Geography and Socioeconomic Development in Latin America and Caribbean

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Introduction

Geography has strong and pervasive effects on economic and social development. On a worldwide scale, geographical patterns are especially dramatic (Figure 1). The tropics are almost uniformly poor, and few of the nontropical countries are among the poorest. If geography were unimportant, one would expect to see similar economic conditions throughout the world, subject to some random variation. In fact, poor countries are rarely interspersed in the richer regions, and those few rich countries in the poor regions are usually readily explained by oil or other high-value natural resource deposits.

Two simple facts suggest the magnitude of the economic impacts of geography. Tropical countries have an average income per capita of just one-third that of non-tropical countries. Likewise, landlocked countries have an average income per capita of only one-third the income of countries with access to the sea.[1]

In the long view, geography is one of the few classes of variables that can explain systematic differences across regions of the world. Culture becomes highly malleable as

[1] Specifically, using 1995 purchasing-power-parity GDP per capita estimates (World Bank, 1998), 72 tropical countries have an average GDP per capita of $3,326, while 78 nontropical countries have an average GDP per capita of $9,027. Tropical is defined as most of the land area being within ±23.45º latitude, the band within which the sun is directly overhead at some point in the year. The 29 non-European landlocked countries have a GDP per capita of $1,771, while the 105 non-European countries with access to the coast have a GDP per capita of $5,567. The European landlocked countries are surrounded by one of the richest markets in the world.

one moves from a timeframe of decades to centuries, and has a long-term tendency to adapt to its environment. History is the long accumulation of chance and accident. Unless there is strong persistence of the consequences of early events, history too is subject to the influence of geography.

Physical geography mainly impacts economic and social development through three pathways: accessibility, agricultural productivity, and disease. The accessibility of a region, especially to the sea, is crucial for making the region's industry and services competitive in world markets. Despite the abundance of air cargo services in modern times, almost all but lightweight, high value goods still trade internationally by sea. Large cities, the site of most industrial and service activity, are usually located near the coast or navigable rivers.

The economic disadvantage of the tropics can be largely attributed to lower agricultural productivity and a higher burden of disease. Natural disasters, especially hurricanes, probably also play a role, but one that is difficult to quantify for lack of good data. Hurricanes are much more prevalent in certain tropical regions, and can eliminate the entire infrastructure and fixed investment of affected coastal regions from time to time.

Agricultural yields depend sensitively on climate and soil resources. Climate and soil conditions are characteristically different in temperate and tropical ecological zones. Furthermore the tremendous differences in the natural plant and animal communities of the tropics and the temperate zones suggest that the productivity of the narrow range of plants used for agricultural staples would also be systematically different between the two regions. Although it is possible, in principle, for food staples to be adapted to be equally productive in temperate and tropical zones, in practice this has not happened. Even after accounting for differences in input use in agriculture, tropical yields of the main agricultural crops are starkly lower than temperate yields.

The range and intensity of many diseases, particularly vector-borne ones, vary according to climate. Malaria, hookworm, and schistosomiasis, in particular, are great debilitators, and have been relatively easy to control in temperate zones, by still defy major control efforts in the tropics.

Are these broad geographical patterns relevant for the Latin American and Caribbean region? The geography of Latin America is a good predictor of differences in economic development. The tropical Caribbean and the temperate Southern Cone differ greatly by almost any measure of development. Within Brazil, there is a gulf between the dry, poor Northeast, the rich, temperate Southeast, and the still sparsely populated wet tropical Amazon region. In all of the neighboring countries with an Amazonian frontier, the jungle regions are a world apart. In Nicaragua, the malarial east coast is isolated from the more productive west coast. For Bolivia, being landlocked is a fundamental aspect of economic life, and the highlands, the valley region, and the tropical lowlands have each developed separate urban centers with limited connections between them. Similar patterns hold for the distinct geographical zones of Colombia, Ecuador, and Peru.

Returning to the world map of income levels in Figure 1, there are more middle income countries in the tropics of Latin America than the rest of the tropics, making it appear that the region is less bound by the general rule that the tropics are poorer. The geographical gradients within Latin America are nevertheless clear and dramatic. As seen in Figure 2, the 1995 purchasing-power parity GDP per capita levels in the region follow roughly a U-shape in latitude, with much higher levels in the temperate south, and a minimum level just below the equator in the 20° South to 0° latitude band. The geographical tropics is defined as the region from 23.45° South to 23.45° North where the sun is directly overhead at some point during the year. The tropics has much lower income levels than temperate South America or temperate Mexico (the countries which correspond to each latitude band are shown in Figure 3). The average GDP per capita of $4580 U.S. dollars in the 20° South to 0° latitude band is just under half the level at the temperate high points.

The variation in income by latitude within Latin America is more striking given that the countries in the region share many common aspects of colonial and cultural history. While one might surmise that the variation in economic development across the continents is primarily a consequence of divergent historical experiences rather than geography, this position is less plausible within continents. The pattern of development within Latin America and the Caribbean is consistent with the pattern within Africa and Eurasia. The non-tropical northern and southern extremes of Africa are the wealthiest regions of the continent, and tropical and subtropical southern Europe and East Asia are poorer, in general, than the temperate north.

Population density is a rough indicator for how hospitable the land is to an agrarian society. Despite the dramatic and accelerating population growth of the past few centuries, the relative distribution of the world's population has been remarkably stable. The population distribution of Latin America and the Caribbean was determined relatively late in this process due to the devastating impact of disease brought by the Europeans, which killed off the majority of the indigenous population. The present day population distribution largely conforms to the European settlement patterns (including slaves which they brought) plus indigenous highland populations that survived the Columbian exchange. As with other regions of the world, nonetheless, population shows a bimodal pattern with respect to latitude (Figure 4), with peaks in the temperate mid latitudes, and lower densities in the far south and the tropics. The highest population densities in the 10º to 20º North latitude of central Mexico and Central America are something of an exception, but consistent with a relationship between climate and population since most of this population lives in the highlands with a temperate climate.

In the tropics, there are not only lower income levels per person, but also fewer people on the land. A simple story of poverty in the tropics due to excessive population pressure cannot be sustained. The low population density in the tropics implies that the economic productivity of the land is even more unequally distributed than incomes in the region. Figure 5 shows the latitudinal variation in GDP per land area, the product of GDP per capita and population density. The economic output per land area in the tropical band of

10º South to 0º latitude at $39,000 per square kilometer is less than a quarter the GDP density at 20º to 30º North and South.

The relationship between geography and development in the region extends beyond purely economic indicators. Latin American infant mortality rates peak in the tropics (Figure 6) and decline more or less continually to either side of the peak. The highest rates in the 10º to 20º South are more than double the rate in the southern temperate zone, and 50% higher than the rates in the northern temperate zone. Part of these differences in infant health are surely due to income differences, but only part, as discussed below. The tropics is a more challenging disease environment, regardless of income levels.

The Geographical Regions of Latin America and the Caribbean

The impact of geography on development in the region involves more than just latitude gradients. The climatic zones of the region are usefully characterized by the Köppen classification system. Köppen's ecozone system is one of the first climatic classifications, developed a century ago, but remains the most useful and widely used. The classification of zones, shown in Figure 7, depends on temperature and precipitation data, and as modified by Geiger, elevation.[2] The main ecozones in Latin America are tropical (A), dry (B), temperate (C), and high elevation (H). The ecozones allow us to identify major geographical differences within the region: temperate versus tropical, highlands versus the lowland in the tropics, and dry versus temperate outside of the tropics.

[2] See Strahler and Strahler, 1992, pp. 155-160.

Several other geographical factors have had a strong impact on the economic activity and population distribution of the region. Coastal areas are distinct from the inland; sharing a border with the huge U.S. market distinguishes the north of Mexico; and direct access by sea to Europe historically has differentiated the Caribbean and Atlantic coast from the Pacific coast. The Köppen ecozones and these simple patterns form the basis of seven broad geographical zones for the region: Border, Tropical Highlands, Lowland Pacific Coast, Lowland Atlantic Coast, Amazon, Highland and Dry Southern Cone, and Termperate Southern Cone (Figure 8).

The Border zone comprises the arid or temperate climate in the north of Mexico, next to the U.S. This zone is sparsely populated (see Figure 9), has higher than average GDP levels per person than the rest of Mexico and the rest of Latin America (see Figure 10), and contains most of the Mexican *maquiladora* manufacturing assembly industry due to its proximity to the U.S. market.

The Tropical Highlands cover the highland regions of Central America and the Andean Countries north of the Tropic of Capricorn. This zone has very high population densities despite its difficult access to the coast, and is home to most of the indigenous people in Latin America. This zone has the lowest GDP per person on the continent. Average incomes levels are low despite two important exceptions in the zone, Mexico City and Bogotá, which have high income levels for Latin America. The poverty of this area highlights the challenge of the historical persistence of population in areas with geographical disadvantages. If the people do not move to more geographically favored regions, and the geographical barriers cannot be overcome, these concentrations of poverty will persist.

The Lowland Pacific and Atlantic Coast zones are tropical with some small areas of dry ecozone. The Pacific Coast has the highest population density of the seven geographical zones. The Atlantic Coast also has dense population, though less than the Pacific. The two coastal zones have a GDP per person about 20% higher than the Highland zone they abut, with similarly high population concentrations. The coastal zones have excellent access to the sea and international trade, of course, but must face the burden of disease and agricultural challenges of a tropical environment.

The Amazon zone is still largely uninhabited compared with the rest of the geographical zones, despite migration in the past decades with its accompanying environmental consequences. Perhaps surprisingly, the GDP per person in the Amazon is higher than adjacent coastal and highlands zones. This is due to two factors: a migration equilibrium, and resource rents. Settlers will move to the difficult environment of the Amazon if they expect income opportunities to be better than where they left. The migrants are also more likely to be working age males with no dependents. This results in high average income per person. A second factor is that much of the GDP of the region comes from natural resource rents of mining and large plantations that are often owned by investors who don't reside in the jungle, so that GDP per capita is probably higher than average household incomes per capita.

The two Southern Cone zones are both high income, like the northernmost Border zone. The Temperate Southern Cone has a substantial population density, while the Highland and Dry Southern Cone has a population density barely higher than the Amazon. The average GDP per capita and the population density of the Temperate Southern Cone is somewhat less than it would otherwise be because of the inclusion of temperate ecozones in Paraguay and Bolivia, both landlocked, poorer countries.

Looking at the average income levels and population densities of the geographical zones in Table 1, the four tropical zones have the lowest GDP per capita levels, clustered around $5,000 except for the Highlands at $4,343. The three temperate regions in the Southern Cone and northern Mexico have much higher income, averaging from $7,500 to $10,000. Population densities follow a very different pattern, with very low densities in the arid Southern Cone and Mexican Border zones, intermediate in the Temperate Southern Cone, and higher in the tropical Coastal and Highland zones. The product of GDP per capita and population density is the density of economic production per land area. By this metric the three densely populated tropical zones have a high density of GDP per land as does the Temperate Southern Cone. The Mexican Border region is intermediate and the arid Southern Cone and the Amazon, very low. Although the GDP densities are similar across these groups of tropical and temperate zones, the temperate regions achieve a higher GDP per person with a lower population density, while the tropical regions struggle with the opposite combination.

