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PRELIMINARY
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Geography and Economic Development: Some Empirical Findings

Introduction

The role of geography in economic development has been woefully under-analyzed in recent decades. That geography and development are closely linked is the very first, powerful impression one gets in examining the global distribution of economic activity. Virtually all developed countries are in the temperate zone; virtually all tropical countries are under-developed; and virtually all poor temperate zones countries in the Northern Hemisphere are far from major markets, often landlocked and frequently transiting from socialism.[1] Among the top 30 countries ranked by 1994 per capita GDP, only four small countries — Hong Kong, Singapore, Oman, and Trinidad & Tobago — are in the tropics. These countries have a combined population of just 12 million, or 1.3% of the combined population of the top-30 countries.[2] Moreover, Oman and Trinidad & Tobago achieve high income because of oil deposits while Hong Kong and Singapore are two city states that service a much poorer hinterland.

Virtually all landlocked countries outside of Europe are poor. In total, there are 33 landlocked countries with population greater than 1 million in 1994. Of these, 27 are outside of Europe. The richest of these are Turkemenistan (1994 GDP per capita, $3280), Kazakhstan ($3200), and Botswana ($3130). Not only are these countries poor, with ranks 47th, 48th and 49th in the world respectively, but all three clearly owe even these rather meager income levels to natural resources, energy in the cases of Turkmenistan and Kazakhstan, and diamonds in the case of Botswana. Taken as a group, the 27 non-European landlocked countries have an unweighted per capita GDP of just $1531.

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[1]The tropics may be defined as the region between the Tropic of Cancer and the Tropic of Capricorn (i.e., within 23.5° N and S latitude), or according to ecozone, based on temperature, growing season, and other climatological attributes. When we refer to the tropics, we will generally refer to the geographical definition, and use the term “tropical ecozone” for the latter definition.

[2]All rankings and other country data refer to a sample of 142 countries. We aim for a comprehensive set of countries with populations of 1 million or more in 1994. In total, our data include 5.507 billion people, of an estimated global population in 1994 of 5.601 billion, or 98.3 percent of the total world population. The main countries missing from the sample, because of unavailability of data, are: Afghanistan, Albania, Bosnia & Herzegovina, Cambodia, Cuba, Iraq, Lebanon, and Yugoslavia (Serbia and Montenegro).

Remarkably, these basic patterns of economic development are almost completely ignored when we move to "more scientific" cross-country empirical studies of economic growth. In the vast recent literature on cross-country growth and GDP, Hall and Jones, 1996, is one of the only studies other than studies recently undertaken at HIID (Lee, Radelet, and Sachs, 1997; Sachs and Warner, 1997; Radelet and Sachs, 1997) to include geographic determinants of cross-country income, in that case, distance from the equator. An earlier fine study that put emphasis on geographical factors in the poor performance of tropical economies is Kamarck (1976), but this study has been largely neglected by recent work. In general, the geographical correlates of development are either overlooked or are treated as historical coincidences. The nearly universally poor performance of the tropics and of most landlocked economies is taken as evidence neither about the underlying sources of economic development nor about future development prospects of the lagging regions. Even introducing the role of geography as one among many factors of development is often castigated as "geographical determinism."

The neglect of geography was not always the case. Adam Smith in *The Wealth of Nations* put great stress on geography as a determinant of economic development. In Smith's analysis, development depends on specialization, which in turn depends on the scope of the market. The scope of the market in turn is limited by transport costs, so development and specialization is expected to be most advanced in regions benefitting from low transport costs. In Smith's day, and ours, these are generally the regions accessible to sea transport, still the dominant and low-cost form of international trade. As Smith noted, industrial development almost always proceeds first "upon the sea coast, and along the banks of navigable rivers . . . and it is frequently not till a long time after that that those improvements extend themselves to the inland part of the country." Smith went on to note, that by virtue of poor transport conditions:

> All the inland parts of Africa, and all that part of Asia which lies any considerable way north of the Euxine [Black] and Caspian seas, the antient Scythia, the modern Tartary and Siberia, seem in all ages of the world to have been in the same barbarous and uncivilized state in which we find them at present. (p. 25)

Alas, these regions continue to be among the least developed in the world today.

The same considerations about the scope of the market favor economic development in regions that are proximate to major population centers. Remote areas, even those with access to the sea, of course face higher transport costs than regions closer to major population centers. One implication is that economic development in the Southern Hemisphere may be intrinsically less favored than in the Northern Hemisphere, simply because most of the habitable land mass and therefore most of the world's population lies in the North. If we focus on the temperate zones in the Northern and Southern hemispheres -- the most promising region for economic development as we shall argue -- there are 65 Northern temperate-zone countries and only 7 Southern temperate zone countries (Argentina, Australia, Chile, Lesotho, New Zealand, South Africa,

Uruguay) with population greater than 1 million.[3] The combined population in these Southern temperate zone countries is 116.3 million, or just 3.7 percent of the 3.1 billion people in the Northern temperate-zone countries. The land area in the Southern temperate zone is approximately 12.8 million km^2, or 18 percent of the 70.5 million km^2 in the Northern temperate zone.[4]

In addition to proximity and access to the sea, there are other fundamental linkages of geography and development. Adam Smith, naturally, knew very little about the effects of climate on disease, since it was only one hundred years after *The Wealth of Nations* that the germ theory of disease was established, and still later that the underlying complex ecology of parasitic, bacterial, and viral diseases began to be unraveled. We now know that geography importantly affects the burden of infectious disease. It is no accident, or mere result of poor public health policies, that the heaviest burden of infectious disease are found in the tropics, since tropical ecozones tend to be most favorable for disease vectors such as mosquitoes and mollusks, and since the winter season of the temperate climates keep the populations of disease agents and disease vectors in check. In a simple cross-country regression of life expectancy on per capita GDP, proportion of land in various ecozones, and the proportion of the population close to the sea, we find that life expectancy at birth is some 6.9 years less in the wet tropics, and some 8.2 years less in the dry tropics, than in the temperate zone.[5] Moreover, coastal populations on average show a life expectancy that is 3.5 years greater than inland countries, controlling for income and ecological zone. While these estimates certainly need refinement, they do suggest that public health is directly tied to geography, after controlling for per capita income levels. Since

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[3]We define a temperate-zone country as one in which more than 50 percent of the land area is outside of the tropics, i.e. more than 50 percent lies outside of the region between 23.5° N and S latitude.

