperature and rainfall in March
TRNJUN	Interaction between temperature and rainfall in June
TRNSEP	Interaction between temperature and rainfall in September
DINT1	Interaction between population density and rainfall in December
DINT2	Interaction between population density and rainfall in March
DINT3	Interaction between population density and rainfall in June
DINT4	Interaction between population density and rainfall in September
DINT5	Interaction between population density and temperature in December
DINT6	Interaction between population density and temperature in March
DINT7	Interaction between population density and temperature in June
DINT8	Interaction between population density and temperature in September

Variable	Description
DENS	Population density, population per Km2
DENS2	Square of population density
PYOUNG	Percentage of the population bellow 15 years of age
POLD	Percentage of the population above 65 years of age
EDUC	Average years of schooling (adults over 25 years)
ED2	Square of average years of schooling
R 1	Dummy variable to North region
R 2	Dummy variable to Northeast region
R 3	Dummy variable to Minas Gerais
R 4	Dummy variable to the states of Sao Paulo and Rio de Janeiro
R 5	Dummy variable to South region
R 6	Dummy variable to Center-West region
ALT	Altitude measured in meters
ALT2	Square of altitude
SEA	Distance from the sea in Km
SEA2	Square of the distance from the sea
EINT 1	Interaction between education and rainfall in December
EINT 2	Interaction between education and rainfall in March
EINT 3	Interaction between education and rainfall in June
EINT 4	Interaction between education and rainfall in September
EINT 5	Interaction between education and temperature in December
EINT 6	Interaction between education and temperature in March
EINT 7	Interaction between education and temperature in June
EINT 8	Interaction between education and temperature in September

Appendix 3: Regressions

Regression 1

Dependent variable: Cardiac Morbidity
Number of observations = 3618 Log likelihood = 12714.7
Number of positive obs. = 3601
Fraction of positive obs. = 0.995301

Parameter	Estimate	Standard Error	t-statistic	P-value
C	-.041803	.049578	-.843189	[.399]
RNDEC	.987370E-03	.518726E-03	1.90345	[.057]
RNDEC2	-.113322E-05	.237631E-05	-.476882	[.633]
RNMAR	-.114587E-03	.512156E-03	-.223735	[.823]
RNMAR2	.472273E-05	.173326E-05	2.72476	[.006]
RNJUN	-.474173E-04	.395333E-03	-.119943	[.905]
RNJUN2	.590045E-05	.290550E-05	2.03078	[.042]
RNSEP	-.405167E-03	.784212E-03	-.516655	[.605]
RNSEP2	-.197358E-04	.940214E-05	-2.09907	[.036]
TNDEC	.716934E-02	.492946E-02	1.45438	[.146]
TNDEC2	-.130927E-03	.856528E-04	-1.52858	[.126]
TNMAR	-.785532E-04	.326374E-02	-.024068	[.981]
TNMAR2	.778446E-05	.538488E-04	.144561	[.885]
TNJUN	.149910E-02	.173885E-02	.862126	[.389]
TNJUN2	-.256579E-04	.321761E-04	-.797421	[.425]
TNSEP	-.450867E-02	.250159E-02	-1.80232	[.071]
TNSEP2	.762585E-04	.439841E-04	1.73378	[.083]
TRNDEC	-.304911E-04	.181246E-04	-1.68230	[.093]
TRNMAR	-.543532E-05	.192645E-04	-.282142	[.778]
TRNJUN	-.893724E-05	.155305E-04	-.575464	[.565]
TRNSEP	.237744E-04	.265902E-04	.894102	[.371]
DINT1	-.239779E-04	.263420E-04	-.910255	[.363]
DINT2	.998177E-05	.170629E-04	.584999	[.559]
DINT3	.223138E-04	.231569E-04	.963592	[.335]
DINT4	-.777499E-04	.870111E-04	-.893563	[.372]
DINT5	-.352862E-03	.352300E-03	-1.00159	[.317]
DINT6	.429913E-03	.336941E-03	1.27593	[.202]
DINT7	-.153982E-03	.170755E-03	-.901772	[.367]
DINT8	.839166E-04	.157362E-03	.533270	[.594]
DENS	-.417055E-03	.173580E-02	-.240267	[.810]
DENS2	.218696E-05	.121766E-05	1.79603	[.072]
PYOUNG	.020896	.459007E-02	-4.55242	[.000]
POLD	.065463	.011473	5.70579	[.000]
EDUC	.407774E-02	.311527E-02	1.30895	[.191]
R1	-.396312E-02	.118391E-02	-3.34749	[.001]
R2	-.226383E-02	.849008E-03	-2.66644	[.008]
R3	-.164845E-02	.607672E-03	-2.71273	[.007]
R5	.179945E-02	.799798E-03	2.24988	[.024]
R6	-.676718E-03	.838903E-03	-.806670	[.420]
ALT	-.658101E-05	.253862E-05	-2.59236	[.010]
ALT2	.332616E-08	.256630E-08	1.29609	[.195]
SEA	.527497E-05	.303786E-05	1.73641	[.082]
SEA2	-.372615E-08	.256627E-08	-1.45197	[.147]
ED2	-.577845E-04	.805873E-04	-.717042	[.473]

