GEOGRAPHY, CHILD HEALTHCARE, CHILD EDUCATION, AND ECONOMIC DEVELOPMENT*

1. Introduction

New theories of economic growth coupled with empirical research have brought economic geography back to the forefront of the development debate. The prevailing development paradigm of market-oriented economic policies combined with the rule of law does not appear to be sufficient to make all countries rich. Attempts to statistically deduce causes of underdevelopment, or to extrapolate impacts of possible development policies, fail when they assume the same set of underlying factors for all countries. We will provide evidence that differences in the level of development among developed (non-poor) countries are based on far different criteria than among poor countries.

Among the criteria which are more important in less developed countries are location and climate (temperature) conditions, which some authors collectively refer to as a country's 'geography'. Including measures of relative location and of environmental conditions such as temperature provides insightful dimensions to development (Sachs, 2001; Redding and Venables, 2003 among others). The non-tropical northern and southern extremes of Africa are the wealthiest regions of the continent. In East Asia, the tropical and sub-tropical regions are generally poorer than the temperate north. As discussed by Gallup *et al*. (2003), in Latin America, the tropical zone of Central America and the Andean countries north of the Tropic of Capricorn have very high population densities and the lowest *per capita* GNP on the continent along with limited port access. The disadvantages of these tropical and sub-tropical regions certainly seem to be related to their lack of development, an argument supported by much recent evidence (Lee, 1957; Kamarck, 1976; Moreno and

* The authors would like to thank Beth Colvin and Joan Githaiga for their able assistance, and Kirsten Madden for helpful comments. The usual caveat applies.

Trehan, 1997; McMichael and Haines, 1997; Bloom and Sachs, 1998; Bloom and Williamson, 1998; Gallup *et al*., 1999; Hall and Jones, 1999; Harrison and Huntington, 2000; Masters and McMillan, 2000; Hausman, 2001; Sachs, 2001; Gallup *et al*., 2003 among others).

These economists suggest that countries left behind have distinguishing 'geographical' characteristics. Some of the explanations emphasize distances and accessibility. For example, the countries located in tropical latitudes face larger transportation costs to access international markets in mid-latitude countries. Even Adam Smith (1776) long ago observed:

> "There are in Africa none of these great inlets, such as the Baltic and Adriatic Seas in Europe (…) to carry maritime commerce into [or out of] the interior parts of that great continent"[1].

Other explanations point to the region's climate. Diamond (1997) and McCullough (1997) explain how tropical humidity wreaks havoc on many things including iron, books and furniture. Gallup *et al*. (2003) posit that 'geography' influences economic and social development through four basic channels: agricultural productivity, health conditions, the frequency and intensity of natural disasters, and access to markets. In this regard, recently the Bill Gates Foundation's work focused on child immunizations and education in the tropics.

If one region of a larger country is poor because its climate undermines agricultural productivity, its location impedes market access, or its population distribution facilitates endemic disease, then traditional growth-oriented policies that allocate funding to the country's national government may not suffice to foster growth there. Internal barriers need to be removed and behaviors changed. In a similar way, poverty throughout such a country may persist despite increased education and social programs (expanded nutrition programs, improvement in teaching materials, increased education of girls, etc.) when the factors contributing to that poverty are geographically as well as economically diverse. Better labor force training will likely result in migration to prosperous regions of the country. These are conditions that require data collection and analysis at a larger geographical scale in order to account for those regional differences.

The contribution of this paper stems from combining a stronger geographic perspective and the use of random effects, generalized least

[1] A. Smith (1776) Book I, Chapter III, 'That the Division of Labor Is Limited by the Extent of the Market'. Also see Landes (1998), Kamarck (1976), and Lee (1957).

square (GLS) analysis including some interaction variables. To our knowledge, no previous work emphasized the interaction of geography with child healthcare and education. We will show that the geographic factors are statistically significant influences on development. We will also show that different relationships between development and these factors are at work in poor areas than in non-poor countries.

The remainder of the paper will be organized as follows: section 2 explains the underlying data and methodology. Section 3 discusses the empirical model. Section 4 presents the empirical results of the three hypotheses. Lastly, we offer some concluding remarks in section 5.

2. Data and methodology

This paper reviews the factors influencing the development status of a sample of 44 countries (table 1), using annual data spanning the period 1980-2000. For the purposes of empirical testing, countries

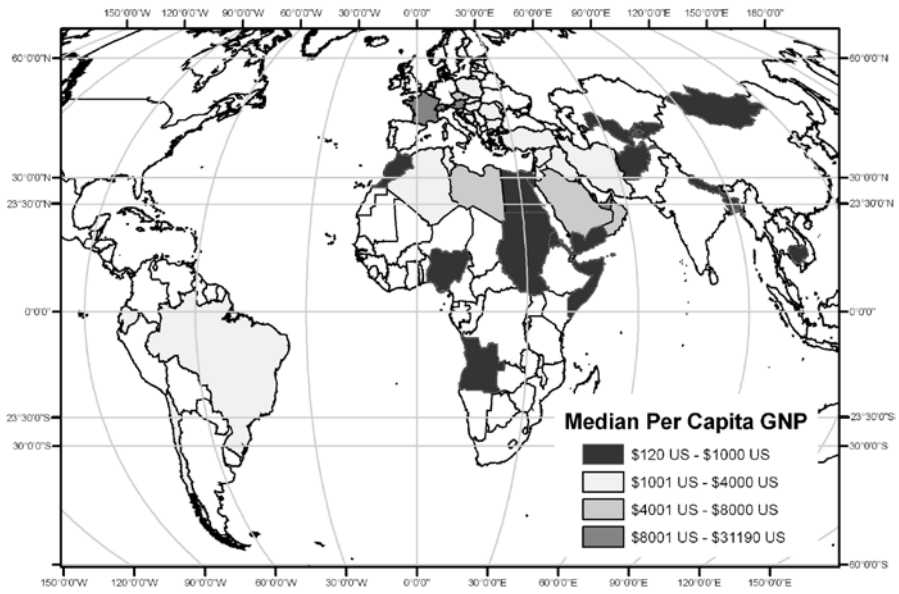
Table 1 - *Countries Included in the Sample*

