Geography, Demography, and Economic Growth in Africa*

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I. Introduction

Sub-Saharan Africa's poverty is one of the most obdurate features of the world economy. For the entire post-Industrial Revolution period, Africa has been the world's poorest region and also its slowest growing.[1] Angus Maddison (1996) has prepared the most reliable estimates of world and regional gross domestic products for the period 1820-1992. Figure 1 shows Africa's estimated long-term growth profile compared with other regions. According to these estimates, Africa began the modern era at approximately one-third of the income level of the richest region as of 1820, Western Europe. It arrived in 1992 at approximately one-twentieth of the income level of the richest region, the so-called Western Offshoots, which in Maddison's jargon includes the United States, Canada, Australia, and New Zealand.[2] Maddison estimates that Africa's 1992 per capita income was approximately that of Western Europe in 1820, $1,284 in Africa compared with $1,292 in Europe (in common purchasing power 1990 international dollars). Of course, such a comparison is only a gross approximation, yet it dramatically highlights the extent of Africa's economic plight.

Africa's poor economic growth has been chronic rather than episodic. As shown in Table 1, Maddison estimates that Africa had slow growth during each of the major sub-periods that he examines: 1820-70 (before the colonial era in Africa); 1870-1913 (the onset of colonial rule until World War I); 1914-1950 (the World Wars and the Great Depression); 1950-73 (late colonial rule and early independence); and 1973-1992 (the recent period). Many observers point to Africa's growth during the 1950-73 period, and the subsequent slowdown, as an argument that Africa's post-independence governments severely undermined the potential for rapid economic growth. It is apparent from the table, however, that even in this most successful sub-period, Africa's growth lagged behind the rest of the world. In a quite different perspective, many observers at the start of Africa's independence from colonial rule in the early 1960s believed that Africa's long period of slow growth would end once the colonial yoke was removed. This manifestly did not happen, and in fact growth plummeted. African per capita income growth averaged 1.5 percent in the 1960s, 0.8 percent in the 1970s, and –1.2 percent in 1980s. Output per capita continued to decline from 1990 to 1996 at a rate of –0.9 percent per year.[3] This record of growth is perhaps the greatest single disappointment and surprise of recent African history.

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[1]For simplicity, we will refer to sub-Saharan Africa more simply as Africa. In the cases when we are referring to the entire continent we mention that explicitly.

[2]The Maddison data allow other relevant comparisons. Africa's per capita income increased by a factor of almost 2.5 between 1820 and 1992. Although not negligible, this figure is small compared to other regions of the world. For example, per capita income increased by factors of 14.9, 7.4, and 5.9 from 1820 to 1992 among Western countries, Latin America, and Asia, respectively. Correspondingly, per capita income in Africa was 68 percent of the world average in 1820, but only 24 percent by 1992. Relative to per capita income in western Europe, income in Africa declined from 35 to 7 percent over the same period.

[3] The income growth figures are population-weighted averages of PPP-adjusted per capita income data. Up

Africa's overall slow growth has continued despite intensive reform efforts during the past decade, and despite a few important successes. During the decade 1985-96, per capita economic growth averaged –0.6 percent per year (population-weighted). A remarkable 21 out of 42 countries for which data are available experienced negative per capita economic growth. There were a few notable success stories. Equatorial Guinea and formerly war-torn Mozambique lead the way with growth rates averaging 8.4 and 5.5 percent per annum, respectively (Equatorial Guinea grew at a rate of 21 percent per annum from 1992 to 1995 on the basis of significant discoveries and development of offshore oil). Traditionally fast-growing Mauritius and Botswana achieved per capita growth of more than 4 percent per year, while recent-reformer Uganda grew at a rate of 3.3 percent per year. Ghana, a long-standing reformer since the early 1980s, grew at a rate of 1.5 percent. In 1995, average African per capita growth achieved a recent high of 1.7 percent per year, apparently the result of policy reforms in preceding years combined with good weather conditions on much of the continent. In 1996, it appears that per capita growth was about the same at 1.6 percent per year, and then declined in 1997 to 0.8 percent per year. A recent IMF forecast for 1998 puts growth at 1.1 percent.[4] (Despite the recent growth, the 1997 per capita income level was approximately 2.9 percent below the 1991 level). The World Bank places Africa's 1996 per capita GDP at $1259 in (1987 PPP-adjusted prices), 5.9 percent of the U.S. level. Fifteen of the world's poorest 20 countries are in Africa. Moreover, our estimates indicate that 47 percent of the population of Africa lived in abject poverty -- below one dollar per day -- in 1990. Finally, in terms of the UNDP (1997) human development index, which takes into account life expectancy and literacy as well as per capita GDP, 32 of the poorest 40 countries (and 19 of the bottom 20) are in sub-Saharan Africa.

In recent debate, five sets of factors have been most frequently invoked to account for Africa's poor economic performance:

- external conditions: the legacy of centuries of slave trade and colonial rule, and Cold War manipulations of African politics;
- heavy dependence on a small number of primary exports and resulting terms of trade declines and volatility;
- internal politics: authoritarianism, corruption, and political instability;
- economic policies: protectionism, statism, and fiscal profligacy;
- demographic change: rapid population growth;
- social conditions: deep ethnic divisions in African society, indicated by high levels of ethnolinguistic and religious diversity and low levels of "social capital" as variously measured.

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through the 1980s, they are drawn from the Penn World Tables Version 5.6. For the 1990s, the figures come from the World Bank's *World Development Indicators 1998*.

[4] See Calamitis (1998), p. 2.

Although there is some evidence in support of all these explanations, we believe that they miss an even bigger truth. At the root of Africa's impoverishment, in our view, lies its extraordinarily disadvantageous geography, which has helped to shape the nature of African societies and Africa's interactions with the rest of the world. Throughout the old world and the new world, tropical regions have lagged far behind the temperate regions in economic development, and Sub-Saharan Africa is by far the most tropical of all the major regions in the world economy (in the simple sense of the highest proportions of land and population in the tropics). Moreover, in several dimensions -- climate, soils, topography, and disease ecology -- its environment is without parallel in raising obstacles to growth. The consequences include chronically low agricultural productivity (especially in food production), high disease burdens, and very low levels of international trade, with trade concentrated in a few primary commodities.

Africa's economic performance is further impeded by its demographic circumstances, which are themselves most likely related to Africa's poor geographic and economic conditions. Africa has the world's highest youth dependency ratios, a consequence of its combining the world's highest rates of fertility with falling levels of infant and child mortality. High youth dependency ratios impose a substantial drag on African economies by reducing their productive capacity per capita. Low life expectancies and extremely youth-heavy age distributions also tend to be associated with lower rates of savings and investment (as conventionally measured), and therefore slower economic growth. The youthful structure of Africa's population pyramid and the sluggishness of its demographic transition to lower rates of fertility indicate that African economies will labor under the burden of rapid population growth for decades to come.

A few countries in the tropics made significant breakthroughs in economic growth in the past twenty-five years, in almost all cases through the promotion of manufacturing or service-sector exports. The experience of these countries suggests that technologies in manufactures and services can diffuse across climatic zones much more readily than technologies in agriculture. It is probably no coincidence that the biggest tropical success stories -- Hong Kong and Singapore -- are small island economies with negligible agricultural sectors and rapid growth in manufacturing and service-sector exports.[5] With but one exception (the Indian-Ocean country of Mauritius), no African country made a similar transition to export-led growth in manufactures or services. This is partly the result of Africa's greater inherent difficulties, but also, in our view, because neither African governments nor the IMF and World Bank promoted the kinds of institutions needed for such a transition. The ultimate irony of "structural adjustment programs" of the Bretton Woods institutions is that they promoted virtually no structural change. After twenty years of reform, Africa remains stuck as an exporter of a narrow range of primary commodities (e.g., oil, diamonds, copper, gold, coffee, tea, cocoa, palm oil, and rubber), most of which are suffering long-term declines in their international terms of trade.

Much too little is known about the effects of climate, topography, and natural ecology on public health, nutrition, demographics, technological diffusion, international trade, and other

[5]As we point out later, these island economies were also blessed by the fact that as islands, they were better able to control vector-borne tropical diseases, such as malaria (which was in fact eradicated in both economies).

determinants of economic development to make definitive claims. Thus, at many points in this paper we raise informed speculation, rather than definitive proof. One goal of the paper is to stress the need for intensified research on the complex issues at the intersection of ecology and human society.

Our paper could well be misunderstood. Some will regard it as a new case of "geographic determinism," that Africa is fated to be poor because of its geography. Some will regard it as a distraction from the important truth that geographic difficulties or not, African governments seriously mismanaged economic policy in the past generation. Let us therefore be clear at the outset. We believe emphatically that economic policy matters, and our formal econometric results show that to be true, a point we have also made in related recent studies (especially Sachs and Warner, 1997). We nonetheless focus most of our attention on geography for three reasons. First, there is little to be gained from yet another recitation of the damage of statism, protectionism, and corruption on African economic performance. Amen. Second, most economists are woefully neglectful of the forces of nature in shaping economic performance, in general and in Africa in particular. They treat economies as blank slates, upon which another region's technologies and economic history may be grafted. Our profession's formal models tend to be like that; so do our profession's standard statistical analyses of cross-country growth. A healthy counter-example is the recent study of world economic history by Landes (1998), which assigns geography an important role in long-term differential performance in the very first chapter.

Third, and perhaps most importantly, good policies must be tailored to geographical realities. If agricultural productivity is very low in Africa for climatological reasons, perhaps the real lesson is that growth should be led much more by outward-oriented industry and services, rather than yet another attempt to blindly transplant "integrated rural development" strategies from other parts of the world that are not customized to Africa's unique conditions. At the very least, intensified scientific research on tropical agriculture in Africa -- along the lines of what underpinned the Green Revolution in South and East Asia -- is warranted, since current technologies are an insufficient basis for dramatic improvements in agriculture.

The paper is organized as follows. In Section II we discuss the general problems of tropical development, and put Africa's problems in a worldwide tropical perspective. In Section III, we discuss demographic trends in Africa, putting stress on the low levels of population density and urbanization and the delayed demographic transition in Africa compared with other developing regions. In Section IV we use standard cross-country growth equations, augmented by demographic and geographic variables, to account for the relative roles of geography, demography, and policy in Africa's recent growth experience. In Section V we turn our attention to future growth strategies, and especially the urgent need for urban-based export growth in manufacturing and services. Finally, in Section VI, we summarize our conclusions and discuss the agenda for future research.

II. Africa's Geography and Economic Development

At the root of Africa's long-term growth crisis is Africa's extraordinary geography. As Fernand Braudel (1995) wrote in 1963, "In understanding Black Africa, geography is more important than history. The geographical context is not all that matters, but it is the most significant." (p.120). (Braudel is also quoted approvingly in an excellent chapter on Africa in Sowell (1998). Sowell also puts great stress on geography, especially the role of geography in "making cultural interaction more difficult," both between Africa and the rest of the world, and within Africa).[6] Sub-Saharan Africa is the world's tropical region *par excellence*, with 93 percent of its land area lying within the geographical tropics (that is, between the Tropic of Cancer and the Tropic of Capricorn).

An overview of tropical versus temperate-zone development

In all parts of the world, not just in Africa, tropical economic development lags far behind temperate-zone economic development. In 1995, tropical economies averaged $3326 in GDP per capita (PPP adjusted 1990), while the non-tropical countries averaged $9027 in GDP per capita.[7] Only two of the top 30 countries in a world ranking of GDP per capita lie in the tropics: Hong Kong and Singapore. These are also the only two tropical economies that the World Bank currently classifies as high-income economies. And what is true across countries is also true within countries that straddle the tropics and temperate zones, such as Australia and Brazil: the temperate regions within these countries are much more highly developed than tropical regions (see Llussa, Sachs, and Gallup, 1998, for the case of Brazil).

Note that within Africa, the small temperate zones at the north and south ends of the continent have significantly higher incomes than the tropical core. The five North African countries have an average 1995 income of $4371 (PPP adjusted 1990), compared with tropical sub-Saharan Africa's average of $1732, and non-tropical South Africa's $7348. The average of four southern African countries, two of which are temperate zone (South Africa and Lesotho), and two of which straddle the tropics (Botswana and Namibia), is $5438. According to the *World Development Report* of the World Bank (1997a, Table 1, p. 214), the three fastest growing countries in Sub-Saharan Africa during 1985-95 were Botswana, Mozambique, and Namibia, all of which straddle the tropics and temperate zones at the southern end of the continent.

Productivity growth in the tropics has lagged far behind productivity growth in the mid-latitudes during the entire period of modern economic growth, and all evidence suggests that the temperate zone continues to be the dynamic center of innovation in the world economy. Well more than 90 percent of global R&D expenditure originates in the northern mid-latitude economies, and

[6] See also, Diamond (1997), Landes (1998), and Reader (1998) for extremely comprehensive and illuminating treatments of long-term linkages among geography, health, and economic development. See also, Hall and Jones (1997) for recent empirical evidence that geography, i.e., a country's distance from the equator, is strongly positively associated with income per capita.

[7] The calculations are based on the universe of countries with populations of 1 million or more, a total of 150 countries covering approximately 99 percent of the world's population. Since many countries straddle the tropics, for purposes of discussion we define a tropical country as one in which half or more of the land area lies between the Tropic of Cancer (23.45° N) and the Tropic of Capricorn (23.45° S). There are 72 such countries, of which 39 are in Africa. These countries have a combined 1995 population of 2.3 billion, or 41 percent of the total in our universe of countries. The combined land area of these countries is 45 million km^2, out of a total of 129 million km^2, or 35 percent.

at least that percentage of patents worldwide originate in the same region. Such differences in productivity growth and innovative dynamism probably reflect four inter-related factors at play. First, many kinds of technologies, for example in agriculture and construction, do not transfer well across ecological zones, a point we stress below. Second, the temperate zones have long had much higher rates of endogenous technical change than the tropics. One reason for this might be the simple fact that the northern hemisphere mid-latitudes have had many more people than the tropics throughout history (at least since 1500), and so have offered a much larger market for innovation. Since innovation has crucial increasing-returns-to-scale properties, this advantage would tend to cumulate over time. Third, the tropics seem to pose several *inherent* difficulties, especially in agriculture and public health. Fourth, the tropics are disadvantaged simply because they are far away from the large, mid-latitude markets, and many kinds of firms choose to locate near larger markets in order to lower transport costs from suppliers and to final customers. Problems of transport costs are especially acute in Africa, both within the continent and between Africa and the rest of the world. Distance, by itself, is *not* the main explanation of the shortfall in tropical development, however. The southern hemisphere temperate zone economies are even farther away from the main world markets than are the tropics, and yet are considerably richer in per capita terms. The problem seems to lie with the tropics itself.

Figures 2a to 2e show the allocation of world population, land area, population density, aggregate GDP, and GDP per capita, by 10-degree latitude bands. (Note that the geographical tropics extends from 23.45° N to 23.45° S latitude. For convenience, we have used 10° latitude bands in the Figure, so that the tropical region is closely but not exactly captured by the bands from 20°N to 20°S latitude).[8] To make the allocations of GDP by latitude band, we maintain the (counterfactual) simplification that per capita incomes are uniform *within* countries, so that the geographic allocation of GDP within the country that extends across one latitude band is allocated solely according to the distribution of its population across bands. This procedure no doubt overstates the share of income in the tropics, since (as we have pointed out) the per-capita income gradient *within* countries favors temperate-zone regions compared with the tropical regions.

The first important point of the table is that the bulk of human population (62 percent) and almost half of the land mass (45 percent) are between 20°N and 50°N. Indeed, almost three-fourths of the human population (73 percent) resides in the great Eurasian land mass and closely associated islands, of which only a very small part (8 percent of the land, and 14 percent of the population) lies in the geographical tropics. Interestingly, the northern hemisphere mid-latitudes are not only the most populated area, but also the most densely populated region. Population densities fall off in the high latitudes (above 50°N) as well as in the tropics and the southern hemisphere non-tropics. We believe that this differential population density, at a deep level, reflects three forces. First, as we discuss below, the photosynthetic potential for food production is probably highest in the mid-latitudes, as a basic biological condition. This would give advantage in achieving high population densities to both the northern and southern hemisphere mid-latitudes relative to the tropics and the

[8] If we define the tropics by tropical latitudes (between 23.45°N and 23.45°S) we find that 1.2 billion people live in the tropics, in a world population of 5.7 billion, or 21 percent. The tropical land area is 31 million km^2, in a world habitable land area of 129 million km^2, or 24 percent. The average tropical population density is 39.1 persons per km^2, compared with the non-tropical population density of 45.2 persons per km^2.

high latitudes. Second, long-term endogenous technical change, which was inherently favored by the large populations in the temperate region (interacting with scale-effects in innovation), gave a further boost to the population carrying capacities of the mid-latitudes. Third, the southern hemisphere mid- and high-latitudes have very little land, and therefore intrinsically offer a very small local market compared to the northern hemisphere. Even if technologies in the temperate northern and southern hemispheres are fully transferable, enterprises will choose to locate in the northern hemisphere rather than the southern hemisphere in order to benefit from the proximity to markets.

Figure 2e shows the remarkable U-shaped distribution of per capita GDP according to latitude band. The northern and southern mid- and high-latitudes are rich compared with the tropical zone. This figure strongly suggests that technologies readily diffuse between the northern and southern temperate regions, so that Argentina, Australia, Chile, New Zealand, and South Africa benefit from the technological advances of the northern temperate zone, as well as sharing some intrinsic advantages relative to the tropics. The small southern markets do not support large populations, or large population densities, because of their great distance from the main world markets, but they do support high per capita living standards. In Figures 3a to 3c we show the same latitude variation in GDP per capita for three sub-regions: the Americas, Africa, and Asia and Oceania. In all three cases, the U-shaped pattern is plainly evident.

The combination of large land area, high population density, and high per capita income in the northern mid- and high-latitudes leads to a remarkable concentration of overall world GDP in this region. No less than 69 percent of world GDP on a PPP basis falls within the range of 20°N and 60°N. Only 12 percent of world GDP lies within the range 20°N to 20°S.[9]

The tropical environment and agricultural productivity

As we have already stated, we believe that the income lag in the tropics reflects three forces: endogenous technical change biased toward the large temperate-zone markets, inherent difficulties of technical diffusion across ecological zones, and inherent liabilities of the tropics in at least two areas: agriculture and health. In this section, we discuss the problems of agriculture, both why agricultural technologies do not easily diffuse from the temperate zone to the tropics, but also why the tropics are inherently disadvantaged in food production. We also discuss Africa's special features in this regard. In the following section, we turn to a comparable discussion regarding health.

The tropics include a wide array of climatic and ecological zones, but there are several important common features. First, temperatures at sea level are uniformly high throughout the tropics all year round, with the major temperature gradients involving altitude (a decline of approximately 0.4 - 0.5° C for each 100m of altitude), and land mass (higher temperatures in the interior of continents, lower temperatures when moderated by the sea or monsoon rainfall). Second, insolation is generally high year round, except where it is limited by cloud cover, as it tends to be

9. 69 percent is based on an equal allocation of GDP per capita within countries. If in fact the per capita income is higher in temperate zones than tropical zones in countries that straddle both regions, then the share of GDP in the northern temperate band would be even higher.

over the equator. Third, there is no freezing except at very high altitudes, such as in the tropical Andes region, or the highest mountains of East Africa. Fourth, day and night are approximately equal in length the entire year, with little variation. On the equator, all days are 12 hours in length (not considering diffuse sunlight at dusk and dawn). At the tropical boundaries (23.45°N and 23.45°S), the shortest days (at the winter solstice) are approximately 11 hours, and the longest days (at the summer solstice) are approximately 13 hours.