EINT1	-.348007E-04	.267097E-04	-1.30292	[.193]
EINT2	.300744E-05	.231018E-04	.130182	[.896]
EINT3	.237007E-04	.334174E-04	.709232	[.478]
EINT4	.186404E-05	.601184E-04	.031006	[.975]
EINT5	-.199830E-03	.277770E-03	-.719408	[.472]
EINT6	-.912603E-04	.218230E-03	-.418185	[.676]
EINT7	-.150867E-03	.164569E-03	-.916744	[.359]
EINT8	.308465E-03	.201438E-03	1.53131	[.126]
SIGMA	.705265E-02	.831582E-04	84.8100	[.000]

Standard Errors computed from analytic second derivatives (Newton)

Regression 2:

Dependent variable: Respiratory Morbidity
Number of observations = 3618 Log likelihood = 9448.10
Number of positive obs. = 3609
Fraction of positive obs. = 0.997512

Parameter	Estimate	Standard Error	t-statistic	P-value
C	-.190324	.123722	-1.53831	[.124]
RNDEC	.278389E-02	.128409E-02	2.16799	[.030]
RNDEC2	-.498452E-05	.584274E-05	-.853113	[.394]
RNMAR	-.648329E-03	.127505E-02	-.508473	[.611]
RNMAR2	.149004E-04	.432323E-05	3.44659	[.001]
RNJUN	.157850E-02	.985863E-03	1.60114	[.109]
RNJUN2	.142313E-04	.723870E-05	1.96600	[.049]
RNSEP	-.608125E-03	.195444E-02	-.311151	[.756]
RNSEP2	-.438197E-04	.234578E-04	-1.86802	[.062]
TNDEC	.028987	.012303	2.35613	[.018]
TNDEC2	-.498819E-03	.213765E-03	-2.33350	[.020]
TNMAR	-.774051E-02	.814369E-02	-.950491	[.342]
TNMAR2	.153627E-03	.134363E-03	1.14337	[.253]
TNJUN	-.150661E-02	.433941E-02	-.347192	[.728]
TNJUN2	.544738E-04	.802927E-04	.678440	[.497]
TNSEP	-.492353E-02	.623801E-02	-.789280	[.430]
TNSEP2	.659079E-04	.109676E-03	.600932	[.548]
TRNDEC	-.881989E-04	.448495E-04	-1.96655	[.049]
TRNMAR	-.120297E-04	.479596E-04	-.250830	[.802]
TRNJUN	-.959100E-04	.387174E-04	-2.47718	[.013]
TRNSEP	.392220E-04	.662731E-04	.591824	[.554]
DINT1	-.652404E-04	.657587E-04	-.992119	[.321]
DINT2	.480957E-04	.425961E-04	1.12911	[.259]
DINT3	.817360E-04	.578031E-04	1.41404	[.157]
DINT4	-.306864E-03	.217209E-03	-1.41276	[.158]
DINT5	-.120273E-02	.879443E-03	-1.36761	[.171]
DINT6	.164190E-02	.841100E-03	1.95208	[.051]
DINT7	-.598247E-03	.426258E-03	-1.40348	[.160]
DINT8	.214306E-03	.392832E-03	.545542	[.585]
DENS	-.288922E-02	.433314E-02	-.666773	[.505]
DENS2	.633798E-05	.303975E-05	2.08503	[.037]
PYOUNG	-.030529	.011450	-2.66630	[.008]
POLD	.049830	.028630	1.74049	[.082]
EDUC	.012157	.777126E-02	1.56439	[.118]
R1	-.443496E-02	.295372E-02	-1.50148	[.133]
R2	-.115962E-03	.211859E-02	-.054735	[.956]
R3	-.190599E-02	.151640E-02	-1.25692	[.209]
R5	.206397E-02	.199639E-02	1.03385	[.301]
R6	.217019E-02	.208944E-02	1.03865	[.299]
ALT	-.126143E-04	.633657E-05	-1.99071	[.047]
ALT2	.716848E-08	.640581E-08	1.11906	[.263]
SEA	-.300549E-06	.757617E-05	-.039670	[.968]
SEA2	.435272E-08	.638567E-08	.681640	[.495]
ED2	-.152657E-03	.201078E-03	-.759195	[.448]
EINT1	-.114082E-03	.666371E-04	-1.71199	[.087]
EINT2	.511113E-04	.576436E-04	.886677	[.375]

EINT3	.486479E-05	.833841E-04	.058342	[.953]
EINT4	.149881E-03	.149876E-03	1.00004	[.317]
EINT5	.199237E-03	.692976E-03	.287509	[.774]
EINT6	-.114625E-02	.544672E-03	-2.10447	[.035]
EINT7	-.312547E-03	.410816E-03	-.760795	[.447]
EINT8	.832250E-03	.502490E-03	1.65625	[.098]
SIGMA	.017607	.207328E-03	84.9213	[.000]