Poor Countries (*per capita* GNP < $1000)	Non-Poor Countries
Afghanistan* (2)	Algeria
Angola (11)	Austria*
Bangladesh (21)	Brazil
Cambodia (11)	Bulgaria
Ecuador (1)	Chile
Egypt (16)	Czech Republic*
Eritrea (6)	Denmark
Kyrgyzstan* (4)	France
Mongolia* (3)	Grenada
Morocco (10)	Hungary*
Nepal* (21)	Iran
Nigeria (18)	Iraq
Somalia (11)	Kuwait
Sudan (18)	Lebanon
Syria (6)	Libya
Tanzania (8)	Lithuania
Uzbekistan* (3)	Malta
Yemen (8)	Oman
	Poland
The number in parentheses above represents the number of years during the 1980-2000 data collection period, that the poor country had a *per capita* GNP below $1000.	Romania
	Saudi Arabia
	Slovakia*
	Switzerland*
	Tunisia
	Turkey
	United Arab Emirates

An asterisk (*) following a country's name indicates that it is landlocked.

are separated into two groups: 'poor' countries (real *per capita* GNP of $1000 or less at least one year during the data period), and 'non-poor' countries (real *per capita* GNP over $1000). The sample includes 18 poor countries, of which nine are located in the 'tropics' (between the Tropics of Cancer, 23° 30′ N, and Capricorn, 23° 30′ S) concentrated in Africa and Asia, and two more straddle one of the two Tropics (see Figure 1). Of the 26 non-poor countries

FIGURE 1

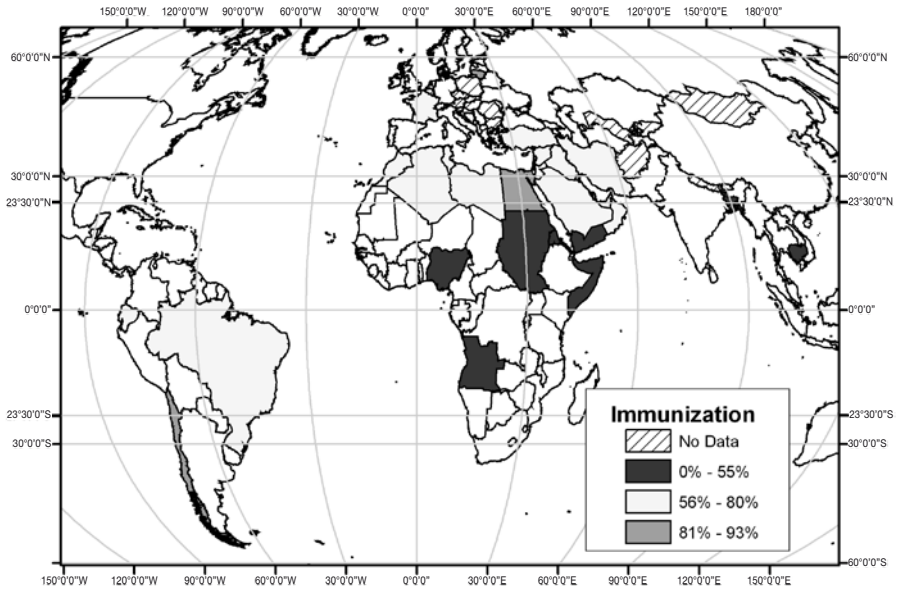


Development is represented by *per capita* GNP taken as a median of 1980-1997 values.

only one is completely 'tropical' and seven more straddle one of the two Tropics; the other 18 will be referred to as 'mid-latitude'. As a note, countries are only included in the poor sample in years where *per capita* GNP was below $1000. Thus only three countries were actually in the poor sample over all 18 years in the panel data set (see Table 1 for more detail on the breakdown of the poor and non-poor samples).

The variables are listed in Table 2, along with their operational definitions and data sources. *Pcgnp* is our indicator of economic development. *Gpc*, *gfdi* and *stindex* represent the available stock

FIGURE 2



Immunization for diphtheria, pertussis and tetanus represents a standard for health care development. Again this value represents a median of 1980-1997 values. A significant number of countries, many of them non-poor, have no reported data.

TABLE 2 - *Variable Definitions*

Variable	Definition	Source
pcgnp	*per capita* gross national product (US$)	World Bank Data CD, 2002
gpc	gross private capital flows (% of GNP)	World Bank Data CD, 2002
gfdi	gross foreign direct investment (% of GNP)	World Bank Data CD, 2002
stindex	index of science and technology capacity	RAND
litkid	literacy in children 15 and under (% literate)	World Bank Data CD, 2002
dptimmun	DPT immunization (% of population)	World Bank Data CD, 2002
infmort	infant mortality (infant deaths per 1000 births)	World Bank Data CD, 2002
conflict	conflict in the country (0 or 1)	University of Texas Inequality Project, 2000
avgtemp	average temperature, for all locations and for earliest records through 1991 (°C)	Calculated from data in Global Historical Climatology Network, 2000
dist40N	distance from 40°N to the nearest point in the country (a negative number indicates the country is south of 40°N) (in km)	Measured from maps in Hudson, 2000
port	availability of a port in the country (0 or 1)	World Bank Data CD, 2002
distport	average of distances from the (nearest) principal port to points in the country that are farthest from and closest to the port (in km)	Measured from maps in Hudson, 2000
healthtemp	interaction term = avgtemp*dptimmun	Authors' calculations
healthed	interaction term = dptimmun*litkid	Authors' calculations

of capital. *Dptimmun* and *infmort* are alternative measures of child healthcare. Geographical conditions are summarized in the *avgtemp* variable, a surrogate for climate considerations, and locational factors, *dist40N*, *port* and *distport*. Two additional variables, *healthtemp* and *healthed*, are interaction variables, formed by multiplying the values of two independent variables. The data set is in the form of panel data: where available, as many as 18 years' worth of data is included for each country on each variable.