Within these common parameters, tropical climates vary greatly due to latitude, altitude, ocean currents, the size and configuration of land masses, the location within continents (east coast climates, for example, being markedly different from west coast climates), relation to mountain ranges, and other phenomena. Our analysis of the effect of climatic variation within tropical Africa is based heavily on the Köppen-Geiger classification system, as reported in McKnight (1996). Around the equator in Africa, and most of the tropics around the world, lies a zone of intense year-round rainfall and high temperatures, which produces the great equatorial rainforests of West Africa (and similarly, the rainforests of the Amazon Basin, and of Southeast Asia). In Africa, this band is concentrated within the range from 5°S to 5°N latitude, but also exists in West Africa (Liberia and Sierra Leone) around 10°N. In the approximate 5° - 20° degrees latitude bands both north and south of the equator, the climate is generally characterized by a wet summer season and dry winter season. The alternating wet and dry seasons, with high temperatures around the year, produce the vast savannahs (grasslands) that cover roughly sixty percent of the African continent. The farther from the equator within this band, the longer is the dry season. Closer to the equator, the climate supports grassy woodlands; at the far edges of the band, the region is extremely dry and supports only open grassland, as in the Sahel region just south of the Sahara desert. Beyond 20° latitude, the arid zone tends to become desert. In the northern hemisphere in Africa, these deserts include the Sahara and parts of the Horn of Africa. In the southern hemisphere, these include the Namib and Kalihari deserts.

Much of East and southern Africa rests on a high plateau at least 1000 m above sea level, with a range of mountains of much higher altitudes. The high plateau reduces the intense heat of the tropics, and generally receives more precipitation than at sea level. In part this is an orographic effect, in which the mountains push up moist tropical air brought from the Indian Ocean by easterly trade winds, resulting in condensation and rainfall. Thus, while coastal East Africa is extremely hot and generally arid, the Eastern highlands are cooler and much better watered. The results are profound: most of the populations of East Africa live up in the highlands and therefore far from the sea. As we note later, what is gained in agriculture is sorely lost in transport costs!

The climate in tropical Africa differs from other parts of the tropical world for several key reasons. First, because Africa is a large landmass, vast interior parts of the continent become extremely hot, as the temperature is not moderated by proximity to the sea or monsoon rainfall. This differs, for example, from the island economies of Southeast Asia, where temperatures at a similar latitude and altitude are moderated. Second, Africa misses out on the great monsoon rainfalls that provide vital seasonal precipitation to South Asia and East Asia. A lesser monsoon phenomenon occurs in West Africa, but not in East Africa. Thus, other than in a part of West Africa (centered on Nigeria), Africa lacks the high seasonal precipitation of Southeast Asia. Either it rains all year round, as near the equator, or seasonal rainfalls are generally much less than in Southeast Asia. Higher precipitation occurs in the East African highlands due to orographic effects.

As a result of lower rainfall and higher mean temperatures, much of Africa's soil-water balance (measured as precipitation minus potential evapotranspiration) is highly unfavorable, and much less favorable than many other tropical regions of the world.[10] As a result, much of Africa suffers from a serious problem of aridity and a constant risk of drought. In addition, rainfall variability (measured as absolute average percentage departure from the mean) is much higher in Africa than in tropical America and Asia (see Strahler and Strahler 1992, p. 187, Figure 10.24), so that the risk of drought is accordingly increased for this reason as well. The World Bank drought indicators (World Bank, 1997b, p. 241), show that 29 countries experienced at least one year of drought during 1983 to 1995. These countries have 50.9 percent of the African population. Twenty-four countries (with 46.7 of the population) experienced at least two years of drought, and 14 countries (with 28 percent of the population) experienced three or more years of drought.

Tropical climates pose serious difficulties for agricultural productivity, especially for many food staples. As Chang (1968) has argued regarding the humid tropics, "the rational choices are fewer and less appealing in the humid tropics than in most other climatic regions of the world." In addition to obvious factors such as temperature and rainfall, Chang cites several biological phenomena that distinguish plant growth in the tropics and temperate zones. The first is *photoperiodism*: many plants use the length of sunlight as a stimulus to flower. Since there is little variation in day length in the tropics, there is no induction of flowering for many temperate-zone plant species, while many tropical food species (such as sweet potatoes and yams) are "short-day" plants, specifically adapted to the twelve-hour sunlight in the growing season. The second is *vernalization*: many plants require a period of cold temperatures in order to flower and develop. The third is *radiation variation*: many plants require variation in insolation to grow well, and do not develop properly if they are always receiving the same intensity of solar radiation. A fourth problem, specific to the humid tropics, is the *lack of a dry season*: many plants bloom during the dry period of the growing season, and cannot bloom if rains are continuous. All four factors deeply constrain the variety of plant crops that can grow in the tropics. The key economic plant species endemic to the tropics (e.g., sweet potato, yam, taro, coconut, oil palm, cocoa, coffee, tea, groundnut, cassava, nutmeg, banana, mango, papaya, among others) are all specially adapted to these conditions.

In addition to these factors which limit the *variety* of plant crops, there are also basic biological factors that limit agricultural yields in warm tropical zones. Crop yields depend on net photosynthesis, that is the generation of energy net of the energy that the plant itself uses to stay alive

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[10] The soil-water balance compares the rate of precipitation, which makes water available for photosynthesis, with the losses of water due to evaporation and transpiration (loss of water vapor through leaf pores of plants). The latter two categories are combined in the term evapotranspiration.

Potential evapotranspiration measures the rates of evaporation and transpiration that would take place if there were an abundant supply of water and a complete cover of vegetation. Thus, in a barren desert, for example, actual evapotranspiration may be essentially zero (since there is neither precipitation nor transpiration), but potential evapotranspiration could be very high, since the high temperatures would promote rapid evaporation and transpiration in the presence of ample precipitation and vegetation cover.

and to develop. Plant consumption of energy, or respiration, is temperature-dependent, with higher respiration in warmer conditions. In areas where temperatures remain very high at night, losses of net photosynthetic potential are particularly high. What is gained by sunlight during the day is lost at a rapid rate at night, so that net photosynthetic potential in the warm tropics is therefore reduced. As Chang (p. 347) notes, "other things being equal, an increase of 2 to 3 degrees Centigrade of mean annual temperature, particularly night temperature, can spell the difference between profit and loss in the operation of tropical plantations."

As temperature (especially nighttime temperature) is such an important regulator of net photosynthetic potential, many of the most fertile areas of the tropics are at relatively high altitudes, such as the highlands of East Africa and the Andes, the mountainous spine of Central America, and the Himalayan foothills in Southeast Asia. These environments generally enjoy not only lower nighttime temperatures but also greater precipitation (due to orographic rainfall) and, often, high-nutrient volcanic soils. But in these cases, the increased productivity comes at a heavy cost: the economic isolation of populous communities from regional and international trade due to the high transport costs from the mountain regions. It is the irony of tropical highlands that Africa's most densely populated countries are Rwanda and Burundi (244 per km^2 and 259 per km^2, respectively), which lie in the inter-lacustrine highlands of the Great Lakes region. These countries enjoy plentiful rainfall and sub-tropical temperatures, but at the cost of profound economic isolation, which, coupled with other factors, places them among the world's ten poorest countries.

The tropics face another problem in addition to high temperature. It is usually supposed that usable sunlight during the growing season is much greater in the tropics than in the mid latitudes, and that photosynthetic potential is therefore greater. We all carry images of the sweltering tropical sun high in the sky beating down upon the earth and contributing to lush tropical foliage in areas of abundant precipitation. But this image is fundamentally misleading. Sunlight in the tropics is around 12 hours per day during the entire year. In the mid latitudes, by contrast, sunlight during the interval between the vernal and autumnal equinoxes is considerably longer than 12 hours per day, (with much less than 12 hours in the interval between the autumnal and vernal equinoxes). At the 40^{th} latitude, for example, the summer solstice has 15 hours of sunlight. Thus, *for crops that are grown once or twice a year, in a four- to eight-month period), the amount of sunlight available for the annual crop cycle will actually be much higher in the mid-latitudes than in the tropics!* (This conclusion holds even after accounting for the varying angle at which sunlight strikes the earth at different latitudes and times of the year.) The extent of tropical sunlight, by contrast, is greater for crops that can grow year round (such as bananas or oil palm), or in regions like Eastern Java where precipitation patterns and water control allow for multiple crops throughout the year (rather than crops timed in conjunction with the rainy season).

If we combine the effects of sunlight and night-time respiration, it appears that the intrinsic advantages of the temperate zones in photosynthetic potential for crops with a four- to eight-month growing season can be very large. As Porter (1995) concludes: "The net effect of these latitudinal differences is that crops that can be grown in a four to six-month period (e.g. maize, wheat, sorghum, soybeans, and cotton) will have higher yields [in the mid-latitudes] than their counterparts grown in the tropics." (p. 46). Thus, the disadvantages of the tropics can be very large when viewed from the standpoint of net photosynthetic potential. For both cereals and root crops, yields in the tropics are much lower than in the temperate zones, and are especially low in Africa.

The example of cotton is instructive, since cotton is grown in both temperate and tropical climates, and since the European colonial powers attempted to develop profitable cotton production in tropical Africa. In almost all cases, the outcomes in the African colonies were very disappointing, because of the low yields that were achieved. Figure 4, from Porter (1995), suggests that these low yields are an intrinsic feature of the lower photosynthetic potential of the low-altitude tropics relative to the temperate zones and the highland tropics of Peru (where night-time respiration is considerably reduced by cooler temperatures). We hasten to add that the issue of intrinsic geographical differences in agricultural productivity remains understudied and a matter of continuing debate, but one that agricultural economists should surely turn to with more focus and effort.

Of course, agricultural productivity is affected by more than temperature and sunlight. Water, soil, and pests are three additional considerations of profound importance. The question of water is again complicated, since what counts is the soil-water balance, which, as noted above, is precipitation net of potential evapotranspiration. Because of the very high temperatures in the tropics, evapotranspiration is very high, and usable water is therefore often scarce even in areas of relative high rainfall. *Much of tropical Africa is therefore vulnerable to arid or semi-arid conditions, except for three regions: those parts of West and Central Africa that receive equatorial rainfall, parts of West Africa that receive monsoon rainfall, and parts of the East African highlands*. Moreover, as we noted earlier, African rainfall outside of the narrow equatorial rainforest band is highly variable, so that much of Africa is vulnerable to drought conditions. There is also evidence of a long-term decline in rainfall in the Sahel, which may be linked to anthropogenic climate change, both local (possibly resulting from deforestation and overgrazing) and global (resulting from greenhouse gas emissions).

Very little African agriculture is under irrigation, arguably because of problematic soils, topography, and lack of suitable water supplies. Only 4.0 percent of crop lands are irrigated, compared with 11.1 percent in Latin America, 35.1 percent in South Asia, and 51.8 percent in China (World Bank 1998, Table 3.2). In short, much of Africa is dry, vulnerable to drought, and without recourse to irrigation. It is, we should add, one of the most interesting and important practical questions for Africa's agricultural future to judge whether significantly more land could be the subject of cost-effective irrigation. If the current lack of irrigation is a matter of social custom, land-use patterns, public goods provision, and appropriate technologies, then much more land could perhaps be irrigated in the future, with important effects on productivity. If instead, the limited agriculture reflects intrinsic weaknesses due to the manifold factors that we have mentioned, the future improvements in productivity are likely to be deeply hindered by the continued dependence on rain-fed irrigation.

Soil is another complex issue. Soil quality is multidimensional (related to texture, capacity to hold water, nutrient content, and other factors) and also crop-specific. Moreover, the qualities of soil can be highly variable within a narrow geographical range. In some parts of the tropics, volcanic soils provide a rich nutrient base, so that high population densities are often found in well-watered volcanic zones, such as the island of Java, the islands of the Philippines, parts of the central Mexican

Valley, and parts of the highlands of East Africa. In much of Africa, however, soils are very poor. Much of Africa is heavily weathered, with very poor soils as a result, with a large concentration of oxisols in Central Africa.[11]

As is well known, the problems of soils are greatly compounded in rainforest environments since torrential rains leach the soils of nutrients. As a result, the great bulk of nutrients found in rainforest ecosystems are actually found above ground, in the plant growth itself, rather than in the soils. The soils maintain their fertility only by the rapid decomposition of dead plant material, which is then quickly recycled into new plant growth. When rainforests are cleared for agriculture, the nutrient cycle is broken, and the soils are quickly depleted of their nutrients, which is why shifting (swidden) cultivation has characterized traditional agricultural systems in rainforest ecozones.

The disease environment of tropical agriculture is another complicating factor. As we will discuss with regard to human disease, many veterinary disease vectors are concentrated in the tropics, since cold weather, and especially freezing, are barriers to vector reproduction and survival. Thus, much of African woodlands (the zone between the equatorial rainforest and the arid savannah both north and south of the equator) were effectively off limits to cattle raising until very recently because of trypanosomiasis (cattle sleeping sickness), transmitted by the tropical tsetse fly. In addition to animal diseases, plant pests are prolific, since they too are uncontrolled by freezing temperatures as in the mid-latitudes. Thus, various kinds of insect pests such as locusts are far more destructive in the tropical environment. Similarly, crop damage due to massive rodent populations unconstrained by winter months is also rife.

If we make a quick summary, tropical agriculture, especially food production, is faced with chronic problems of low yields and fragility due to low photosynthetic potential, high evapotranspiration, low and variable rainfall, highly weathered soils, veterinary diseases, and plant and animal pests. In Africa, these problems are especially severe. Large parts of equatorial West Africa are rainforest zones, with high very temperatures, fragile soils, extreme precipitation, and therefore extreme limits in food potential. These regions specialize in cash crops such as cocoa adapted to the humid tropical environment, and tend to be net importers of foodstuffs. Outside of the equatorial zone, a large part of the continent lies in semi-arid or arid zones, also difficult for food production because of water insufficiency and the ever-present risk of drought. The moderately watered woodland areas also suffer from serious pests, poor soils, and high temperatures. Much of the relatively successful agriculture takes place in the East African highlands, but East African populations are, as a result, relatively isolated from internal and international trade.

Infectious disease and African development

[11]Oxisols are "very old, highly weathered soils of low latitudes , with an oxic horizon and low CEC [cation-exchange capacity." (Strahler and Strahler, p. 460). "The level of plant nutrients under natural conditions are so low that the yields obtainable under hand tillage are very low, especially after a garden patch has been used for a year or two. Substantial use of lime, fertilizers, and other industrial inputs is necessary for high yields and sustained production." (Strahler and Strahler, p. 472).

Tropical populations have lower life expectancies at birth (LEB) than temperate-zone populations, and the effect seems to be true *even after controlling for per capita income levels*. In our cross-country growth equations reported below, we show that low LEB is highly predictive of slow economic growth, after controlling for initial income levels, economic policy, and a set of demography and geography variables. The (unweighted) average LEB of all non-African tropical countries in 1992 was 66.3 years, as opposed to 49.8 years in tropical Africa. This compares with an LEB of 70.4 years in the non-tropical countries. In a simple regression of life expectancy on per capita income and mean ambient temperature (as a measure of tropical conditions), we find that hotter climates display systematically lower life expectancies. The point estimate suggests a loss of 2.3 years of LEB for each 10 degree Centigrade increase in average annual temperature. We do not attribute this to the direct effects of heat on body stress, since the best evidence shows that populations can become well acclimatized to a very wide range of ambient temperatures, and that even hard physical work effort is not generally impeded by high temperatures except under extreme conditions.[12] Rather, we believe that high temperatures affect nutrition and disease ecology, which indirectly affect human morbidity and mortality. One key linkage is through endemic vector-borne infectious diseases. The evidence suggests that the burden of infectious disease is vastly higher in the tropics than in the temperate zones, both as a percentage of total disease burden (as measured by total DALYs) and in absolute DALYs per capita.[13]

Africa's health conditions are very poor even in comparison with the rest of the tropics.[14] With a life expectancy of 53.8 years in 1995, Africa has the poorest health status of any region of the world. The nature of the disease burden faced by Africans is significantly different from that faced by other regions: 42.5 percent of lost DALYs in sub-Saharan Africa are caused by infectious and parasitic diseases (Murray and Lopez 1996, p. 261), as compared with 28.9 percent in India (the next highest area in terms of the percentage of DALYs lost because of infectious diseases), and 2.8 percent in the European market economies.

The interactions of geography and disease burden are indeed extremely complex. Why Africa has been so extraordinarily vulnerable to many infectious diseases is not fully known. To understand the interaction of geography and disease, epidemiologists need to unravel an enormous number of channels of potential interaction. Climate may affect health by affecting nutrition, disease vectors, human behavior, prevalence of parasites, exposure to natural disasters, and so on. There are also significant feedback mechanisms from one factor (e.g., nutrition) to another (e.g., vulnerability

[12]Heat is debilitating when the body's heat load is non-compensable through sweating. This occurs when ambient temperatures are around or above body temperature, and when humidity is very high. In this case, heat stress can occur rapidly in association with heavy physical labor.

[13]DALYs are disability-adjusted life years. The burden of disease refers to DALYs lost due to disease or injury. This measure aims to combine morbidity and mortality into a single summary measure of disease burden. See Murray and Lopez (1996).

[14] For example, using 1965 data for a sample of 107 countries, the regression of log life expectancy at birth (LEB) on log income per capita (LY), percent of the country's land area located within the tropics (TR), and an Africa dummy (AF), yields the following result: LEB = 3.2 + .12 LY - .06 TR - .18 AF (R^2 = .75), in which all coefficients have p-values less than 0.1. These results, which are closely comparable to those based on 1995 data, indicate that income-adjusted life expectancy is relatively low in Africa, even by tropical standards.

to a specific infectious disease). Since very little is known about many of these interactions in the tropical setting, and since the quality of data on causes of death and morbidity are horrendous in most of Africa, we are not in a position to describe the disease ecology of the African tropics in any detail. We illustrate the core issues by looking at two infectious diseases of profound consequence for Africa, the traditional killer malaria, and the new epidemic killer, HIV/AIDS. Lessons from zoonotic diseases such as malaria no doubt shed light on other endemic infectious diseases such as yellow fever and chagas disease (transmitted by the mosquito *Aedes aegypti*), leishmanaisis (transmitted by the sand fly), trypanosomiasis (transmitted by the tsetse fly), schistosomiasis (transmitted by snails), and various helminth (worm) infestations, such as onchocerciasis (river blindness), roundworm, and hookworm.[15]

Malaria

Malaria is widely recognized as one of the most serious health problems faced by the region. It is estimated that one to two million Africans die from malaria each year out of a continent-wide total of roughly nine million deaths per year. Malaria is a parasitic disease caused by the protozoan plasmodium, which is transmitted among human hosts by an intermediate insect host, the mosquito of genus anopheles. When the female mosquito bites a human for a blood meal, it may transmit the plasmodium if it is already an infective carrier of the parasite, or it may absorb the plasmodium from a human host, if it is not yet infective. In the latter case, it may then transmit the disease to a new human host in a subsequent blood meal. There are four types of plasmodia (*P.falciparum*, *P.malariae*, *P.ovale*, and *P.vivax*) of which the *P.falciparum* is by far the most deadly. There are also several species of anopheles (including *An.gambiae*, *An.funestus*, *An.arabiensis*, *An.nili*, and *An.coustani*) of which *An.gambiae* is the most important vector of falciparum malaria.

Individuals that contract and survive repeated episodes of malaria gradually acquire partial or full immunity. In endemic communities, therefore, children have by far the highest rates of morbidity and mortality. However, even many adults in highly endemic regions exhibit clinical malaria, though generally with far less lethality than in children. Acquired immunity is, however, quickly lost if the individual leaves the malarial environment for several years or more. There is no vaccine or other long-term medical prophylaxis. Therapeutic treatments exist, but fail to reach a large proportion of affected individuals because of costs, availability, and knowledge, and many first-line drugs (chloroquine, mefloquine, fansidar) are losing their effectiveness as a result of the rapid spread of drug resistance.

Malaria has a complex biological cycle, since it exists in many stages both in the human and mosquito. The disease ecology of malaria depends not only the density of anopheles mosquitoes relative to the human population, but also on the mosquito longevity relative to the life cycle of the plasmodium within the mosquito. In order for a mosquito to become infective, it must first absorb

[15]On the mathematical biology of vector-borne infectious disease in general, see Anderson and May (1995), especially Chapter 14. On the public health perspective on tropical disease, see various essays in Jamison, *et al*. (1993). On the biology of hookworm, see Hotez and Pritchard (1995). They estimate that one in five in the world population suffers from hookworm, with a heavy concentration in the tropics, since the worm larvae need a warm and moist environment to survive and grow before infecting a human host.

the plasmodium in its sexually reproductive (gametocyte) stage from one human host, and then serve as an intermediate host during which the plasmodium reproduces within the mosquito and matures to a new infective (sporozoite) stage. It is only after this process is completed, which lasts from 10 to 20 days, that the mosquito can transmit the disease to a new human carrier. This latency period in the mosquito is of the same order of magnitude as the life span of the mosquito itself. If the mosquito dies before the latency period is completed, then it never becomes infective, even though it carries the parasite. The crucial biological fact for our purposes is that *the latency period is highly temperature-dependent*, with a much shorter latency period at higher ambient temperatures. In a cold climate, the mosquito inevitably dies before it becomes infective. In a hot tropical climate, the mosquito has a high likelihood of becoming infective before it dies, and therefore transmitting the disease to a new human host.