[4]Of course, the higher proportion of land area than population in the Southern temperate zone highlights the very low population densities in most of the Southern temperate economies, especially the higher income economies.

[5]The classification of ecozones is based on the Holdridge classification system, as is based on underlying relations of precipitation, temperature, solar radiation, growing season, etc. The specific regression is as follows. For a sample of 126 countries, the left-hand-side variable is life expectancy at birth (LEB) in 1992. This is regressed on per capita GDP in 1994, the inverse of GDP in 1994 (denoted IGDP), various ecozones, and the proportion of the country population within 100km of the coastline (denoted 100km). (Note that the years of LEB and GDP differ by two years, as a result of data availability). Only the tropical ecozones turned out to be significant in the regression estimates, so that the non-tropical ecozones were dropped from the equation. The resulting estimate is (with t-statistics in the parentheses): LEB = 70.26 (55.42) + 0.00029 (3.23) GDP - 9784 (8.66) IGDP - 6.88 (4.30) WET TROPICS - 8.22 (4.71) DRY TROPICS - 4.31 (2.40) DESERT TROPICS + 3.54 (2.38) POP100km, N = 126, RMSE = 4.83, R^2 adj = 0.79.

health and longevity of the population directly affect productivity levels (Fogel, 1995) and other household decisions such as saving and investment, we expect that geography can importantly condition economic performance through effects on public health.

Similarly, we have gained considerable knowledge about the linkages of agricultural productivity to geographical conditions, including soil quality, water availability, temperature, growing season, and other factors that differ significantly be geographic region (see Gallup, 1997, for recent evidence). Differing agricultural productivity not only affects income levels and the nutrition attainments of local populations, but also the density of human settlement, and hence the scope of the local market. Regions such as the Sahel in Africa, with very poor ecological conditions for agricultural, are among the least densely populated parts of the world. Local markets are therefore very small, and the prospects for industrialization based on local demand are accordingly very limited. In general, the tropics present great difficulties for agricultural productivity, for a variety of reasons including the leaching of soils in the wet tropics; insufficiency of moisture in the dry and desert tropics; and the high prevalence of veterinary disease and pests. On average, agricultural productivity in the tropics seems to be at least one-third below that of temperate zones, controlling for factor inputs (see Gallup, 1997).

A final geographic factor that may affect overall per capita income is the location of high-value natural resources, such as energy, precious metals, and the like. Except for a handful of special cases (like Botswana and diamonds), energy is by far the most important commodity group. Countries that sit on large energy deposits exhibit high income per capita, though they also show low economic growth during the period 1965-90 and a low extent of industrialization beyond the energy and petrochemical sectors (Sachs and Warner, 1997).[6] One imperfect measure of energy endowments is the annual production of *primary* energy (i.e., energy production before conversion to electricity or petroleum products). Using World Bank data, we estimate that the temperate zone countries produce around 87 percent of global primary energy, and consume around 89 percent of global energy, while the tropical countries produce around 13 percent and consume around 11 percent of global energy.[7] As a whole, the tropical countries are therefore net exporters of energy, though the net energy imports of the temperate zone countries constitute merely 3 percent of their use.

As a first pass, then, we identify at five fundamental geographic factors that will affect the economic development prospects of a region:

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[6]Thus, the low-population OPEC countries of the Persian Gulf exhibit very high levels of per capita income, but very low growth rates. The presence of large hydrocarbon deposits seems therefore to generate a one-time boost to income and consumption, but without a continuing positive effect (and perhaps even a negative effect) on subsequent economic growth.

[7]These are author's calculation based on the reports of energy use and net energy imports in the 1996 World Development Report of the World Bank.

(1) proximity to major markets;

(2) access to sea-based trade;

(3) climatic effects on disease burdens and public health;

(4) agricultural productivity

(5) natural resource endowments, especially energy resources

These considerations strongly favor the *coastal, Northern, temperate-zone regions* relative to other parts of the world as the location for broad-based development and industrialization.[8] There are only four areas of the world characterized by extensive coastline, temperate climate, and proximity to large population masses: Western Europe, (including the North Atlantic and the Mediterranean Basis), the Pacific coastline of China, Korea, and Japan, the East Coast of North America, and the West Coast of North America.

There are a few other coastal areas in temperate zones, but each of these is less advantageous for one or more reason. The Southern hemisphere coastal regions, including Chile, Argentina, Southern Africa, Australia, and New Zealand, face the daunting problem of being around 8,000 km from the world's major population centers. This has not been a barrier to high per capita income in Australia and New Zealand, but has surely limited population concentrations and prevented the development of a major "growth pole" in the Southern temperate economies. Population densities in Australia and New Zealand are exceedingly low, with just 2.3 inhabitants per km^2 in Australia and 13.1 inhabitants per km^2 in New Zealand, compared with an average worldwide density of 42.8 inhabitants per km^2.[9] There are also some small slivers of temperate coastline in the Persian Gulf and around the Indian Sub-continent, but these regions are hindered by the fact that most of the nearby land mass lies in tropical ecozones. The Persian Gulf region, of course, is also mainly desert and mountainous, thereby further limiting population densities, and therefore the scope of the regional market.