Standard Errors computed from analytic second derivatives (Newton)

Regression 3:

Dependent variable: Tumor Morbidity
Number of observations = 3618 Log likelihood = 11833.6
Number of positive obs. = 3523
Fraction of positive obs. = 0.973742

Parameter	**Estimate**	**Standard Error**	**t-statistic**	**P-value**
C	.037373	.058443	.639473	[.523]
RNDEC	.114672E-02	.620265E-03	1.84876	[.064]
RNDEC2	-.125020E-05	.289694E-05	-.431559	[.666]
RNMAR	-.415227E-05	.608130E-03	-.682792E-02	[.995]
RNMAR2	.390353E-05	.205489E-05	1.89963	[.057]
RNJUN	.499527E-03	.473118E-03	1.05582	[.291]
RNJUN2	.229231E-05	.350100E-05	.654757	[.513]
RNSEP	-.751062E-03	.100013E-02	-.750963	[.453]
RNSEP2	-.205681E-04	.128483E-04	-1.60084	[.109]
TNDEC	.412808E-03	.581069E-02	.071043	[.943]
TNDEC2	.923260E-05	.100929E-03	.091476	[.927]
TNMAR	-.148779E-02	.387230E-02	-.384213	[.701]
TNMAR2	.245102E-04	.636604E-04	.385015	[.700]
TNJUN	.193814E-02	.205050E-02	.945202	[.345]
TNJUN2	-.201111E-04	.379177E-04	-.530389	[.596]
TNSEP	-.319076E-02	.297140E-02	-1.07382	[.283]
TNSEP2	.313020E-04	.527246E-04	.593689	[.553]
TRNDEC	-.372166E-04	.217557E-04	-1.71066	[.087]
TRNMAR	-.484497E-05	.229092E-04	-.211486	[.833]
TRNJUN	-.244333E-04	.186287E-04	-1.31159	[.190]
TRNSEP	.251522E-04	.342721E-04	.733897	[.463]
DINT1	-.145684E-04	.308849E-04	-.471699	[.637]
DINT2	-.231259E-05	.199981E-04	-.115641	[.908]
DINT3	-.115607E-05	.271664E-04	-.042555	[.966]
DINT4	.163319E-04	.102012E-03	.160098	[.873]
DINT5	-.128260E-03	.412991E-03	-.310565	[.756]
DINT6	.313977E-04	.395087E-03	.079470	[.937]
DINT7	-.212819E-04	.200268E-03	-.106267	[.915]
DINT8	.836833E-04	.184443E-03	.453708	[.650]
DENS	.115411E-02	.203432E-02	.567319	[.570]
DENS2	-.397314E-06	.142745E-05	-.278338	[.781]
PYOUNG	-.012366	.542794E-02	-2.27824	[.023]
POLD	.031820	.013520	2.35356	[.019]
EDUC	-.542618E-02	.366943E-02	-1.47875	[.139]
R1	-.255176E-02	.142443E-02	-1.79143	[.073]

R2	-.128163E-02	.100052E-02	-1.28096	[.200]
R3	.035119	.715412E-03	49.0894	[.000]
R5	-.663175E-03	.939549E-03	-.705843	[.480]
R6	-.202010E-02	.995450E-03	-2.02933	[.042]
ALT	-.425733E-05	.299290E-05	-1.42248	[.155]
ALT2	.275705E-08	.301868E-08	.913330	[.361]
SEA	.146481E-05	.362270E-05	.404343	[.686]
SEA2	-.166172E-08	.308032E-08	-.539463	[.590]
ED2	.145003E-04	.949458E-04	.152722	[.879]
EINT1	-.552144E-04	.316485E-04	-1.74461	[.081]
EINT2	-.211755E-04	.272427E-04	-.777290	[.437]
EINT3	-.243611E-04	.393192E-04	-.619572	[.536]
EINT4	.180491E-03	.715605E-04	2.52222	[.012]
EINT5	-.899987E-04	.329545E-03	-.273100	[.785]
EINT6	.685299E-04	.257574E-03	.266059	[.790]
EINT7	-.204875E-03	.194319E-03	-1.05432	[.292]
EINT8	.455382E-03	.238530E-03	1.90912	[.056]
SIGMA	.826313E-02	.985023E-04	83.8877	[.000]

Standard Errors computed from analytic second derivatives (Newton)

Regression 4:

Dependent variable: Hydric Morbidity
Number of observations = 3618 Log likelihood = 12964.4
Number of positive obs. = 3574
Fraction of positive obs. = 0.987839