Table 3 presents descriptive statistics for the variables utilized in the regressions. As would be expected, low-income countries

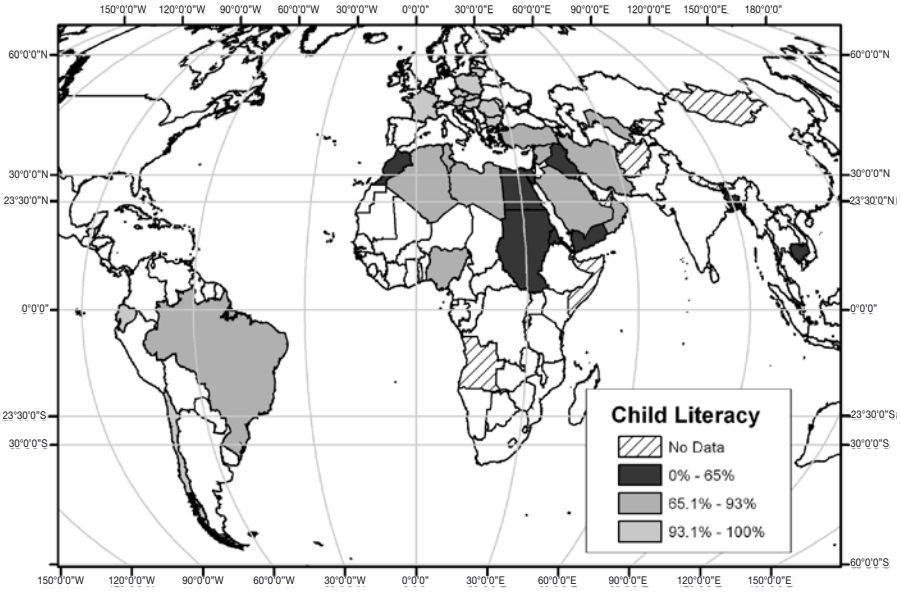
TABLE 3 - *Descriptive Statistics*

	Non-Poor Countries				Poor Countries			
Variable	N	Mean*	Min.	Max	N	Mean*	Min.	Max.
pcgnp	415	7682.84 (9196.93)	1000	44,060	172	413.63 (259.96)	100	990
gpc	211	6.88 (7.72)	.36	44.75	111	2.94 (3.12)	.07	17.52
gfdi	340	1.84 (2.28)	0	20.29	144	1.44 (2.48)	0	18.43
stindex	334	.14 (.66)	-.48	1.6	114	-.42 (.10)	-.51	-.05
litkid	375	89.61 (12.18)	49	100	112	58.52 (12.72)	37.3	95.4
dptimmun	358	78.81 (23.09)	0	100	154	49.57 (30.92)	1	98
infmort	150	31.83 (25.02)	0	109.2	50	97.18 (27.54)	31	151.8
conflict	415	0.26 (.44)	0	1	172	.419 (.49)	0	1
avgtemp	415	16.09 (7.71)	3.72	28	172	23.53 (5.36)	.27	30
dist40N	415	-1191.29 (2361.96)	-8222	1792	172	-2454.31 (1646.08)	-5900	500
port	415	0.83 (.38)	0	1	172	.78 (.42)	0	1
distport	415	427.68 (343.46)	8	1450	172	489.95 (306.61)	72	1300

* Standard deviations are given in parentheses.

tend to have relatively low capital flows and foreign investment. Low-income countries also fare poorly in terms of healthcare and education as measured by immunization rates, infant mortality rates, and child literacy levels (figures 3 and 4). Further, poor countries are

FIGURE 3

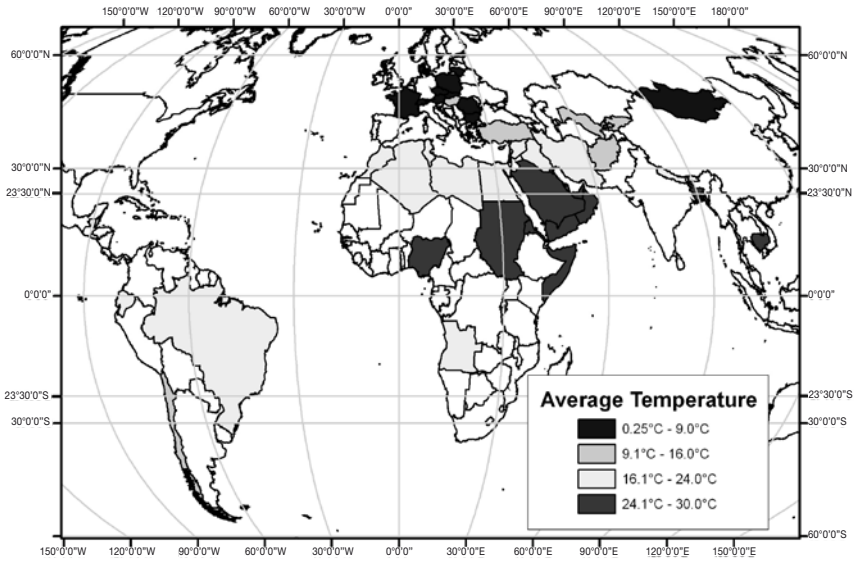


Literacy among 15-year old children is an assessment of the education system of each country, and an indicator of the potential for the next generation of citizenry. As might be expected, poor countries have the lowest literacy rates.

quite different from non-poor countries in terms of environmental and locational characteristics. In general, as table 3 also indicates, poor countries tend to be located further south and are typically much warmer than non-poor countries. Most low and lower-middle income countries have average temperatures above 16 degrees Celsius whereas high-income and higher-middle income countries mostly have average temperatures below 16 degrees Celsius (figure 4). Figures 1-4 provide graphic illustrations of mean differences of key variables across countries.

Using locational, environmental and socioeconomic data, along with random effect generalized least square (GLS) analysis, and panel data regression (for 1980-2000), our empirical tests focus on three hypotheses related to the geographic interaction of the variables. Unfortunately, as noted in Diamond (1997), Olsson and Hibbs (2003), and Clifton and Romero-Barrutieta (2006), a large number of geographical factors can interact in different ways to influence development. Globally, it is difficult to measure all factors and to

FIGURE 4



Environmental conditions are effectively summarized by average temperature, as displayed on this map. Clearly, latitude is the most important determinant of temperature.

know how to combine them. One factor may be important in one region, another somewhere else, leading researchers to conclude that none of the geographic factors is significant. Thus, to simplify the complexity of interaction of the geographic variables, we split them into three components (hypotheses):

i) climate will impact development. The impact will be particularly pronounced in developing countries that are dependent on agriculture. Since most very poor countries are in tropical zones, our primary hypothesis is that there will be a negative relationship between temperature and income. In developed countries the relationship may only be significant after controlling for some technological factors. The variables representing technology are growth in private capital (*gpc*), foreign direct investment (*fdi*), and scientific index (*stindex*);

ii) access to the outside world will affect development. As trade increases in importance, impediments to trade will retard growth. Again this is likely to be particularly true in developing countries. Our measures of global access include availability of a domestic

port, distance to 40 degrees North latitude, and whether each country is landlocked or not. We hypothesize that landlocked countries will be less developed;

iii) child healthcare and education expenditures are positively related to development. We hypothesize that higher levels of expenditure on healthcare and education will be positively related to development among both the developed and developing sets of countries.