History

The geographical remoteness and isolation of the Americas played a central role in the devastation of the indigenous people at the point of first contact with Europeans. Humans were not native to the Americas until quite recently, probably about 11,000 B.C.[3] The first human settlers were most likely small nomadic groups crossing the cold Bering Straits, so they carried few Old World diseases with them from Northern Asia, in particular, no "crowd" diseases such as smallpox, measles, and typhus, and no tropical diseases. When Christopher Columbus arrived, followed by other conquistadors and explorers, the toll of Old World disease was catastrophic to the indigenous peoples of the New World, in some cases wiping out whole tribes before a shot was fired.[4] The implausibly lopsided victories of Cortés over the Aztec and Pizarro over the Inca are attributable more to smallpox than to Spanish firearms and horses. The emperors of both the Incas and the Aztecs and large percentages of the population were killed by smallpox before the decisive battles with the Spaniards even began. By 1618, Mexico's initial population of about 20 million had collapsed to about 1.6 million.[5] According to McNeill, "ratios of 20:1 or even 25:1 between the pre-Columbian populations and the bottoming-out point in Amerindian population curves seem more or less correct, despite wide local variation."[6]

Geography most likely played a hand in the pre-Columbian settlement patterns in the Americas. The main empires, the Aztec and the Inca, were in the highlands, probably

[3] Diamond, 1997, p.49.
[4] Many chilling examples are documented by Crosby (1972, 1986).
[5] Diamond, 1997, p. 210.
[6] McNeill, 1976, p.190.

due to better climate for agriculture and more benign disease environment. With no use of the seaborne trade, or even wheeled transport, access to the sea was not an economic disadvantage for these civilization. The major exception to the highland New World civilizations was the Mayans in the tropical lowlands, but the dense population in the Yucatan peninsula mysteriously collapsed before contact with Europeans.[7] The current concentration of indigenous peoples of Mexico, Central America, and the Andean countries in the highlands was also a function of where indigenous people survived the introduction of Old World diseases. Highland populations are protected from the lowland tropical diseases of malaria, yellow fever, hookworm which contributed to the extinction of substantial Amerindian populations from most of the Caribbean islands.

Colonization has played a complicated role in the current patterns of economic development, but it is not very helpful for explaining the dramatic geographical variation in present-day Latin America and the Caribbean. Most of the countries in the region share the same colonial heritage, despite very different economic outcomes. The countries with a supposedly more progressive British, French, and Dutch, rather than Iberian, heritage are among the poorest countries in the region (and all tropical).

Moreover, as shown by Diamond (1997), geography had a profound role in determining which countries were colonizers and which countries were colonized. Eurasia was highly favored relative to the other continents in terms of domesticable crops and livestock both

[7] Substantial evidence points to sustained drought brought on by the El Niño climatic oscillation as the cause of the Mayan collapse, due to high population density agriculture on fragile tropical soils. See Fagan, 1999, chapter 8.

by chance, and due to the large area of contiguous, ecological zones.[8] The constant proximity of settled humans to their livestock and their own waste in Eurasia facilitated the adaptation of new diseases to humans, such as smallpox, measles, chickenpox, and a range of intestinal parasites. The concentration of sedentary populations in cities made possible by agricultural advances provided a constant pool of new infectives to sustain "crowd diseases" such as tuberculosis and influenza. This heady brew of infectious disease proved to be devastating to unexposed populations, and largely explains the easy conquest of the Americas and Australasia. The technological advances made possible by the agricultural advantages of Eurasia also explains the eventual European domination of Africa.

When Europeans brought Africans to the New World as slaves, they also imported a panoply of African diseases new to the Americas. Malaria, yellow fever, hookworm, schistosomiasis, and other diseases further devastated the indigenous population and have had a persisting impact on the burden of disease since then. Most of these diseases remain major public health and economic problems in the American tropics to the present day.

The imported African diseases also plagued the European colonizers in the tropical regions of the New World, especially the Caribbean. Haiti was the graveyard for two

[8] The lack of domesticable livestock in the Americas, for use in agriculture as well as war, was probably due to the impact of first human settlers of the Americas 13,000 years ago on large mammals, ironically similar to the deadly impact of European settlers on the descendants of the original American settlers. American mammals had no experience of coevolution with humans until the Asian migrants' sudden appearance, and thus no natural wariness and defenses against human attack. In the Americas, as in Australia, the first human settlers brought about the extinction of most of the large mammals. See Crosby, 1986, pp. 273-281.

large colonial armies (see box). Yellow fever and malaria devastated successive invasions by the British and the French. The British lost over 14,000 men on the island in the 1790s, the great majority to disease, not battle.[9] Whole regiments of hundreds of troops were entirely lost to disease.

In 1801, Napoleon sent a hand-picked invasion force to Haiti to quell the slave revolt after the French Revolution. Although at their high mark the French armies occupied virtually the whole territory, the guerrillas waited for yellow fever and malaria to take their toll. By 1803, 55,000 French soldiers and sailors were dead, mostly of disease, with only 10,000 returning safely to France.[10] The losses to the British and the French in Haiti were greater than either side's losses at Waterloo.

Box – The Climate of Haiti Destroyed Two Large European Armies, Allowing the U.S. to Double Its Territory.[11]

[In the general chaos brought on by the French Revolution, the richest of France's colonies, Saint Domingue, later to become Haiti, began to slip from her grasp. With the promulgation of the Rights of Man in a colony based on a brutal system of slavery, armed resistance to the white planters progressed from the mixed-race, pro-slavery, *mulâtres* to a general revolt by the African slaves by 1791.

Britain and Spain, both at war with Republican France in the 1790s, agreed to divide the prize of St. Domingue between them. Spain fought by proxy through the rebel slave bands in the north, but Britain invaded with its own troops in the south in 1793. Realizing that neither Spain nor Britain would brook an end to slavery, the rebels cast off the Spanish and turned to attack the British. Though rarely directly engaged by the rebels until near the end, the British succumbed to the geography of St. Domingue. The British commander had assured London that he could take the territory with 877 troops, but reinforcements could not keep up with the ever increasing toll of yellow fever and malaria. In a typical case, Lieutenant Thomas Howard's regiment of 700 hussars lost 500 of their number in one month with only seven battle deaths. In the end, disease and the rebels forced the British to evacuate with over 14,000 dead. Edmund Burke summed up the debacle: "The hostile sword is merciful: the country itself is the dreadful enemy."

[9] Heinl and Heinl, 1978, p. 81.
[10] Heinl and Heinl, 1978, p. 121.
[11] Based on Heinl and Heinl, 1978.

When Napoleon consolidated his power in France after 1799, he turned to reconquering the prized colony of St. Domingue and using it as a springboard to reassert French control of the Louisiana Territory. His downfall was the same as Britain's. French troops could not survive in Haiti's disease environment. Leclerc, Napoleon's brother-in-law, quickly occupied almost the whole colony with 20,000 troops in 1802. Then yellow fever and malaria took hold. The mortality from yellow fever exceeded 80 percent, and to hide the losses, the dead were carted away at night and military funerals suspended. With all but two of his corps commanders dead, Leclerc himself would succumb to yellow fever before the year was out.

The French struggled on with massive reinforcements until 1803 before pulling out the surviving remnants of the army. Only 10,000 men made it back to France, with 55,000 dead in the colony. The hemisphere's second independent republic, Haiti, was born, soon to provide refuge and support to Simón Bolívar in his darkest hour in 1815. Napoleon was forced to give up his designs on the Louisiana Territory, which he sold to the United States. The tenacity of the Haitian rebels was essential to the only successful slave revolt in history, but victory depended on Haiti's crushing burden of tropical disease.]

Several theories connect geography to the institution of slavery. Slavery of Africans in the New World is notable for being concentrated in the tropics. Most slaves were sent to Caribbean islands or Brazil, and even in the United States, slavery was concentrated in the subtropical South. The simplest explanation for the predominance of slave labor in the tropics is that other labor was not available for the backbreaking work required to produce the extremely profitable tropical plantation crops. In the hostile post-Columbian disease environment of the Caribbean, the Amerindian population was driven to extinction on some islands, and close to it on the others. Free and indentured European settlers would have been difficult to attract to work in plantation labor gangs at a location where they had a substantial risk of dying of malaria, yellow fever, and other diseases. The French found this environment well suited for a hellish penal colony (French Guiana of *Papillon* fame, Charriere, 1969) where there was little worry that escaping prisoners would survive. Enslaved Africans were the only easily available labor force which could be compelled to work in tropical plantation agriculture.

Engerman and Sokoloff (1997) argue that slavery predominated in the tropics, not because of its hostile disease environment, but because the institution of slavery was more economically productive on tropical plantations (though disastrous for those who actually did the work) while free labor was more productive in the temperate New World. The tropical climate was suitable for certain crops (sugar, tobacco, cacao, coffee, cotton, and rice) that were conducive to production on large-scale plantations, while New World temperate zones were conducive to grain-based agriculture with efficient smallholder production. Furthermore, the tropical plantation crops could be cultivated by gang labor forced to work rapidly without significant risk of damage to the crops. Hence, Engerman and Sokolof argue that economies based on slave labor in Latin America and the Caribbean resulted in high levels of inequality with far-reaching consequences for institutions and economic development in these countries. The Spanish colonies had relatively little slavery, but the Amerindians, with a slave- or serf-like status, were a large percentage of the population in all these colonies until the end of the nineteenth century. This disparity resulted in high inequality and restrictive economic institutions similar to the slave states.   The institutional environment (due to the historical, though not persisting, impact of geography), according to Engerman and Sokolof, is what explains the divergence in Latin America and the Caribbean economic performance vis-à-vis the United States and Canada.

Coelho and McGuire (1997) propose a different explanation for the concentration of slavery in the tropics. Africans, due to their exposure to tropical diseases over very many generations, had both greater genetic and acquired immunity to tropical diseases, especially malaria, yellow fever, and hookworm. Most sub-Saharan African ethnic groups have two blood characteristics: the Duffy factor and the sickle cell trait. The Duffy factor confers immunity to the milder *vivax* form of malaria, while the sickle cell trait provides partial protection from the more deadly *falciparum* malaria. Most Africans were immune from yellow fever due to exposure as children (when the disease is milder), and even non-immune Africans have lower death rates from the disease for poorly understood reasons. Likewise West Africans, from which most New World slaves descended, have a clear, but poorly understood, tolerance of hookworm.

The alternative source of unskilled labor for New World plantation agriculture, indentured Europeans, were less productive than Africans in the disease environment of the tropics and the subtropical U.S. South compared with the temperate U.S. North. As noted above, indigenous Amerindians were not a viable alternative labor source in the tropics (except the highlands) because most did not survive the onslaught of European and African diseases, and those that did lacked the resistance to tropical diseases of Africans.[12] If superior disease resistance was the economic justification for importing African slaves, at great expense, it points to the large economic burden of disease in the tropics, even for the Africans who were somewhat better adapted to coping with it.

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[12] Not only did Amerindians lack the genetic adaptation to tropical diseases of Africans, but New World peoples have much less genetic diversity than Old World, especially African, peoples, which makes them less able to develop resistance. By one measure, indigenous South Americans have one quarter the genetic diversity of Africans (Coelho and McGuire, p.92).