Parameter	**Estimate**	**Standard Error**	**t-statistic**	**P-value**
C	.043057	.044722	.962787	[.336]
RNDEC	.442636E-03	.468394E-03	.945009	[.345]
RNDEC2	-.122511E-05	.214892E-05	-.570108	[.569]
RNMAR	-.842378E-03	.462276E-03	-1.82224	[.068]
RNMAR2	.382837E-05	.156510E-05	2.44609	[.014]
RNJUN	.324373E-03	.356905E-03	.908848	[.363]
RNJUN2	-.662131E-06	.262127E-05	-.252600	[.801]
RNSEP	.445290E-03	.730995E-03	.609155	[.542]
RNSEP2	.530566E-05	.900505E-05	.589186	[.556]
TNDEC	.163146E-02	.444585E-02	.366962	[.714]
TNDEC2	.118736E-04	.772135E-04	.153776	[.878]
TNMAR	-.860061E-02	.295335E-02	-2.91216	[.004]
TNMAR2	.125497E-03	.486473E-04	2.57974	[.010]
TNJUN	.297181E-03	.156904E-02	.189404	[.850]
TNJUN2	.209619E-04	.290216E-04	.722285	[.470]
TNSEP	.500359E-02	.226295E-02	2.21109	[.027]
TNSEP2	-.126032E-03	.399329E-04	-3.15611	[.002]
TRNDEC	-.136140E-04	.163788E-04	-.831200	[.406]
TRNMAR	.164172E-04	.174019E-04	.943416	[.345]
TRNJUN	-.218597E-04	.140169E-04	-1.55953	[.119]
TRNSEP	-.262626E-04	.248925E-04	-1.05504	[.291]
DINT1	-.318910E-04	.237428E-04	-1.34318	[.179]
DINT2	.190162E-04	.153788E-04	1.23652	[.216]
DINT3	.162682E-04	.208693E-04	.779528	[.436]
DINT4	-.652327E-04	.784211E-04	-.831827	[.406]
DINT5	-.548896E-03	.317522E-03	-1.72869	[.084]
DINT6	.641891E-03	.303686E-03	2.11366	[.035]
DINT7	-.238229E-03	.153907E-03	-1.54788	[.122]
DINT8	.154044E-03	.141825E-03	1.08616	[.277]
DENS	-.789908E-03	.156443E-02	-.504917	[.614]

DENS2	.194986E-05	.109765E-05	1.77640	[.076]
PYOUNG	-.015355	.414851E-02	-3.70124	[.000]
POLD	-.011829	.010346	-1.14337	[.253]
EDUC	.160160E-02	.280845E-02	.570281	[.568]
R1	.441648E-02	.107315E-02	4.11543	[.000]
R2	.227157E-02	.766199E-03	2.96473	[.003]
R3	.589200E-03	.549275E-03	1.07269	[.283]
R5	-.993565E-03	.722771E-03	-1.37466	[.169]
R6	.128315E-02	.756893E-03	1.69528	[.090]
ALT	-.262323E-05	.229095E-05	-1.14504	[.252]
ALT2	.155575E-09	.231555E-08	.067187	[.946]
SEA	.263189E-05	.274293E-05	.959518	[.337]
SEA2	-.278708E-08	.231403E-08	-1.20442	[.228]
ED2	-.661002E-04	.726505E-04	-.909839	[.363]
EINT1	-.511491E-04	.241034E-04	-2.12207	[.034]
EINT2	.713605E-04	.208217E-04	3.42722	[.001]
EINT3	.182576E-04	.301146E-04	.606270	[.544]
EINT4	.984921E-05	.543266E-04	.181296	[.856]
EINT5	-.799811E-04	.251372E-03	-.318178	[.750]
EINT6	.851301E-05	.197170E-03	.043176	[.966]
EINT7	-.249960E-03	.148399E-03	-1.68438	[.092]
EINT8	.225652E-03	.181821E-03	1.24106	[.215]
SIGMA	.635593E-02	.753124E-04	84.3942	[.000]

Standard Errors computed from analytic second derivatives (Newton)

Regression 5:

Dependent variable: Vector Morbidity
Number of observations = 3618 Log likelihood = 3936.47
Number of positive obs. = 1098
Fraction of positive obs. = 0.303483