The policy implications of these hypotheses are far-reaching. The implications extend to a much greater focus on the challenges that ranked highest within the set of developing countries. Agreement with our hypotheses would call for technological innovation to be directed at the problems of tropical temperature, access to the sea (outside world), and spending on child healthcare. That is, policy must first deal with problems of tropical ecology and make the necessary adaptations. Then focus can be directed towards human and physical-capital building.

3. Empirical model

The underlying empirical model is derived from a production function, which includes gross private capital stock (*gpc*), foreign direct investment (*gfdi*), and the labor force. The production function can be written as:

$$Y_{it} = f(F_{it}, K_{it}, L_{it1}) \tag{1}$$

where Y_{it} is *per capita* real GDP, F_{it} is foreign capital stock, K_{it} is domestic capital, and L_{it} is human capital (labor force). We assume that equation (1) is in log-linear form. Taking first difference of both sides, the following estimable form of the production function is obtained:

$$y_{it} = \beta_o + \beta_1 f_{it} + \beta_3 k_{it} + \beta_4 l_{it} + \beta_5 z_{it} + \varepsilon_{it} \tag{2}$$

where *i* and *t* represent country and time indicators, respectively. Y_{it} is *per capita* real GNP, X_{it} is a vector of independent variables, and ε_{it} is the error term. Separating the geographic variables set by the three hypotheses from other control variables, the equation can be written as:

$$\mathrm{Y}_{it} = \alpha + \beta X_{it} + \theta Z_{it} + \varepsilon_{it} \tag{3}$$

where X_{it} represents three hypotheses' variables: climate, access to the outside world, and child healthcare, consecutively. Each hypothesis was tested separately, with all other variables included in the set

of control variables, Z_{it}. Tables 4a and 4b show the results for the climate (temperature) hypothesis. 5a controls for the healthcare variable (child immunization) and access to the world variable (port). 5b controls for the technology variables (growth in private capital, growth in fdi, and the scientific index). Tables 5a and 5b display the results for the healthcare variables (immunizations and infant mortality, respectively). Immunizations and infant mortality are highly correlated. Table 6 displays the results for access to the outside world (port and distance from 40°N).

An estimable form of equation (3) is:

$$\ln pcgnp=\beta_0+\beta_1 gpc+\beta_2 gfdi+\beta_3 stindex+\beta_4 litkid+ \beta_5 dptimmun+\beta_6 infmort+\beta_7 conflict+\beta_8 avgtemp+\beta_9 dist40n+ \beta_{10} port+\beta_{11} disport+\beta_{12} healthtemp+\beta_{13} healthed+\varepsilon_{it} \quad (4)$$

All variables are defined in table 2. For analytical purposes, because some of the variables are highly correlated, only a subset of the variables are included each time to serve the analysis specifics.

Random-effect GLS regressions were run in order to analyze the 44 countries. In all regressions the dependent variable, *per capita* GNP (*pcgnp*), is transformed into its natural logarithmic form. Each analysis assessed *pcgnp* in terms of a different set of factors, considering all variables implied by the three hypotheses[2]. For comparison in each analysis we ran three regressions: one for the complete sample of countries, one for the non-poor countries, and one for the poor countries. For brevity, we report the empirical results for climate, healthcare and education, access to outside markets (location), and technology for the poor and non-poor countries – where the clearest dichotomies exist.

Kennedy (1992) and Greene (2003) among others, have shown that the GLS random effects models (treating intercepts as random variables across pool members) are better than fixed effects models (having different intercepts estimated for each pool member) if the data are a drawing of observations from a large population. When the data set is sampled from a large population, the random effects model will be more reasonable because it saves a lot of degrees of freedom[3]. Greene (2003) posits that none of the desirable properties

[2] Using infant mortality (*infmort*) as a healthcare variable gave similar results. Because immunization and infant mortality are highly correlated, we used separate regressions (tables 4, 5).

[3] See Kennedy (1992, p. 222-223).

of the estimates in the random effects model rely on the sample size. The maximum likelihood estimate of the error term variance is exactly equal to an average of n estimators each based on the T number of observations for unit *i*. Since T can be small, this variance may be relatively large. But, each term provides some information about the parameter. The average over the n cross-sectional units has a variance of order 1/nT, which will approach zero as n increases, even if we regard T as fixed. Thus, nothing in this treatment relies on T getting large. As a matter of fact, the typical panel data set is based on data sets for which it does not make sense to assume that T increases without bound[4].

The empirical results and analyses of these three hypotheses are presented below and in tables 4-6. In each analysis, the causative model was specified differently in order to test different combinations of independent variables.

4. The empirical results

4.1 Development and Climate

Climate influences healthcare and economic development through several channels. In tropical eco-zones, absence of seasons makes disease control efforts more difficult because reproduction of the vectors of transmission takes place rather evenly through the year. Since most of the population suffering from these diseases is too poor to pay for vaccinations or treatment, technological investments reinforced the difficulty of controlling these diseases. The recent privatization trend (through the structured adjustment program) may have exacerbated these problems given the prevalence of poverty and the need for government support. As Acemoglu *et al*. (2001) and Gallup *et al*. (2003) emphasize, policies and institutions generated different healthcare results that correspond to climate differences. European colonizers created better institutions in colonies with mild climates where they opted to settle permanently. Colonizers established more exploitative and less constructive systems of government where climate conditions were harsher. The legacy of those original institutions may still be affecting the quality of government and the provision of public services in the former colonies.

---

[4] See Greene (2003, p. 293-337), Chamberlain (1984), and Nickell (1981).