The difficulties of operating in a tropical environment were abundantly clear during the building of the Panama Canal. The abandonment of the project by the French (1881-1889) and the early failures by the Americans (1904-1905) showed that intensive disease control was a necessary condition for its completion. The general work environment in the humid tropics was difficult: "the effect of the climate on tools, clothing, everyday personal items, was devastating. Anything made of iron or steel turned bright orange with rust. Books, shoes, belts, knapsacks, instrument cases, machete scabbards, grew mold overnight. Glued furniture fell apart. Clothes seldom ever dried."[13] The decisive challenge, though, was malaria and yellow fever. Although the French made major investments in medical care, in the 1880s they did not understand the means of transmission of these two major mosquito-borne diseases. Besides the fearsome mortality of workers and the recurrent debilitation of those who survived, many of the most dynamic project leaders and engineers perished from tropical disease. On top of unrealistic technical goals and organizational difficulties, the loss from disease was more than the project could sustain. At least twenty thousand lives were lost to disease during the nine years of the French effort.[14]

U.S. President Theodore Roosevelt, the prime mover behind the American attempt to build the canal, immediately recognized the importance of disease control from his own experiences in the tropics: "I feel that the sanitary and hygienic problems … on the Isthmus are those which are literally of the first importance, coming even before the engineering."[15] When the Americans revived the construction of the canal in 1904, a

[13] McCullough, 1977, p. 135.
[14] McCullough, 1997, p. 235.
[15] McCullough, 1997, p. 406.

crucial element of their success was William Gorgas. He demonstrated in Havana in 1901 what few believed possible: endemic yellow fever could be eliminated by intensive mosquito control. Once Gorgas was given substantial resources and support in 1905, he carried out a similar feat in Panama. In one of the most intensive vector control efforts before or since, Gorgas was able largely to eliminate the threat of both yellow fever and malaria by denying mosquitoes the pools of stagnant water they need to breed, using an army of health inspectors that went house to house. The provision of clean water and other public health measures reduced the incidence of other diseases. Contrary to popular impression, malaria was a greater threat to health than yellow fever in Panama, as Gorgas recognized, with higher mortality under both the French and American canal projects. [16]

Yellow fever is no longer a major public health problem due to a successful worldwide control effort by the 1930s and the development of an effective vaccine. The situation for malaria is completely different. The worldwide eradication effort that started in the 1920s and intensified in the 1950s and 1960s was largely a failure in the tropics, and no vaccine strategies have yet proven viable. Currently, all the inexpensive drugs for treatment of and protection from malaria are losing their effectiveness in the face of resistance strains.

The problem of poverty in the tropics is nothing new. The U-shaped gradient of income levels by latitude, with low incomes in the tropics and much higher incomes in the higher latitudes has persisted for as long as we have data. The data for GDP per capita is

[16] McCullough, 1997, p. 139.

reliable for the larger countries in the Americas back to 1900, shown in Figure 11.[17] Incomes in the tropical countries of Brazil, Peru, Colombia, and Venezuela are less than half the level of temperate Chile and Argentina, and lower than Mexico and Cuba on the tropical fringe. The tropical Latin American countries had much lower incomes than temperate U.S. and Canada by a factor of three or four a century ago.

The available GDP per capita estimates for 1800 are more tenuous and sparse (Figure 12), but show the same pattern by latitude.[18] The tropics are poorer than the temperate countries with the clear exception of Cuba. At this time, Cuba was a rich slave colony with one of the highest incomes in the hemisphere. The Caribbean slave colonies were tremendously economically productive for their time, although the fruits of this product went to very few. Haiti, France's richest colony, most likely had income levels similar to Cuba in the 1780s before the slave rebellion destroyed the plantations, but low levels afterwards.[19] High output levels (for a pre-industrial economy) were sustained in the tropical climate with slavery, but with emancipation in the nineteenth century, Cuba's income levels fell back to tropical levels.

[17] The GDP per capita data for 1900 are from Maddison, 1995, Table C-16d, p. 188, except for Cuba in 1913, from Coatesworth, 1998, Table 1.1, p. 26.
[18] The GDP per capita data for 1800 are from Coatesworth, 1998, Table 1.1, p. 26.
[19] Haiti's exports in 1788 were $41 million (then the French colony of Saint Domingue). By 1971 Haiti's exports of $40 million still had not caught up in *nominal* terms with the value of exports two centuries earlier. See Heinl (1978, p.2).

Geography and Economic Development

At least two aspects of physical geography are robustly correlated with the level of economic development and economic growth: accessibility and the tropics.[20] Accessibility for economic purposes depends on good connections to the main world markets. For most goods, the world markets are dominated by a relatively small number of Northern industrialized countries, in Europe, North America, and Japan. Proximity to these regions is a substantial economic advantage.

For the minority of "developing" countries that have in fact enjoyed rapid economic growth in the past generation, the export of labor-intensive manufactures has played a prominent role. Trade in these goods depends largely on seaborne transport. With the actual cost of transport a small fraction of the value of the final goods, why, though, would transport costs have a significant economic impact? When investment goods are imported, as they almost always are outside of the most prosperous countries, transport costs serve as a tax on investment that varies depends on the country's accessibility. If the inputs to production are also imported as they usually are in export manufactures, the impact of this tax is greatly magnified.[21] It is not unusual in offshore assembly manufacturing for the value of inputs to be 70% of the value of the finished export. If shipping costs are ten percent of the value of the goods shipped, applied both to the imported inputs and the exported finished good, transport costs make up a remarkable 56% of the domestic value added.[22] If transport costs are half this rate, at five percent,

[20] See Gallup, Sachs, and Mellinger (1999) and related papers discussed therein.
[21] This is shown formally in Gallup, Sachs, and Mellinger (1999).
[22] The ratio of transport costs to local value added is equal to the costs of shipping the input in and the export out, all divided by the value of the output less the value of the imported inputs. For an export with a

then the ratio of shipping costs to value added falls to 25%. Such a difference in transport costs is often enough to render the higher shipping cost location entirely unprofitable.

Access to the sea within a country, not just the distance from international markets, is crucial for economic accessibility. Not only are overland transport costs much higher than sea shipping, especially in poor countries with limited infrastructure, but offloading and reloading of goods from ship to ground transportation is expensive. The cost of shipping goods overland within the country can be as high as the cost of shipping them by sea to a far-flung foreign port.[23] As shown in Radelet and Sachs (1998), almost all countries with macroeconomic success in labor-intensive manufacturing exports have populations *almost totally within 100 kilometers of the coast*.

The tropics have had much poorer economic performance than the rest of the world, as discussed in the introduction. The tropics are, essentially, a band of poverty. The clearest reasons for this pattern are the impacts of climate on agricultural productivity and disease. These topics are taken up individually below. Among tropical health problems, malaria in particular is strongly correlated with poor economic performance. The relationship of malaria to poor economic performance is distinguishable from the tropics, per se, because the intensity of malaria varies considerably within the tropics. Among the

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value of one, the cost of shipping is the value of inputs (0.7) plus the value of the export (1) times the shipping cost (10%), all divided by value added (1-0.7 = 0.3), or 0.1(1.7)./0.3 = 56%. If shipping costs are only 5%, then the landed price of inputs is 5% less, or 0.7(1-0.05) = 0.665, and value added is 1-0.665 = 0.335. The ratio of shipping cost to value added is 0.05(1.665)/0.335 = 25%.

[23] Shipping cost data are hard to come by, but a recent UNCTAD study showed that for landlocked African countries, the cost of shipping a sea crate overland was 25%-228% the cost of shipping the crate by sea from the nearest port to Europe. See Radelet and Sachs, 1998.

major health problems in the tropics, malaria is also the least likely to be ameliorated by economic growth. Living conditions and household behavior have quite limited impact on malaria prevalence, unlike the scourges of diarrhea, cholera, tuberculosis, schistosomiasis, etc.

The broad connections between geography and GDP per capita levels for major regions of the world can be seen in Figure 13. The proximity of countries in each region to core world markets is measured by the distance of the capital city in kilometers to the nearest of Tokyo, New York, and Rotterdam. Within-country access to the sea is measured by the percent of the population living within one hundred kilometers of the coast or an ocean navigable river. For inland landlocked countries, this will be zero. Tropical location is measured by the percent of the country's land area within the geographical tropics, and malaria prevalence is an index which weighs both the percent of the population at risk for malaria, and the percent of the infected population that suffers from the most severe kind of malaria.[24]

Sub-Saharan Africa, the poorest region, is the farthest from major world markets, has the smallest share of the population living near the coast, is the most tropical, and has by far the worst malaria. Latin America and the Caribbean does better on all these scores, especially malaria. As shown by the average purchasing-power-parity GDP per capita in parentheses below each region name, Latin America enjoys an income level almost three times higher than Africa. Geographical endowments are also consistent with lower levels of economic development in Latin America than in East and Southeast Asia. East Asia is

[24] Detailed descriptions of these variables can be found in Gallup, Sachs, and Mellinger (1999).

closer to a major world market, on average, has a mostly coastal population, is less tropical than Latin America, though severe malaria is somewhat more prevalent in East Asia. East Asia also has about twice the income level of Latin America. Western Europe is the most favored region here with an income level almost twice the level of East Asia. Europe is in the midst of one the richest world markets, has almost 90% of the population near the coast or a navigable river, and is nontropical with no malaria. In cross-country regressions, all these variables have strong correlations with levels of GDP per capita, even after controlling for other factors like colonial history and recent economic policies.[25]

The concentration of economic activity in geographically favored regions of the world is impressive. The coastal land area of temperate countries in Northern hemisphere comprises only 3% of the world's inhabited land area, but it produces at least 32% of the world's output.[26]

The Latin American region as a whole fares reasonably well when comparing its geographical endowments to the rest of the *developing* world. Countries in Latin America have good access to the sea with two exceptions: Bolivia and Paraguay. The population is mostly concentrated on the coasts. The states bordering the Caribbean are all close to the large North American commercial market. Agriculture in the region benefits from large areas with temperate climate due to latitude or elevation. Most vector-borne diseases, including malaria, do not have the virulence found in Africa. The

[25] See Table 2 in Gallup, Sachs, and Mellinger (1999).
[26] Gallup, Sachs, and Mellinger, 1999, p. 128.

favorable geography of the Latin American region accounts for it having many of the higher income countries in the worldwide tropics. Although the Latin America compares favorably in terms of geography and income levels with the rest of the developing world, it does not compare well on either count with highly industrialized countries in Europe, North America, and Japan.

Though scrutinizing the relationship of geographical characteristics to income levels is suggestive, it is not make clear whether geography has *continuing relevance* for future economic development. Income levels could be affected by historical processes that depended on geography, despite future economic growth being largely independent of geography. The "New Economic Geography" of Paul Krugman, Anthony Venables, and others follows this line of reasoning – locations with initial geographical advantages serve as catalysts for developing networks, but once the network is established, physical geography ceases to have an impact on economic activity.[27] The forces of agglomeration can create a differentiated economic geography even if there was little geographical variation in the first place.

The endogenous processes described in economic geography models reinforce and magnify the direct impacts of physical geography and help to explain the dynamics of the process. Natural ports, for example, become the focal points for the development of cities, which can become more dominant over time if the economies of agglomeration outweigh the costs of congestion. If these processes dominate, though, and the impact of

[27] See XX, Venables, and Krugman (1999), Krugman (1995),

physical geography does not persist, we are unlikely to find a strong relationship between geography and economic growth, once we have controlled for the initial conditions. Is it true, for instance, that Hong Kong and Singapore still depend on their excellent access to major shipping lanes for their future economic success, or was that just important to get them started? Is the disease burden in Africa just a reflection of the continent's poverty, perhaps due to the accident of colonization, or will it be an independent drag on African development because it is tied to the tropical climate? To address the continuing relevance of geography to economic development, we look at the cross-country relationship of geographical variables to economic growth controlling for other important determinants of growth, including initial conditions.