Parameter	**Estimate**	**Standard Error**	**t-statistic**	**P-value**
C	.142415	.033663	4.23065	[.000]
RNDEC	-.610380E-03	.322799E-03	-1.89090	[.059]
RNDEC2	.163335E-05	.132125E-05	1.23622	[.216]
RNMAR	-.510624E-03	.311902E-03	-1.63713	[.102]
RNMAR2	.949319E-06	.952953E-06	.996186	[.319]
RNJUN	.884504E-03	.245545E-03	3.60220	[.000]
RNJUN2	-.126687E-05	.160404E-05	-.789795	[.430]
RNSEP	-.184385E-02	.482545E-03	-3.82110	[.000]
RNSEP2	.869853E-06	.549444E-05	.158315	[.874]
TNDEC	-.553618E-02	.337671E-02	-1.63952	[.101]
TNDEC2	.113618E-03	.584323E-04	1.94443	[.052]
TNMAR	-.645186E-02	.218505E-02	-2.95272	[.003]
TNMAR2	.100241E-03	.365335E-04	2.74381	[.006]
TNJUN	-.936178E-03	.109596E-02	-.854211	[.393]
TNJUN2	.244333E-04	.198927E-04	1.22826	[.219]
TNSEP	.333553E-02	.163427E-02	2.04100	[.041]
TNSEP2	-.738910E-04	.284573E-04	-2.59656	[.009]
TRNDEC	.226781E-04	.111843E-04	2.02767	[.043]
TRNMAR	.174019E-04	.115959E-04	1.50070	[.133]
TRNJUN	-.398896E-04	.962662E-05	-4.14368	[.000]
TRNSEP	.719608E-04	.164332E-04	4.37899	[.000]
DINT1	.147959E-04	.130658E-04	1.13241	[.257]
DINT2	.541882E-05	.842517E-05	.643171	[.520]
DINT3	.108944E-04	.113594E-04	.959062	[.338]
DINT4	-.488095E-04	.434639E-04	-1.12299	[.261]
DINT5	.203673E-03	.176412E-03	1.15453	[.248]
DINT6	-.498713E-04	.169889E-03	-.293552	[.769]
DINT7	-.392552E-04	.857946E-04	-.457548	[.647]
DINT8	-.101556E-03	.777771E-04	-1.30573	[.192]

DENS	-.614054E-03	.858190E-03	-.715522	[.474]
DENS2	-.192700E-05	.615986E-06	-3.12831	[.002]
PYOUNG	-.377964E-02	.284159E-02	-1.33011	[.183]
POLD	-.054059	.733910E-02	-7.36588	[.000]
EDUC	.228649E-02	.211116E-02	1.08305	[.279]
R1	.316498E-02	.674426E-03	4.69286	[.000]
R2	.110017E-02	.539147E-03	2.04058	[.041]
R3	.106054E-03	.432560E-03	.245177	[.806]
R5	-.112382E-02	.606699E-03	-1.85235	[.064]
R6	-.455393E-04	.527523E-03	-.086327	[.931]
ALT	-.425442E-05	.176291E-05	-2.41330	[.016]
ALT2	-.186863E-08	.187358E-08	-.997354	[.319]
SEA	.890222E-06	.188621E-05	.471962	[.637]
SEA2	-.755446E-09	.151770E-08	-.497757	[.619]
ED2	-.287452E-04	.492385E-04	-.583794	[.559]
EINT1	-.787028E-06	.176689E-04	-.044543	[.964]
EINT2	-.335277E-05	.127118E-04	-.263753	[.792]
EINT3	.211324E-04	.197418E-04	1.07044	[.284]
EINT4	.350619E-04	.377158E-04	.929632	[.353]
EINT5	-.120037E-03	.190365E-03	-.630563	[.528]
EINT6	-.674658E-04	.134905E-03	-.500099	[.617]
EINT7	.112358E-03	.101789E-03	1.10384	[.270]
EINT8	-.663598E-05	.128858E-03	-.051499	[.959]
SIGMA	.334839E-02	.721465E-04	46.4109	[.000]

Standard Errors computed from analytic second derivatives (Newton)

Regression 6:

Dependent variable: Malaria Morbidity
Number of observations = 3618 Log likelihood = 511.756
Number of positive obs. = 621
Fraction of positive obs. = 0.171642

Parameter	**Estimate**	**Standard Error**	**t-statistic**	**P-value**
C	1.17254	.692558	1.69306	[.090]
RNDEC	-.477440E-02	.715446E-02	-.667333	[.505]
RNDEC2	-.512016E-04	.256467E-04	-1.99642	[.046]
RNMAR	-.012315	.616442E-02	-1.99769	[.046]
RNMAR2	.434338E-04	.192765E-04	2.25321	[.024]
RNJUN	-.010154	.482303E-02	-2.10529	[.035]
RNJUN2	.168690E-03	.313029E-04	5.38897	[.000]
RNSEP	-.016535	.991917E-02	-1.66694	[.096]
RNSEP2	.254269E-03	.104233E-03	2.43943	[.015]
TNDEC	.036078	.067135	.537388	[.591]
TNDEC2	-.383349E-03	.115541E-02	-.331786	[.740]
TNMAR	-.078449	.043356	-1.80942	[.070]
TNMAR2	.692124E-03	.833709E-03	.830174	[.406]
TNJUN	-.428244E-02	.023676	-.180876	[.856]
TNJUN2	-.116828E-03	.461361E-03	-.253224	[.800]
TNSEP	-.011942	.034238	-.348780	[.727]
TNSEP2	.418614E-03	.599311E-03	.698492	[.485]
TRNDEC	.220356E-03	.243829E-03	.903734	[.366]
TRNMAR	.438160E-03	.226561E-03	1.93397	[.053]
TRNJUN	.239623E-03	.180559E-03	1.32712	[.184]
TRNSEP	.576799E-03	.333135E-03	1.73143	[.083]
DINT1	.181797E-03	.228930E-03	.794119	[.427]
DINT2	.191467E-04	.142610E-03	.134259	[.893]
DINT3	-.397579E-04	.189637E-03	-.209652	[.834]
DINT4	-.660681E-03	.720590E-03	-.916862	[.359]
DINT5	.377948E-02	.310879E-02	1.21574	[.224]