TABLE 4A - *Temperature on Economic Growth GLS Regression*

Model: ln $pcgnp_{it}=\beta_0+\beta_1 avgtemp_{it}+\beta_2 port_{it}+\beta_3 dptimmun_{it}+\beta_4 healthtemp_{it}+\varepsilon_{it}$

	Non-Poor	Poor
sd(u_country)	1.0385	.2770
sd(e_country_t)	.2825	.2492
sd(e_country_t + u_country)	1.3210	.5262
corr(u_country, X)	0 (assumed)	0 (assumed)

Random-effects GLS regression

	Non-Poor	Poor
Number of obs	358	154
n	29	17
R-sq within	0.0027	0.0044
between	0.1009	0.5046
overall	0.0949	0.5058
chi2 (4)	3.60	30.
prob > chi2	0.460	0.000

Regression Coefficients and Probabilities – Non-Poor

lpcgnp	Coeff.	Std. Err.	z	P>|z|	95% Conf.	Interval
avgtemp	-.0007	.0330	0.02	0.984	-.0639	.0652
port	-.9475	.6133	-1.54	0.122	-2.1496	.2546
dptimmun	-.0025	.0033	-.74	0.457	-.0090	.0041
healthtemp	.0001	.0002	0.58	0.563	-.0002	.0004
_cons	9.0916	.5933	15.33	0.000	7.9288	10.2543

Regression Coefficients and Probabilities – Poor

lpcgnp	Coeff.	Std. Err.	z	P>|z|	95% Conf.	Interval
avgtemp	-.0751	.0267	-2.81	0.005	-.1273	-.0228
port	.9818	.2595	3.78	0.000	.4732	1.4903
dptimmun	.0018	.0065	.27	0.787	-.0010	.0146
healthtemp	0	.0003	-0.03	0.976	-.0005	.0005
_cons	6.747	.5780	11.67	0.000	5.6140	7.8800

TABLE 4B - *Impact of Temperature on Growth GLS Regression: Controlling for gpc, fdi, and stindex*

Model: ln $pcgnp_{it}=\beta_0+\beta_1 avgtemp_{it}+\beta_2 gpc_{it}+\beta_3 gfdi_{it}+\beta_4 stindex_{it}+\varepsilon_{it}$

	Non-Poor	Poor
sd(u_country)	.3041	.3006
sd(e_country_t)	.2436	.2791
sd(e_country_t + u_country)	.5477	.5797
corr(u_country, X)	0 (assumed)	0 (assumed)

Random-effects GLS regression

	Non-Poor	Poor
Number of obs	171	69
n	13	9
R-sq within	0.3855	0.0297
between	0.8242	0.8336
overall	0.8035	0.5811
chi2 (4)	184.7	12.87
prob > chi2	0.0000	0.011

Regression Coefficients and Probabilities – Non-Poor

lpcgnp	Coeff.	Std. Err.	z	P>|z|	95% Conf. Interval	
avgtemp	.0420	.0218	1.92	0.054	-.0008	.0847
gpc	.0250	.0041	6.15	0.000	.0170	.0329
gfdi	.0847	.0156	5.42	0.000	.0540	.1153
stindex	1.3031	.1950	6.68	0.000	.9210	1.6852
_cons	6.9591	.3731	18.65	0.000	6.2277	7.6904

Regression Coefficients and Probabilities – Poor

lpcgnp	Coeff.	Std. Err.	z	P>|z|	95% Conf. Interval	
avgtemp	-.0758	.0307	-2.47	0.014	-.1361	-.0156
gpc	-.0133	.0141	-.95	0.344	-.0409	.0142
gfdi	-.0175	.0139	-1.26	0.207	-.0448	.0097
stindex	1.3864	1.8025	.77	0.442	-2.1465	4.9192
_cons	7.452974	.5830246	12.783	0.000	6.310267	8.595681

TABLE 5A - *Healthcare and Growth GLS Regression: Using Dpt Immunization as a Measure of Child Healthcare*

Model: ln $pcgnp_{it}=\beta_0+\beta_1 avgtemp_{it}+\beta_2 dist40n_{it}+\beta_3 port_{it}+\beta_4 dptimmun_{it}+\beta_5 litkid_{it}+\beta_6 healthed_{it}+\varepsilon_{it}$

	Non-Poor	Poor
sd(u_country)	.9877	.3004
sd(e_country_t)	.2754	.2002
sd(e_country_t + u_country)	1.2631	.5006
corr(u_country, X)	0 (assumed)	0 (assumed)

Random-effects GLS regression

	Non-Poor	Poor
Number of obs	338	103
n	28	10
R-sq within	0.0186	0.1272
between	0.1584	0.7432
overall	0.1629	0.5003
chi2 (6)	10.4	35.8
prob > chi2	0.108	0.0000

Regression Coefficients and Probabilities – Non-Poor

lpcgnp	Coeff.	Std. Err.	z	P>|z|	95% Conf. Interval	
avgtemp	.0230	.0335	.89	0.371	-.0357	.0956
dist40n	.0001	.0001	1.02	0.306	-.0001	.0003
port	-.9210	.5905	-1.56	.119	-2.0783	.2364
dptimmun	-.0040	.0055	-.72	0.469	-.0148	.0068
litkid	.0036	.0063	.57	0.568	-.0088	.0159
healthed	0	.0001	.19	0.851	-.0001	.0001
_cons	8.5494	.7353	11.63	0.000	7.1081	9.9906

Regression Coefficients and Probabilities – Poor

lpcgnp	Coeff.	Std. Err.	z	P>|z|	95% Conf. Interval	
avgtemp	-.1512	.0295	-5.12	0.000	-.2090	-.0934
dist40n	-.0001	.0001	-0.93	0.350	-.0003	.0001
port	(dropped)					
dptimmun	.0132	.0044	2.99	0.003	.0046	.0220
litkid	.0114	.0086	1.32	0.107	-.0055	.0282
healthed	-.0002	.0001	-2.64	0.008	-.0004	-.0001
_cons	7.691377	.7267741	10.583	0.000	6.266926	9.115828

TABLE 5B - *Healthcare and Growth GLS Regression: Using Infant Mortality as a Measure of Healthcare**

Model: $\ln pcgnp_{it}=\beta_0+\beta_1 gfdi_{it}+\beta_2 distport_{it}+\beta_3 avgtemp_{it}+\beta_4 conflict_{it}+\beta_5 \inf mort_{it}+\beta_6 litkid_{it}+\beta_7 dist40n_{it}+\varepsilon_{it}$

	Non-Poor	Poor
sd(u_country)	.6016	.0
sd(e_country_t)	.2331	.2206
sd(e_country_t + u_country)	.8347	.2206
corr(u_country, X)	0 (assumed)	0 (assumed)

Random-effects GLS regression

	Non-Poor	Poor
Number of obs	118	31
n	17	9
R-sq within	0.4546	0.2235
between	0.2912	0.8558
overall	0.5547	0.6911
chi2 (7)	78.86	51.45
prob > chi2	0.0000	0.0000

*Only 17 of the non-poor countries reported data on infant mortality.