The force of infection increases with the prevalence of the mosquito relative to the human population and even more strongly with the longevity of the mosquito (which matters since longevity must exceed latency for the infection to be transmitted).[16] For this reason, malaria tends to be holoendemic (or "stable transmission") in hot climates; epidemic (or "unstable transmission") in warm but not hot climates such as the subtropics or lower tropical highlands, and absent in cool climates (such as above the 2000 m level in most of the tropics, or in most temperate zones).[17]

This crucial ecological point is consistent with evidence on reductions in the prevalence of malaria since World War II. In 1946, malaria extended to many subtropical regions, such as southern Spain and Italy, the Levant, and Central Asia. The U.S. Government and the World Health Organization spearheaded a global eradication campaign, with various phases, during the 1960s and 1970s. The campaign involved a mix of measures (which varied by region and over time), including mosquito control through DDT spraying, larval control, and intensified case management for infected individuals. The campaign was a failure relative to its initial bold goal of malaria eradication, but it did succeed in a limited range of areas, mainly the areas of the subtropics where malaria was still prevalent in 1946, such as southern Europe. Other notable successes included Hong Kong, Mauritius, and Singapore (which were greatly advantaged by their island geography),[18] and Malaysia, in which mosquito prevalence was easier to control for other reasons.

In sum, malaria was controlled in those ecological zones where the force of infection was least, specifically the subtropics rather than the tropics. The failure of Africa to control the disease

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[16]The force of infection is usually measured by the Basic Reproductive Rate (BRR) of the disease, which measures the number of new cases that result from the introduction of one new case into a population. When the BRR is greater than one, an epidemic or endemic disease pattern occurs; when the BRR is less than one, the disease extinguishes itself from the population naturally.

[17]Epidemiologists also speak of "stable" transmission, in which almost all individuals in the community contract the disease at an early stage of life, and of "epidemic" transmission, in which periodic outbreaks of the disease occur that lead to a sudden, pronounced increase in prevalence (as a result of excessive rainfall, for example). Hot tropical climates are characterized by stable transmission, while cooler climates are characterized by epidemic transmission.

[18]Islands are easier for vector control measures since the mosquitoes do not easily return once they have been eradicated.

is not mainly the result of poor public health measures, unresponsive governments, or the poverty of Africa, but rather of the natural environment, in which mosquito longevity exceeds the latency period of mosquito infectivity. Actually, Africa's malaria problem is the world's worst for additional ecological reasons. It turns out that *Anopheles gambiae* is indigenous to sub-Saharan Africa, and has a much smaller population (if any) in other tropical regions. *Anopheles gambiae* is by far the most infective vector of falciparum for reasons related to the detailed biology of the mosquito species.

The development implications of malaria and other vector-borne diseases, are hard to ascertain with precision, though they are likely to be very serious. Numerous studies have estimated the microeconomic costs of the disease, including both the direct and indirect costs. Personal medical care costs, including expenditures on medicines, treatment fees, transportation to health facilities, and prevention measures such as bednets and insecticides, have been estimated to range between $5 and $75 per household per year (Chima and Mills 1998) in Africa. Furthermore, there are public health expenditures on prevention and treatment of the disease, which vary widely across the region and are difficult to estimate as the symptoms of the disease often make it difficult to identify. Estimates of the loss of productivity associated with malaria vary widely. Chima and Mills (1998), in a recent review of studies that estimate time lost to both the illness itself and to the care of sick family members, report a range of 1 to 5 days of productivity loss per person to malaria due to adult illness, and 1 to 4 days loss per sick child. The illness also reduces the returns to investments in schooling, as it causes children to miss school days, and is believed to diminish long-term cognitive performance. Incorporating both direct medical costs and costs of lost productivity, Shepard *et al* (1991) estimate that the annual economic burden of malaria in Africa was $0.8 billion in 1987, representing 0.6% of Africa's GDP. They projected a rise due to increasing case severity and drug resistance, to 1% of GDP in 1995.

We hypothesize that the *indirect* costs of falciparum malaria are much higher than the direct costs, though this is merely a conjecture based on macroeconomic evidence. Sachs and Gallup (1998) have found in cross-country growth equations that falciparum malaria is associated with reduced annual GDP growth of more than one percentage point, after controlling for other standard policy and structural variables. We surmise that these high costs come not through the microeconomic effects, but rather by raising the barriers of technical diffusion and foreign investment into endemic malarial regions. Historical accounts of Africa's interactions with the rest of the world in the past 500 years repeatedly stress that malaria was a major barrier -- perhaps the major barrier -- to Africa's normal integration into the world economy. Until the advent of quinine in the second half of the nineteenth century, Europeans could barely survive in coastal settlements, much less venture into the interior. As of 1790, there were only around 25,000 Europeans living in all of continental Africa, of which an estimated 21,000 (84 percent), lived in the temperate-zone Cape Colony! (Hugon, 1991, p. 18).

Hall (1996) says this about the period of Portuguese exploration and colonization on the African coastline:

> Eastern Africa and western India were the obvious places where a good harbor and some surrounding land might be seized then declared a Portuguese possession. Africa, however,

> had already proved to be infested with deadly fevers: the Kilwa fort . . . had to be abandoned after only seven years. On the mainland further south, small trading stations set up at Sofala and Mozambique were intended to give succour to ships which had rounded the Cape, but these ships often discovered more dead and dying on shore than they were themselves carrying. (P. 214-5)

Similarly, Thomas (1997) cites historian C. L. R. Boxer as pointing to malaria as one of the main reasons why Portugal did not found a colony in Luanda (Angola) in the sixteenth century. And of course nineteenth century explorer David Livingstone cited quinine, together with the breech-loading rifle, as the vital tools in his mission to "civilize" Africa.

Malaria continues to present serious obstacles to foreign investment and tourism in many parts of Africa. Foreign businessmen lack the immunity to malaria acquired by African adults who have experienced repeated bouts of the disease since early childhood. Prophylaxis via existing medicines is imperfect, and often not feasible for prolonged stays beyond a few weeks. Similarly, malaria presents an obstacle to Africans traveling abroad for prolonged stays, since their acquired immunity will be lost within a couple of years when not boosted by repeated infection.

HIV/AIDS

HIV/AIDS is perhaps the single most daunting health problem currently hanging over Africa's economic future, even more daunting than malaria. From 1985 to 1995 over four million Africans died of AIDS, and nearly ten million more deaths are expected by 2005. Of the greater than 30 million people in the world living with HIV infection, 21 million are in sub-Saharan Africa. Among HIV-infected people in the world, 6 out of 10 men, 8 out of 10 women, and 9 out of 10 children live in Africa. In 1998 an estimated 600,000 newborns in Africa will be HIV-infected; many more will be infected as infants through breastfeeding, which remains for many a better nutrition option than relying on costly infant formula consumed with unsafe water. AIDS has greatly jeopardized the economic and social futures of 8 million African children who have been orphaned by the disease. Nearly half of the world's 16,000 new HIV infections per day occur in Africa, suggesting a continuing epidemic of AIDS cases in the future given the lengthy time lag (about eight to ten years for adults) between infection and the onset of clinical symptoms. As over 80 percent of AIDS deaths have occurred among 20-49 year olds, the epidemic is offsetting decades of normal improvement in life expectancy in several African countries (Bloom et al., 1996, UNAIDS 1998).

HIV infection varies considerably across countries in Africa. Surveillance data collected among representative samples of pregnant women suggest that one in four adults in Botswana, Zambia, and Zimbabwe is infected, with rates approaching one in three in a number of urban areas. By contrast, HIV prevalence is considerably lower in Angola (2.1 percent), Equatorial Guinea (1.2 percent), and Senegal (1.8 percent). Complicating the HIV problem in Africa is the fact that several types and subtypes of the virus are spreading at different rates in different parts of the continent. At least one subtype of the AIDS virus (HIV-I-C) is rapidly spreading throughout southern Africa and is replacing other subtypes already common in East Africa.

Because of its economic, social, and cultural conditions, Africa has been and continues to be extremely vulnerable to the spread of HIV. Unlike malaria, it is more difficult and conjectural to link geography to the virulence of the current AIDS epidemic. Specific factors that underlie Africa's extreme vulnerability include: high rates of multiple sexual partnering and of sexually transmitted diseases; continued widespread use of untested and contaminated blood and blood products and non-sterile medical practices; reliance on breastfeeding, which carries a 10-14 percent risk of HIV transmission from an infected mother to her child;[19] low rates of condom use; low levels of education; and very high proportions of the population in the sexually active years (discussed later). In addition, large numbers of intra-continental migrants and refugees and high rates of urbanization (especially young men seeking seasonal work) contribute to the spread of HIV through increased anonymity and separation from family.

HIV/AIDS imposes a heavy economic burden on many African economies. Notwithstanding the inaccessibility of the expensive ($16,000 per year) "drug cocktails" currently used to treat those infected with HIV in wealthy industrial countries, the cost of detecting HIV infection and treating its clinical manifestations (for example, pneumonia, tuberculosis, diarrhea, and fever) is quite significant, well in excess of per capita public expenditures on health care in Africa (between $10 and $15 per year). Even access to health care centers is extremely limited in many rural areas of Africa, and transportation costs for those seeking care can be a nontrivial share of household income. There are currently no vaccines, cures, or inexpensive treatments available for HIV infection, and none in sight due to the scientific complexity of the HIV and its ability to mutate.

HIV infection is also exacerbating the burden of other major diseases. As the single largest risk factor for the progression of tuberculosis infection from primary/latent to active, HIV is also contributing to the resurgence of tuberculosis as a major disease in Africa. An estimated 12 million Africans are infected with both HIV and mycobacterium tuberculosis. In 1990, there were over 7 million cases of tuberculosis in Africa, and over 500,000 deaths. Like malaria and HIV, tuberculosis also has a great proclivity for mutating into drug-resistant strains that are extremely costly to treat, if they can be treated at all.

Perhaps even more important than the direct medical costs of AIDS, however, are the indirect costs embodied in the loss of income and output among those affected. Because heterosexual sex is the dominant transmission category for HIV, AIDS tends to disproportionately afflict working-age adults, greatly exacerbating the economic burden imposed by the medical care costs associated with the disease. Estimates, based on macro-simulation models, of the impact of AIDS on economic growth in Tanzania and Malawi by Cuddington (1993) and Cuddington and Hancock (1994) find an average reduction of GDP per capita growth of 0.25 percentage points per year. Using similar models, Over (1992) estimates a reduction of 0.15 percentage points in sub-Saharan Africa. By

[19] Recent trials have demonstrated that mother-to-infant transmission can be reduced by up to 50 percent through the use of oral ziduvidine (AZT) by mothers in resource-poor settings. Although the cost of this drug protocol is roughly $70 per treatment, the UN system has succeeded in persuading its producer, Glaxo-Wellcome, to negotiate agreements with different countries to hopefully reduce that cost. However, most African countries have yet to negotiate such agreements. Also, there are ancillary costs associated with HIV testing and counseling that may make the full cost prohibitively expensive for many people, given the severity of poverty in Africa.

contrast, Bloom and Mahal (1997) examine cross-country data from 1980 to 1992 and find no evidence of a statistically significant effect of AIDS on the growth rate of income per capita; however, their point estimates are negative and comparable in magnitude to those reported by Over (1992).

Africa's HIV/AIDS epidemic may also have important consequences for poverty and income inequality. The early data from Africa suggested a positive association between HIV infection and affluence (presumably because multiple sexual partnering and the demand for commercial sex increase with income). However, more recent data reveal an emerging and intensifying linkage between HIV infection and poverty, mainly because the uneducated have the least access to knowledge about behaviors that put them at high risk for contracting or transmitting HIV. HIV thus has considerable potential to further immiserize Africa's poor.

Transport barriers and African development

Poor agricultural conditions and high disease endemicity would be barriers enough to African growth, as they have been in other parts of the tropics. In fact, Africa's situation is made dramatically worse by the continent's remarkable disadvantages in transport costs compared to other regions of the world. Among Africa's transport difficulties include seven main factors: (1) large distances from major world markets in the northern mid-latitudes (a common plight of the tropics); (2) separation from Europe by the vast Sahara desert (larger in area than the continental United States); (3) a very small coastline relative to land area;[20] (4) an unusual shortage of natural ports along the coastline; (5) populations generally far from the coast; (6) the highest proportion of landlocked states of any continent (and of the proportion of the population within landlocked states); and (7) the absence of rivers which are navigable by ocean-going vessels into the interior of the continent (such as the Rhine, the Mississippi, the Amazon, and the Yangtze Rivers, in other continents). Earlier research by one of us (Sachs) has demonstrated that differences in transport costs, appropriately defined, can help to explain differences in overall growth performance.

Adam Smith made the point about Africa's trade difficulties 222 years ago in Book 1 of the *Wealth of Nations*. First, Smith stressed the importance of sea-based trade as critical to an extensive division of labor:

> As by means of water-carriage a more extensive market is opened to every sort of industry than what land-carriage alone can afford it, so it is upon sea-coast, and along the banks of navigable rivers, that industry of every kind naturally begins to subdivide and improve itself, and it is frequently not till a long time after that those improvements extend themselves to the inland part of the country.

He then drew implications for Africa and Central Asia:

[20]Remarkably, Western Europe has about one-eighth the land area of Africa (3.5 million km^2 compared with 29 million km^2), but Western Europe's coastline is about 50% longer (54 thousand km compared with 35 thousand km).

> All the inland parts of Africa, and that part of Asia which lies any considerable way north of the Euxine [Black] and Caspian seas, the antient Sycthia, 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 . . . There are in Africa none of those great inlets, such as the Baltic and Adriatic seas in Europe, the Mediterranean and Euxine seas in both Europe and Asia, and the gulphs of Arabia, Persia, India, Bengal, and Siam, in Asia, to carry maritime commerce into the interior parts of that great continent . . . (p. 25)

As Table 2 demonstrates, Smith's concerns about "inland" Africa continue to apply to the current distribution of the population within the continent. Only a small proportion of Africa's population, around 19 percent, lives within 100 km of the coast, and this number changes little, to a mere 22 percent, if we also include populations proximate to ocean-navigable rivers. This compares with 67 percent of the U.S. population near the coast or ocean-navigable rivers and 89 percent in Western Europe. Africa's low percentage seems to be due to three factors: (1) the continent is very large, so that land area relative to coastal area is small in comparison with a smaller region such as western Europe; (2) much of the population lives in the interior highlands, presumably attracted there by agricultural considerations of cooler temperatures and better precipitation; and (3) there are no extensive navigable rivers that run from the coast to the interior of the continent, such as the Mississippi or St. Lawrence seaway system in the U.S., the Rhine in Europe, and the Yangtze in China.[21] These problems are further compounded by the political boundaries in the continent, which have left no fewer than 14 landlocked countries with populations in excess of 1 million, and fully 28 percent of the sub-Saharan population living in landlocked economies.

We also report population densities near to the coast (within 100 km) and inland (beyond 100 km). Based on earlier research reported in Gallup and Sachs (1998), we expect that a high coastal population density supports economic growth, by facilitating a richer division of labor. In contrast, it appears that high *inland* population densities are neutral or detract from economic growth. Isolated populations are unable to enjoy a high division of labor because many of the inputs needed for modern production must come from international trade. High transport costs frustrate the needed trade linkages, and keep the inland market too small to support a refined division of labor. From the table we see that Africa's coastal population density is the lowest of any region in the world, for reasons we have already noted: an unusually high proportion of the population is settled in the interior, where agriculture prospects are better. Inland population densities are also fairly low, but high relative to coastal population densities.

The bottom line is extraordinarily high transport costs, especially over land within the continent, but also from low-volume sea ports to major markets in Europe, the U.S., and Asia. According to World Bank estimates, for example, the cost of shipping a twenty-foot-equivalent (TEU) container from the West African port of Dakar to landlocked Bamako, Mali, a distance of around 1,000 km, was equal to $770 in 1995, which is approximately 45 percent of the cost of shipping the container from Dakar to a Rotterdam ($1,610), a shipping distance of around 5,000 km!

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[21] All of the major rivers, including the Nile, the Niger, the Congo, the Zambezi, have sharp cataracts on their traverse to the sea, which make these rivers non-navigable by ocean-going vessels, at least in the absence of large-scale canal building to bypass the cataracts.

Moreover, the price of a container shipment from Senegal to Rotterdam was around the same cost as a container from Singapore to Rotterdam, despite the fact that the latter distance (via the Suez Canal) is roughly 17,000 km. This high cost of sea transport from Africa per shipping kilometer probably reflects the relatively low volumes of trade, and lesser competitiveness of Africa's ports.

One convenient summary measure of transport costs on imports is the ratio of CIF import prices (which include cost of insurance and freight) to FOB import prices. The CIF/FOB ratio is much higher in Africa than for any other region. The unweighted CIF/FOB ratio in 1995 for African countries was 1.195 (19.5 percent higher CIF prices than FOB prices), compared with 1.098 in East Asia, and 1.106 in Latin America.

III. Demography of Africa

Africa's population grew at an average annual rate of 2.6 percent between 1950 and 1995 and more than trebled during that period, reaching 561 million. This rate of increase is historically unprecedented among major regions of the world over comparable periods of time. Asia and Latin America, the other main regions of the developing world, also experienced rapid population growth during the past half century, but at lower rates of 2.0 and 2.3 percent respectively (UNPOP 1996). Africa's share of world population, was fairly constant and below 5 percent from 1820 until the 1930s, but has increased steadily since, reaching over 8 percent in the early 1990s (Maddison 1996).[22] A rising share of world population, coupled with a declining world income share, is one of the most important stylized facts of Africa's post-Independence experience (Figure 5).

Population density, urbanization, and ethnic fractionalization

Most of Africa is sparsely populated, with an average population density of 25 persons per square kilometer (as compared with 148 for Asia and 21 for Latin America). Africa's low average population density reflects the weighted combination of vast expanses of almost empty desert (5 people per square kilometer in Chad), large areas of sparsely populated savannahs (with weak agricultural potential), and few areas of relatively dense population, mainly in the East African highlands near the Great Lakes, especially Burundi and Rwanda. Other regions of relatively high population density include the section of coast running from southern Côte d'Ivoire to Nigeria, and the Indian Ocean island economies (e.g., Reunion and Mauritius).

Low levels of population density in Africa are reflected in correspondingly low levels of urbanization. Only 31 percent of Africa's population lives in urban centers (World Bank 1998). This contrasts sharply with Latin America's high level of urbanization (74 percent), but is comparable to Asia's rate (30 percent). Furthermore, African urban centers are small by world standards. The largest sub-Saharan African city, Lagos, ranks 19th among the world's largest cities. Some capital cities,

[22] Africa's rising share of world population can be contrasted with its declining share of world population from 1700 and 1900, as population growth accelerated in Europe and the slave trade resulted in an absolute depopulation of the continent from 100 million in 1700 to a low of 90 million in 1850 (Tarver 1996, Manning 1987, Austen 1987).

such as Gaborone in Botswana, are little more than trading posts by world standards. Despite lower fertility rates in Africa's urban centers, urban population growth is proceeding more rapidly than in any other region of the world (about 5 percent per year since 1965) as a result of large-scale migration from rural areas (Cohen 1993).