This analysis suggests four especially favored regions for economic development: Western Europe (embracing both the North Atlantic and the Mediterranean basin); the temperate Pacific

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[8]It might be conjectured that the energy-rich Persian Gulf region could also be a major locus of industrialization. Despite the relatively high per capita incomes in the region, this has not been the case. As we noted in the text, Sachs and Warner, 1997 have shown that high energy endowments raise per capita GDP but actual depress economic growth. In any event, the Persian Gulf region is mostly desert and as a result has a very low population density, thereby greatly limiting the scope of the regional market.

[9]Total land mass of the 142 countries in the sample is 128 million km^2, compared with a population of 5.507 billion.

basin, including Japan, Korea, and coastal China; the East coast of North America, and the West coast of North America. Indeed by the end of the 19th century, these four regions are far ahead of the rest of the world in economic development according to the data produced by Angus Maddison for the OECD (1996). Of course there are also serious anomalies to this basic pattern. China, a temperate-zone, coastal economy at the center of the world's greatest concentration of population, has lagged far behind the advanced economies in the past two centuries, after leading the world in technology for perhaps one millenium.[10] While Japan began to industrialize rapidly after Meiji Restoration of 1868 (which implanted capitalist institutions in a formerly closed and feudalistic social structure), China stagnated for decades afterward, partly because of the meagre attempts at institutional reform. Some Southern Hemisphere economies — especially Argentina, Australia, and New Zealand — reached very high income levels despite large distances from major markets, but they did so with very small populations and very low population densities. The rapid development of North America is itself somewhat problematical: it too was relatively far from major European markets, but made up for its relatively small internal market at the start of the 19th century through favorable economic institutions and the enormous advantages of an open, fertile, temperate-zone hinterland, which resulted in highly favorable land-to-man ratios and very high per capita income levels from the very start of the 19th century.

The specific patterns of income within the four Northern temperate coastal zones are obviously complex. A large literature analyses the comparative performance of the Mediterranean basin and the North Sea, to understand why economic primacy within Europe shifted from the former to the latter after the 15th century (the main reason, it seems is the huge advantage of the North Atlantic in oceanic trade with Asia and the Western Hemisphere). A similarly large literature analyses the reasons why Japan, rather than China, initiated industrialization in the late 19th century, with the answer apparently lying more in politics than economic geography. In North America, the issue is the growing industrial lead of the North Atlantic region over the Southern Atlantic region until the middle of the 20th century. The causes seem to be both geographical (lower disease burden, more extensive inland navigable rivers, closer proximity to coal deposits) and political (the pernicious effects of plantation slavery on the economic and social system of the South). The East Coast of North America developed much more rapidly than the West Coast mainly because of the much closer proximity and economic importance of Europe relative to Asia.

Before proceeding further, two cautionary remarks are called for. The geographic advantages of one region or another vary over time with changes in technology and the global patterns of human settlement. Before the technological advances in oceanic navigation, for example, the quieter waters of the Mediterranean had shipping advantages over North Atlantic. The economic center of leadership shifted from Venice and Genoa to Lisbon, Amsterdam, and London only after the discoveries of the sea routes to Asia and the opening of the New World to European settlement. In neolithic times, at the start of large-scale agricultural settlement and accompanying urbanization (e.g. around 3,000 BCE), sea-based transport counted for very little,

[10]Many scholars point to Chinese leadership between 500 and 1500 AD. China's relative decline is often attributed to the Ming Dynasty's closure of Chinese sea-based trade after 1433.

and economic development was especially favored by the high fertility of alluvial agriculture, rather than by access to the open sea. The earliest civilizations, such as Mesopotamia and Egypt therefore developed along river valleys rather than ocean coasts. These regions, the world's most advanced at the start of civilization, are now greatly disadvantaged by their relative isolation from global trade (neither the Tigris and Euphrates of Mesopotamia, nor the Nile, are sea-navigable). In this way, changes in transport and communications costs render new regions open to trade, while undermining the long-standing advantages of other regions.

Second, this analysis should not be misinterpreted as any sort of claim of geographic determinism or geographic reductionism. Geography is just one factor among many that contribute to economic performance, albeit an important factor mostly neglected. Cross-country growth equations presented later show that *both* policy and geography matter for economic development. The world is filled with relatively controlled experiments in which two geographically linked countries adopted very different institutional and policy regimes, with very different economic outcomes. One may think of West Germany and East Germany, South and North Korea, Austria and Czechoslovakia, Estonia and Finland, among many "close cousins," all demonstrating the vast advantages of open, market-based, private-sector-led development.

Geography and Institutional Develoment

We have noted one set of channels from geography to economic development: transport costs, public health, and population density. These channels are represent a direct link of geography and productivity. There is another, more subtle, set of channels. Geography may also affect the quality of *political and economic institutions*, after controlling for direct productivity effects. For example, history suggests that coastal economies have been more market-oriented than interior economies, not only in the extent of trade itself, but in the choice of political and economic institutions. The inventions of modern banking, financial instruments of international trade, commercial law, stock markets, accounting practices, insurance markets, and the like, arose in the leading coastal cities of Europe, especially Venice, Genoa, Amsterdam, and London. Moreover, governance in such coastal economies was seemingly much more directed to protection of property rights and private capital accumulation than in contemporaneous agrarian-based polities.

It is not hard to see why governance might differ in coastal and interior polities. Suppose that both a coastal and interior polity have a revenue-maximizing predatory government. In each case, the government imposes a revenue-maximizing levy on the population. If the factors of production in the coastal economy are more mobile than in the hinterland — a reasonable assumption comparing mercantile-based coastal economies and agrarian-based interior economies — then the revenue-maximizing predatory government will charge a lower tax rate in the coastal economy. More generally, the optimal choice of the coastal polity may be to provide a sound rule of law in order to *attract mobile capital*, while the optimal choice of the hinterland polity may be to *tie labor* to the land through institutions of serfdom, corvee labor, and the like.