Regression Coefficients and Probabilities – Non-Poor

lpcgnp	Coeff.	Std. Err.	z	P>|z|	95% Conf.	Interval
gfdi	.1330	.0171	7.77	0.000	.0995	.1665
distport	-.0001	.0005	-.11	0.916	-.0011	.0009
avgtemp	.0036	.0298	.12	0.903	-.0548	.0620
conflict	.0515	.0717	0.72	0.472	-.0890	.1921
infmort	-.0094	.0033	-2.87	0.004	-.0158	-.0030
litkid	-.0117	.0085	-1.38	0.168	-.0285	.0050
dist40n	.0001	.0001	1.46	0.143	-0	.0002
_cons	9.4442	1.0608	8.90	0.000	7.3650	11.5233

Regression Coefficients and Probabilities – Poor

lpcgnp	Coeff.	Std. Err.	z	P>|z|	95% Conf.	Interval
gfdi	.0217	.0397	.55	0.584	-.0560	.0995
distport	.0008	.0003	3.05	0.002	.0003	.0014
avgtemp	-.1258	.0305	-4.12	0.000	-.1857	-.0660
conflict	-.0802	.1565	-.51	0.608	-.3869	.2265
infmort	-.0154	.0066	-2.33	0.020	-.0283	-.0025
litkid	-.0256	.0121	-2.11	0.035	-.0494	-.0018
dist40n	-.0002	.0001	-1.50	0.133	-.0004	.0001
_cons	11.22709	1.2623	8.93	0.000	8.7969	13.7448

Conflict which represents institutional factors is insignificant in all the regressions performed (available from authors upon request). It is shown here as an example.

TABLE 6 - *Access to International Markets and Growth GLS Regression*

Model: ln $pcgnp_{it}=\beta_0+\beta_1 avgtemp_{it}+\beta_2 dist40n_{it}+\beta_3 port_{it}+\varepsilon_{it}$

	Non-Poor	Poor
sd(u_country)	.9730	.4597068
sd(e_country_t)	.2985	.2739708
sd(e_country_t + u_country)	1.2715	.5351545
corr(u_country, X)	0 (assumed)	0 (assumed)

Random-effects GLS regression

	Non-Poor	Poor
Number of obs	415	172
n	30	18
R-sq within	0.0042	0.0000
between	0.0388	0.5131
overall	0.0757	0.4915
chi2 (3)	1.96	14.89
prob > chi2	0.5817	0.0019

Regression Coefficients and Probabilities – Non-Poor

lpcgnp	Coeff.	Std. Err.	z	P>|z|	95% Conf. Interval	
avgtemp	.0007	.0285	0.02	0.980	-.0551	.0565
dist40n	.0001	.0001	1.21	0.226	-.0001	.0003
port	.1242	.2721	0.46	0.648	-.4091	.6576
_cons	8.2176	.4488	18.31	0.000	7.3379	9.0973

Regression Coefficients and Probabilities – Poor

lpcgnp	Coeff.	Std. Err.	z	P>|z|	95% Conf. Interval	
avgtemp	-.0758	.0239	-3.170	0.002	-.1227	-.0290
dist40n	0	.0001	0.193	0.847	-.0001	.0002
port	1.0037	.3253	3.085	0.002	.3661	1.6412
_cons	6.8875	.3595	19.158	0.000	6.1829	7.5922

We explore the relationship between climate and development level using average temperature (*avgtemp*) as an independent variable. Climate, more so than other explanatory variables used, clearly epitomizes the dichotomies that do exist between more and less developed countries.

The empirical results generally indicate no statistically significant relationship between temperature and economic output in the non-poor sample. Table 4b is the sole exception. In this particular

specification, there is a positive relationship between *avgtemp* and *pcgnp* because of the inclusion of technology variables as discussed below. A literal interpretation of the *avgtemp* coefficient in table 6 indicates a one-degree increase in *avgtemp* increases *pcgnp* by roughly four per cent. Our overall interpretation of the results is of a weak climate-development relationship in more developed countries.

Thus, technology improves climate conditions and bolsters economic development. As endogenous growth theory indicates, technology enhances productivity because it saves other resources and therefore lowers costs of production (increasing returns to scale) (Romer, 1990; Barro and Sala-i-Martin, 2004). The disparity between tropical and temperate agricultural productivity exceeds and, to a large extent, accentuates the income gap between tropical and temperate zones. Consider some important crops: reports of the Food and Agriculture Organization (FAO) of the United Nations (1999 and 2000) show that productivity of cereals, root crops, oil crops, and vegetables in tropical eco-zones is about forty-five to sixty-four per cent. As our results indicate, one important factor is that technology is more adapting to climate in non-poor countries, possibly because technology is mainly made for non-tropical regions. The technological factors are consistently statistically and practically significant for the set of non-poor countries. The 95 per cent confidence intervals in tables 4b and 5b indicate the following: a one per cent increase in *gpc* for non-poor countries increases *per capita* GNP by about 1.7 to 3.3 per cent. A one per cent increase in *gfdi* increases *per capita* GNP by roughly 5.4 to over 16.5 per cent, and a one point increase in *stindex* roughly doubles *per capita* GNP. Given variation in these variables in the sample of non-poor countries (see table 3), there is again an indication of considerable economic significance as well as statistical significance.