We start with a baseline equation similar to those in Barro and Sala-i-Martin (1995), in which average income growth between 1965 and 1990 is a function of initial income in 1965, the initial level of education in 1965 (measured by average years of secondary school in population), the log of life expectancy at birth in 1965, the openness of the economy to international trade, and the quality of public administration.[28] We find the standard results for these variables: conditional on the other variables, poorer countries catch up by growing faster, and output is an increasing function of education, life expectancy, openness, and the quality of public administration. To these variables we add three measures of geography: the country's share of population within 100 kilometers of the coast and the share of land in the geographical tropics. Landlocked countries, with no population within 100 kilometers of the coast, experienced 1.0 percentage point per year

[28] The dates are determined by data availability. The specifics of the variables used are found in Gallup, Sachs and Mellinger (1999).

slower growth in GDP per capita than coastal countries.[29] Tropical countries grew at 0.9 percentage point per year slower than temperate countries.

Adding a measure of the intensity of malaria at the start of the period, we find that countries at high risk of malaria grew at 1.2 percentage points slower than countries free from malaria. Most of Sub-Saharan Africa has a malaria index of one, or the whole country at high risk of falciparum malaria. Such a large estimated impact of malaria on economic growth is striking, especially since we have controlled for general health conditions (life expectancy), and a general tropical effect. The one country in the Americas with a malaria index of one, Haiti, is also the poorest country in the hemisphere. A reduction in malaria over the period 1965-1994 was also strongly correlated with faster economic growth. The estimates imply that a severely malarial country which reduced malaria by 50 percent over the 1965-90 period would grew 1.0 percentage point per year faster.[30] In fact, there was discouragingly little malaria reduction over this period in most countries, with the largest average reductions in Latin America (6 index points out of 100) compared to Africa (3 points), East Asia (3 points), and South Asia (1 point). Dividing up the world by ecological zones determined by temperature and precipitation, the desert and subtropical zones showed some decline over the period (9 and 5 points, respectively), but the tropical zones actually saw an increase in malaria intensity of 5 points.

[29] All the regression results are found in Appendix Table 1.
[30] See Gallup and Sachs, 1998, for a discussion of reverse-causality issues when relating changes in malaria to changes in GDP.

The regressions show support for the notion that there are agglomeration effects from population concentrations on the coast, but diminishing returns to dense populations in the interior. Countries with high population density within 100 kilometers of the coast grew faster over the period, and countries with high population density in the interior grew slower, but not quite statistically significantly slower.

The contribution of geography and other variables to the economic growth of different regions of the world can be decomposed from the regression estimates. Table 2 shows the estimated impact of specific variables in the growth differences between Latin America and Sub-Saharan Africa, East and Southeast Asia, and the industrialized OECD member countries.[31,32] Average growth of GDP per capita in Latin American and Caribbean countries from 1965 to 1990 was 0.9 percent per year, somewhat higher than Sub-Saharan Africa's 0.3 percent, but less than half of the OECD's 2.7 percent growth, and lower still than East and Southeast Asia's dramatic 4.5 percent per year. The "explained" row in Table 2 shows the sum of the predicted contribution of the explanatory variables below, and is quite close to the actual differences in the regional growth rates. "Initial GDP per capita" is the predicted effect of initial income on subsequent growth. Since, *other things being equal*, poorer countries grow faster, the fact that Latin America started out with higher income levels in 1965 than Sub-Saharan Africa or East and Southeast Asia accounts for some of Latin America's slow growth, but not for Latin America's poor performance relative to the OECD countries. The other explanatory variables are grouped into two broad categories: geography and health, and

[31] The estimates in Table 2 are calculated from Regression 3 in Appendix Table 1.
[32] OECD is the Organization of Economic Cooperation and Development, an organization of the richest countries. Here we use membership as of 1973, including Western Europe, North America, Japan, Australia, and New Zealand.

policy and education. Geography and health account for most of Latin America's higher growth than Africa, after initial income is taken into account, almost none of the difference with East Asia, and about a quarter of the difference with the OECD countries. Policy clearly matters - trade openness and institutional quality account for most of the growth difference between Latin America and East Asia and Southeast Asia.

The big difference in growth rates between Latin American and Sub-Saharan Africa are correlated with health differences. Initial health, in terms of life expectancy and malaria, were much better in Latin America in 1965 than in Africa. Compared to East Asia, Latin America had rather similar geographical characteristics. Its lower population density on the coast seems to be less conducive to growth, but its lower malaria risk offset that. Compared to the industrialized OECD countries, Latin America had several geographical disadvantages. It is substantially tropical, started out with a lower life expectancy, and had worse falciparum malaria. The worse initial malaria compared to the malaria-free OECD was offset by the reduction in malaria in Latin America over the period (by 7 points out of 100). Latin America's low population density inland offset its low population density on the coast.

Latin America has made great strides since 1965 in terms of pursuing policies conducive to international trade and making government institutions more efficient and responsive to citizens, which this simple analysis suggests is crucial. Geography appears also to play and important role in Latin America's performance compared to the wealthiest countries. Improving health, including malaria, and overcoming other tropical and accessibility problems could help Latin America to catch up economically with the more developed countries in the world.

With enough investment in infrastructure, one can overcome any barrier to access. A highspeed motorway and efficient port facilities should solve most problems of the physical accessibility of regions. The reason that they don't exist throughout the isolated regions of the developing world is that they are very expensive. Moreover, in areas of difficult geography, such as highly mountainous regions, humid tropical zones (where the soils and torrential rains make it difficult to build durable roads), long distances to the sea, and no good natural ports (most extreme in landlocked countries), building such infrastructure is very much more expensive than in coastal, temperate states. To see whether infrastructure investment is less productive in geographically difficult environments, we examine whether infrastructure has a smaller impact on economic growth in countries with limited access to the coast. In landlocked countries (countries with no population on the coast), initial road stocks and initial electricity generation capacity are actually negatively correlated with subsequent growth.[33] In coastal countries, there is no significant correlation between initial infrastructure and subsequent growth (after accounting for policies, institutions, etc.). The results suggest that it is more difficult to achieve a good rate of return from infrastructure in countries with poor coastal access, but that infrastructure investment is not a panacea even in coastal countries.

[33] See Regressions 4 and 5 in Appendix Table 1. Road length and electicity generating capacity data come from Canning (1998).

From the point of view of trading access to major world markets, the Caribbean basin is ideally situated, close to the large U.S. market. With conducive trade policies and complementary infrastructure, nearby countries should have a competitive advantage over the more successful East Asian export manufacturers. Why would forms go all the way across the Pacific to take advantage of low wages for manufacturing assembly in East Asian countries when educated, low wage workers are only a couple of hundred miles away from the U.S.? Trade policies in the Caribbean and the development of export processing zones (EPZs) have started to take advantage of this potential.

The role of EPZs as a stepping stone to the development of an export manufacturing sector highlights the importance of coastal access. As shown in Figure 14 and Table 3, of the 210 export processing zones in Latin America and the Caribbean in 1997, 152 or them, or 72% were within 100 kilometers of the coast.[34] Most of the inland EPZs are in Northern and Central Mexico, with good overland access to the U.S. market, and landlocked Bolivia. Excluding Mexican and Bolivian EPZs, 112 out of 119, or 94% are on the coast.

Caribbean and Central American economies are being buoyed by deepening trade ties with the U.S. while many South American countries are currently facing economic crises. Economic performance within Mexico shows this trend. GDP per capita growth the Mexican states that border the U.S. grew 0.3% slower than the other Mexican states in 1960-1980 when the economy was largely closed to external trade (Figure 15). With the trade liberalization in the 1980s opening the economy to the U.S. market, growth in the

[34] Many of the EPZ locations in Figure 14 have more than one EPZ. The data source is WEPZA (1997).

border states was 0.4% faster than the other states (though the country as a whole had a declining GDP per capita). In period 1990-1995 with the advent of NAFTA, despite the continuing decline in GDP per capita, the northern border states grew 0.8% faster than the rest of the states.

Geography has strong correlations with differences in income levels and economic growth across countries. Does geography also explain differences in income across regions within the countries of Latin America? A set of studies for Mexico, Colombia, Peru, Bolivia, and Brazil addressed the role of geography within countries. Table 4 shows the percent of income level variation "explained", or accounted for, by geographical variables in these countries. The geographical variables used (as well as the measure of income used) differ substantially across the studies, ranging from measures of climate to soils to proximity measures. For countries with province level income measures, geography accounted for the majority of income variation, from 66 to 72 percent. The percentage of household income variance explained was less, from 7 to 47 percent, but given the many factors that affect household outcomes, these are still large numbers. The strength of the association between geography and regional income levels is impressive since, due to migration and government transfers across regions, income varies less within countries than across countries.

Latin America is famous for its unequal income distribution. These estimates in Table 4 imply that a large part of regional disparities within these Latin American countries are tied to geographical factors, and even a substantial share of between-household inequality is correlated with geography.

The role of geography in shaping economic development within Latin American countries has been important historically and in the present. In Colombia, for example, trade between the major regions was minor. Until this century, roads only connected villages within each region, with no roads across regions. In 1930, the main link from the capital, Bogota, to the outside world was a twelve day steamboat trip down the Magdelena River. The geographical barriers still mean that Colombia has one of the lowest road densities in Latin America. In most countries, there has been a strong tendency for income levels to converge across states or regions. This is so regular a tendency in many of the countries studied that it seems to occur at similar rates.[35] In Colombia, however, there is no clear sign of convergence across the *departamentos*, probably due in substantial measure to the geographical barriers between them. The mountains make access difficult, and the wide variation in ecological zones between the high mountains and the tropical lowlands means that many techniques, such as agriculture, are not transferable. When trying to explain the causes of *municipio*[36] growth, proximity to regional markets remains the most important explanatory variable, and there are strong effects of tropical disease (malaria and cholera) on *municipio* growth. The tropical disease effect is even larger in a subsample of the poorer *municipios*.[37]

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[35] Barro and Sala-i-Martin (1995).
[36] *Municipios* are the second level administrative subdivision, below *departamentos.* If *departamentos* correspond to U.S. States, *municipios* correspond to U.S. counties.
[37] See Sanchez and Nuñez (1999).

Mexico, like Colombia, is heavily influenced by its geography. The large regional disparity has lessened very little over time, and none since 1960. Geography differences contributed between 45 and 62 percent of the cross-state income inequality.

Geography's influence in pervasive in Latin American economic development, explaining a substantial share of household differences, regional differences, cross-country differences, and the average Latin American economic growth compared to the other regions of the world.

Agriculture

One of the basic reasons why economic development is depressed in the tropics could be lower agricultural productivity. The disparity between tropical and non-tropical agricultural output per farmworker (Figure 16) is even more pronounced than the disparity between tropical and non-tropical income levels (Figure 1). Most individual crops tell the same story. For nine of ten important crop categories in Table 5, the non-tropical yields are higher than yields in the geographical tropics. This is true not only for essentially temperate crops like wheat, but for typically tropical crops like maize, sugarcane, bananas, and coffee.