To see the possible implications, consider the following simple model. Potential per capita income of region i at time t is given by Y_{it} , and actual income per capita is y_{it}. In the manner of convergence models, economic growth depends on the gap between the two.

(1) $dy_{it}/dt = \lambda(Y_{it} - y_{it})$

Potential income depends on geographic factors $G_{it;}$ on the quality of economic and political institutions, Q_{it}; and on idiosyncratic factors represented by an "error" term ϵ_{it}.

(2) $Y_{it} = f(G_{it,} Q_{it}, \epsilon_{it})$

At the same time, the quality of institutions may depend directly on geography, as we have just noted. Moreover, Q_{it} is likely to depend on the *actual* level of development that has been achieved. This latter link, in which the quality of institutions depends on the contemporaneous level of development, is the central hypothesis of modernization theory, which holds that institutions such as democracy, the state bound by the rule of law, and the independence of the press and the judiciary, depend on the existence of a financially independent civil society, which in turn is fostered by an adequate level of economic development. Civil society "tames" the Leviathan; while civil society itself depends on the achievement of an adequate level of development so that private citizens and associational groups have the wherewithal to defend themselves against the state. Thus,

(3) $Q_{it} = g(G_{it}, y_{it}, v_{it})$

The term v_{it} represents idiosyncratic shocks to country i at time t.

In this formulation, poor geography can lead to a low-level income trap, in which an economy remains poor even though an equilibrium with high per capita income also exists. The possibility of an income trap results from the two-way causation between development and institutions: economic development both depends on the quality of institutions, while the quality of institutions depends on the level of economic development. Countries can remain poor because they have poorly functioning institutions, while they have poorly functioning institutions because they are poor.

To show the potential role of poor geography in causing a low-level trap, consider the following simple example of the model (1) - (3). Suppose that there are just two levels of public institutions ("poor" and "favorable") and that good institutions arise only when the economy reaches a threshhold level of income $\underline{y}$.[11] (For some aspects of institutional quality, the empirical evidence presented below supports the notion of a non-linear threshold). When $y < \underline{y}$, institutions

[11]For concreteness, we might think about the quality of institutions as measuring the cost of enforcing private contracts. Enforcement costs are high when institutions are poor, e.g. when courts are ineffective and when the public administration engages in high levels of corruption.

are poor ($Q_{it} = Q^p_{it}$); when $y \geq \underline{y}$, then institutions are favorable (Q_{it}^f). The relationship between income and institutional quality is the step-function shown as the QQ schedule in Figure 1. There is also an upward-sloping dy/dt = 0 schedule, along which $y_{it} = Y_{it} = f(G_{it,} Q_{it}, \epsilon_{it})$. This is drawn as the YY schedule.

The economy moves along the QQ schedule (which is a contemporaneous relationship between y and Q). When $y < \underline{y}$, the economy is on the Q^p portion of the QQ schedule. When $y > \underline{y}$, the economy is on the Q^f portion of the schedule. The direction of change in y is as shown by the arrows. For $y < \underline{y}$, the economy always moves to the low-level equilibrium at E^l. For $y \geq \underline{y}$, the economy moves to the high-level equilibrium at E^h. Thus, the equilibrium outcome depends on the initial level of income (whether y is greater than or less than $\underline{y}$).

Now, consider how favorable or unfavorable geography may affect the chances of a low-level equilibrium. Three cases are shown in Figure 2, corresponding to (a) very poor; (b) mediocre; and (c) advantageous geography. Poor geography shifts the YY schedule downward, since there is lower potential income at any given level of institutional quality. Poor geography may also *raise* the threshold at which civil society is able to discipline the Leviathan (that is, $\underline{y}$ rises). This is the case, for example, if being landlocked strengthens the predatory hand of the government by reducing the mobility of factors of production, and thus their capacity to escape government taxation. In that case, an even higher threshold of income $\underline{y}$ may be necessary before the government is "tamed."

Thus, for two reasons, poor geography makes it more likely that the economy gets trapped at the lower level equilibrium, and also reduces the steady-state income at the low-level equilibrium. If geography is highly disadvantageous, as shown in Figure 2(a), there is no longer a low-level trap, but simply a unique, very-low-level equilibrium. On the other hand, if geography is highly advantageous, there may be a unique, high-level equilibrium. Such an economy has both productivity and institutional advantages over its poorly endowed counterpart. Even at low levels of income, public institutions will tend to be of relatively high quality; and second, even with poor institutions, per capita income will tend to be high because of the high productivity of the economy.

Empirical evidence on geography, development, and institutional quality

We are far from the stage to implement a model such as (1) - (3). We need considerably more data collection and analysis before we can estimate a linked political-economy model of the sort sketched in (1) - (3). We have too few time series of institutional quality to estimate (2). We also have too little evidence for the functional forms of (1)-(3), and functional forms will be critical in exploring the possibilities of multiple equilibria and low-level traps. At this point, we therefore proceed much less ambitiously, to piece together some evidence on (1) - (3) short of a full model. First, we examine the global patterns of income per capita and income growth for their relations to geography. Second, we examine the linkages of geography and institutional

quality.

The Global Pattern of GDP Per Capita in 1994

We examine the distribution of GDP per capita in 1994, measured at purchasing power parity, for all countries in the world with population greater than 1 million and available data. Our discussion has suggested that economic development (proxied by GDP per capita) will be affected by four main geographic variables: proximity to major markets; access to the sea; climate, through its affects both on disease burdens and agricultural productivity; and the presence of natural resources, especially energy. We implement a simple regression model as follows.