Conversely, there is a consistent and statistically strong negative relationship between *avgtemp* and *pcgnp* in the sample of poor countries. This relationship is present regardless of model specification (see tables 4-6). The coefficients on *avgtemp* indicate that a one-degree increase in average temperature reduces *per capita* GNP from about 7.5 to 15 per cent. More broadly, the reported 95 per cent confidence intervals from the tables for poor countries indicate that a one-degree increase in *avgtemp* will reduce *pcgnp* by at least 1.5 per cent and could have an effect as high as 20 per cent. Given the standard deviation for average temperature is over 5 degrees Celsius in the sample of poor countries, this indicates the effect of climate on income is practically quite large as well as statistically significant.

4.2 Development and Access to Outside Markets

Recent work by Gallup *et al*. (1999 and 2003) shows that access to the rest of the world is crucial for economic development[5]. Foreign markets provide the scale, degree of competition, and access to technological and managerial changes that produce efficiency. Several factors determine the cost of access to foreign markets including the existence of a port (*port*) and distance from temperate areas (we used 40° N latitude, *dist40N*). Industrial countries in Europe, North America, and Asia dominate the world markets. Distance from temperature zones is not significant for all countries (table 6).

Tables 4a, 5a, and 6 show the GLS regressions for poor and non-poor countries with respect to port access. After controlling for *avgtemp* and other factors, evidence indicates that the existence of a port is particularly significant for poor countries and relatively insignificant for non-poor countries. Poor countries depend heavily on foreign trade and those that are landlocked are usually the poorest. A large number of non-poor countries are in temperate zones where transportation and communication are more developed, and thus, have steady access to the outside world even in the absence of a port, or where much of the country is relatively isolated from a port.

Again the differences between the non-poor and poor samples are rather stark. While domestic port access has relatively little effect on *per capita* GNP in the sample of non-poor countries, results presented in table 6 indicate that the presence of a domestic port roughly doubles *per capita* GNP in the poor countries. Additionally the results have strong statistical as well as economic significance.

4.3 Child Healthcare and Child Education

The results generally indicate, as anticipated, positive relationship between better child healthcare (as measured by immunization rates or infant mortality) and real GNP *per capita* and between education (as measured by literacy rates) and real GNP *per capita*. While the results for the non-poor sample are relatively weak, we again see significant relationships for the poor country sample.

Tables 5a and 5b present evidence of a statistically significant relationship between immunization rates (*dptimmun*) and real

[5] 5. Gallup *et al*. (2003) page 37. Also, see Gallup *et al*. (1999).

per capita GNP. The results also indicate a positive relationship between child literacy rates and *per capita* GNP. Additionally there is significant evidence of an interaction effect between literacy (representing education) and immunization rates (representing healthcare) as measured by *healthed*.

Statistically, the negative sign on *healthed* indicates that the positive return to immunizations is reduced by a higher literacy rate and that the positive return to education is reduced as immunization levels rise. We interpret this result as follows: a more educated population with increased knowledge of such things as basic sanitation and nutrition will be less affected if not immunized and an immunized population might suffer less from the potential ill health effects of lacking basic education.

5. Concluding remarks

This paper examined the importance of including locational and environmental factors when analyzing economic development. Policy implications of economic development aid should be assessed by examining factors within targeted countries. Using GLS, three hypotheses have been investigated to study the impact of climate (temperature), access to the outside world, interactions of healthcare and education, and technology on economic development. The main results can be summarized as follows:

i) for poor countries, evidence indicates temperature has a substantial impact on developmental level (as measured by *per capita* GNP) regardless of controls in place for other potential income determinants. Conversely climate (temperature) appears to be largely unrelated to income levels in the sample of non-poor countries. However, the inclusion of technology in non-poor climate conditions has a positive impact on development. This would tend to indicate that poor countries that are relatively dependent on agriculture will be particularly vulnerable to adverse climate conditions;

ii) healthcare and education expenditures will have positive impact on development. Again the impact is considerably more pronounced in developing countries. This result is largely intuitive. However, our results also provide evidence of a negative interaction between healthcare and education expenditures perhaps indicating that the two are substitutes for each other in terms of development in the poorest countries;

iii) the existence of a port is particularly significant for poor countries. It is insignificant for non-poor countries. In non-poor countries the existence of developed infrastructure diminishes the importance of port availability (or lack thereof).

The results elucidate that promotion of healthcare (immunization) and scientific research that help adapt the necessary technology to climate are imperatives to economic development. Studies such as Echeverría's (1990) have shown that agricultural research on different crops in different countries using different methodologies has had high rates of return in some tropical areas. Yet, public funding for research on tropical agriculture and disease has been declining (Sachs, 1999 and 2000). Tropical diseases such as malaria are not affected by spill over effects of medical research in developed countries that are mostly in temperate areas. Tropical countries are too poor and, therefore, their markets are too thin to induce pharmaceutical firms to invest in tropical disease research.

Furthermore, access to global markets should be the primary guide for investing in outlets to other markets including ports, roads, airports, and railways. Without investments in transportation infrastructure economic growth will be impeded. Internal migrations to more productive (resourceful) parts of a country with easier access to international markets may also be in order.

Osman Suliman

Millersville University of Pennsylvania, Department of Economics, PA, USA

Kenneth Smith

Millersville University of Pennsylvania, Department of Economics, PA, USA

Charles Geiger

Millersville University of Pennsylvania, Department of Geography, PA, USA

REFERENCES

Acemoglu, D., S. Johnson and J.A. Robinson (2001), "'The Colonial Origins of Comparative Development: An Empirical Investigation", *American Economic Review*, 91(5), 1369-1401.

Barro, R.J. and X. Sala-i-Martin (2004), Economic Growth, MIT Press: Cambridge.

Bloom, D. and J.D. Sachs (1998), "Geography, Demography, and Economic Growth in Africa", *Brookings Papers on Economic Activity*, 29(2), 207-296.

Bloom, D.E. and J.G. Williamson (1998), "Demographic Transitions and Economic Miracles in Emerging Asia", *World Bank Economic Review*, 12(3), 419-455.

Chamberlain, G. (1984) , *Panel Data*, in: Z. Griliches and M. Intriligator (Eds), "Handbook of Econometrics", Volume 2, Chapter 22 , North Holland: Amsterdam.