DINT6	-.144794E-02	.291620E-02	-.496516	[.620]
DINT7	-.513957E-03	.147041E-02	-.349533	[.727]
DINT8	-.146890E-02	.134597E-02	-1.09133	[.275]
DENS	-.967610E-02	.015320	-.631613	[.528]
DENS2	-.231230E-04	.119540E-04	-1.93433	[.053]
PYOUNG	-.187638	.059334	-3.16240	[.002]
POLD	-1.49379	.165117	-9.04685	[.000]
EDUC	.261934E-02	.048562	.053938	[.957]
R1	.089032	.013199	6.74525	[.000]
R2	.054325	.010955	4.95912	[.000]
R3	.028276	.962239E-02	2.93855	[.003]
R5	-.013516	.014684	-.920476	[.357]
R6	.056951	.010515	5.41621	[.000]
ALT	-.175177E-03	.353525E-04	-4.95513	[.000]
ALT2	.476523E-07	.401849E-07	1.18583	[.236]
SEA	.353727E-04	.379048E-04	.933198	[.351]
SEA2	-.463238E-07	.284750E-07	-1.62682	[.104]
ED2	-.110928E-02	.994889E-03	-1.11498	[.265]
EINT1	.609345E-03	.379638E-03	1.60507	[.108]
EINT2	-.584369E-03	.239833E-03	-2.43657	[.015]
EINT3	.118502E-03	.370206E-03	.320098	[.749]
EINT4	.725604E-03	.711416E-03	1.01994	[.308]
EINT5	-.203954E-02	.383848E-02	-.531340	[.595]
EINT6	.123171E-02	.285530E-02	.431377	[.666]
EINT7	.158780E-02	.204119E-02	.777876	[.437]
EINT8	-.584523E-03	.254008E-02	-.230120	[.818]
SIGMA	.053685	.152511E-02	35.2007	[.000]

Standard Errors computed from analytic second derivatives (Newton)

Regression 7:

Dependent variable: Cholera Morbidity
Number of observations = 3618 Log likelihood = 437.537
Number of positive obs. = 114
Fraction of positive obs. = 0.315091E-01

Parameter	**Estimate**	**Standard Error**	**t-statistic**	**P-value**
C	-.099342	.055478	-1.79065	[.073]
RNDEC	.249419E-03	.447020E-03	.557958	[.577]
RNDEC2	.225817E-05	.129220E-05	1.74754	[.081]
RNMAR	-.663884E-03	.447062E-03	-1.48499	[.138]
RNMAR2	-.238327E-05	.989837E-06	-2.40774	[.016]
RNJUN	.449563E-03	.257102E-03	1.74858	[.080]
RNJUN2	-.196318E-05	.134405E-05	-1.46064	[.144]
RNSEP	-.116143E-03	.594220E-03	-.195454	[.845]
RNSEP2	-.295677E-05	.513803E-05	-.575467	[.565]
TNDEC	.260874E-02	.461800E-02	.564906	[.572]
TNDEC2	-.654045E-04	.842438E-04	-.776372	[.438]
TNMAR	.381192E-02	.261208E-02	1.45934	[.144]
TNMAR2	-.399809E-04	.386020E-04	-1.03572	[.300]
TNJUN	.189729E-03	.135023E-02	.140516	[.888]
TNJUN2	-.421355E-04	.225448E-04	-1.86897	[.062]
TNSEP	.512323E-03	.229457E-02	.223276	[.823]
TNSEP2	.937626E-05	.415848E-04	.225473	[.822]
TRNDEC	-.148178E-04	.166256E-04	-.891263	[.373]
TRNMAR	.306091E-04	.166608E-04	1.83720	[.066]
TRNJUN	-.129283E-04	.105040E-04	-1.23080	[.218]
TRNSEP	.393593E-05	.224463E-04	.175349	[.861]
DINT1	-.290443E-05	.743151E-04	-.039083	[.969]
DINT2	-.376794E-04	.389452E-04	-.967498	[.333]
DINT3	.329986E-04	.302508E-04	1.09083	[.275]
DINT4	-.806843E-04	.931463E-04	-.866210	[.386]