With regard to proximity to major markets, we have identified (largely on an *a priori* basis) four coastal, Northern hemisphere, temperate zone regions as the most likely poles of economic development: Western Europe; the East coast of North America; the West coast of North America; and the Asian Pacific coast. For each of these regions, we identify a core port city as the center of the region: Rotterdam, New York, Los Angeles, and Tokyo. Then, for every country in our sample, we measure the air distance to the *closest* core city, and use this as our measure of proximity to major markets. We then take the natural logarithm of the distance, and denote the variable LAIRDIST.[12] This minimum air distance calculation puts Latin America closest to U.S. markets; Africa, Eastern Europe, and the former Soviet Union closest to Western Europe; and South and East Asia closest to Japan. Note that rather than relying on air distances we would ideally like to measure the actual land- and sea-based shipping distances. We leave this refinement for later work.

With regard to access to the sea, we explored three different measures. First, using GIS-based data on the global population, we have estimated the proportion of each country's population residing close to the coast (see Mellinger, 1997, for details). We take a threshhold of 100 km (approximately 61 miles), and then measure the fraction of the population within the 100 km band, which we denote as POP100km. The coast is defined to include ocean coastline below the Arctic Circle, the Black Sea, and the Saint Lawrence - Great Lakes system. Second, we take the fraction of each country's land mass within the same 100 km band, denoted as L100km. Third, we take the ratio of each country's coastline (in km) to the country's surface area (in km^2). These three measures are highly correlated, though with some interesting discrepancies. In the United States, for example, the POP100km is 0.51, while L100km is only 0.21. This reflects the high densities of U.S. population along the coastline.

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[12]We experimented with a variety of ways of entering the distance for the three "core" economies, the U.S., Japan, and the Netherlands. In the end, we designated the distance of these economies from the core cities as 140 km, based on a trial regression in which we added dummy variables for the three countries. In fact, the results reported in the text do not in any way depend on the presence or exclusion of these three countries from the overall sample, or on the use of a dummy variable for the countries rather than the imputed distance of 140 km.

With regard to climate, we use two measures of the tropical zone. The first is strictly geographical: the proportion of a country's land area between 23.5° N and S Latitude, denoted TROPICAR. The second measured is based on an ecological classification of tropical climates, using the Holdridge Ecological Classification System, denoted ECOTROP. Using a GIS-based division of the world into ecological zones, we calculate the proportion of each country's land area within tropical ecological zones.[13] These two measures of the tropics are highly correlated, but with some key differences.

With regard to energy resources, we first calculated the primary energy production per capita as a first measure of energy endowments. This variable is indeed highly correlated with GDP per capita in both bivariate and multivariate regressions. However, because it can be argued that high primary energy production might be the *result* of high GDP per capita rather than the cause, we have opted for a less precise but more "exogenous" indicator of energy endowments. We create a dummy variable ENERGYX, equal to 1 if the country is a net primary energy exporter, and equal to 0 if the country is self-sufficient or a net primary energy importer. We interpret net exports of energy as signifying a large "exogenous" endowment of primary energy deposits. In fact, the basic result are similar whether we used ENERGYX or the more precise measure of energy production per capita. Both energy and the other geographical variables are highly significant in both variants of the regression model.

We estimate the most basic form of the model as follows:

$$(4)\ \ln(GDP_i) = \beta_0 + \beta_1 \ln(LAIRDIST_i) + \beta_2\, COAST_i + \beta_3\, TROPIC_i + \beta_4\, ENERGYX + \epsilon_i$$

where we examine alternative measures of COAST and TROPIC, as described above. The results are shown in Table 1. As we see in the table, the four geography variables explain around 60 percent of the cross-country variance in per capita income levels. The highest explanatory power is achieved with the geographical -- rather than ecological -- definition of the tropics, and with the POP100km version of the coastline variable. It might be argued that a high POP100km is a result of development (as the population moves to the coast to take advantage of sea-based trade), rather than a cause of development. For that reason, we also estimate equation (4) using POP100km as a causal variable, but also using L100km as an instrumental variable for POP100km. The proportion of land near the coast should be a good predictor of the proportion of population near the coast, without being subject to the possibility of reverse causation.

The regression estimates suggest strong adverse affects associated with a large distance from major markets, a low density of population near the coast, and a tropical geography. According to the baseline regression (regression 1 in Table 1), a doubling of distance from major markets (e.g. from 2000 miles to 4000 miles) is associated with an 21 percent reduction in 1994 per capita income. A landlocked economy (with POP100km = 0) is estimated to have a GDP per

[13]There are several tropical zones, including humid tropics, rainforest, dry tropics, desert tropics.

capita 72 percent lower than a coastal economy (with POP100km = 1.0). A tropical economy on average shows a per capita GDP fully 62 percent lower than a temperate-zone economy. Finally, energy exporters on average have 68 percent higher per capita GDP than net oil importing economies, controlling for the geographical variables.[14]

Given the high statistical significance of these geographical variables, it is interesting to note the profound differences in geographical endowments of the various major regions of the world, as shown in Table 2. The data show unweighted averages of the countries in the various geographical groupings. Western Europe and East Asia stand out as having extraordinarily high proportions of their populations living within 100 km of the coast, 69 percent and 81 percent respectively. This has made both regions major trading centers. Western Europe, however, is entirely in the temperate zone, while an average of 70 percent of the land area of East Asia is tropical. Moreover, Western Europe is tightly integrated around its central port area (an average distance of just 921 air miles from the national capital to Rotterdam), while East Asia in an enormous region, with an average distance of 3,395 miles from Tokyo (the assumed economic center of the region). If we sum up the elements — high population concentration near the coastline, compact area of several coastal economies, temperate zone — the great geographical advantages of Western Europe become clear. Of course, E.L. Jones, Fernand Braudel, and other economic historians have long emphasized these distinctive features of the European land mass.