Certain crops, certainly, are more productive in the tropics, such as treenuts, or tropical fruits. Few of these crops, though, are major parts of the food system. Table 6 shows the contribution of different crop categories to the world food supply. Cereals provide almost half of all calories in food, and almost as much of protein consumption. Oilcrops, the only crop category for which yields are higher in the tropical countries than non-tropical countries, makes up just ten percent of food calories, and only three percent of protein.

Tropical yields are much lower than non-tropical yields for most crops, such as coffee which has less than half the yield per hectare in tropical countries. But these differences could be due, in whole or part, to the inputs used. Fertilizers, tractors, improved seed, and labor will all affect yields whether or not the climate is ideal for the crop. Farmers in wealthier countries will use more non-labor inputs per hectare since these inputs are inexpensive compared to their own labor and land values. So the low yields in the tropics could be due to poverty in the tropics rather than contributing to poverty. Estimates in Gallup and Sachs (1999) show that tropical yields are much lower controlling for differences in input use.[38] Tropical and dry ecozones, which make up most of the geographical tropics, have yields thirty to forty percent lower than temperate ecozones for the same input use. Moreover, agricultural productivity grew about two percent per year more slowly in tropical and dry ecozones than temperate ones.

The same pattern of differential agricultural productivity appear within Latin America and Caribbean, even though countries within the region is more similar to each another than the rest of the world. For most crops, yields in tropical Latin American countries are much lower. A few crops are exceptions: sugarcane, oilcrops, and coffee, but none of the

[38] Pricing and other agricultural policy has a substantial effect on how much farmers produce, and how much inputs they use, but to a first approximation, should not affect yields given inputs.

yield differences for the tropics and non-tropics for these crops are statistically significant (Table 7).

The diet in Latin America, especially in the tropical countries, is different from other parts of the world. If the crops eaten by people in tropical Latin American countries are relatively more productive in the tropics, the yield differences between the tropics and non-tropics for other crops are less of a problem. The last column of Table 6 shows calorie consumption in Central America by crop. Indeed, Central Americans eat much more maize, sugar, and pulses, which make up 54 percent of their calorie consumption compared to only 16 percent for the rest of the world. However, maize in particular, and also beans, are among the least favored crops in the tropics compared to the non-tropics both in the world as a whole and within Latin America. Sugar, whether produced from sugarcane or sugarbeet, does not differ substantially in yield in the tropics and outside (in locations where it is actually cultivated).

Crop yields have grown tremendously in the last few centuries, so it is difficult to speak of inherent levels of agricultural productivity in one region of the world or another. This is equally in true in recent times of Latin America. Table 8 shows the rapid growth of crop yields in the region for most of the staple crops, but the growth rates are quite different between tropical and non-tropical regions. The yields of a few crops (coffee, fruits, vegetables, and oilcrops) was slightly higher in the tropical countries (and not statistically significantly different), but the staples all grew more slowly. Cereals in general as well as maize in particular, potatoes and root crops, and pulses all had clearly lower growth rates in the tropics. The disappointing tropical trends for these crops in the regions are also similar for the world as a whole. Bananas, an important export crop in the tropical parts of the region, actually saw a decline in average Latin American yield in the last 37 years.

Health and Disease

Life is short in the tropics. Figure 17 combines state or provincial life expectancy data for Bolivia, Peru, Brazil, Colombia, and Mexico in 1995 with national data for the other Latin American countries.[39] Inhabitants of the temperate northern and southern ends of Latin America can expect to live about 75 years, but the trend line sags markedly in the tropical middle, dropping down to 65 years just south of the equator. The very low average lifespans, below 60 years, are all in the tropics, seeming to drip from the sagging trend line. The below-60 life expectancies are in provinces of Bolivia and Peru, and in Haiti. The two provinces close to the equator with life expectancies above 75 years are also in Peru: the capital Lima and its sister *departamento* of Callao, a clear sign of the regional disparities within the country.

Poor health and poverty are closely linked. Bolivia and Haiti, with the low life expectancies, are poor countries. Peru is not as poor, on average. We have already seen

[39] The subnational state and provincial data come from various national sources described in the [OCE-RED geography volume - what is the right citation?]. The national data are from World Bank (1998).

that income per capita is lower in the tropics than the temperate zones of Latin America. Perhaps poor health in the tropics is simply due to poverty, not direct geographical influences. If we are concerned with life expectancy as a measure of human welfare, it doesn't matter much whether climate affects it directly, or indirectly through economic development: welfare is lower in the tropics. If we want to change health conditions, though, it matters a great deal whether it is necessary to curtail the transmission of disease directly, or it is perhaps more effective to invest resources in economic growth which will solve the health problems indirectly.

To assess the direct influence of climate on disease, we control for the influence of income levels. Provincial life expectancy in Latin America is still strongly correlated with climate after taking into account income levels. Provincial GDP per capita levels are independently correlated with life expectancy, but their inclusion does not change substantially the association of climate with health.

One of the most robust correlates of health status is the education of mothers. When the influence of female literacy on health is included along with income levels, it is large and significant, and income loses its independent association with life expectancy.[40] Climate, however, is still strongly correlated with health outcomes. Controlling for female literacy and GDP per capita, life expectancy is four years lower in the wet tropics as in the moist temperate zone.[41] The regression results predict that life expectancy is seven years lower in the wet tropics than in desert and dry regions with the same income and female

[40] These regression results are shown in Appendix Table 2.
[41] The ecological, or climate, zones are shown in Figure X.

literacy. Similar results pertain to infant mortality, which is a component of life expectancy. Infant mortality is four percent higher in the wet tropics than in humid temperate regions, and six percent higher than dry regions, other factors being equal.

One of the most conspicuous differences between the disease environment in tropical versus temperate areas is malaria. Only in tropical regions of the world does malaria remain a major, and intractable, health problem. Figure 18 shows the distribution of malaria in Latin America at three points in time: 1947, 1965, and 1994. Although malaria prevalence has been reduced, its core tropical zones resist control. Malaria is strongly related with climate, and there is no indication that it is affected by income levels or by female literacy.[42]

The role of geography in provincial health conditions across countries in Latin America is confirmed by within-country analyses of Brazil and Peru. In these two studies, 61 to 71 percent of variation in infant mortality and child malnutrition was accounted for by geography (without controlling for other factors) as shown in Table 9. Controlling for other community characteristics, Alves et al. (1999) finds that Brazilian regions with higher temperature have lower child and adult height, and lower rates of child survival. Health is an essential component of the good life. The wide disparities in health status across communities within these two Latin American countries are largely tied to geographical differences.

[42] See again Appendix Table 2.

Although geography is largely immutable, the disease prevalence in particular climates is not. Our results suggest that rising income levels *per se* will not take care of health in the tropics; direct action is required. For some tropical diseases there are few affordable and effective treatment and control stategies; for others the means of conquering the disease are well known, but major efforts of education and mobilization required. The prime example of the former is malaria. Vector control in the worst effected areas is at best a holding action, and the effective drugs are rapidly losing their effectiveness due to drug resistance. Vaccines are still many years from development, due to little funding and the extraordinary complexity of the pathogen and its life cycle. Tropical diseases do not get the benefits of spillovers from biomedical and pharmaceutical research in the developed countries, because there *are* no significant tropical developed countries. The tropical countries are too poor to offer an attractive stand-alone market to induce pharmaceutical firms to invest in drug development for tropical diseases.

Geography, Inequality, and Social Cohesion

The relationship between geography and inequality is more ambiguous than in the roles of geography discussed in other parts of the chapter. Some strong patterns exist, but they are difficult to explain. Notably, inequality rises as latitude falls: the South has much more income inequality than the North. Figure 19 shows income inequality, measured by the Gini coefficient (0-100), versus latitude. This is not a tropical phenomenon *per se*. Income distribution becomes steadily less equal as latitude decreases, with greater inequality in the temperate far southern latitudes than in the tropical latitudes. This is also not a consequence of income. It is difficult to find a systematic relationship between income levels and income inequality (Li, Squire, and Zou, 1998).

The variation in income distribution within Latin America conforms to the world pattern, as seen in Figure 19. Income distribution tends to be lower in the tropical northern end of the region, and increase as one moves south.

The relationship of latitude and income distribution persists when one controls for other factors.[43] GDP per capita and its square have no statistically significant association with income inequality, but formerly Spanish colonies have strongly higher income inequality and formerly Socialist countries have strongly lower inequality (for now, at least). Countries with high proportions of Muslims, Roman Catholics, and Hindus in their populations have lower inequality other things being equal (compared to Protestants, Animists, Atheists, etc.). Countries that have kept their economies open to international trade have more equal societies, probably due to the stimulation of labor-intensive employment. None of these partial effects gets rid of the strong correlation of latitude and inequality.

In Latin America, language is a source and a mark of inequality. The non-Spanish speaking indigenous people are mostly very poor and marginalized. Their langage difficulties working in the mainstream economy keeps them that way. The social exclusion due to language barriers can be roughly measured by the fraction of the

[43] The regression results can be found in Appendix Table 3.

population which does not speak the most widely spoken language in the country.[44] Figure 20 shows that this measure of linguistic diversity is much higher for the tropics in the world as a whole, and in Latin America. The sparseness of the fundamental network of language in the tropics is consistent with the notion that the tropics is a difficult environment for the creation a range of essential networks: trade and division of labor as well as social intercourse needed for effective institutions. Disease creates barriers to the movement and mixing of people; tropical climatic and soil conditions makes the building of infrastructure networks difficult; and low incomes due to geographical obstacles makes it difficult for communities to look towards broader horizons.

In Latin America, language diversity within a country is also related to the geographical diversity within a country, in addition to its association with the tropics (Figure 21).[45] A wide range of ecological conditions creates barriers to economic and social connections within a country. Although this pattern is strong in Latin America, it is not characteristic of Africa and weaker in the rest of the world (not shown).

Engerman and Sokoloff (1997) develop a theory, mentioned above, that links geography to social inequality and institutions, and ultimately to the lagging economic performance of Latin America. They argue that slave labor had a comparative advantage in tropics, due to the production techniques suited to tropical plantation agriculture. The legacy of slavery led to unequitable societies with institutions that were not conducive to economic development. Two links in this chain of argument seem to have weaknesses, especially

[44] Get data source for Gunn2 from Easterly.
[45] Describe Herfendahl ecozone diversity measure.

for explaining relative economic development within Latin America. The first is that the former slave societies generally have less income inequality now than the countries with little or no slavery (with the exception of Brazil). The former Spanish colonies in Latin America had little slavery, while almost all the Caribbean countries and Brazil had economies based on slave plantations.[46] Current income (or expenditure) inequality in the former Spanish colonies is much higher than most of the non-Spanish former slave economies, as shown in Table 10. All of the former slave economies with data have Gini coefficients lower than the average Gini coefficient in the former Spanish colonies (51.0), with the exception of Brazil. Twelve of the fifteen former Spanish colonies have higher Gini coefficients than the average Gini for former slave economies (45.7). The Spanish colonies had several institutions inimical to an equitable income distribution, such as the peon-like status of indigenous people and a general neglect of mass education, but these were not the result of slavery and particularly not a consequence of tropical plantations. Perhaps part of the difference in the former Spanish colonies is that without explicit slavery, there was no explicit emancipation.