Clifton, E.V. and A. Romero-Barrutieta (2006), "Institutions versus Geography: Subnational Evidence from the United States", IMF Working Papers No. 169.

Demurger, S., J. Sachs, W. Woo, M.S. Bao, G. Chang, and A. Mellinger (2002), "Geography, Economic Policy, and Regional Development in China", NBER Working Papers No. 8897.

Diamond, J. (1997) Guns, Germs, and Steel, W.W. Norton & Company, Inc.: New York.

Echeverría, R.G. (1990), *Assessing the Impact of Agricultural Research*, in: R. Echeverría (Ed.), "Methods for Diagnosing Research System Constraints and Assessing the Impact of Agricultural Research", ISNAR: The Hague.

FAO (1999), The FAOSTST Database, Food and Agriculture Organization of the United Nations: Rome, <http://apps.fao.org/default.html>.

FAO (2000), The FAOSTST Database, Food and Agriculture Organization of the United Nations: Rome, <http://apps.fao.org/default.html>.

Gallup, J.L., J.D. Sachs and A.D. Mellinger (1999), *Geography and Economic Development*, in: B. Pleskovic and J.E. Stiglitz (Eds), "World Bank Annual Conference on Development Economics 1998", The World Bank: Washington, DC.

Gallup, J.L., A. Gaviria and E. Lora (2003), Is Geography Destiny? Lessons from Latin America, Stanford University Press: Stanford, a copublication with The World Bank: Washington, DC.

Global Historical Climatology Network (2000), GHCN Version 2, (Global dataset of climate data), National Climatic Data Center, Arizona State University: Tempe, AZ; Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory: Oak Ridge, TN.

Greene, W.H. (2003), Econometric Analysis, 5th edition, Prentice Hall: Upper Saddle River, NJ.

Hall, R.E. and C.I. Jones (1999), "Why do some Countries Produce so much more Output per Worker than other Countries?", *The Quarterly Journal of Economics*, 114(1), 83-116.

Harrison, L.E. and S. Huntington (2000), Culture Matters: How Values Shape Human Progress, Basic Books: New York.

Hausman, R. (2001), "Prisoners of Geography", *Foreign Policy*, 22(1), 44-53.

Hudson, J.C. (2000), Goode's World Atlas, 20th Edition, John Wiley & Sons for Rand McNally: New York.

Kamarck, A. (1976), The Tropics and Economic Development: A Provocative Inquiry in the Poverty of Nations, The John Hopkins Press: Baltimore.

Keller, W. (2000), "Geographic Localization of International Technology Diffusion", NBER Working Paper No. 7509.

Kennedy, P. (1992), A Guide to Econometrics, The MIT Press: Cambridge.

Lee, D. (1957), Climate and Economic Development in the Tropics, Harper and Brothers: New York.

Masters, W.A. and M.S. McMillian (2000), "Climate and Scale in Economic Growth", CID Working Paper No. 48.

McCullough, D. (1997), The Path Between the Seas: The Creation of the Panama Canal, 1870-1914, Simon and Schuster: New York.

McMichael, A.J. and A. Haines (1997), "Global Climate Change: The Potential Effects on Health", *British Medical Journal*, 315(7111), 805-809.

Moreno, R. and B. Trehan (1997), "Location and the Growth of Nations", Federal Reserve Bank of San Francisco Working Papers in Applied Economic Theory No. 97-02.

Nickell, S.J. (1981), "Biases in Dynamic Models with Fixed Effects", *Econometrica,* 49(7), 1417-1426.

Olsson, O. and D.A. Hibbs Jr. (2005), "Biogeography and Long-Run Economic Development", *European Economic Review*, 49(4), 909-938.

Redding, S. and A.J. Venables (2003), "Geography and Export Performance: External Market Access and Internal Supply Capacity", NBER Working Paper No. 9637.

Romer, P.M. (1990), "Endogenous Technological Change", *Journal of Political Economy*, 98(5), S71-102.

Sachs, J.D. (1999), "Helping the World's Poorest", *The Economist*, August 14th, 17-20.

Sachs, J.D. (2000), "A New Map of the World", *The Economist,* June 24th, 81-83.

Sachs, J.D. (2001), "Tropical Underdevelopment", NBER Working Papers No. 8119.

Smith, A. (1776), Wealth of Nations, <http://socserv.mcmaster.ca/econ/ugcm/3ll3/smith/wealth/wealbk01>.

University of Texas (2000), University of Texas Inequality Project, <http://utip.gov.utexas.edu/>.

World Bank (2002), World Development Indicators, CD-ROM, The World Bank: Washington, DC.

ABSTRACT

We investigate whether geography (temperature and access to international markets), child healthcare, and education matter in economic development for a panel of 44 poor and non-poor countries using random effects GLS analysis over the period 1980-1997. Temperature and market access are particularly important geographical factors in poor countries. Child healthcare and education are important for development and, interestingly, we find negative interaction between them, indicating a potential substitution effect. The results indicate that climate (temperature) has a positive relationship with development in non-poor countries only, when the technology-promoting variables are included. Temperature has a negative relationship with the development of poor countries.

Keywords: Land-locked, Climate, Child Healthcare, Child Education, GLS

JEL Classification: O1, O3, O4

RIASSUNTO

Fattori geografici, assistenza sanitaria, istruzione dell'infanzia e sviluppo economico

Lo studio esamina l'influenza esercitata da fattori geografici (quali il clima e la possibilità di accesso ai mercati internazionali), dall'assistenza sanitaria e dall'istruzione dell'infanzia sullo sviluppo economico di un gruppo di 44 paesi, poveri e non poveri, attraverso una analisi dei minimi quadrati generalizzati per il periodo 1980-1997. Il clima e l'accesso ai mercati internazionali risultano essere elementi geografici particolarmente importanti per i paesi poveri. L'assistenza sanitaria e l'istruzione dell'infanzia risultano anch'essi importanti per lo sviluppo economico, ma è da notare che l'indagine segnala la esistenza di una possibile sostituibilità tra i due fattori. I risultati indicano che la temperatura, nel caso in cui si includano le variabili che determinano progresso tecnologico, ha un effetto positivo sullo sviluppo solo nei paesi non poveri. Nel caso dei paesi poveri invece, il rapporto tra temperatura e sviluppo è negativo.