Remarkably, just 11 percent of the Russian population, and just 14 percent on average of the populations of the transition countries of Eastern Europe and the former Soviet Union, live within 100 km of the coastline. In fact, during most of Russian history, the proportions of population near the coast were even smaller, since Russian gained access to the Black Sea only in the 18th century. In fact, most of the transition region of Central Europe and the former Soviet Union is far from the sea, and far from Western European markets (an unweighted average air distance of 2,438 km). A remarkable 16 of the 27 transition economies are landlocked. Clearly, the economic problems of Russia and most of the other transition economies goes beyond system transformation. These countries are far from the sea, and far from their closest major markets in Western Europe.

It should be obvious that (4) is inadequate for two fundamental reasons. First, even if geography affects the potential level of income of a region, current income may differ from potential income for a variety of reasons (war, previous political or economic history). Therefore, rather than estimating income per capita in levels, it is more typical to estimate a growth equation, with an error-correction mechanism linking growth to the *gap* between the current level of income and the long-term potential, as in equation (1) earlier. We turn to turn to growth estimates shortly. Second, we know that geography is only one of many variables that affect economic development, and that variables excluded from (4), such as economic policy choices, may well be correlated with the included variables, thereby biasing the estimated effects of

[14]Of course, as noted earlier, a more precise effect of energy endowments would require a more suitable measure of those endowments than the simple 0-1 variable that we are using.

geography.

As a first step, let us add three political economy variables to the basic regression. First, former colonies may exhibit a retrogression of income relative to long-time independent states.[15] We therefore add a dummy variable NEWSTATE, equal to 1 if the country gained independence after 1945, and 0 if the state existed before 1945. We expect NEWSTATE to have a negative effect on the level of GDP per capita in 1994. Second, we add a dummy variable for a country which was engaged in an extensive war on its national territory at some time after 1945. The variable is denoted as WARDUM (equal to 1 if war, 0 otherwise). Third, we include a dummy variable for a country which operated under socialist economic organization for a substantial part of the post-war period. We denote the variable as SOCIAL, equal to 1 if there was an extended socialist interval, and 0 otherwise. All three variables NEWSTATE, WARDUM, and SOCIAL are all highly significant, though their inclusion does not alter the statistical significance or economic importance of the geography variables. According to regression (5), 1994 per capita income in the post-colonial states is 30.5 percent lower than in long-established states, controlling for the other factors.[16] Economies that were socialist for a significant period before 1994 display a level of per capita income 47.9 percent below those of non-socialist economies with comparable geographical attributes. This presumably measures (crudely, to be sure!) the legacy of the socialist experience in lost GDP per capita. Finally, the occurrence of war in the postwar period is associated with an average reduction in per capita GDP of 40.1 percent. Of course, it would be much more advantageous to code for the severity and extent of war, a task for later work. We also don't, at this stage, distinguish between the costs of contemporary war and legacies of past wars.

The level regressions indicate a strong statistical linkage between geography and income. We may be able to improve upon these results by respecifying the regression model as a cross-country growth equation, in which growth depends on the *gap* between the current and long-run income level, where the long-run income level Y depends on geography, economic policy, and other variables. The typical specification of the cross-country growth model is:

(5) $dlny/dt = \beta_0 + \beta_1'Z - \beta_2 ln(y_0)$

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[15]There are at least two reasons. First, the colonial experience may have hindered development, leaving the country poorer than otherwise at the moment of independence. Second, the post-colonial economy may suffer from various legacies of colonialism, including the difficulty of a new young state establishing effective political and economic institutions.

[16]Another possibility, of course, is that it was the most economically weak states that fell prey to colonial rule during the era of imperialism. Therefore, if there are unmeasured features of a national economy causing poorer development prospects, those unmeasured factors may be correlated with NEWSTATE, causing a spurious estimated relationship between NEWSTATE and low per capita GDP.

Z is a vector of explanatory variables, including the geographical variables. y_0 is the base year GDP. Note that we can solve the differential equation (5) for the implied long-run income level by setting dlny/dt = 0, so that ln Y = $(\beta_0 + \beta_1'Z)/\beta_2$. In related work (Lee, Radelet, and Sachs, 1997; Radelet and Sachs, 1998), we have estimated equation (5) using three types of explanatory variables in the vector Z: (1) geographic variables such as tropical area, population near the coastline, natural resource endowments, and a direct measure of transport costs (calculated as the ratio of CIF imports to FOB imports); (2) economic policy and institutional quality; and (3) demographic variables, including life expectancy and population growth. Note that an estimate of equation (5) only shows the direct effects of geography on potential income, not the indirect effects via the link between geography and the quality of institutions.

Without repeating the estimates found in the earlier papers, we may summarize the empirical findings as follows. First, even after controlling for government policies and institutional quality, geographical variables are highly significant. There is evidence that higher shipping costs impact adversely on growth rates (Radelet and Sachs, 1997). There is evidence that tropical economies grow less rapidly than temperate-zone economies, controlling for income levels and economic policies. In the growth estimates, the annual growth "penalty" for tropical countries is estimated to be -0.81 percentage points. There is evidence that countries with a higher ratio of coastline to land area growth more rapidly, and that landlocked countries suffer a growth deficit of around 0.7 percentage points per year. Note that an annual growth deficit translates into an implicit penalty on steady-state GDP. The tropics deficit, for example, of 0.81 per year holding constant the initial income level, is consistent with a long-run per capita income shortfall of 33 percent, smaller than estimated by the "snapshot" cross-section regression in Table 1.[17]

Geography and Quality of Institutions

We hypothesized earlier that geography might affect the quality of political and economic institutions, even controlling for per capita income levels. We gave one example: coastal polities, compared with interior polities, may be characterized by less predatory government behavior because of the higher elasticity of factor supplies in the coastal polities. Differences in agricultural organization, population density, and other factors related to climate, could similarly induce a relationship between climatic zone and institutional quality. Political institutions are also likely to be affected by a country's neighbors. Thus, controlling for a country's own per capita income, location in the tropics could be associated with poorer governmental institutions through spillover effects from neighboring countries. Similarly, institutional innovations both favorable (such as innovations in commercial law) and unfavorable (such as military coups) tend to diffuse across neighboring countries. War or violence in nearby countries can force costly defensive actions in an economy, with deleterious effects on the budget and other institutions.