The second weak link in Engerman and Sokolof's argument is that it is difficult to find evidence that inequality results in poor economic performance. Two recent papers that appear to demonstrate this, Alesina and Rodrik (1994) and Persson and Tabellini (1994), were based on examining economic growth in a limited number of countries using income distribution data with serious comparability problems, and a limited set of alternative explanatory variables. Now that more abundant and higher quality income

[46] The main exception is the former Spanish colony of Cuba, which was a slave economy. Interestingly, Cuba presumably has among the lowest income inequality in the region.

distribution data are available (Deininger and Squire, 1996), the cross-country negative correlation between initial income inequality and economic growth has disappeared (Li, Squire, and Zou, 1998, and Forbes, 1998).

The first indication that income distribution does a poor job of explaining economic performance *within* Latin America is that the richer Southern Cone countries have some of the highest income inequality. In addition, when the initial income distribution is included in the economic growth regressions already discussed in this chapter, it has a small *positive*, but statistically insignificant coefficient, whether institutional quality is also included in the regression or not.[47] One might surmise that even though income distribution has no correlation with average income growth, it still matters for the poor. Gallup, Radelet, and Warner (1998) find that the incomes of the poor grow just as fast as average income growth, on average, but that in countries where the poor get a smaller share of income, the poor's income grows somewhat *faster*, allowing the poor to catch up.

[47] The regression results (not shown) are obtained by including the Gini coefficient in 1965 in Regression 2 of Appendix Table 1.

Policy and Conclusions

Geography may be largely immutable, but its impact on the economy and society are not. The right policies or technological developments can overcome many geographical obstacles. Tackling geographical problems has important "public good" aspects. Investments to overcome these obstacles, such as disease control or roads, typically benefit whole regions rather than particular individuals. To make these investments at the socially desirable level, they need coordination by the government or other organizations. The individual will not capture the benefits that he or she provides to the wider society, and so is likely to invest less than is desirable. No individual would likely take upon themselves the task of controlling a dispersed disease vector, for example, but everyone benefits when each person contributes a small amount to the eradication of the disease. The sharing of the burden requires coordination.

Latin America has large population concentrations in geographically difficult environments such as the highlands of Central America and the Andean region, the Brazilian northwest, and Haiti. If nearby areas develop rapidly, some of the problems of these difficult environments may be spontaneously solved by migration to the dynamic neighboring regions. However, the persistence of poverty in these population concentrations over the centuries indicates that migration is unlikely to be the main solution. Population growth is often higher in poor, geographically disadvantaged regions, offsetting the benefits of outmigration.

Infrastructure

More active approaches to reducing geographical disparities through infrastructure investments face all the difficulties of regional development programs. By the nature of isolated places, infrastructure is typically more expensive to extend there (i.e. it exhibits strong scale economies), so the benefits to those living in isolated areas must be large indeed to support these costs. Furthermore, if the purpose is to bring industry and white-collar services to these regions, there are usually strong synergies, or economies of agglomeration. These synergies make the returns to new infrastructure investments higher in the already well-connected, accessible cities. Bringing industrial and service activities to a disadvantaged region is a chicken and egg problem. These activities depend on the presence of other industry and services as well as a range of complementary infrastructure. Firms do not want to establish in an isolated place unless the infrastructure is in place and the other firms are also going to establish themselves there. Cost recovery for the infrastructure is not possible unless it attracts a good number of firms. To get this all moving simultaneously is expensive and risky. Government efforts to provide these elements in a coordinated package have a poor track record (Richardson and Townroe, 1987). In contrast to government-sponsored export processing zones, which have often been successful and are usually sited in the most geographically favored locations, industrial estates in lagging regions have often ended up empty. They were built, but nobody came.

More systemic approaches to disadvantaged regions in the form of regional development agencies have also not been encouraging. These sizable regional development bureaucracies usually have trouble carrying off the complex coordination necessary to get economic networks established in places where they have not done so on their own. The poor Northeast of Brazil has a long history of such efforts. With the contribution of decades of migration out of the region, the Northeast has caught up a little bit with the wealthier Southeast, but not very much. The poorest Brazilian state in 1960 was Piauí in the Northeast, with a GDP per capita only 11% of the GDP of the richest state of São Paulo in the Southeast. By 1995, Piauí was still the poorest state in Brazil, with a GDP per capita that had risen to only 16% of the GDP of the richest state of São Paulo (Azzoni, et al., 1999). The strategy of opening up the Amazonian frontier for poor settlers from the Northeast has caused major environmental damage, had limited economic success, and exacerbated tropical disease problems.

The most ambitious attempts to shift economic activity to the hinterlands, the movement of national capitals to the less-developed interior, has proved very costly without establishing a self-sustaining economic base. The experience of relocating the capital in Brazil, Pakistan, and Ivory Coast does not recommend it to other countries.

Despite the limited success of grand regional infrastructure projects, it is difficult to accept leaving isolated regions to their own devices. Lack of access to infrastructure is closely associated with poverty, since infrastructure provides the enabling environment for economic activity. A “basic needs” approach to infrastructure may provide an effective approach to reducing poverty in geographically-challenged regions, and may also have a higher economic rate of return than large, top-quality infrastructure projects.

Rudimentary feeder roads, electricity, and telecommunications are needed to bring isolated regions into the rest of the economy. The new technologies for micro electricity generation and standalone telecommunications links may prove most cost-effective precisely in these isolated places. Basic connections to the rest of the economy are essential not only for stimulating the local economy but to give residents the links necessary to take advantage of opportunities in the outside world, by migrating.

A different approach to providing cost-effective infrastructure in isolated regions is decentralization, already well advanced in many Latin American countries. Decentralization can be a two-edged sword for overcoming geographical obstacles. Decentralization allows greater adaptation of government to local conditions, especially helpful in geographically varied countries, but it may reduce the cross subsidization of poor regions by wealthier regions (unless, of course, the poorer regions were previously subsidizing the richer regions). In a decentralized system, local services are only as good as the capacity and quality of local government, which may be low in isolated, poor regions.

Agriculture and Health in the Tropics

The failure of economic development in much of the tropics is due in part to the difficulty of fostering productive agriculture and good health there. Basic and applied research in tropical agricultural and health problems are high priorities. Most technological advances in the wealthiest countries, which carry out almost all scientific research and development, hold at least the potential of being adopted by the poor countries in the tropics. The big exceptions are in the areas of agriculture and disease because their biological processes are distinct in the tropics. Malaria, for instance, simply is not a serious problem for rich countries.

In the developed world, more and more of the cutting-edge scientific research in health and agriculture is being carried out by large private firms rather than in government and academic research institutes. These firms presently have no financial incentive to invest in similar research on tropical problems. Developing country consumers cannot afford to pay premium prices for new drugs and vaccines, so they do not provide a profitable market. At the same time the tropics is left out of the revolution in corporate scientific research, public funding for research on tropical agriculture and disease has been, if anything, declining. The research and development budget of the entire CGIAR system of institutes studying developing world agricultural problems is less than half of the R&D budget of one life-sciences multinational, Monsanto.[48]

With a new era of rapid advances in biology, applied research on the obstacles to tropical agriculture and disease appears promising. Tropical agricultural research, most of it public, has had very high rates of return. Echeverría's (1990) compilation of the estimated rates of return on agricultural research in Latin America is presented in Table 11. These studies assessed research on different crops in different countries using different methodologies, but what is striking is how uniformly high the estimates are. Of the 58 rate of return estimates, only 4 are below a 15 percent rate of return per year. The average rate of return is 57%, and the median is 44%. These huge paybacks on research

[48] Sachs (1999, p.19).

investments indicate that not enough agricultural research is being undertaken. Even if agricultural research did not have such high economic returns, investing in agricultural improvements can still be justified in terms of its impact on the poor. The near-term welfare of more than half the households in low income countries (69% of the labor force in 1990),[49] and an even higher proportion of the poorest households, still depends on agriculture.

The rate of return to investing in tropical medical research is difficult to calculate and in any case ignores the principle benefit to human welfare of better health. Nevertheless, the level of funding for research on tropical health problems is pitifully low. A good example is malaria, one of the most important tropical diseases. An estimated 2.4 billion people are at risk worldwide, with 300-500 million clinical cases of the disease each year, and 1.5 to 2.5 million deaths per year. Due to lack of market incentives, there is essentially no malaria research by private pharmaceutical firms. Total worldwide research funding was only $84 million in 1993 (Welcome Trust, 1999), much of it from the militaries of wealthy countries, who are concerned about the readiness of their soldiers overseas.

Latin America has better health than would be predicted by its income level, especially for a region that is highly tropical.[50] A part of this is probably due to the strong public health institutions in the region and a series of successful regionwide disease control

[49] World Bank, 1997, p. 220.
[50] Using a simple regression to predict average life expectancy in 1995 using the natural logarithm of GDP per capita, Latin American and Caribbean countries have an average life expectancy four years longer than would be predicted by GDP alone. If one also controls for tropical location, Latin American and Caribbean life expectancy is eight years higher than expected.

programs. Public health efforts have been coordinated by the Pan American Health Organization (PAHO) and its precursors since the 1920s, predating the post-war establishment of the World Health Organization (WHO). Even now for most major diseases, the WHO does not have comparable data on incidence or prevalence levels for less developed countries, but PAHO usually does for its member countries.

National public health departments in many Latin American countries received early support from the Rockefeller Foundation. This work together with the Foundation's successful program to control yellow fever in Latin American and Caribbean by the early 1940s, the elimination of the malaria-carrying *Anopheles gambiae* mosquito in Brazil in the 1930s, hookworm control in the 1920s, and early financial support for PAHO constituted a remarkable impact on one institution on the disease burden in Latin America. To this one can add the Rockefeller Foundation's support for agricultural research in Mexico in the 1940s which eventually became CYMMIT, bringing elements of the Green Revolution to Latin America. The Foundation help found the respected CIAT agricultural research institute in Colombia and others in the region. The outsized impact of the Rockefeller Foundation on tropical health and agriculture in Latin America (whether always for the best or not) can be attributed to several factors. The Foundation funded projects that would not have been funded from other sources. They were most successful when they transferred institutional approaches to problems that had proven themselves in the U.S. or elsewhere, often creating new Latin American institutions in the process. The Foundation waited to find local researchers and institutions which were receptive to the approaches being advocated by the Foundation.

New Technologies

In the future, the new telecommunications technologies and the Internet may reduce the significance of geographical barriers, but they are not panaceas. The widespread use of these technologies, especially to make money providing services to outside world, will require a highly educated population beyond the reach of all but a small elite in poor countries in the near future. Although this sort of technical change could reduce isolation, it may benefit the already accessible locations at least as much. Despite the dramatically lower user cost of telecommunications in recent years, the infrastructure investment required is often large. One could have expected similar revolutionary change in access from the telephone, but it has not made geographical barriers obsolete.

Bibliography

Alesina, Alberto, and Dani Rodrik. 1994. "Distributive Politics and Economic Growth," *Quarterly Journal of Economics* 109:465-490.

Azzoni, Carlos, Naércio Menezes, Filho Tatiane, Menezes Raul, and Silveira Neto. 1999. "Geography and Regional Income Convergence among Brazilian Sates," OCE-RED background paper.

Barro, Robert J., and Xavier Sala-I-Martin. 1995. *Economic Growth*. New York: McGraw Hill.