DINT5	.913019E-03	.477936E-03	1.91034	[.056]
DINT6	-.116383E-02	.513191E-03	-2.26783	[.023]
DINT7	.120299E-02	.447598E-03	2.68765	[.007]
DINT8	-.136760E-02	.654868E-03	-2.08836	[.037]
DENS	.012041	.511028E-02	2.35632	[.018]
DENS2	-.299132E-04	.161786E-04	-1.84893	[.064]
PYOUNG	.271090E-02	.260257E-02	1.04162	[.298]
POLD	-.016625	.618264E-02	-2.68899	[.007]
EDUC	.228011E-02	.348210E-02	.654809	[.513]
ALT	-.918756E-06	.279999E-05	-.328129	[.743]
ALT2	.408479E-08	.278954E-08	1.46432	[.143]
SEA	.549303E-05	.244314E-05	2.24835	[.025]
SEA2	-.270825E-08	.183276E-08	-1.47769	[.139]
ED2	-.950116E-04	.626927E-04	-1.51551	[.130]
EINT1	-.172428E-05	.274510E-04	-.062813	[.950]
EINT2	.174883E-04	.177173E-04	.987071	[.324]
EINT3	-.128260E-04	.187298E-04	-.684788	[.493]
EINT4	.163707E-04	.553455E-04	.295791	[.767]
EINT5	.309550E-03	.270351E-03	1.14499	[.252]
EINT6	-.566659E-03	.239879E-03	-2.36226	[.018]
EINT7	.776974E-03	.207815E-03	3.73877	[.000]
EINT8	-.570320E-03	.221917E-03	-2.56997	[.010]
SIGMA	.119409E-02	.876359E-04	13.6256	[.000]

Standard Errors computed from analytic second derivatives (Newton)

Regression 8:

Dependent variable: Meningitis Morbidity
Number of observations = 3618 Log likelihood = 3123.38
Number of positive obs. = 503
Fraction of positive obs. = 0.139027

Parameter	**Estimate**	**Standard Error**	**t-statistic**	**P-value**
C	.295832E-02	.253293E-02	1.16794	[.243]
RNDEC	-.101684E-03	.399465E-04	-2.54551	[.011]
RNDEC2	.504643E-06	.216443E-06	2.33153	[.020]
RNMAR	-.396326E-04	.311077E-04	-1.27405	[.203]
RNMAR2	-.119686E-05	.203093E-06	-5.89317	[.000]
RNJUN	-.207168E-04	.206020E-04	-1.00558	[.315]
RNJUN2	.280028E-06	.147043E-06	1.90439	[.057]
RNSEP	.242221E-03	.620404E-04	3.90425	[.000]
RNSEP2	-.320079E-05	.829437E-06	-3.85899	[.000]
TNDEC	-.115536E-02	.238047E-03	-4.85349	[.000]
TNDEC2	.197559E-04	.443366E-05	4.45588	[.000]
TNMAR	.457336E-03	.166258E-03	2.75076	[.006]
TNMAR2	-.931653E-05	.319321E-05	-2.91760	[.004]
TNJUN	.249844E-03	.107469E-03	2.32480	[.020]
TNJUN2	-.987346E-05	.242449E-05	-4.07239	[.000]
TNSEP	.431062E-03	.157518E-03	2.73659	[.006]
TNSEP2	-.453088E-05	.310266E-05	-1.46032	[.144]
TRNDEC	.166263E-05	.147889E-05	1.12425	[.261]
TRNMAR	.391178E-05	.124723E-05	3.13638	[.002]
TRNJUN	.193604E-06	.857296E-06	.225831	[.821]
TRNSEP	-.746969E-05	.226440E-05	-3.29875	[.001]
DINT1	.112165E-05	.922165E-06	1.21632	[.224]
DINT2	-.599749E-06	.711149E-06	-.843353	[.399]
DINT3	-.878635E-06	.858446E-06	-1.02352	[.306]
DINT4	.518911E-05	.338108E-05	1.53475	[.125]
DINT5	.161191E-04	.122813E-04	1.31249	[.189]
DINT6	-.295900E-04	.140609E-04	-2.10442	[.035]
DINT7	.119540E-04	.693145E-05	1.72461	[.085]

DINT8	-.146253E-05	.579925E-05	-.252193	[.801]
DENS	.969084E-04	.669412E-04	1.44767	[.148]
DENS2	-.583046E-07	.315296E-07	-1.84920	[.064]
PYOUNG	-.108955E-02	.233422E-03	-4.66773	[.000]
POLD	-.367447E-02	.531038E-03	-6.91942	[.000]
EDUC	-.267386E-03	.141631E-03	-1.88791	[.059]
ALT	.128827E-06	.115343E-06	1.11690	[.264]
ALT2	-.231662E-09	.117795E-09	-1.96666	[.049]
SEA	-.102846E-05	.220634E-06	-4.66139	[.000]
SEA2	.368438E-09	.253299E-09	1.45455	[.146]
ED2	-.250000E-05	.402169E-05	-.621630	[.534]
EINT1	.695469E-05	.160257E-05	4.33970	[.000]
EINT2	.251136E-06	.163262E-05	.153824	[.878]
EINT3	.446133E-05	.152372E-05	2.92792	[.003]
EINT4	-.482400E-05	.387589E-05	-1.24462	[.213]
EINT5	.452315E-04	.143352E-04	3.15526	[.002]
EINT6	-.271050E-04	.128800E-04	-2.10442	[.035]
EINT7	-.172559E-05	.108784E-04	-.158626	[.874]
EINT8	-.992753E-05	.113229E-04	-.876767	[.381]
SIGMA	.165902E-03	.593185E-05	27.9681	[.000]