Two main factors, at least, would seem to explain Africa’s very low rates of urbanization. First, of course, is the low productivity of agriculture. Local food production cannot support large adjoining urban areas. Many of Africa’s urban areas must be fed, at least in part, from international imports, rather than a local hinterland. Second, much of the population is in the highlands or at least away from coasts and navigable rivers, while urbanization is strongly favored by a coastal (or riverine) location, because urban areas need low transport costs to facilitate trade. Africa’s urban areas have therefore tended to result from two conditions: either as administrative and political capitals, economically dependent on government spending rather than their own international exports earnings; or as service centers for mining economies. In this case too, the urban areas do not export to world markets, but rather live on the foreign exchange earned in the mining region. Thus, the highest rates of urbanization in Africa as of 1994 are found in: Congo, an oil exporter (58 percent); Mauritania, an iron ore exporter (52 percent); South Africa, a gold and diamond exporter (50 percent); Gabon, an oil exporter (49 percent); Cameroon, an oil exporter (44 percent); and Zambia, a copper exporter (43 percent).

Low population densities and low rates of urbanization tend to raise the costs of providing infrastructure services such as road networks, telephone systems, container port services, and urban sewerage, and are therefore important factors, in addition to low income, in accounting for the very poor state of affairs of African infrastructure. In general, Africa's infrastructure (other than South Africa and Mauritius) is among the worst in the world. As one example, the total length of paved roads in all of sub-Saharan Africa outside of South Africa was estimated to be 171,000 km as of 1992, about 16 percent *less* than the total of paved roads in Poland alone, which stood at about 206,000 km. Poland has a mere 1.4 percent of the corresponding land area, and just 8 percent of the corresponding population, and of course is itself not a high-income country. Moreover, the World Bank estimates that just 39 percent of this sparse network of paved roads were actually in good condition. As another example, Africa had approximately 2.4 million main telephone lines in 1995, or 0.47 lines per 100 households, about the same number of phone lines as in Norway (with less than one percent of Africa’s population).

Africa’s demography, together with its geography, no doubt also account for a factor much discussed in recent writings on African growth: the high extent of linguistic diversity in Africa. This linguistic diversity has been taken as a measure of strong ethnic cleavages in African societies and a barrier to trade, and thereby as a potential explanation of Africa’s growth shortfall. We are skeptical of using linguistic diversity as an explanatory variable in this way, since such linguistic diversity is itself a function of demographic and geographical variables that have a large and direct effect on economic performance. We find that African countries *do not* have an especially high rate of linguistic diversity compared to other regions of the world, once we account for tropical environment (which, by restricting mobility, may plausibly promote linguistic diversity), the low proportion of the population near the coastline, the low population density, and a dummy variable for Latin America and the Caribbean (reflecting the extinction of many ethnic and linguistic groups following the Spanish colonization and the accompanying demographic collapse).

Delayed demographic transition

While most of the developing world has undergone a process of demographic transition, from regimes of high fertility and high mortality to ones of low fertility and low mortality, this process has stalled or progressed exceedingly slowly in Africa. As in most of the developing world, mortality declined sharply in Africa with the introduction of modern public health practices and health technologies after World War II.[23] The impact on child survival was particularly large, because antimicrobials are often powerful treatments for infectious diseases such as acute respiratory infections and diarrheal disorders. Yet, unlike other developing regions, corresponding declines in fertility have not occurred to any appreciable degree (until, perhaps, very recently).

The combination of falling death rates, concentrated in the youth cohort, and stable birth rates have two principal demographic consequences:[24] rapid population growth and a skewing of the age structure toward the young ages (see Figures 5, 6, and 7). Indeed, population growth averaged 2.3 percent in the 1950s, 2.4 percent in the 1960s, 2.7 percent in the 1970s, and 2.9 percent from 1980 to present. Asia and Latin America have undergone a reverse process such that population growth has fallen, from rates of 2.4 and 2.7 percent in the 1960s to rates of 1.5 and 1.7 by the 1990-95 period. Africa's current rate of population growth, which translates into a population doubling time of just two decades, is huge by historical and comparative standards, and is certainly unsustainable over the long run.

Accelerating population growth has resulted in a swelling of the youth cohort and a consequent increase in the ratio of the dependent to working-age population (Figures 6 and 7). The working-age population in Africa (15 to 64 year-olds) is roughly half of total population and has actually fallen slightly as a share of the total population since 1950. This contrasts dramatically with the higher (60 to 70 percent) and generally rising share found in other regions. Cross-country data indicate that the number of 15 to 64 year-olds in Africa grew at almost an identical rate to the total population from 1965 to 1990. This stands in sharp contrast to the non-African world, in which the working-age population grew, on average, 0.35 percent per year faster than the total population over the same period. This difference, between African and world trends, accounts for Africa's high youth dependency ratio compared to other regions. Africa's youth dependency burden poses a significant impediment to the growth of income per capita, since labor force participation, productivity, and savings are low among the dependent-age population, relative to both the working-age population and to their consumption and investment requirements.

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[23] These technologies include the introduction of chloroquine, sulfa drugs, and powerful antibiotics such as penicillin and streptomycin, along with the use of DDT, which became available in 1943.

[24] While life expectancy increased by roughly 20 percent from 1960 to 1995, infant mortality fell by 40 percent, from 159 to 96 deaths per thousand births, over the same period.

Table 3a reports total fertility rates and infant mortality rates across major world regions and demonstrates Africa's divergence from demographic trends elsewhere. It is striking that African fertility is so closely comparable to that observed in Asia and Latin America in the 1950s. Africa's demographic uniqueness, therefore, is *not* in the *level* of fertility but in the *persistence* of such a high level of fertility in the face of mortality declines. High fertility is the most salient feature of the continent's stalled demographic transition and the cause of its accelerating population growth and remarkably young age structure.

Contraceptive use increased modestly from a prevalence rate of 5 percent in 1960 to 17 percent in 1990. East Asian contraceptive prevalence increased from 13 to 75 percent over the same period, and even in poorer South Asia, usage increased from 7 to 41 percent (Bongaarts 1994). Table 3b summarizes fertility and contraceptive prevalence data collected in household surveys in 17 African countries in the late 1980s and early 1990s. The most striking feature of Table 3b is that, among most countries, not only total fertility rates, but also "wanted" fertility rates, are above 5.0. Thus, the mere provision of contraceptives is, by itself, unlikely to reduce fertility significantly in Africa. Africa's population problem is one of high desired fertility, not unmet need for contraceptive services. Unlike all other developing regions, eliminating unwanted fertility would have negligible to small effects on the achievement of replacement fertility levels (2.1 children per woman). Indeed, Africa's low levels of unwanted fertility are consistent with the pattern of extremely low rates of contraceptive prevalence among married women. Rather, high fertility in Africa probably reflects a combination of low socioeconomic development (i.e. education, gender inequality) and sociocultural practices that reinforce preferences for large families.

There is an extensive literature on the determinants of fertility in Africa (Boserup 1985, Caldwell and Caldwell 1987, Caldwell 1991, 1994, Bledsoe 1994, Ainsworth *et al* 1995, Pitt 1995). This literature notes that, even after accounting for differences in infant mortality, income, education, and urbanization, Africa typically remains a positive outlier (Chesnais 1992, Cohen 1993).[25] Explaining why this is so is an important research question.

High fertility in Africa appears to reflect a variety of factors. First, rural African children continue to be viewed as the current generation's main source of old age insurance. In rural areas market activity is limited and corresponding financial institutions are poorly, if at all, developed and therefore limit the scope for monetary savings for old age. Formal labor market activity is also limited, which tends to reduce perceived fertility costs. Children are also an important source of labor in rural settings, assisting both in small-holder cash crop agriculture (e.g., coffee) and in household work (Caldwell 1982, 1991). Second, high fertility in rural Africa is reinforced by sociocultural institutions and practices that create incentives for large family sizes. The long history of low population densities and the ever-present struggle for mere survival in an environment of drought, low yields, slave trade, and infectious disease no doubt imbued cultural practices and social institutions in Africa with powerful norms of high fertility and large families, and these norms and practices have changed only slowly in the face of rapid declines in infant mortality rates, and rising population densities which limit the availability of farm land to divide among the children.

[25] See Chesnais (1992) for a discussion of variance of socioeconomic "thresholds" and the onset of fertility decline in a not exclusively African context.

Social structures that promote high fertility include child fosterage, communal-based land tenure, and polygyny. The common practice of children being raised in households headed by someone other than their parents reduces the costs of raising children. Caldwell and Caldwell (1987) report that in West Africa as many as one-third of all children live with people other than their parents, a feature also emphasized by Bledsoe (1994). In addition, communal-based land tenure places a premium on family size as village leaders distribute land according to family "need." In a system where private title to land is unavailable, yet land remains the primary factor of production, a large family is the best way to acquire access to increased land resources. Finally, polygyny continues to be widely practiced in Africa, especially West Africa, and dilutes conjugal bonds. Each wife in a family encompasses a discrete economic unit, responsible for the care of her children. Husbands, while having access to the fruits of their children's labor, have little responsibility for their welfare.

To test some of these hypotheses, we assembled an unbalanced panel dataset for 103 countries at six points in time between 1960 and 1990. We regressed the log of the total fertility rate on income and income squared, infant mortality, schooling, gender gaps in schooling, geography, time, and financial market depth (measured by the ratio of liquid liabilities to GDP). The results reveal that fertility tends to increase with infant mortality and tropical location. The results also reveal that fertility has tended to decline over time and that it decreases with income, education, the degree of gender equality in schooling, and financial market depth. In addition, there is considerable fertility variation across geo-climatic regions. Finally, an Africa dummy has a small but significant positive coefficient, consistent with other literature on the subject. These results imply, however, that high fertility rates in Africa will decline as economic and social development proceeds.

Implications of demographic change in Africa

The dominance of youth in Africa's population creates enormous momentum for continued population growth. Even if the total fertility rate were immediately reduced to the replacement level of 2.1 children per woman, Africa's population would still increase to more than one billion (that is, by over 50 percent) during the next century, as today's children progress through the prime childbearing years (Bongaarts 1997). Correspondingly, dependency ratios would remain high for decades to come, depressing the growth of income per capita, as discussed below. Much of the most rapid population growth is occurring in regions least suitable for rapid economic growth: rural, landlocked and arid areas of the continent, most of which are already under tremendous demographic stress (see Gallup and Sachs, 1998). Rising population densities in these low-productivity interior regions not only threaten economic growth, but also intensify environmental degradation (deforestation, soil erosion, depletion of water aquifers).

Rapid population growth will continue to impose a great burden on African governments to provide basic education. Indeed, Africa is the only region of the world in which enrollment rates fell during recent decades, though the data are of uncertain quality. According to World Bank (1997) data, primary school enrollment rates fell in sub-Saharan Africa from 1980 to 1993, from 68 to 65 percent of the primary school age cohort for females and from 90 to 78 percent of the cohort for males. Nonetheless, increased numbers of primary school graduates (due to overall population increases) has led to increased demand for secondary education, which has also strained education budgets. Moreover, it is extremely difficult to improve the low quality of education in Africa when there is so much pressure to serve ever-expanding populations. For example, the correlation is 0.52 between the number of students per primary school teacher and the ratio of the dependent to total population in 1990 for the 106 developing countries with data. Spending per primary school student in Africa, at an average of $126 (1985 PPP) per annum, is only 45 and 30 percent of levels found in Latin America and Asia. The number of students per teacher, at 43, is much higher than levels in Latin America (28) and Asia (32) (Barro and Lee 1997).

IV. Evidence on African Growth from Cross-Country Growth Regressions

Empirical growth equations

Empirical cross-country growth equations are now a well established tool among development economists, and were employed previously by Sachs and Warner (1997) in the case of Africa. This paper extends those earlier results, including new demographic and geographical data among other things. As described in detail in Barro and Sala-i-Martin (1995) these models are typically based on the Solow-Swan or Ramsey models of output per worker. Equations (1) and (2), below, capture the essence of the model:

$$g_y = a(y^* - y_t) \qquad (1)$$

where g_y is the growth rate of output per worker, α is the rate of convergence to the steady state and is between 0 and 1, y* represents the steady state level of income per worker, and y_t represents current income per worker. Equation (1) implies that a country's rate of growth at any given time is proportional to the difference between its current income, y_t, and its steady-state level of income, y*. The poorer a country is with respect to its steady state, the faster it can be expected to grow -- the conditional convergence hypothesis. The higher a country's steady-state level of income, the faster its expected rate of growth for a given level of initial income.

Empirically, the steady state is assumed to be determined by a set of factors *X*, according to:

$$y^* = Xb \qquad (2)$$

where *X* is a matrix of variables that typically include measures of human capital, health status, natural resource abundance, and economic policy.

Substituting (2) into (1) and adding an error term ε yields the following estimable equation:

$$g_y = ay_t + abX + e \qquad (3)$$

Although the foregoing model refers to output per worker, economic growth is usually operationalized in terms of output per capita, which is preferable as a measure of welfare. Following Bloom and Williamson (1998), we account for this difference by noting the following identity:

$$\frac{Y}{P^T} = \frac{Y}{P^W} \cdot \frac{P^W}{P^T} \tag{4}$$

where P^T is total population, P^W is the working-age population (ages 15 to 64, for which more accurate data are available for more countries than is true for labor force data), and Y is aggregate output. Taking differentials we have:

$$g_{\tilde{y}} = g_y + g_{workers} - g_{population} \tag{5}$$

where $g_{\tilde{y}}$ is the growth rate of GDP per capita and g_y is the growth rate of GDP per working-age person. Incorporating this into the standard neoclassical model gives us the following estimable equation (with $g_1 = - g_2 = 1$):

$$g_{\tilde{y}} = a\ y_T + a\ b\ \ X + g_1\, g_{workers} - g_2\, g_{population} + e \tag{6}$$

The introduction of the latter two terms in equation (6) is unnecessary in demographically stable populations, i.e., populations in which the growth rates of all ages groups are identical. However, most populations of the world are highly destabilized. Including the population growth rate and the growth rate of the economically active population accounts for the fact that a high dependency ratio implies a lower per capita output, as the contribution of the dependent population to output is less than its consumption. In addition, there is some evidence of a negative association between dependency ratios and savings rates (Higgins and Williamson 1997, Kelley and Schmidt 1996). Populations with high rates of fertility have large numbers of young dependents who need to be fed, clothed, housed, educated, and provided with medical care, but who contribute relatively little to aggregate output. As the size of the working-age population increases relative to the total population, the productive capacity of the economy expands, on a per capita basis. This expansion, which may occur either because of increased employment per capita or increased savings per capita, creates the potential for more rapid growth of income per capita.

If there are no direct effects of population growth on steady state income, the coefficients on $g_{workers}$ and $g_{population}$ should be 1 and –1 respectively. However there is an extensive literature on both possible positive (e.g. Boserup 1981, Kuznets 1973) and negative (Coale and Hoover 1958, Ehrlich 1968) effects of population growth on steady-state income. We therefore do not constrain the coefficients either to be unity or to equal each other in absolute terms.

In addition to the demographic variables, we must specify the *X* vector of explanatory variables. In general, in the large cross-country growth literature, this list of variables include: policy variables (e.g., trade policy, fiscal policy); indicators of the quality of public institutions; and proxies for human capital (e.g., years of schooling) and public health (e.g., life expectancy at birth). Our specification adheres to this literature.

Our strategy is to add two kinds of geographical variables (one of which is also demographic in nature) related to the tropics, and related to transport conditions. In particular, we introduce the share of the country's land area in the geographical tropics as one explanatory variable (expecting, of course, that tropical land area will be associated with lower steady-state per capita income, y*, and with lower growth); we also introduce population density near the coast (less than 100 km) and population density away from the coast (greater than 100 km) as additional explanatory variables. As discussed in Gallup and Sachs (1998) we expect that high population density near the coast is beneficial for growth and steady-state income (by expanding the size of the market, and the division of labor), while high population density away from the coast is either neutral or negative for growth and steady-state income, since remote regions are less likely to urbanize and industrialize, and thereby take advantage of an increased division of labor, while decreasing returns to scale associated with traditional agriculture are likely to reduce steady-state income, y*. We also introduce the ratio of the length of a country's coastline to its land area as an additional indicator of access to international trade.

We are especially interested in the coefficient on life expectancy at birth (our proxy for health status), which has a strong connection to both Africa's geography and demography. Although it is not an ideal measure of health, it is widely available and widely used in this context. We interpret it as capturing possible effects of health on economic growth that may operate through lower morbidity (i.e., a more productive labor force), higher returns to investments in human capital (directly because of increased longevity), and increased savings at all ages for a longer period of retirement.[26]

Econometric results

We report results from a standard cross-country specification based on data for 73 African and non-African countries from 1965 to 1990. Table 4 describes the data.

Column 1 of Table 5 reports the results for a "naïve" cross-country regression that excludes the geography and demography variables. We include only six variables (initial income, schooling, financial market depth, openness, quality of institutions, and public savings) as well as an Africa dummy. Despite this relatively parsimonious specification, the regression explains 71 percent of the cross-country variation in growth rates. In keeping with most other studies (e.g., Barro 1997, Sachs and Warner 1995), the coefficients on openness, institutional quality, and public savings are positive and significant, suggesting the importance of economic policy and institutions as factors in economic growth. Initial income has a negative and significant coefficient (suggesting conditional convergence). The schooling and liquidity coefficients are both positive, but not very well determined. Given the marginal significance of the schooling coefficient in column 1, and its insignificance in other specifications not reported here, we drop the schooling variable in order to

[26] The theoretical models and empirical results discussed here do not address some rather thorny issues related to reverse causality. See Bloom, Canning, and Malaney 1998 for a detailed treatment of these issues and for evidence that the basic findings presented here are upheld when some of the potentially endogenous variables analyzed here are appropriately instrumented.

increase our sample size to 73 countries.[27] Column 2 reports estimates for the modified specification on this larger sample.

Despite the considerable explanatory power of the policy variables, the Africa dummy variable is negative and highly significant in both columns 1 and 2. The coefficient in column 2 suggests that, other things equal, income per capita grew 2.1 percentage points more slowly in African economies than in non-African economies over the 1965 to 1990 period.[28] This result is also consistent with results reported in other studies and suggests that other influences on growth, not captured in the specification, are operative in Africa (Barro 1991, Easterly and Levine 1998, Temple 1998). This has led some researchers, such as Easterly and Levine, Temple, and Collier and Gunning (1998), to posit that social characteristics, such as ethnolinguistic heterogeneity and stocks of social capital, may be key "missing factors" in Africa's poor growth performance.

We augment the "naïve" regression in column 2 with geography and demography (including health) variables. The results are reported in column 3. We control for age structure as described in the previous section. We also enter two pure geographic variables: (1) the percentage of a country's land area in the tropics and (2) the ratio of coastline distance to land area. Including these variables in the empirical specification dramatically reduces the magnitude of the coefficient of the Africa dummy and eliminates its statistical significance. This result suggests that the augmented specification better captures the fundamental processes underlying economic growth, both in Africa and elsewhere. Note also that the coefficients on life expectancy, the working-age population, and the coastline-to-land-area ratio are positive and significant. The coefficient on tropical coverage is negative and significant, while the coefficient on overall population growth is negative and nearly significant. The results on the policy variables are qualitatively unchanged by the introduction of the geography and demography variables. In column 4, we impose the (statistically supported) restriction that the coefficients on the growth rates of overall population and working-age population are equal in absolute value, with little effect on the other results.

Column 5 introduces two additional variables that lie at the intersection of geography and demography: (1) population density along the coast and (2) population density in the interior. As hypothesized above, the coefficient on coastal density is positive and significant, while that on inland density is small and insignificant. However, introducing the population density variables diminishes the size of the coefficient on the coast-to-land-area ratio and renders it insignificant, since the variables measure similar things.[29] The Africa dummy remains small and insignificant.[30]

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[27] Pritchett (1996) also finds evidence that the direct effect of schooling on economic growth is insignificant. By contrast, Benhabib and Spiegel (1994) find evidence of a significant positive association.

[28] An F test was also conducted to test whether the coefficient estimates for African economies are significantly different than those for non-African economies. The resulting test statistic, based on the regression reported in column 2 of Table 5, accepts the hypothesis of structural stability, a result also echoed by Easterly and Levine (1998a). This finding suggests that Africa's slow growth was due to differences in fixed effect and the level of model variables and *not* due to differences in parameters between Africa and the rest of the world.

[29] In landlocked countries, for example, the ratio of coastline to land area is zero, while coastal population density is also zero. In general, countries with small coastlines to land area also tend to be countries with low population density near the coast.