Canning, David. 1998. "A Database of World Infrastructure Stocks 1950-1995." Mimeo, Harvard Institute for International Development. Available at http://www.cid.harvard.edu/Infra11.html.

Charriere, Henri. 1969. *Papillon*. Paris: R. Laffont.

Coatesworth, John H. 1998. "Economic and Institutional Trajectories in Nineteenth-Century Latin America," in Coatesworth, John H., and Alan M. Taylor, eds. Latin America and the World Economy Since 1800. Cambridge: Harvard University Press.

Coelho, Philip R. P., and Robert A. McGuire. 1997. "African and European Bound Labor in the British New World: The Biological Consequences of Economic Choices*,"* *Journal of Economic History* 57(1): 83-115.

Crosby, Alfred W. 1972. The Columbian Exchange: Biological and Cultural Consequences of 1492. Westport, Conn.: Greenwood Press.

Crosby, Alfred W. 1986. Ecological Emperialism: The Biological Expansion of Europe, 900-1900. Cambridge: Cambridge University Press.

Deininger, Klaus and Lyn Squire. 1996. "A New Data Set Measuring Income Inequality," *World Bank Economic Review* 10(3, September):565-91.

Deininger, Klaus, and Lyn Squire. 1998. "New Ways of Looking at Old Issues: Inequality and Growth," *Journal of Development Economics* 57(2):259-87.

December 1998. Diamond, Jared. 1997. Guns, Germs, and Steel: The Fates of Human Societies. New York: W. W. Norton.

Echeverría, R. G. 1990. "Assessing the Impact of Agricultural Research," in Echeverría, R. G., ed., *Methods for Diagnosing Research System Constraints and Assessing the Impact of Agricultural Research - Volume II, Assessing the Impact of Agricultural Research*. The Hague: ISNAR.

Engerman, Stanley L., and Kenneth L. Sokoloff. 1997. "Factor Endowments, Institutions, and Differential Paths of Growth Among New World Economies: A View from Economic Historians of the United States," in Haber, Steven, ed. *How Latin America Fell Behind: Essays on the Economic Histories of Brazil and Mexico, 1800-1914*. Stanford: Stanford University Press.

Fagan, Brian. 1999. Floods, Famines, and Emperors: El Niño and the Fate of Civilizations. New York: Basic Books.

FAO. 1999. The FAOSTAT Database. http://apps.fao.org/default.htm.

Forbes, Kristin. 1998. *Growth, Inequality, Trade, and Stock Market Contagion: Three Empirical Tests of International Economic Relationships.* Massachusetts Institute of Technology Economics Ph.D Dissertation.

Gallup, John Luke, Steven Radelet, and Andrew Warner. 1998. "Economic Growth and the Income of the Poor," Mimeo, Harvard Institute for International Development.

Gallup, John Luke, Jeffrey D. Sachs and Andrew D. Mellinger. 1999. "Geography and Economic Development"(with) in Pleskovic, Boris, and Joseph E. Stiglitz, eds., *World Bank Annual Conference on Development Economics 1998.* Washington, DC: The World Bank.

Gallup, John Luke, and Jeffrey D. Sachs. 1998. "The Economic Burden of Malaria." Mimeo, Harvard Institute for International Development. Available at http://www.hiid.harvard.edu/research/newnote.html#geogrowth.

Gallup, John Luke, and Jeffrey D. Sachs. 1999. "Agricultural Productivity and the Tropics." Mimeo, Center for International Development.

Griliches, Zvi. 1992. "The Search for R&D Spillovers," *Scandinavian Journal of Economics* 94 (Supplement): S29-S47.

Heinl, Robert Debs, Jr., and Nancy Gordon Heinl. 1978. *Written in Blood: The Story of the Haitian People 1492-1971*. Boston: Houghton Mifflin.

Li, Hongyi, Lyn Squire, and Heng-fu Zou. 1998. "Explaining International and Intertemporal Variations in Income Inequality," *Economic Journal* 108(446):26-43.

Maddison, Angus. 1995. *Monitoring the World Economy: 1820-1992*. Paris: Organization of Economic Cooperation and Development.

McCullough, David. 1977. The Path Between the Seas: The Creation of the Panama Canal, 1970-1914. New York: Simon and Schuster.

McNeill, William H. 1976. *Plagues and Peoples*. Garden City, N.Y.: Anchor Press.

Evenson, Robert E., Carl E. Pray, and Mark W. Rosegrant. 1999. "Agricultural Research and Productivity Growth in India." IFPRI Research Report #109.

Persson, Torsten, and Guido Tabellini. 1994. "Is Inequality Harmful for Growth," *American Economic Review* 84(3):600-621.

Radelet, Steven C., and Jeffrey D. Sachs. 1998. "Shipping Costs, Manufactured Exports, and Economic Growth," mimeo, HIID (http://www.hiid.harvard.edu/pub/other/geodev.html).

Richardson, Harry W., and Peter M. Townroe. 1986. "Regional Policies in Developing Countries," in Nijkamp, Peter, ed., *Handbook of Regional and Urban Economics.* Amsterdam: North Holland, Volume 1: 647-675.

Sachs, Jeffrey. 1999. "Helping the World's Poorest," *The Economist* 352(8132):17-20, August 14.

Sánchez, Fabio, and Jairo Nuñez. 1999. "Geography and Economic Development: A Municipal Approach for Colombia," mimeo, Office of Chief Economist, IADB.

Strahler, Alan H., and Arthur N. Strahler. 1992. *Modern Physical Geography.* Fourth Edition. New York: John Wiley and Sons.

Welcome Trust. 1999. *An Audit of International Activity in Malaria Research*. London: The Welcome Trust.

WEPZA. 1997. WEPZA International Directory of Export Processing Zones and Free Trade Zones. Third Edition. Flagstaff, Arizona: The Flagstaff Institute.

World Bank. 1998. *World Development Indicators 1998 CD-ROM*. Washington, D.C.: International Bank for Reconstruction and Development.

Table 1: Characteristics of Latin American Geographical Zones

Geographical Zone	GDP per person (1995$)	Population Density (persons/sq km)	GDP Density ($1000/sq km)	Area (million sq km)	Population within 100 km of coast (%)
Tropical Highlands	4343	52	226	1.9	11
Lowland Pacific Coast	4950	61	302	0.8	95
Lowland Atlantic Coast	5216	46	240	2.2	83
Amazon	5246	6	31	9	1
Temperate Southern Cone	7552	35	264	3.2	31
Mexican-U.S Border	7861	17	134	1.1	30
Highland and Dry Southern Cone	9712	7	68	2.2	16

Source: Author's calculations from Figures 8-11.

Table 2. Growth Rates in Selected Regions Compared with Latin America

		Latin America - Sub-Saharan Africa	Latin America - East & SE Asia	Latin America - OECD
Growth (GDP per capita 1965-90)		0.6	-3.6	-1.7
Explained		0.7	-3.0	-1.7
Initial GDP per capita		-2.6	-1.1	2.3
Geography & Health	Total	2.8	-0.1	-1.1
	Coastal population density	0.2	-0.5	-0.2
	Inland population density	0.1	0.1	0.2
	Tropics	0.1	-0.1	-0.4
	Life expectancy	1.1	0.0	-0.6
	Malaria	1.3	0.4	-0.1
Policy & Education	Total	0.4	-1.7	-2.9
	Trade openness	0.2	-1.0	-1.3
	Institutional quality	0.0	-0.7	-1.5
	Years of secondary schooling	0.2	0.0	-0.1
Residual		0.0	-0.5	0.0

Table 3. Export Processing Zone Access to the Sea in Latin America and the Caribbean

	Coastal*	Non-Coastal
Export Processing Zones	152	58
Percent of All EPZs	72%	28%
EPZs excluding Mexico and Bolivia	112	7
Percent of All EPZs	94%	6%

* Coastal sites are within 100 kilometers of the sea coast. Many EPZ locations in Figure 14 have more than one export processing zone.

Table 4. Percentage of Variation in Income Levels"Explained" by Geography

Country	R^2 (%)
Bolivia I	68[a,h]
Bolivia II	66[b,i]
Brazil	47[c,j]
Colombia	36[d,k]
Mexico I	70[e,l]
Mexico II	72[f,m]
Peru	7[g,n]

Included variables are:

[a] Altitude, border crossing, regional center and department capital
[b] Altitude and urbanization
[c] Rainfall, temperature, and latitude
[d] Rainfall, altitude, soils, and distance to market, sea, and 2 rivers
[e] Rainfall, temperature, coast, border, population density
[f] Humid, cold, forest, and agricultural land types
[g] Altitude, rainfall, temperature, soils, earthquake

Dependent variable is:

[h] Provincial unsatisfied basic needs
[i] Provincial unsatisfied basic needs
[j] Log household income per person
[k] Log municipal GDP per capita
[l] Log state GDP per capita
[m] Log state GDP per capita
[n] Log household expenditure per capita

Source: IDB studies.

Table 5. Crop Yields in Tropical versus Non-Tropical Countries of the World, 1998

	Tropical yield (MT/Ha)	Non-tropical yield (MT/Ha)	Tropical/ Non-tropical	Statistically significant difference a)
Cereals (milled rice equivalent)	16.5	26.9	0.61	x
Maize	20.1	45.1	0.45	x
Root Crops (Potato, Cassava, etc.)	105	200	0.53	x
Sugarcane b)	647	681	0.95	
Pulses (Beans and Peas)	7.9	13.3	0.59	x
Oilcrops	5.1	4.0	1.28	x
Vegetables	113	177	0.64	x
Fruits	96.0	97.9	0.98	
Bananas	155	201	0.77	x
Coffee	6.5	15.4	0.42	x
Observations c)	108	95		

a) *x* = *p* value less than 5% for *t* test that mean tropical yield is different from mean non-tropical yield.
b) Data are for 1996.
c) This is the number of observations for Cereals. For some crops, not all countries grow the crop.

Source: FAO (1999).

Table 6. Food Supply Per Capita by Product

	World		Central America
	Calories (%)	Protein (%)	Calories (%)
Grand Total	100	100	100
Vegetable Products	84	63	84
Cereals (milled rice equivalent)	50	45	47
Wheat	20	22	9
Rice (milled equivalent)	21	15	3
Maize	5	5	34
Other	3	4	1
Root Crops (Potatoes, Cassava, etc.)	5	3	1
Sugars	9	0	16
Pulses (Beans and Peas)	2	5	4
Oilcrops and Oils	10	3	10
Vegetables	2	4	1
Fruits	3	1	3
Alcoholic Beverages	2	0	2
Other	1	1	0
Animal Products	16	37	16
Meat and Animal Fats	9	18	9
Milk, Eggs, Fish	6	19	7

Source: FAO (1999). Totals may not equal the sum of their components due to rounding.

Table 7. Crop Yields in Non-Tropical versus Tropical Countries in Latin America and the Caribbean, 1998

	Tropical yield (MT/Ha)	Non-tropical yield (MT/Ha)	Tropical/ Non-tropical	Statistically significant difference a)
Cereals (milled rice equivalent)	22.9	33.8	0.68	x
Maize	24.6	51.4	0.48	x
Root Crops (Potato, Cassava, etc.)	122	218	0.56	x
Sugarcane b)	700	632	1.11	
Pulses (Beans and Peas)	7.5	10.4	0.72	x
Oilcrops	6.2	5.3	1.17	
Vegetables	143	161	0.89	
Fruits	135	142	0.95	
Bananas	166	214	0.78	
Coffee	7.1	6.1	1.16	
Observations c)	33	7		

a) $x = p$ value less than 5% for t test that mean tropical yield is different from mean non-tropical yield.
b) Data are for 1996.
c) This is the number of observations for Cereals. For some crops, not all countries grow the crop.