[17]This is calculated as exp(-0.71/1.71)-1, with 0.71 the estimated coefficient on TROPICAR, and 1.71 the estimated coefficient on initial log income.

These possible relationships have been little explored in the development literature. We can not, at this point, offer a comprehensive analysis of the possible direct and indirect channels of geography on institutional quality. Rather we propose to look at the data in a very tentative manner to see whether such linkages are evident. Moreover, we only have systematic data on a cross-sectional basis, since there time-series data are not available for a wide range of countries. Basic modernization theory proposes that the quality of institutions is an increasing function of per capita income. We therefore examine whether institutional quality on a cross-country basis is also related to geographical variables once we have controlled for per capita income:

$$(6)\ \ln(Q_i) = \beta_0 + \beta_1 \ln(y_i) + \beta_2 G_i$$

We estimate (6) using two measures of institutional quality: (1) trade policy during 1965-90; and (2) the 1980 value of the Keefer-Knack index of the Quality of Government Institutions (denoted QGI80).

Sachs and Warner, 1995, calculate the proportion of years between 1965 and 1990 in which government policy supported open trade, where open trade is defined as the absence of high barriers to trade such as tariffs, quotas, inconvertible currencies, or heavy export taxation. This proportion is denoted as OPEN6590. We know that richer countries are likely to adopt more open trade policies. The question here is whether geography also affects the choice of trade policies. To avoid the problems of reverse causation (in which openness causes high income, rather than high income causing openness), we regress OPEN6590 on per capita GDP in the base year 1965. We then include the three main geographical variables: POP100km, AIRDIST, and TROPICAR. We tried entering base-year GDP in two ways, first simply as the logarithm of per capita GDP, and secondly as a spline function, allowing for the slope of the response of openness to vary according to the base-year income level.[18] We do this because we have very little sense of the shape of the "policy reaction function" from income to openness. The simpler version (not shown) yielded a highly significant and positive effect of base year GDP on subsequent openness ($t = 3.6$). The spline-function estimates reported in Table 3 are less precise, but they do suggest a non-linear relationship between openness and ln(GDP), in which the positive effects of income on openness begin only after a threshold income is reached.

The results, shown as regressions (1) - (3) in Table 3, are notable. As expected, higher initial income is associated with more *subsequent* openness of the economy. Interestingly, the

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[18]The spline function works as follows. Six categories of income are established, \$0-600, \$600-1200, \$1200-2400, \$2400-4800, \$4800-9600, and \$9600 and above. Suppose that y lies in the range \$2400 - 4800. The ln(y) may be then be written as $\ln(y) = \ln(600) + [\ln(1200)-\ln(600)] + [\ln(2400)-\ln(1200)] + [\ln(y) - \ln(2400)]$. Each income bracket has its own estimated coefficient: α_1 for income up to \$600; α_2 for income between \$600 and \$1200, etc., so that the estimated effect of ln(y) would be $\alpha_1 \ln(600) + \alpha_2 [\ln(1200)-\ln(600)] + \alpha_3 [\ln(2400)-\ln(1200)] + \alpha_4 [\ln(y) - \ln(2400)]$. Each $\ln(y_i)$ is therefore re-written as the sum of underlying income brackets, which are then entered into the regression equation in order to estimate the α's.

spline-function estimates suggest that higher income begins to promote openness only after a threshold of around $1200 per capita (in 1985 PPP adjusted dollars) is reached. This lends some support to the notion of a low-level trap during the 1965-90 period. The poorest countries were more likely to choose closed trade policies, which thereby kept them poor. At the same time, geography affected the choice of trade policies. The closer a country was to a major market (measured by AIRDIST), the more likely it was to choose an open trade regime. This may have resulted from pressures "from below," since profitable trade opportunities are greater for more proximate countries. Alternatively, it may have resulted from imitation effects and regional negotiations to join in open trade arrangements (as in the cases of the European Union, APEC, NAFTA, etc.).

We also find evidence that more coastal economies also adopted more open trade policies, again consistent with the view that geography affected the internal political dynamic in these countries. To ensure that the estimated relationship is not a result of reverse causation (in which open trade induces a high proportion of the population near the coastline), we also estimate the equation using two-state least squares, with the proportion of land with 100km of the coast as an instrument for POP100km. The estimated effect remains intact. The regression estimates *do not* suggest any differences in policy choices of tropical and non-tropical countries, once we have controlled for distance, income levels, and population near the coast.

Taken as a whole, the regression results support the view that only geographically well-placed poor countries (e.g. Korea, Taiwan), close to major markets and with a high proportion of the population near the coast, were more likely to adopt open trade policies at an early stage in development. Clearly, much more work needs to be done to see whether this interpretation indeed helps to explain why a small subset of poor countries, mainly in East Asia, adopted open trading policies at an early stage in the postwar period, well ahead of most other developing countries.

In regression (4) in Table 3 we present a similar regression estimate for the logarithm of the Keefer-Knack Index of Institutional Quality for 1980. In this case, the income variable is per capita GDP in 1980 (PPP adjusted, in 1985 dollars). The Keefer-Knack index for each country is an average of sub-indexes of government quality over a variety of dimensions: corruption, quality of the bureaucracy, risk of expropriation, and so forth. The index is calculated on a scale from 1 (lowest quality) to 10 (highest quality). We take the logarithm of the index for purposes of estimation. Once again, we estimate a spline function for income, plus additional geographical variables. In this case, POP100km and LAIRDIST were statistically insignficant, and dropped from the equation (and not reported). The proportion of the country's land area in the tropical ecozones, however, shows a strong negative effect on the index, as shown in regression (4) in Table 3. Interestingly, the spline function once again suggests a kind of threshold effect. Higher income is associated with a higher level of the index, but only after a threshold of around $2400 is reached. This threshold effect underscores the possibility of a low-level income trap.