Standard Errors computed from analytic second derivatives (Newton)

Method of estimation - Ordinary Least Squares:

Dependent variable: Infant Mortality
Number of observations: 3818

Mean of dep. var.	=	.052779	LM het. Test	=	644.031	[.000]
Std. dev. Of dep. var.	=	.032949	Durbin-Watson	=	1.29652	[<.000]
Sum of squared residuals	=	.876896	Jarque-Bera test	=	1111.34	[.000]
Variance of residuals	=	.232722E-03	Ramsey's RESET2	=	110.371	[.000]
Std. error of regression	=	.015255	F (zero slopes)	=	286.492	[.000]
R-squared	=	.788387	Schwarz B.I.C.	=	-8.27084	
Adjusted R-squared	=	.785635	Log likelihood	=	10577.7	

Variable	**Estimated Coefficient**	**Standard Error**	**t-statistic**	**P-value**
C	.509923	.101748	5.01161	[.000]
RNDEC	-.679466E-02	.107771E-02	-6.30473	[.000]
RNDEC2	.657114E-04	.488423E-05	13.4538	[.000]
RNMAR	-.187913E-02	.107727E-02	-1.74434	[.081]
RNMAR2	-.218608E-04	.365193E-05	-5.98611	[.000]
RNJUN	.536450E-02	.827701E-03	6.48121	[.000]
RNJUN2	-.106396E-04	.609733E-05	-1.74497	[.081]
RNSEP	-.012254	.164857E-02	-7.43328	[.000]
RNSEP2	.344910E-04	.197946E-04	1.74245	[.082]
TNDEC	-.038053	.010194	-3.73286	[.000]
TNDEC2	.673722E-03	.176825E-03	3.81009	[.000]
TNMAR	.011166	.683527E-02	1.63362	[.102]
TNMAR2	-.989358E-04	.112997E-03	-.875558	[.381]
TNJUN	-.837823E-03	.365540E-02	-.229201	[.819]
TNJUN2	-.418140E-04	.680010E-04	-.614903	[.539]
TNSEP	-.235701E-02	.526210E-02	-.447923	[.654]
TNSEP2	.122273E-04	.925342E-04	.132139	[.895]
TRNDEC	.100625E-03	.376884E-04	2.66991	[.008]
TRNMAR	.125765E-03	.406473E-04	3.09406	[.002]
TRNJUN	-.165154E-03	.327618E-04	-5.04105	[.000]
TRNSEP	.362606E-03	.558924E-04	6.48756	[.000]
DINT1	.904378E-04	.566825E-04	1.59552	[.111]
DINT2	.870578E-05	.367958E-04	.236597	[.813]
DINT3	-.174814E-04	.498412E-04	-.350741	[.726]
DINT4	-.227072E-03	.187276E-03	-1.21250	[.225]
DINT5	.156023E-02	.758697E-03	2.05646	[.040]

DINT6	-.671862E-03	.725087E-03	-.926595	[.354]
DINT7	.362845E-04	.367459E-03	.098744	[.921]
DINT8	-.765527E-03	.339087E-03	-2.25761	[.024]
DENS	-.555892E-02	.374284E-02	-1.48521	[.138]
DENS2	.593803E-06	.260230E-05	.228184	[.820]
EDUC	-.333439E-02	.652368E-02	-.511121	[.609]
ALT	.139829E-04	.534295E-05	2.61707	[.009]
ALT2	-.618628E-08	.539985E-08	-1.14564	[.252]
SEA	.213014E-05	.640389E-05	.332632	[.739]
SEA2	.199545E-08	.533768E-08	.373841	[.709]
ED2	.449672E-03	.169038E-03	2.66019	[.008]
EINT1	.148721E-03	.563808E-04	2.63779	[.008]
EINT2	.163711E-04	.490638E-04	.333670	[.739]
EINT3	-.291906E-03	.683763E-04	-4.26910	[.000]
EINT4	.718237E-03	.127030E-03	5.65408	[.000]
EINT5	-.291727E-03	.585621E-03	-.498150	[.618]
EINT6	-.113803E-02	.463420E-03	-2.45571	[.014]
EINT7	.140077E-02	.345829E-03	4.05047	[.000]
EINT8	-.154152E-03	.424518E-03	-.363122	[.717]
R1	-.273322E-02	.245308E-02	-1.11420	[.265]
R2	.695647E-02	.177991E-02	3.90834	[.000]
R3	.228724E-03	.128586E-02	.177877	[.859]
R5	.668673E-03	.166531E-02	.401530	[.688]
R6	-.549270E-02	.172535E-02	-3.18353	[.001]