Source: FAO (1999).

Table 8. Average Crop Yield Growth, 1961-1998, in Tropical versus Non-Tropical Countries in Latin America and the Caribbean

	Tropical yield growth (%)	Non-tropical yield growth (%)	Tropical - Non-tropical	Statistically significant difference a)
Cereals (milled rice equivalent)	1.8	2.6	-0.8	x
Maize	1.8	3.1	-1.3	x
Root Crops (Potato, Cassava, etc.)	0.6	2.1	-1.5	x
Sugarcane b)	0.8	1.0	-0.2	
Pulses (Beans and Peas)	0.3	0.6	-0.3	x
Oilcrops	2.0	1.8	0.2	
Vegetables	2.5	1.6	0.9	
Fruits	0.3	0.1	0.2	
Bananas	-0.3	0.2	-0.5	
Coffee	1.0	0.5	0.5	
Observations c)	33	7		

a) *x* = *p* value less than 5% for *t* test that mean tropical yield growth is different from mean non-tropical yield growth.
b) Data are for 1961-1996.
c) This is the number of observations for Cereals. For some crops, not all countries grow the crop.

Source: FAO (1999).

Table 9. Percentage of Variation in Health "Explained" by Geography

Country	R^2 (%)
Brazil	76[a,c]
Peru	62[b,d]
Peru	71[b,e]

Included variables are:
[a] Rainfall, temperature, altitude, and region indicators,
[b] Rainfall, temperature, altitude, longitude and latitude
Dependent variable is:
[c] Municipal infant mortality rate
[d] Provincial infant mortality rate
[e] Provincial child nutrition
Source: IDB studies.

Table 10. Income Inequality in Latin America and the Caribbean by Spanish Colonization

Country	Gini Coefficient
Non-Spanish Colonies	45.7
Jamaica	38
Guyana	40
Trinidad	42
Bahamas	45
Barbados	49
Brazil	60
Former Spanish Colonies	51.0
Bolivia	42
Ecuador	43
Peru	45
Costa Rica	46
Venezuela	47
Dominican Republic	49
El Salvador	50
Mexico	50
Nicaragua	50
Honduras	54
Chile	56
Panama	57
Colombia	57
Guatemala	59
Paraguay	59

Source: Latest year data from World Bank (1998).

Table 11. Rates of Return to Agricultural Research and Extension in Latin America

Author	Year	Country	Commodity	Period	Rate of Return
Ayer	1970	Brazil (Sao Paulo)	Cotton	1924-67	
Barletta	1970	Mexico	Crops	1943-63	
			Wheat		90
Elias (revised by Cordomi)	1971	Argentina (EEAT-Tucuman)	Sugarcane	1943-63	33
Hines	1972	Peru	Maize	1954-67	35
Patrick and Kehrberg	1973	Brazil (Eastern)	Aggregate	1968	0
del Rey (revised by Cordomi)	1975	Argentina (EEAT-Tucuman)	Sugarcane	1943-64	35
Monteiro	1975	Brazil	Cocoa	1923-85	19
Fonseca	1976	Brazil	Coffee	1933-95	17
Hertford et al.	1977	Colombia	Rice	1957-80	60
			Soybeans	1960-80	79
			Wheat	1927-76	11
			Cotton	1953-72	0
Wennergren and Whittaker	1977	Bolivia	Sheep	1966-75	44
			Wheat		-48
Scobie and Posada	1978	Colombia	Rice	1957-64	79
Moricochi	1980	Brazil (Sao Paulo)	Citrus	1933-85	18
Avila	1981	Brazil (R.G. Sul)	Irrigated Rice	1959-78	83
		Brazil (Central)			83
		Brazil (N. Coast)			92
		Brazil (S. Coast)			111
		Brazil (Frontier)			114
Cruz et al.	1982	Brazil	Physical Capital	1974-81	53
			Total Investment	1974-92	22
Evenson	1982	Brazil	Aggregate	19??-74	69
Ribiero	1982	Brazil (Minas Gerais)	Aggregate	1974-94	69
			Cotton		48
			Soybeans		36
Yrarrazaval et al.	1982	Chile	Wheat	1949-77	21
			Maize	1940-77	32
Avila et al.	1983	Brazil (EMBRAPA)	Human Capital	1974-96	22
Cruz and Avila	1983	Brazil (EMBRAPA)	Aggregate	1977-91	38
Martinez and Sain	1983	Panama (IDIAP-Caisan)	Maize	1979-82	188
Ambrosi and Cruz	1984	Brazil (EMBRAPA-CNPT)	Wheat	1974-90	59
Avila et al.	1984	Brazil (South Central)	Aggregate	1974-96	38
Feijoo (revised by Cordomi)	1984	Argentina (INTA)	Aggregate	1950-80	41
Pinazza et al.	1984	Brazil (Sao Paulo)	Sugarcane	1972-82	35
Roessing	1984	Brazil (EMBRAPA-CNPS)	Soybeans	1975-82	45
Silva	1984	Brazil (Sao Paulo)	Aggregate		60
Ayres	1985	Brazil	Soybeans	1955-83	46
		Brazil (Parana)			51
		Brazil (R.G. Sul)			51
		Brazil (S. Catarina)			29
		Brazil (Sao Paulo)			23

(continued)

Table 11. Rates of Return to Agricultural Research and Extension in Latin America (continued)

Author	Year	Country	Commodity	Period	Rate of Return
Muchnik	1985	Latin America	Rice	1968-90	
Norton et al.	1987	Peru (INIPA)	Aggregate	1981-2000	
			Rice		17
			Maize		10
			Wheat		18
			Potatoes		22
			Beans		14
Echevarria et al.	1988	Uruguay	Rice	1965-85	52
Evenson	1988	Paraguay	Crops	1988	75
Luz Barbosa	1988	Brazil (EMBRAPA)	Aggregate	1974-97	40
Evenson and da Cruz	1989	South America (PROCISUR)	Wheat	1979-88	110
			Soybeans		179
			Maize		191
Average					57
Median					44

Source: Echeverria, 1990, Table 1.

Appendix Table 1: Determinants of GDP per capita growth 1965-1990

	(1) gr6590	(2) gr6590	(3) gr6590	(4) gr6590	(5) gr6590
GDP per capita, 1965 (log)	-2.4	-2.5	-2.4	-3.0	-2.9
	(8.14)	(8.06)	(7.09)	(7.96)	(7.70)
Years of secondary schooling, 1965 (log)	0.2	0.2	0.1	0.2	0.2
	(1.85)	(1.32)	(0.89)	(1.48)	(0.93)
Life expectancy, 1965 (log)	5.5	4.3	3.4	4.3	5.8
	(6.24)	(4.45)	(3.89)	(4.04)	(4.82)
Trade openness, 1965-1990 (0-1)	1.8	1.7	1.8	1.5	1.7
	(5.19)	(4.79)	(4.66)	(4.00)	(3.99)
Institutional quality (0-10)	0.2	0.3	0.4	0.4	0.4
	(2.71)	(3.32)	(3.47)	(3.61)	(3.32)
Population w/in 100 km of coast (0-1)	1.0	0.9		2.5	5.1
	(3.08)	(3.01)		(2.93)	(3.10)
Share of land in tropics (0-1)	-0.9	-0.6	-0.5	-0.7	-0.5
	(2.17)	(1.35)	(1.44)	(1.34)	(0.94)
Falciparum malaria index, 1965 (0-1)		-1.2	-1.6	-1.4	-1.0
		(2.15)	(2.89)	(2.29)	(1.82)
Change in malaria index, 1965-1994 (0-1)			-1.9		
			(2.94)		
Coastal population density, 1994 (log)			0.2		
			(4.34)		
Inland population density, 1994 (log)			-0.1		
			(1.60)		
Coastal population share * log electricity				0.2	
				(1.92)	
Electricity generating capacity, 1965 (log)				-0.2	
				(2.13)	
Coastal population share * log road length					0.3
					(1.95)
Total road length, 1965 (log)					-0.5
					(2.72)
Constant	-3.8	1.3	4.1	3.0	-4.8
	(1.18)	(0.34)	(1.08)	(0.66)	(1.04)
Observations	75	75	75	71	57
R-squared	0.75	0.77	0.82	0.79	0.81

Robust t-statistics in parentheses

Appendix Table 2: Geography and Health, 1995

	(1) Life expectancy (years at birth)	(2) Infant Mortality Rate (infant deaths/1000 live births)	(3) Falciparum malaria index 1994 (0-1)
log GDP per capita (PPP)	0.416	0.024	-0.014
	(0.64)	(0.01)	(0.42)
Female literacy rate (%)	0.286	-1.452	0.000
	(9.29)**	(7.66)**	(0.24)
Tropical, wet (%)	-4.332	40.722	0.275
	(4.01)**	(4.88)**	(5.22)**
Tropical, monsoon (%)	0.882	3.999	-0.019
	(1.45)	(0.61)	(0.09)
Tropical, some dry (%)	0.850	5.354	0.083
	(1.20)	(1.04)	(2.78)**
Dry steppe (%)	3.210	-18.505	-0.011
	(2.14)*	(2.27)*	(0.72)
Desert (%)	2.481	3.724	-0.012
	(4.27)**	(1.14)	(0.81)
Temperate, dry summer (%)	3.729	-8.720	0.000
	(3.69)**	(1.36)	(.)
Temperate, dry winter (%)	-3.557	26.959	-0.049
	(2.78)**	(1.59)	(1.34)
High elevation and polar (%)	-0.769	3.651	0.012
	(0.89)	(0.77)	(0.26)
Constant	41.716	156.385	0.165
	(8.79)**	(4.68)**	(0.42)
Observations	178	178	139
R-squared	0.64	0.49	0.26

Robust t-statistics in parentheses
* significant at 5% level; ** significant at 1% level

Appendix Table 3. Correlates of the Gini Coefficient

	(1) Gini Coefficient	(2) Gini Coefficient	(3) Gini Coefficient
Latitude (degrees)	-0.257	-0.153	
	(9.06)**	(4.29)**	
GDP per capita, 1995 (log)		13.929	21.836
		(0.66)	(1.00)
GDP per capita squared		-0.807	-1.357
		(0.64)	(1.03)
Former Spanish colony		6.534	7.912
		(2.29)*	(2.49)*
French legal system		2.806	2.728
		(1.15)	(1.04)
Socialist legal system		-7.741	-14.071
		(3.14)**	(4.96)**
Muslim population (0-1)		-5.878	-9.226
		(1.85)	(2.66)**
Roman Catholic population (0-1)		-6.875	-8.129
		(2.72)**	(3.10)**
Roman Hindu population (0-1)		-12.797	-14.016
		(2.84)**	(2.98)**
Trade Openness, 1965-1990 (0-1)		-6.201	-7.735
		(2.11)*	(2.56)*
Constant	45.623	-10.814	-38.506
	(39.78)**	(0.13)	(0.43)
Observations	115	106	106
R-squared	0.44	0.59	0.51

Robust t-statistics in parentheses
* significant at 5% level; ** significant at 1% level