Conclusions and Extensions

We have described empirical evidence that links economic development to geography. The evidence suggests that geography matters for the level of GDP per capita in at least four ways: proximity to markets; access to the sea; climate, presumably through the effects on health and agricultural productivity; and the presence of energy resources. We have not yet demonstrated the underlying mechanisms at work in these relationships. In what ways does climate affect productivity? Is the effect limited to agricultural? Does proximity to major markets matter because of trade costs, the diffusion of ideas, or some other kind of spillover effects across countries? Moreover, if indeed geography is important because of transport costs, public health, agricultural productivity, and the like, how will recent advances in communications, transport logistics, biotechnology, and agronomy affect the global patterns of income?

Even more speculatively, we have introduced a little bit of direct evidence that the choices of government institutions may be directly linked to geography, even after controlling for income levels. Coastal polities, for example, were more prone to adopt open trade policies than interior polities, as our simple reasoning suggested. Institutional quality in 1980 was apparently lower in the tropics than elsewhere controlling for income levels. There are few previous studies along these lines to test, refine, and refute propositions linking politics and geography. We are just at the beginning of this exploration. As we discussed earlier in this paper, the fact that geography may effect development both directly through economic productivity and indirectly through the quality of public institutions may produce an explanation of observed "low-level" income traps, in which poor countries fail to develop beyond a low equilibrium threshold, while richer countries demonstrate a tendency towards income convergence with the high-income countries.

Table 1. Regression Estimates of GDP Per Capita, 1994, on Geographic Variables

	ln(GDP 1994)	ln(GDP 1994)	ln(GDP 1994)
Constant	10.58 (15.48)	10.47 (15.10)	10.60 (17.99)
LAIRDIST	-0.33 (3.85)	-0.33 (3.71)	-0.25 (3.28)
TROPICAR	-0.96 (5.98)	-0.97 (6.02)	-1.00 (7.10)
POP100km	1.27 (7.11)	1.34 (6.89)*	1.01 (6.36)
ENERGYX	0.52 (3.76)	0.52 (3.73)	0.54 (4.52)
NEWSTATE			-0.36 (3.03)
SOCIAL			-0.65 (4.79)
WARDUM			-0.52 (4.64)
N, adj-R^2	N = 138, adj-R^2 = .59	*L100km as instrument; N = 138; adj-R^2 = .59	N = 138, adj-R^2 = 0.71

Note: t-statistics in parentheses

Table 2. Geographic Characteristics of Major Regions

Region	POPULATION WITHIN 100km OF COAST (proportion)	AIR DISTANCE TO CLOSEST MAJOR MARKET , km	SHARE OF LAND IN TROPICS (proportion)	PROPORTION OF COUNTRIES IN REGION WITH NET PRIMARY ENERGY EXPORTS
Western Europe	69	921	0	12.5
East Asia	81	3,395	70	42
Transition Economies	14	2,438	0	20
Sub-Saharan Africa	23	6,237	93	17
Latin America and Caribbean	60	8,729	81	38
South Asia	33	5,587	49	0
Middle East and North Africa	56	3,475	16	54
Selected countries:				
United States	51	NA	0	0
Russia	11	2,220	0	100
China	21	2,090	3	100

Notes: Data are unweighted averages for the countries in the region.

Table 3. Regression Estimates of OPENNESS, 1965-90

	OPENNESS 65-90	OPENNESS 65-90	OPENNESS 65-90	Institutional Quality, 1980
LAIRDIST	-0.14 (3.21)	-0.15 (3.66)	-0.15 (3.51)	
POP100km	0.22 (2.09)	0.21 (2.03)	0.26 (2.26)*	
TROPICS	-0.05 (0.52) (geographic tropics)			-0.22 (2.39) (ecozone tropics)
INCOME (spline function)				
ln(GDP) 0-$600	0.05 (0.17)	0.06 (0.21)	0.05 (0.169)	0.13 (0.29)
ln(GDP) $600-1200	-0.03(0.15)	-0.02 (0.11)	-0.05 (0.26)	0.11 (0.48)
ln(GDP) $1200-2400	0.24(1.29)	0.25 (1.34)	0.24 (1.30)	-0.07 (0.42)
ln(GDP) $2400-4800	0.14(0.54)	0.17 (0.67)	0.17 (0.68)	0.32 (1.71)
ln(GDP) $4800-9600	0.23(0.77)	0.22 (0.73)	0.22 (0.73)	0.49 (2.40)
ln(GDP) > $9600	0.08(0.52)	0.03 (0.02)	0.21 (0.14)	0.38 (0.88)
adj-R^2	adj-R^2 = .48, N = 106	adj-R^2 = 0.48, N = 106	* L100km as instrument; adj-R^2 = .48; N = 106	adj-R^2 = 0.61; N=95

Note: t-statistics in parentheses

Figure 1. Multiple Equilibria with Endogenous Institutional Quality

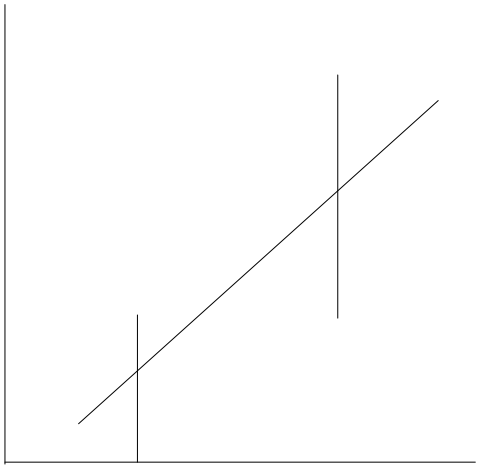

Figure 2. Geographical Conditions and Multiple Equilibria