[30] Although not reported here, we also experimented with specifications that included a measure of ethnolinguistic diversity, which has been hypothesized to be a hindrance to communication and consensus building, and

The final two columns of Table 5 report growth equation estimates separately for the 18 African and the 55 non-African countries in our sample (with the proxy for financial market depth dropped from the specification because of its persistent insignificance). Notwithstanding some differences between the two equations that presumably reflect the small size of the Africa sample, F tests do not permit us to reject the null hypothesis of common regression coefficients between the African and non-African countries. The implication of this result is that economic growth in Africa is slow because Africa is lacking favorable values for the factors that determine steady-state growth in all countries, not because those characteristics are rewarded less generously in Africa than elsewhere.[31]

Based on these estimates, Table 6 decomposes the sources of Africa's growth gap with East and Southeast Asia, Latin America and the Caribbean, and the non-African world generally, over the 1965 to 1990 period, using regression 5 from table 5. After controlling for differential rates of growth due to differences in initial income, Africa grew at a rate 4.3 percentage points slower than East and Southeast Asia, 2.1 percentage points slower than Latin America, and 3.6 percentage points slower than the rest of the world generally. The tables highlight the important direct contributions of age structure, geography, and health, as proximate factors in explaining Africa's relatively poor growth performance. These three factors collectively account for 63, 101, and 78 percent of the three gaps, respectively. These estimates do not account for influences of demography and geography that may operate indirectly through other included variables. For example, rapid population growth and disadvantageous geography may create enormous barriers to good governance. Although a full decomposition of these and other possible channels awaits further research, these initial results are highly suggestive.[32]

Among the policy variables, by far the most important is Africa's lack of openness to international trade. Almost all post-independence governments in Africa adopted autarkic trade policies with the goal of achieving import-substitution industrialization. As elsewhere in the world, that strategy failed decisively, because local markets were far too small to support efficient and competitive industry and because export growth was needed to import capital goods and intermediate products. The result was a serious negative impact on economic growth (and more generally, a vulnerability to macroeconomic upheaval, as shown in Sachs and Warner, 1995 and 1997), estimated

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thus to growth. We found no evidence of either a direct effect on economic growth of ethnolinguistic diversity or of an indirect effect (suggested by Easterly and Levine) operating through economic policy variables.

[31] The 18 African countries in the sample we analyze encompass every country for which all of the requisite data are available. However, this group of countries represents only about two-fifths of all countries in sub-Saharan Africa (45, if we include Eritrea, Madagascar, Mauritius, and Seychelles), and just less than one-half of the 41 sub-Saharan African countries for which we have any data. A comparison of African countries in our dataset to those not included, in terms of selected variables for which we have information, reveals that our sample is representative of sub-Saharan Africa in terms of growth rates of total and working-age populations, growth rates of income per capita, openness to trade, liquidity, quality of institutions, and tropical coverage. By contrast, the countries in our sample tend to have higher initial income, higher coastal and inland population densities, and lower ratios of coastline to land area.

[32] Bloom and Williamson 1998 find that youth dependency has more of a negative effect on economic growth than elderly dependency. Since youth dependency dominates the overall dependency burden much more in Africa than in other regions, an analysis taking into account the growth rate of different segments of the age distribution would likely indicate an even more important role for demography. See the appendix to Bloom and Malaney 1998 for a discussion of the relevant models.

to be 1.2 percent per annum (27 percent of the total gap) in the case of the African countries compared with East Asia, where more open trade policies were chosen.

A number of recent studies have evaluated the sources of slow growth in Africa using panel data (Easterly and Levine 1998, Temple 1998, and Islam 1995). With respect to Africa, some studies have argued (Collier and Gunning 1998) that African growth studies have not accounted for the reasons why growth in Africa slowed so dramatically since 1973.[33] While we do not report detailed results, we did construct a panel dataset and conduct some basic analyses. Following a core specification similar to Easterly and Levine (1998) and adding in variables measuring changes in age structure and geo-climatic conditions leads to conclusions similar to those based on the cross-sectional analyses. We did find, however, that the magnitude (but importantly, not the statistical significance) of the contribution of demographic, health, and geo-climatic conditions is sensitive to the inclusion of infrastructure variables (the natural logarithm of telephones per working-age person). This is not surprising given the discussion of the links between geography and the provision of infrastructure above. Africa's poor infrastructure may reflect in large measure the geographic realities on the continent -- low population density and populations scattered far from coastal regions where infrastructure investments are presumably cheaper and more beneficial.

Both the cross-country and panel data estimates highlight the importance to economic growth of a similar set of factors. Policy, education, and the role of initial income have already received significant attention in the literature. However, the role of age structure, health conditions (and their ecological determinants), and geography have received much less attention in the growth literature. Yet these factors reflect significant aspects of Africa's fundamental conditions and are estimated to account for a sizable share (60 to 90 percent, depending on the point of comparison, see Table 6) of Africa's extremely slow growth.

V. Overcoming Africa's Structural Barriers to Growth

African economies remain characterized by very low levels of income, high proportions of the population engaged in agriculture, urban areas that function as political and administrative centers rather than as exporting regions, and very limited international trade, concentrated in a narrow range of primary commodities. Given these realities, and the geographic and demographic factors that underlie them, what kinds of growth strategies might be effective in Africa’s current conditions?

Just as we started our analysis by placing Africa within the general development context of tropical economies, we can also look for effective growth strategies by examining the success stories among tropical economies, for the lessons that they may hold for Africa. There are, to be sure, precious few successes. Within tropical Africa itself, only two unambiguous long-term success stories are evident: Botswana and Mauritius. Botswana’s case is obviously not generally replicable,

[33] Growth apparently declined at an accelerating rate; per capita growth in Africa (population weighted) averaged 1.5 percent in the 1960s, 0.8 percent in the 1970s, -1.2 percent in the 1980s, and (using World Bank 1998 data) -0.9 percent from 1990 to 1996.

since its success has depended on a very small desert population enjoying the benefits of large and well-managed diamond discoveries. Of course, Botswana has used its resources effectively (trade policy has remained open, democracy has been vigorous and stable, and fiscal policy has been prudently managed), but still, the high ratio of diamond exports per capita is not easily replicated! Mauritius is more apposite, since it was a typical tropical agricultural exporter (mainly sugar cane), which succeeded in export-led growth in manufactures and services. Outside of the African region, the only tropical developing countries that averaged more than 3.0 percent per year in per capita GDP growth during 1965-96 were those in Asia (growth rates in parentheses, based on World Bank 1998): Hong Kong (5.6), Indonesia (4.6), Malaysia (4.1), Sri Lanka (3.1), Singapore (6.3), and Thailand (5.0). Much has been written about these economies (especially since they are also embroiled in current financial upheaval); it is therefore possible to identify some of the key factors of their success that might be relevant for a renewed African growth strategy.

Most importantly, at the core of their growth strategy was an industrial policy that aimed to promote manufacturing (and increasingly service-sector) exports (see Lee, Radelet, and Sachs, 1998, for a more complete discussion). These countries not only aimed to increase export growth, but to diversify away from their traditional dependence on tropical commodities, in order to benefit from the much more rapid growth in world trade in manufactures and services. They recognized that agricultural exports would lack dynamism, both because of limits to the growth of world demand, but also technological limits to the expansion of production. As many observers have noted, success in manufacturing export-led growth was not just a function of market forces. It also required the introduction of key institutions, designed to link domestic labor-intensive manufacturing production with world markets, mainly by attracting multinational enterprises to use the economy as a base for the labor-intensive portions of the production chain. Thus, Southeast Asian economies made novel institutional arrangements with multinational firms to facilitate the outsourcing of labor-intensive operations to the local economies. These institutional arrangements included: export processing zones, or EPZs, in which industrial parks were established for export-oriented production, and in which infrastructure and customs administration were especially geared towards reducing transactions costs for multinational enterprises; duty drawbacks on tariffs on imported raw materials and capital goods used for exports; generous tax holidays for export-oriented foreign investors; and flexibility in labor markets. The strategy was essentially copied from one location to the next. Hong Kong was first in the 1950s, emulated by Korea and Taiwan in the early to mid 1960s. Singapore adopted the export-led manufacturing model around 1967. Malaysia followed in 1971, when Penang Island was established as an export processing zone in emulation of Singapore. Mauritius also adopted the EPZ model in 1971, in emulation of Taiwan's experience.[34] In the 1980s, Thailand and Indonesia began to promote similar manufacturing export schemes. In the early 1990s, the Philippines adopted the approach, as well, focusing in particular on export-oriented consumer electronics.

The pattern of export growth in the rapidly growing export-oriented countries stands in sharp contrast to the export performance of Africa, which, aside from Mauritius and to a small extent South Africa, remained overwhelmingly tied to primary commodities. As we see in Figure 8, tropical Africa (excluding Mauritius) has a nearly 100 percent concentration of exports in primary

[34] In the Mauritius EPZ strategy, export firms were not required to establish themselves within special industrial parks in order to qualify for EPZ-type privileges on taxes, customs, and other export incentives.

commodities, with little change in commodity dependence between 1980 and 1996. Latin America was the second most commodity-dependent region, but it experienced a rather sizeable shift towards manufactures. The developing countries of East Asia, by 1980, were already largely in manufacturing, but they did experience an increased proportion of manufactures in total exports between 1980 and 1996. The group of six fast-growing countries that we noted earlier (Hong Kong, Indonesia, Malaysia, Mauritius, Singapore, Sri Lanka, and Thailand) and Mauritius also had a steep decline in the share of commodities in total exports. Perhaps the most amazing example of Africa's lack of role in manufactures trade is in textiles and apparel, a sector that has lent itself to labor-intensive exports in virtually all parts of the developing world. Other than Mauritius and (very recently) Madagascar in the Indian Ocean, and the North African countries of Egypt, Morocco, and Tunisia, sub-Saharan Africa plays virtually no role whatsoever in textile and apparel trade. According to HIID's estimates in the 1998 Africa Competitiveness Report (HIID 1998, Table 4, p. 40), based on U.S. Trade Commission Data, other than the aforementioned countries only Kenya and Zimbabwe have even miniscule apparel exports, and those add up to only 0.05 percent of global trade.

Was there really an advantage to manufacturing export-led growth over commodity export-led growth in this period? It seems clear that the answer is yes. World demand for manufactures rose far faster than demand for primary commodities in this interval, with a cumulative increase in the dollar value of manufactures trade of 2.7 percent per year, compared to an average annual increase of world commodity trade of 0.65 percent. The terms of trade for commodities producers declined significantly during the period, as shown by the terms of trade of African economies, in Figure 9. Note also the extraordinary fact that Africa suffered an *absolute decline* in the dollar value of per capita export earnings, as shown in Table 7, in contrast to the other regions, for which total earnings per capita rose significantly. If it is true that the manufacturing sector enjoys faster productivity growth than primary commodities, why doesn't the rising supply of manufactures relative to primary commodities lead to a decline in the relative price of manufactures? A large part of the answer is that manufacturing growth involves not just a growth in volumes, but a growth in varieties as well, much faster than the growth in varieties of primary commodities. Thus, manufacturers can find niches in new product lines in which the terms of trade remain strong, even as *overall* manufacturing supply rises much faster than primary commodity supply. Of course, there are other possible answers as well.[35]

Can Africa diversify its exports?

Our main conjecture is that manufacturing and service-sector export-led growth would benefit Africa not only as a much-needed outlet for new exports, but as a way to address some (though not all) of the geographical liabilities facing the continent. In essence, we are surmising that

[35] Part of the story may simply be in price measurement. Quality improvements in manufacturing goods are probably understated in price indices, so price rises over time are probably overstated. This would tend to exaggerate measured increases in the terms of trade of manufactures vis à vis commodities. Two other frequently argued propositions are that the income elasticity of demand is less for primary commodities than for manufactures, and that technical change is primary-resource saving, such as when fiber optic cables replace copper wires, or synthetic rubbers substitute for natural rubber.

at a general level, Africa and many other tropical environments probably have a true comparative advantage in manufactures and services, even though they have been viewed for centuries as suppliers of primary commodities. While there will surely remain a significant niche for a range of agricultural goods endemic to the tropics (coffee, tea, cocoa, etc.), it may simply be a matter of comparative advantage -- especially influenced by the low productivity of food production in the continent -- that Africa should be a net importer of agricultural commodities (mainly foodstuffs), paid for by net exports of manufactures and services.

The continent as a whole admittedly could not follow such a strategy. Successful export-led growth in manufactures in low-wage, low-skilled countries requires low transport costs, especially because typical manufacturing processes involve a significant import component of final output. In the EPZs in the Philippines, for example, each FOB dollar of electronics exports typically requires at least 60 cents of imports (see Radelet and Sachs, 1998). Even slight increases in transport costs on imported inputs in that case can easily wipe out all domestic profits. For this reason, the success stories in manufacturing export-led growth are almost all *coastal economies* well connected to international shipping routes. Thus, a manufacturing export-led growth strategy would probably be most effective in coastal Africa, especially the large urban areas in East and West Africa, places such as Abidjan, Accra, Dar es Salaam, Lagos, Maputo, and Mombasa. Currently, those port cities play almost no such role as export-oriented manufacturing centers. An urban-based export strategy would have other obvious advantages as well. Infrastructure provision is considerably less costly in the more densely populated urban setting, and even vector-borne disease transmission, such as in the case of malaria, is often easier to moderate in the urban setting.[36]

Inland countries, which intrinsically face high transport costs for imported intermediate items, will likely be successful in manufacturing export growth mainly to the extent that they increase the processing of locally produced commodities (so that Uganda would sell roasted and branded coffee, rather than raw beans; while Mali, Uganda, and other cotton producers, would become competitive textile exports, as Uganda was on a very modest scale thirty years ago). Of course all parts of Africa have at least some potential in the service sector as well, especially tourism, but also in several kinds of data transmission and data processing operations (e.g., data transcription and back-office services) that can be outsourced to low-wage countries via telephone and internet connections.

Export success does not emerge automatically as the result of comparative advantage based on relative factor costs. Competitiveness in labor-intensive manufacturing exports requires: (1) effective logistical operations at the port, and low-cost internal transport to the port facilities; (2) duty-free access to imported inputs and capital goods; (3) timely customs administration; (4) physical and security reliability in warehousing; (5) cost-effective access to international telephone and internet services; (6) reliable power supplies; (7) flexibility in the hire and dismissal of workers; (8) low (or zero) taxation of multinational income, at least to be competitive with alternative production sites; (9) reasonable shipping costs to major ports in Europe, the U.S., and Japan. The list is

[36] In the case of malaria, urban centers are less hospitable breeding grounds for the *Anopheles* mosquitoes, which require clean water sites for larval development, and are therefore typically stifled in the more polluted urban setting. Alas, Africa's tropical urban areas at low altitude are generally malarial, but with less stable disease transmission, and therefore possibly with a greater success in transmission control.

straightforward; the achievement of competitiveness is not. Like Michael Kremer's (1993) O-ring theory of development, the process can break down at its weakest link. In much of urban, coastal Africa, it is poor port services, or unreliable power, or abusive customs agents, or duties on imported intermediate inputs, or lack of tax holidays, that frustrates the attraction of export-oriented manufacturing.[37]

Strangely, despite more than a decade of structural adjustment lending by the IMF and World Bank throughout Africa, very little structural change is actually taking place in exports and production. The reasons why these programs have not promoted a diversification and dynamism of exports is an open, empirical question. Our hypothesis is that the programs are not sufficiently directed towards the nitty-gritty work of overcoming the practical obstacles to international manufacturing competitiveness, and that practical policy advice from the IMF and World Bank (such as their longstanding ambivalence or outright opposition to the establishment of export processing zones, and their frequent opposition to tax concessions aimed at attracting export-oriented manufactures) often directly conflicts with diversification of exports.

The real sources of Africa's lack of competitiveness in manufacturing exports are not sufficiently understood. Very little systematic comparison of African economies with other regions regarding factor costs, transport costs, tax arrangements, infrastructure availability, and the like, have yet been undertaken. This basic fact-finding should certainly be a high priority.

VI. Conclusion

The central objective of this paper has been to highlight some deep underlying factors that have hindered African economic growth, not just in the last three decades, but for the entire period of modern economic growth. Identifying these factors and the mechanisms through which they influence growth is a vital step in developing strategies for achieving higher growth rates in Africa. Perhaps our most important finding is that economic policy and governance, which receive the largest share of economists' attention, are important, but perhaps not the dominant factors that have impeded, and continue to deter, economic growth in Africa. Rather, we find that various aspects of tropical geography, demography, and public health are vitally important, and we have argued at length that causality runs strongly from these factors to growth, rather than vice versa (though, of course, some reverse feedbacks exist as well). Our statistical estimates, admittedly imprecise, actually give about two-thirds of the weight of Africa's growth shortfall to the "non-economic" conditions, and only one-third to economic policy and institutions. This doesn't mean that economic policy is unimportant. Indeed, good policies are especially important because economic growth will otherwise be so hard to achieve.

Our findings do suggest, however, that economists ought to lift their gaze above macroeconomic policies and market liberalization, in order to deepen their understanding of the

[37] Tanzania recently attracted a Korean apparel firm that was successfully producing and exporting ready-made clothing for the U.S. market. The U.S. customer recently cancelled the contract, however, because of excessive delays in shipping time due to obstruction and hassles by port and customs authorities. [Personal communications with Economic Advisor to the Prime Minister of Tanzania, August 1998].

linkages between the physical environment and social outcomes. The complex linkages among geography, demography, health, and economic performance surely require much more intensive and systematic examination. For the sake of development in Africa, there needs to be much greater cross-fertilization between fields such as demography, epidemiology, agronomy, ecology, geography, and economics. In short, we need better tools in an area of study perhaps best termed "human ecology," which places social activity and economic development more firmly within the context of the physical environment.

Given this enormous intellectual challenge, Africa surely suffers from a remarkable inattention of the international scientific community to Africa's health, agricultural, and environmental problems. There are, of course, many able scientists in Africa and elsewhere pursuing basic and applied research relevant to Africa's problems, but these efforts are not commensurate with the scale of the problems. Many of the issues that require urgent and intensive examination -- for example, the development of an effective anti-malaria campaign, a better understanding of the virology and epidemiology of Africa's extraordinary AIDS epidemic, the interaction of climate and low life expectancy, and research on tropical forestry and the adaptation of food production to tropical conditions -- are largely international public goods. Scientific research on these topics will naturally be under-provided by private markets and even by the efforts of individual nations. For example, on a per-fatality basis, global expenditures on malaria research are one-fifth of those on asthma, and one-twentieth of those on HIV/AIDS (mainly because AIDS is such a huge problem in industrial countries). The decline in financial support for the Consultative Group for International Agricultural Research -- the main global network supporting agricultural research appropriate to conditions in developing countries -- bodes ill for the pace of innovation in agriculture and animal husbandry in Africa. Of course, new ways have to be found to bring in private-sector research efforts as well in vaccine development, biotechnology research, and other areas. At least part of the financing for an invigorated scientific effort should probably come from redirecting aid programs away from standard policy-based lending and more towards the underlying scientific and technical problems confronting the continent.

Africa was the only major region in the world to experience an absolute decline in export earnings per person between 1980 and 1996. This is not only a vivid illustration of Africa's marginalization in the world economy, but also a proximate cause of slow growth, since Africa has lacked the foreign exchange earnings needed to invest heavily in capital goods from abroad. It seems clear, therefore, that Africa's economic development will require a major commitment to policies and institutions that promote manufactured exports. This orientation was one of the keys to economic growth among many successful tropical countries in East and Southeast Asia. Clearly, general points of economic reform, such as macroeconomic stability, currency convertibility, low inflation, and so forth, are important in this regard, but they are not enough. International competitiveness in manufactures requires a set of effective institutions linking the domestic economy with world markets (often mediated by multinational enterprises). These have not been fostered adequately in the World Bank-IMF programs of recent years. More direct focus on export diversification and manufacturing-sector competitiveness is needed. Most of the major coastal port cities of East and West Africa are candidates for a greatly expanded role in export-led growth. In addition, much more creative effort is needed to promote infrastructure investment, especially as infrastructure in Africa is often shockingly poor. However, one important lesson of recent development experience in other parts of the world is that infrastructure can be increasingly financed privately and in a competitive market setting, rather than by cash-strapped state monopolies as has traditionally been the case in Africa. The rapid urbanization that Africa is currently experiencing will serve to enhance this process by allowing private entrepreneurs to benefit from greater economies of scale in densely populated urban areas.

Africa poses the largest and most complex development challenge facing the world today. Many of the factors that contribute to Africa's apparent growth trap operate unabated or may even be tightening their hold, further weakening the continent's connection to the world economy and its prospects for economic growth and development. On the other hand, pockets of improvement in health and education, the incipient decline of fertility in some countries, and growth of the world economy provide some hope that this challenge will be successfully confronted. On the other side, rapid population growth, environmental stresses, and the AIDS epidemic are enormously disconcerting. Based on the results presented here, it appears that strengthening the orientation of economists and donors towards the forces of geography, demography, and health in Africa's growth crisis constitutes a necessary step in devising more effective approaches to Africa's development challenges.

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Figure 1. Economic Growth by Major World Region, 1820 to 1992

	Western Europe (12)	Western Offshoots (4)	Southern Europe (5)	Eastern Europe (7)	Latin America (7)	Asia (11)	Africa (10)	World Total (56)
1820-1870	1.0%	1.4%	0.6%	0.6%	0.2%	0.1%	0.1%	0.7%
1870-1913	1.3%	1.8%	1.1%	1.0%	1.5%	0.6%	0.4%	1.3%
1913-1950	0.9%	1.5%	0.4%	1.4%	1.5%	-0.1%	0.9%	0.9%
1950-1970	3.9%	2.2%	4.6%	3.5%	2.4%	3.7%	2.1%	2.9%
1970-1992	2.0%	1.7%	2.2%	-0.5%	1.1%	3.4%	0.4%	1.5%
1820-1992	1.5%	1.7%	1.3%	1.1%	1.2%	1.0%	0.6%	1.2%

Source: Maddison (1996), note 'Africa' includes Morroco and Egypt

Table 2. Indicators of Trade Accessibility, by region

Region	N	land area (M sq.km)	pop. (million)	proportion land area in tropics	proportion pop. w/100km coast	proportion pop w/100km coast or river	proportion of population landlocked	distance to core market (km)[1]	1000km coastline/s q. km area	CIF/FOB ratio, 1995	GDP/capita 1995[2]
Sub-saharan Africa	41	24	580	0.91	0.19	0.21	0.28	6237	1.15	1.20	1,488
Western Europe	16	3	383	0.00	0.53	0.89	0.04	922	15.74	1.05	19,367
East and Southeast Asia	12	14	1819	0.30	0.43	0.61	0.00	3396	11.54	1.10	4,996
South Asia	5	4	1219	0.40	0.23	0.41	0.02	5744	2.45	1.10	1,469
Transition Economies	25	24	400	0.00	0.09	0.37	0.28	2439	0.86	1.08	4,108
Latin America	22	20	472	0.73	0.42	0.46	0.03	4651	2.54	1.11	6,332
All others	29	40	780	0.16	0.40	0.57	0.04	3514	2.34	1.09	12,853

Sources: Microsoft, Tobler, CIA, Radelet and Sachs (1998), World Bank (1997a), World Bank (1998)

[1] Unweighted average linear distance from capital cities to the closest port: Tokyo, Rotterdam, New York
[2] PPP adjusted GDP per capita, in constant 1990 US dollars. Regional averages, weighted by population

Table 3a. Fertility and Infant Mortality Levels Worldwide

	Total Fertility Rate	Infant Mortality Rate	Total Fertility Rate	Infant Mortality Rate	Percent Decline in Fertility	Percent Decline in Mortality
Africa	6.6	185	5.7	94	-15%	-68%
Asia	5.9	180	2.8	62	-73%	-107%
Eastern Asia	5.7	181	1.9	41	-111%	-148%
Oceania	3.8	69	2.5	26	-43%	-98%
Latin America and Caribbean	5.9	126	2.9	40	-70%	-115%
Europe	2.6	72	1.6	13	-49%	-171%
Northern America	3.5	29	2.0	9	-54.1%	-117.0%

Source: UN Demographic and Population Estimates

Table 3b. Fertility and Contraception Statistics for Selected Sub-Saharan African Countries

	Fertility rate (number of births per woman)			Proportion of progress toward replacement level (2.1) that could be achieved by reducing fertility rate from total to wanted	Contraceptive prevalence among currently married women
	Total	Wanted	Unwanted		
Country and year					
Burkina Faso 1993	6.9	6.0	0.9	0.19	7.9
Côte d'Ivoire 1994	5.7	4.7	1.0	0.28	11.4
Ghana 1988	6.4	5.5	0.9	0.21	12.9
Liberia 1986	6.5	6.0	0.5	0.11	6.4
Madagascar 1992	6.1	5.2	0.9	0.23	16.7
Malawi 1992	6.7	5.7	1.0	0.22	13.0
Mali 1987	6.7	6.9	*	*	4.7
Niger 1992	7.4	7.1	0.3	0.06	4.4
Nigeria 1990	6.0	5.8	0.2	0.05	6.0
Rwanda 1992	6.2	4.4	1.8	0.44	21.2
Senegal 1992-93	6.0	5.1	0.9	0.23	7.4
Sudan 1989-90	5.0	5.9	*	*	8.7
Tanzania 1991-92	6.3	6.4	*	*	10.4
Tanzania 1994	5.6	5.5	0.1	0.03	17.8
Togo 1988	4.1	5.3	*	*	33.9
Uganda 1988-89	7.3	6.8	0.5	0.10	4.9
Zambia 1992	6.5	5.4	1.1	0.25	15.2
Zimbabwe 1994	4.3	3.5	0.8	0.36	48.1

Source: Macro International, *Demographic and Health Surveys*, various editions.

* Wanted fertility exceeds total fertility. In some cases, this may be due to the fact that some statistics report numbers with respect to all women, and others with respect to currently married women.

Table 3b. Fertility and Contraception Statistics for Selected Sub-Saharan African Countries

Table 4. Data Characteristics

Variable	African countries		Non-African countries	
	mean	standard deviation	mean	standard deviation
GDP per capita growth, 1965-1990	0.55	1.35	2.27	1.75
Log GDP per capita 1965	6.78	0.55	7.89	0.82
Log GDP per worker 1965	0.51	0.53	1.57	0.74
syr1565l[a]	-1.95	1.25	-0.41	0.81
open6590	0.04	0.08	0.50	0.45
icrge80	4.72	1.17	6.22	2.38
lly	22.74	10.25	42.29	20.79
CGB7090	3.00	4.87	1.25	3.45
tropicar	0.94	0.23	0.42	0.47
ldens65c	2.22	1.79	3.91	1.48
ldesn65i	2.65	0.84	2.72	1.62
gpopw	0.027	0.0053	0.022	0.011
gpop	0.028	0.0047	0.018	0.0098

Note: Sample consists of 73 countries (18 African, 55 non-African)

[a] Secondary education data are only available for 65 countries (12 African, 53 non-African)

Table 5: Basic Cross-country Growth Regressions

	1	2	3	4	5	6	7
growth, 1965-1990	naïve specification, including schooling	naïve specification	basic specification	basic specification, constraining demography	basic specification + population density	African countries	Non-African countries
Log GDP per worker, 1965	-1.924 (6.08)**	-1.626 (5.81)**	-1.823 (7.12)**	-1.786 (7.04)**	-1.742 (5.78)**	-1.224 (1.84)	-1.824 (5.68)**
Log years of secondary education	0.347 (1.65)						
Liquid liabilities (% GDP)	0.012 (1.13)	0.013 (1.31)	-.001 (0.14)	0.000 (0.06)	-.001 (0.19)		
Openness	1.590 (2.79)**	1.831 (3.32)**	1.937 (5.25)**	1.862 (4.80)**	1.921 (5.28)**	-.462 (0.15)	1.888 (4.92)**
Quality of institutions	0.364 (2.56)*	0.326 (2.60)*	0.174 (1.83)	0.140 (1.56)	0.126 (1.43)	0.283 (0.81)	0.137 (1.29)
Central government budget deficit (% GDP)	0.115 (2.35)*	0.138 (3.50)**	0.151 (4.30)**	0.149 (4.26)**	0.146 (4.11)**	0.229 (4.58)**	0.093 (2.21)*
Proportion land area in geographical tropics			-1.330 (3.99)**	-1.255 (3.78)**	-1.182 (3.80)**	-.092 (0.08)	-1.261 (3.74)**
km of coastline / km^2 land area			3.710 (1.83)	3.252 (1.59)	1.272 (0.52)	-205.457 (1.28)	4.039 (1.87)
Log population density within 100km of coast					0.149 (2.23)*		
Log population density inland					-.005 (0.06)		
Avg. population growth rate, 1965-1990			-110.817 (1.62)				
Avg. growth rate working-age pop 1965-1990			129.491 (2.30)*				
gpopdiff[a]				147.357 (3.04)**	134.588 (2.66)**	327.246 (3.29)**	165.098 (2.97)**
Log life expectancy, 1965			3.831 (2.91)**	3.436 (3.10)**	3.504 (3.27)**	0.866 (0.25)	3.283 (2.37)*
Africa (dummy)	-2.020 (3.66)**	-2.108 (4.54)**	-.218 (0.47)	-.147 (0.33)	0.010 (0.02)		
Constant	1.750 (2.72)**	1.165 (2.70)**	-13.140 (2.49)*	-11.142 (2.63)*	-11.860 (2.88)**	-3.206 (0.24)	-10.439 (2.00)
Number of observations	65	73	73	73	73	18	55
R-squared	0.71	0.67	0.80	0.79	0.81	0.72	0.81

Absolute value of t-statistics in parentheses
* significant at 5% level; ** significant at 1% level

[a] Difference between average growth rate of working-age population 1965-1990 and average growth rate of total population over the same period.

Table 5: Basic Cross-country Growth Regressions

Table 6: Sources of Africa's Growth Gap

Geography, Demography, and Health	East/SE Asia		Latin America		All non-Africa	
	Gap	Impact	Gap	Impact	Gap	Impact
Portion land area in geographical tropics	7%	-0.32	8%	-0.32	17%	-0.61
Km of coastline/ km^2 land area	0%	-0.08	1%	-0.08	1%	-0.03
Log population density w/100km coast	9%	-0.39	7%	-0.39	7%	-0.25
Log population density inland	0%	0.00	0%	0.00	0%	0.00
gpopdiff[a]	22%	-0.95	32%	-0.95	18%	-0.64
Life expectancy at birth, 1965	24%	-1.05	53%	-1.05	35%	-1.26
Sub-total	*63%*	*-2.80*	*101%*	*-2.80*	*78%*	*-2.79*
Economic Policy and Governance						
Liquid liabilities (% GDP)	-1%	0.02	0%	-0.99	-1%	0.02
Openness	27%	-1.16	13%	-1.16	25%	-0.88
Quality of institutions	5%	-0.20	-1%	-0.20	5%	-0.19
Central government budget deficit[b]	0%	-0.01	-10%	-0.01	-7%	0.26
Sub-total	*32%*	*-1.37*	*2%*	*-1.37*	*22%*	*-0.79*
Total Gap explained	***95%***		***103%***		***100%***	

Notes: Results based on basic specification, including population density, and average regional values over the period 1965-1990. The observed growth gaps were: Africa-East/Southeast Asia: -3.6%, Africa-Latin America: -0.38%, Africa-Non-Africa: -1.7%. These gaps were then adjusted to reflect differences in the expected rate of convergence. Since Africa is the relatively poorer region, this adjustment "widened" the effective gaps to: Africa-East/Southeast Asia: 4.3%, Africa-Latin America: 2.1%, Africa-Non-Africa: 3.6%.

[a] Difference of average growth rate of working-age population, 1965-1990 and average growth rate of total population over the same period.
[b] Average over the period 1970-1990, as proportion of GDP

Table 7. Total Value of Exports in US $ per capita by region, 1980 and 1996

region	1980	1996	ratio, 1996:1980
Tropical Continental Africa	$130	$70	0.54
East/Southeast Asia	$144	$472	3.3
Latin America	$260	$509	2.0
7 Fast Growing Economies*	$361	$1611	4.5

* Mauritius, Hong Kong, Indonesia, Malaysia, Sri Lanka, Singapore, and Thailand

Figure 1. Economic Growth by Major Region: 1820-1992

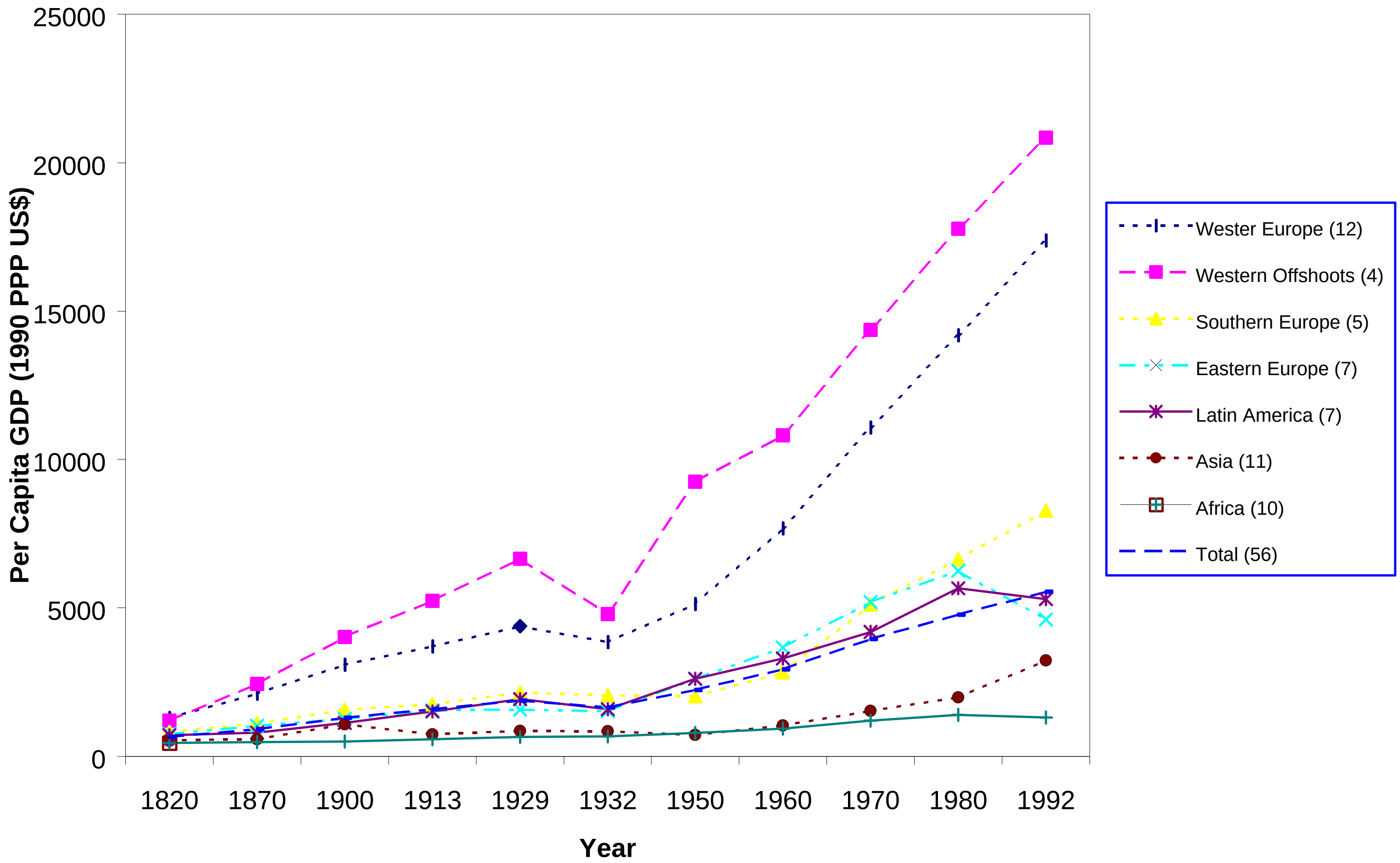
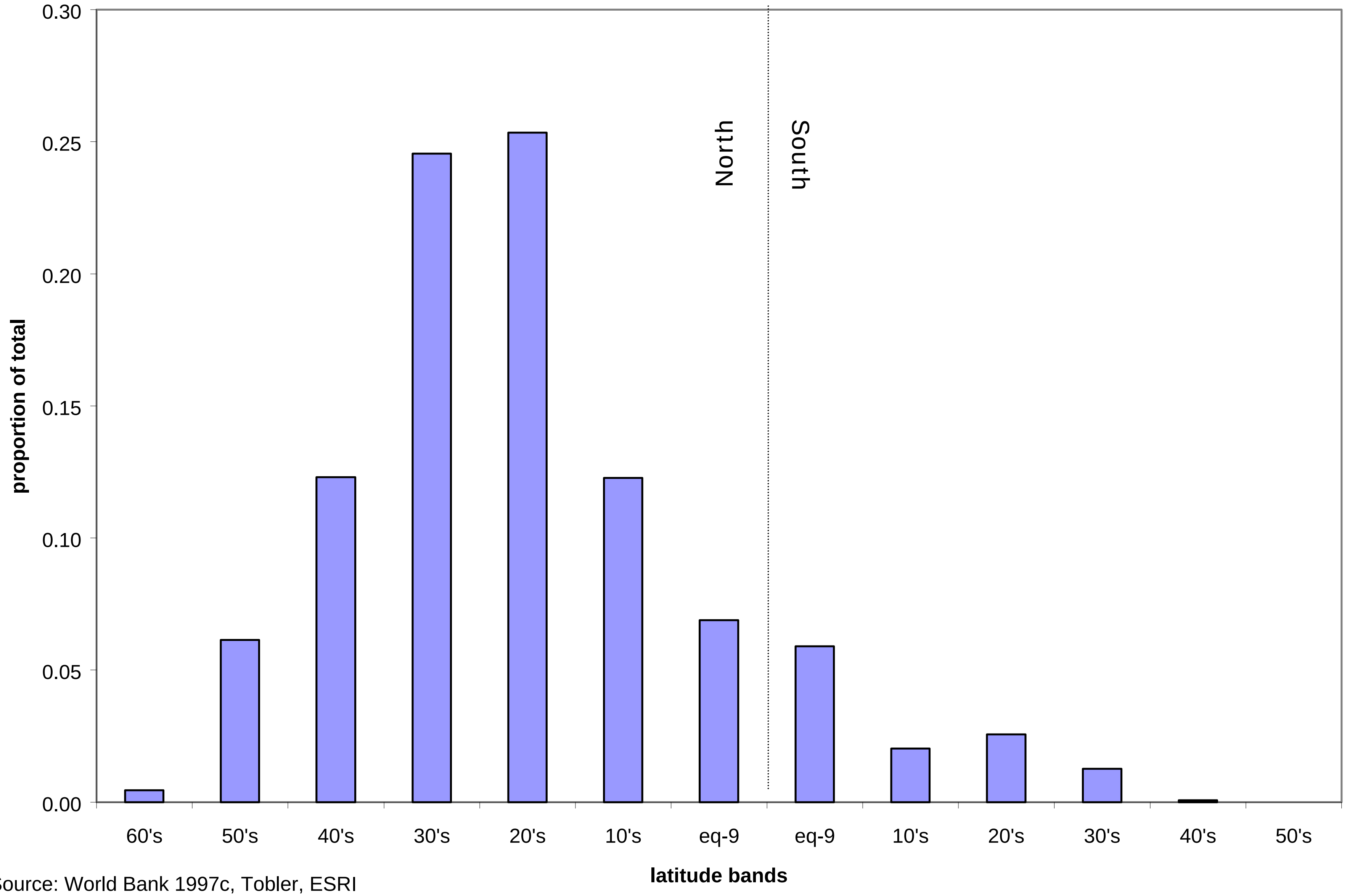
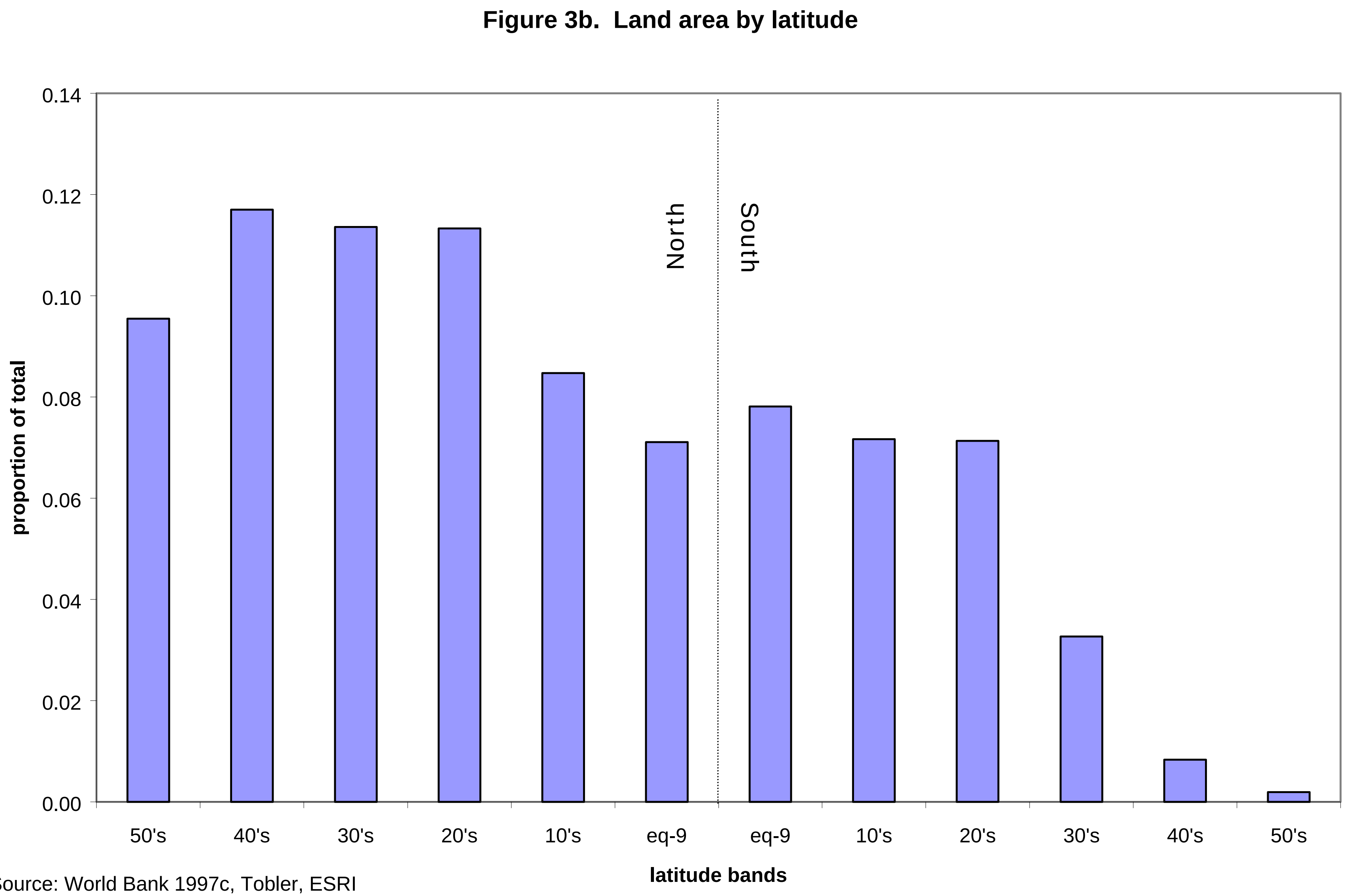


Figure 2a. Population by latitude



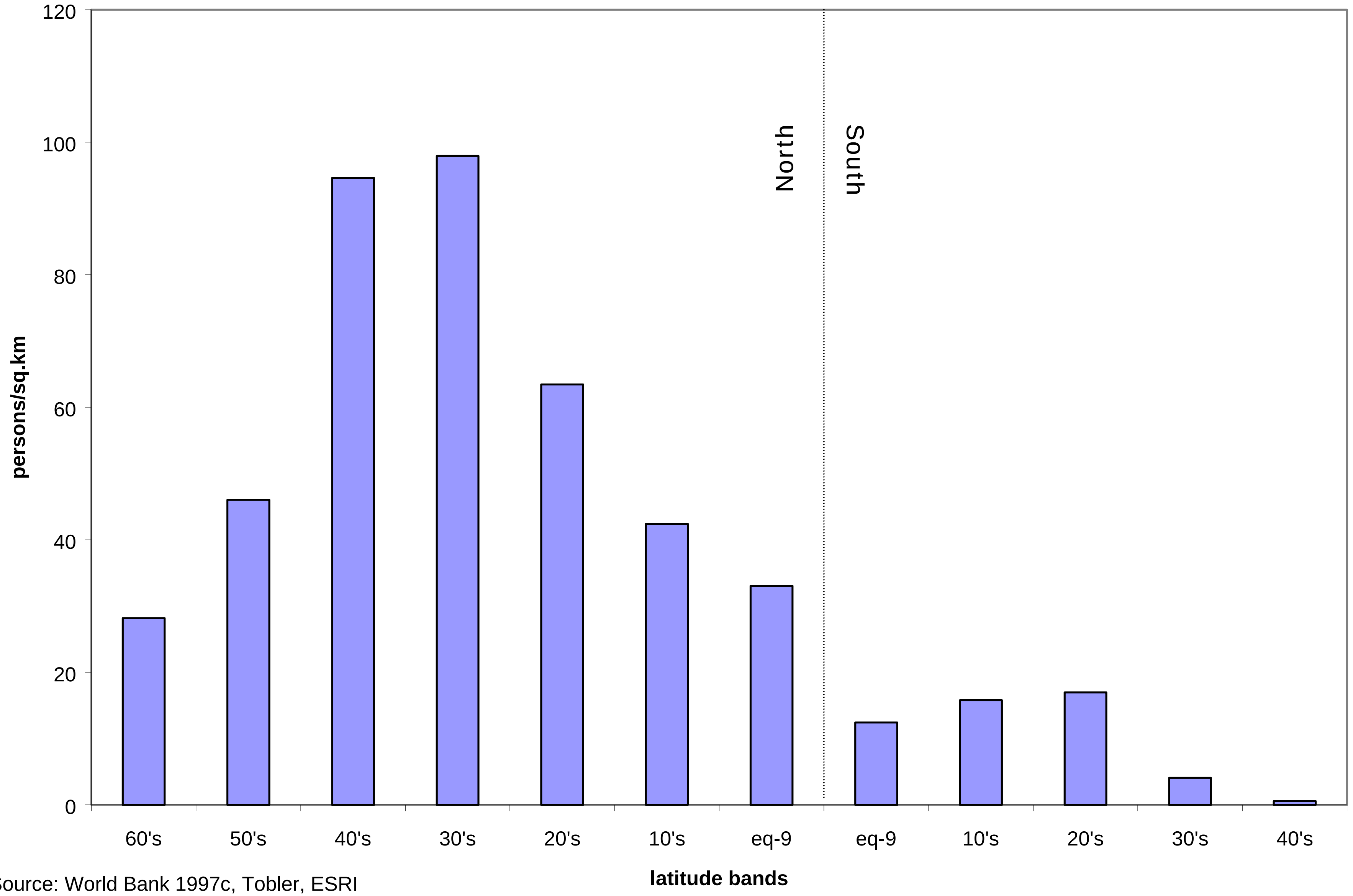
Source: World Bank 1997c, Tobler, ESRI

Figure 2b. Land Area by latitude



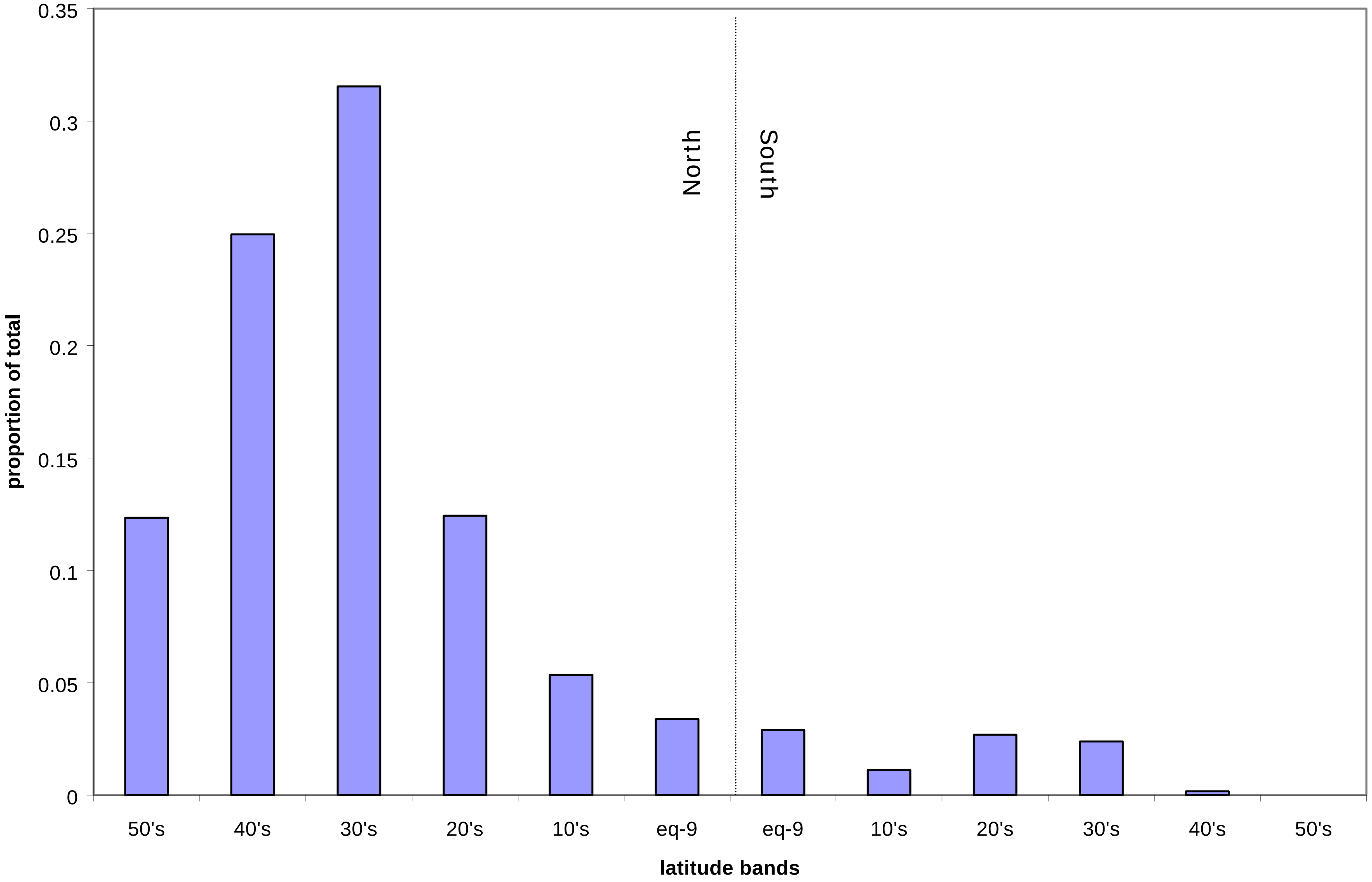
Source: World Bank 1997c, Tobler, ESRI

Figure 2c. Population Density by latitude



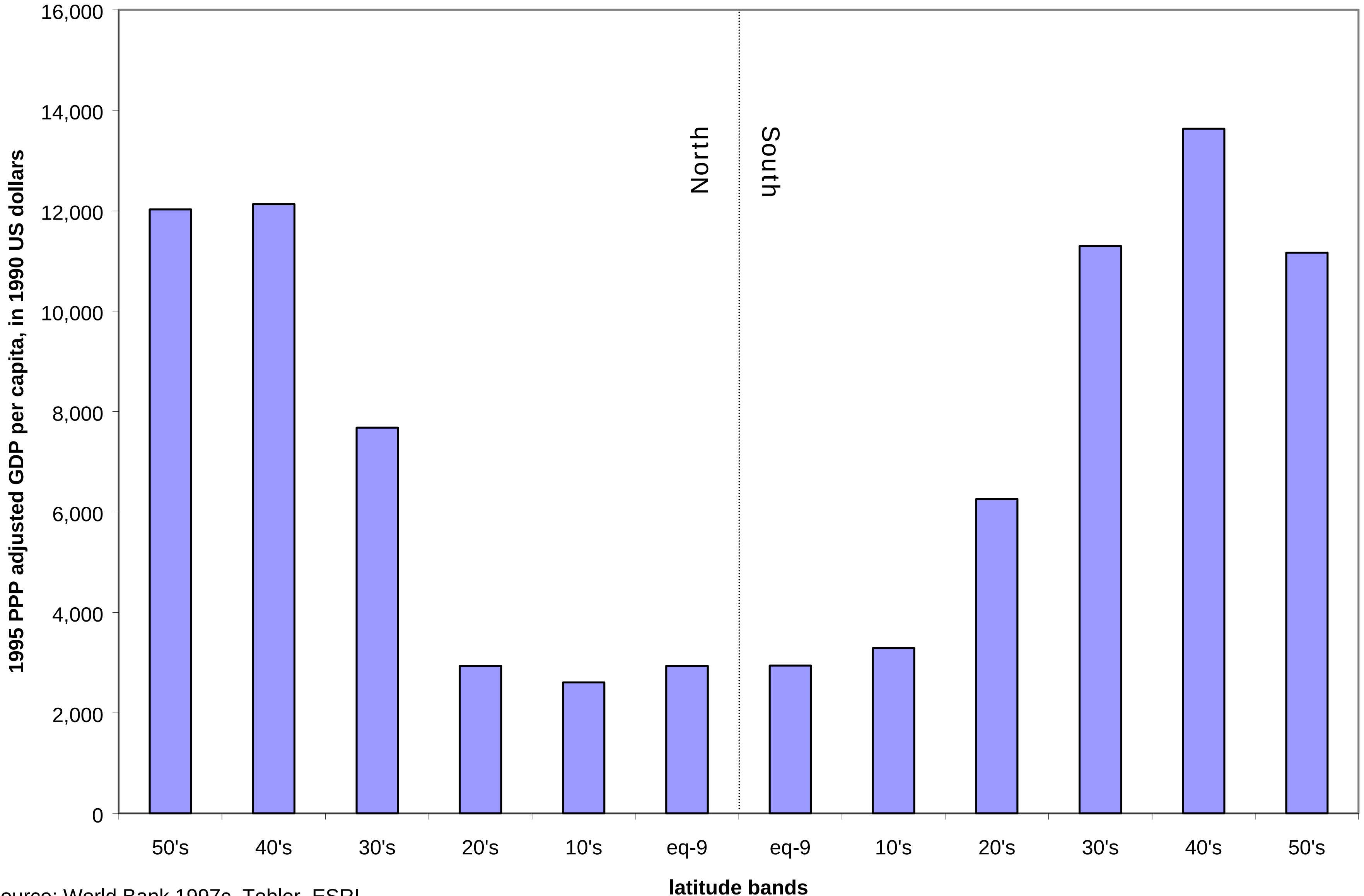
Source: World Bank 1997c, Tobler, ESRI

Figure 2d. PPP adjusted GDP (1995) by Latitude



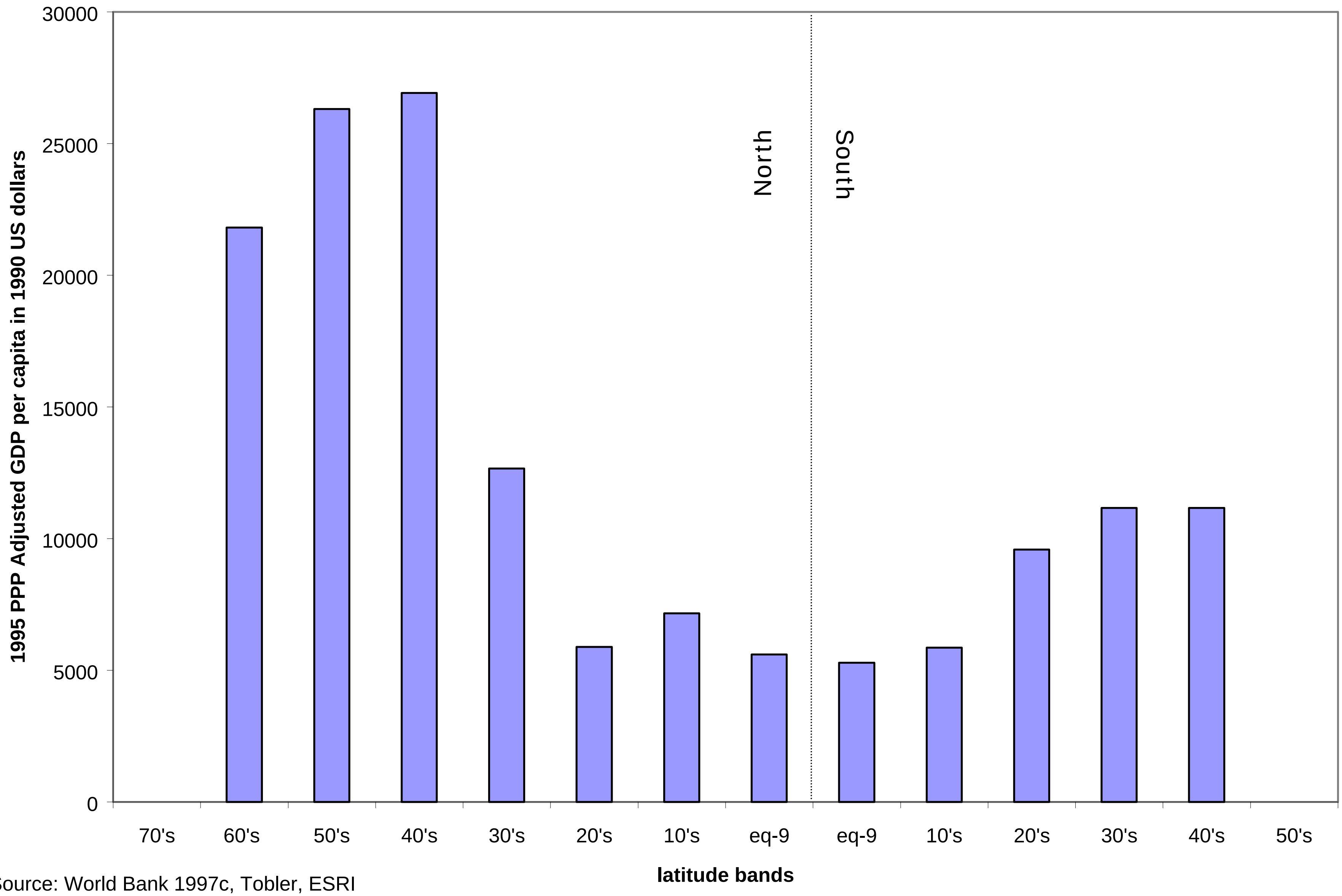
Source: World Bank 1997c, Tobler, ESRI

Figure 2e. GDP per capita by Latitude



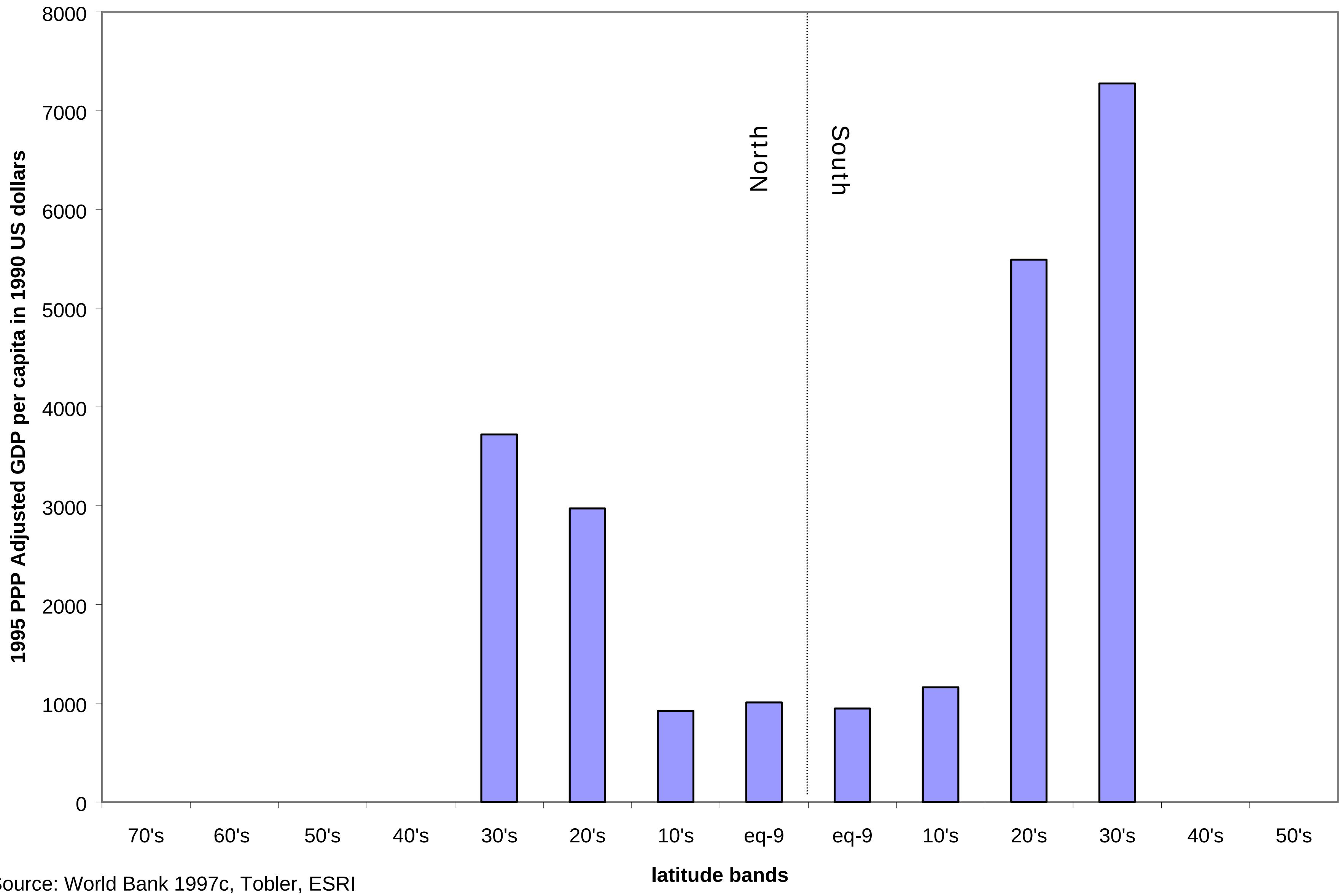
Source: World Bank 1997c, Tobler, ESRI

Figure 3a. GDP per capita by Latitude, Americas



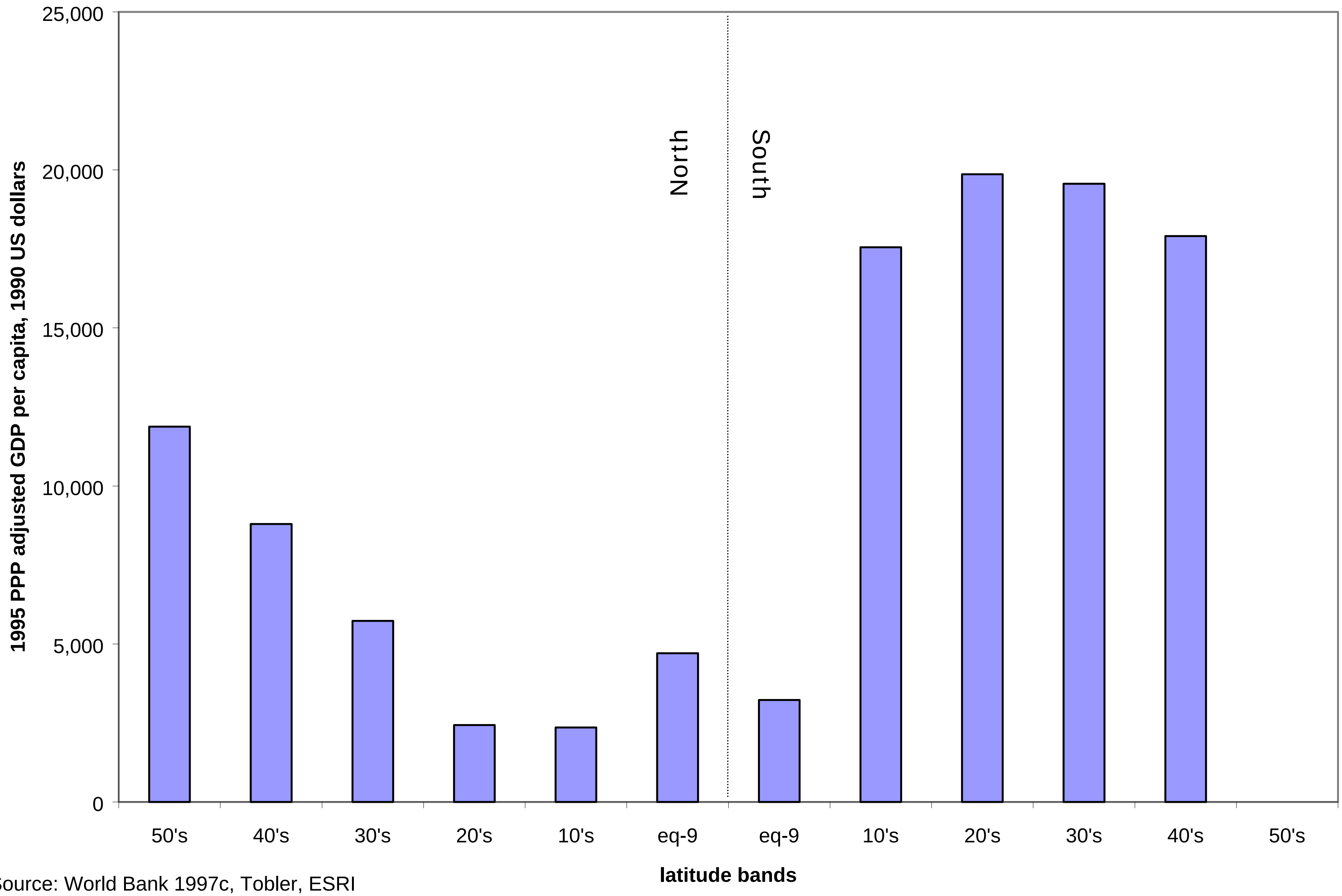
Source: World Bank 1997c, Tobler, ESRI

Figure 3c. GDP per capita by Latitude, Eurasia/Oceania



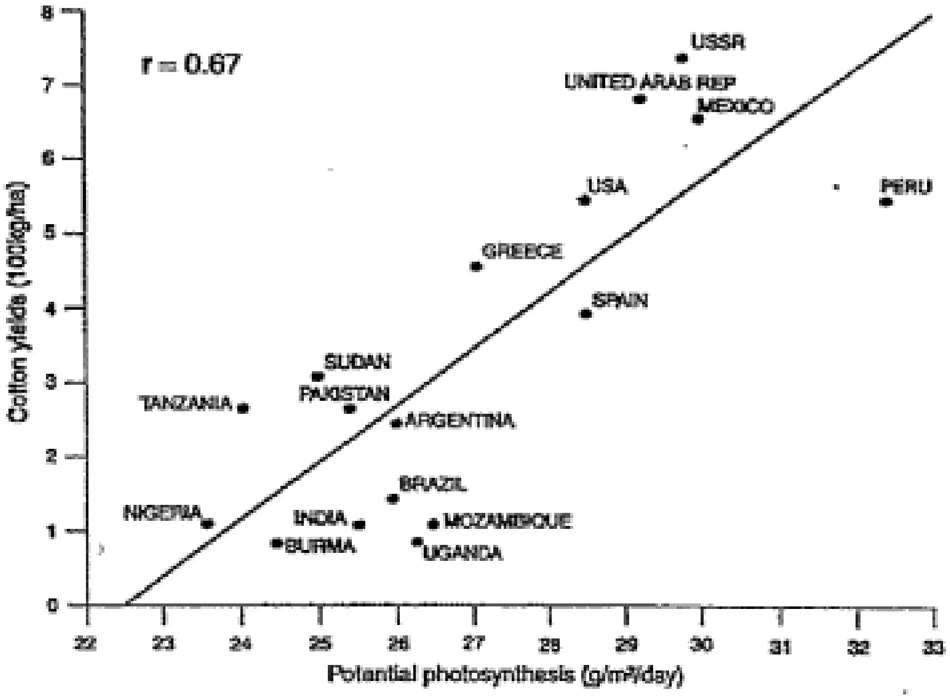
Source: World Bank 1997c, Tobler, ESRI

Figure 3c. GDP per capita by Latitude, Eurasia/Oceania



Source: World Bank 1997c, Tobler, ESRI

Figure 4.



Source: Porter, p.42

Figure 5. Africa's Share of World Income and Population, 1820 to 1992

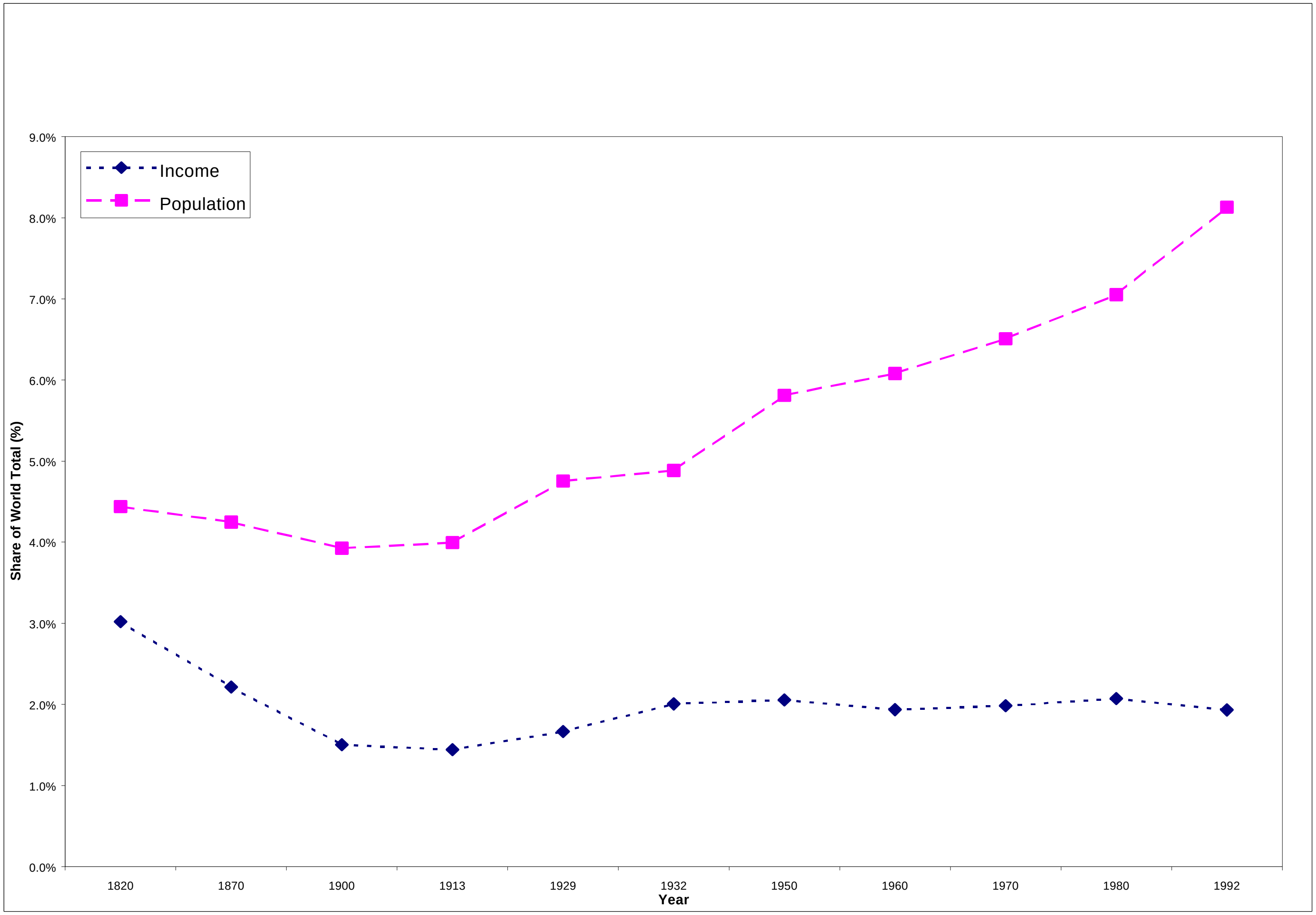


Figure 6. Ratio of Working Age (15-64) to Non-Working Age, 1950-1995
Sub-Saharan Africa and East Asia

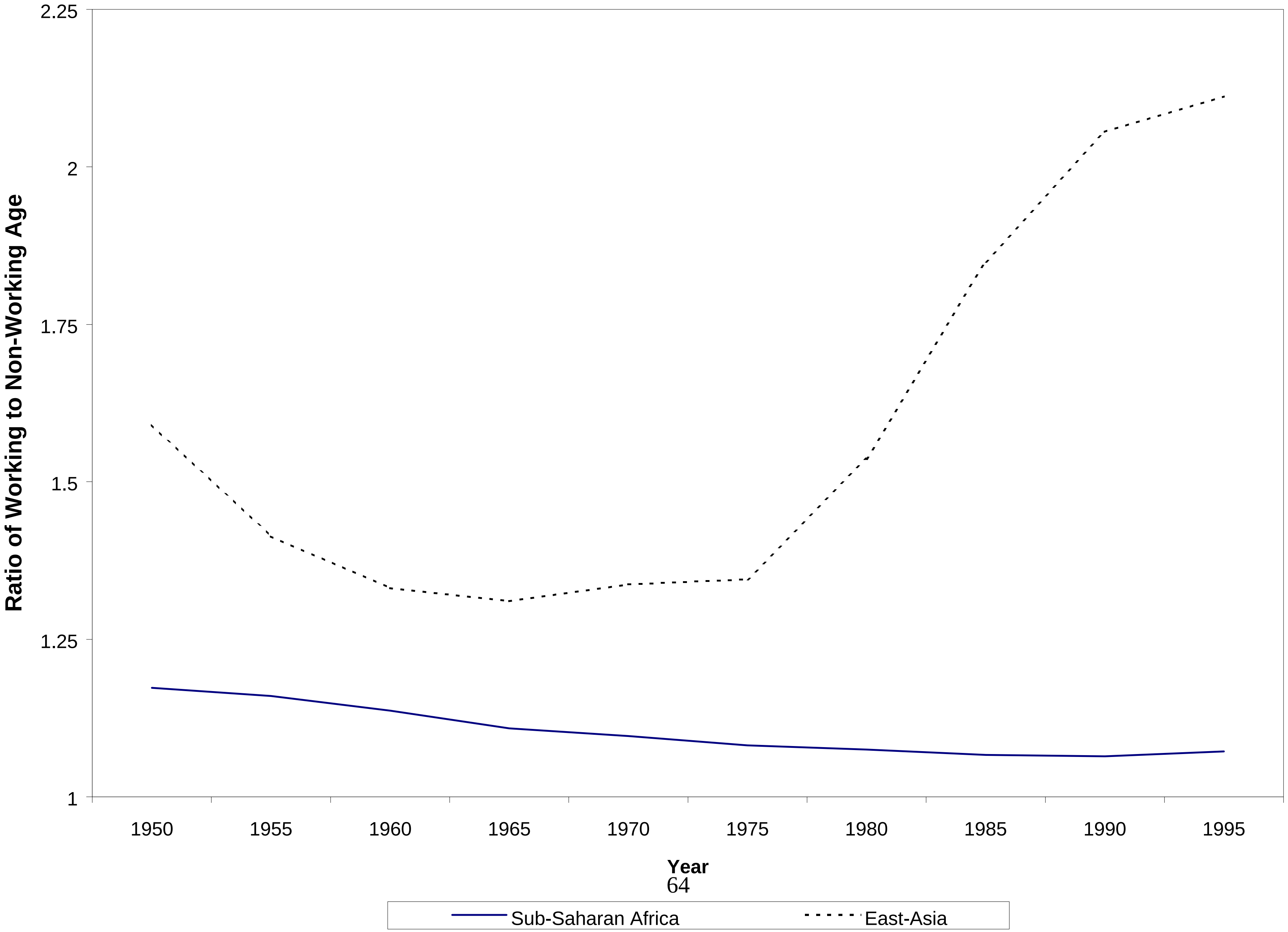
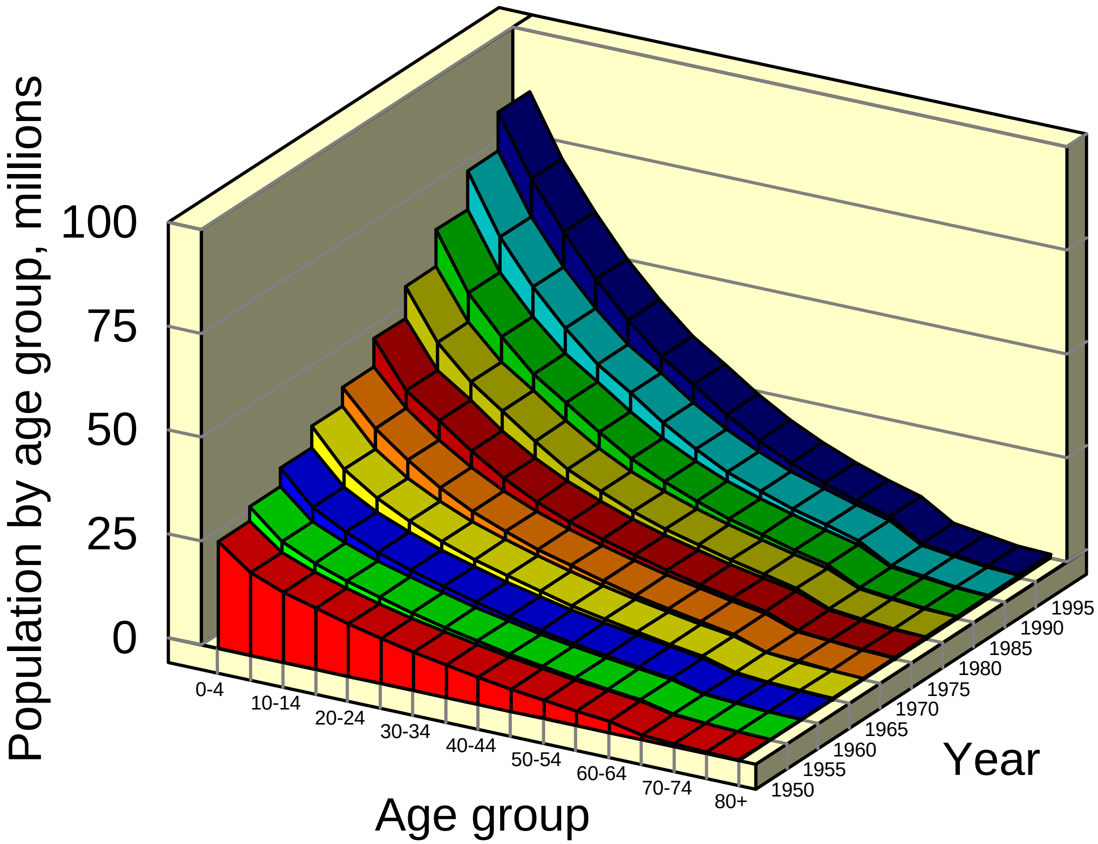


Figure 7. Changing Age Distribution
Sub-Saharan Africa



Source: The Sex and Age Distributions of Population. The 1992 Revision of the United Nations' Global Population Estimates and Projections

Figure 8. Value of Primary commodity exports as proportion of total

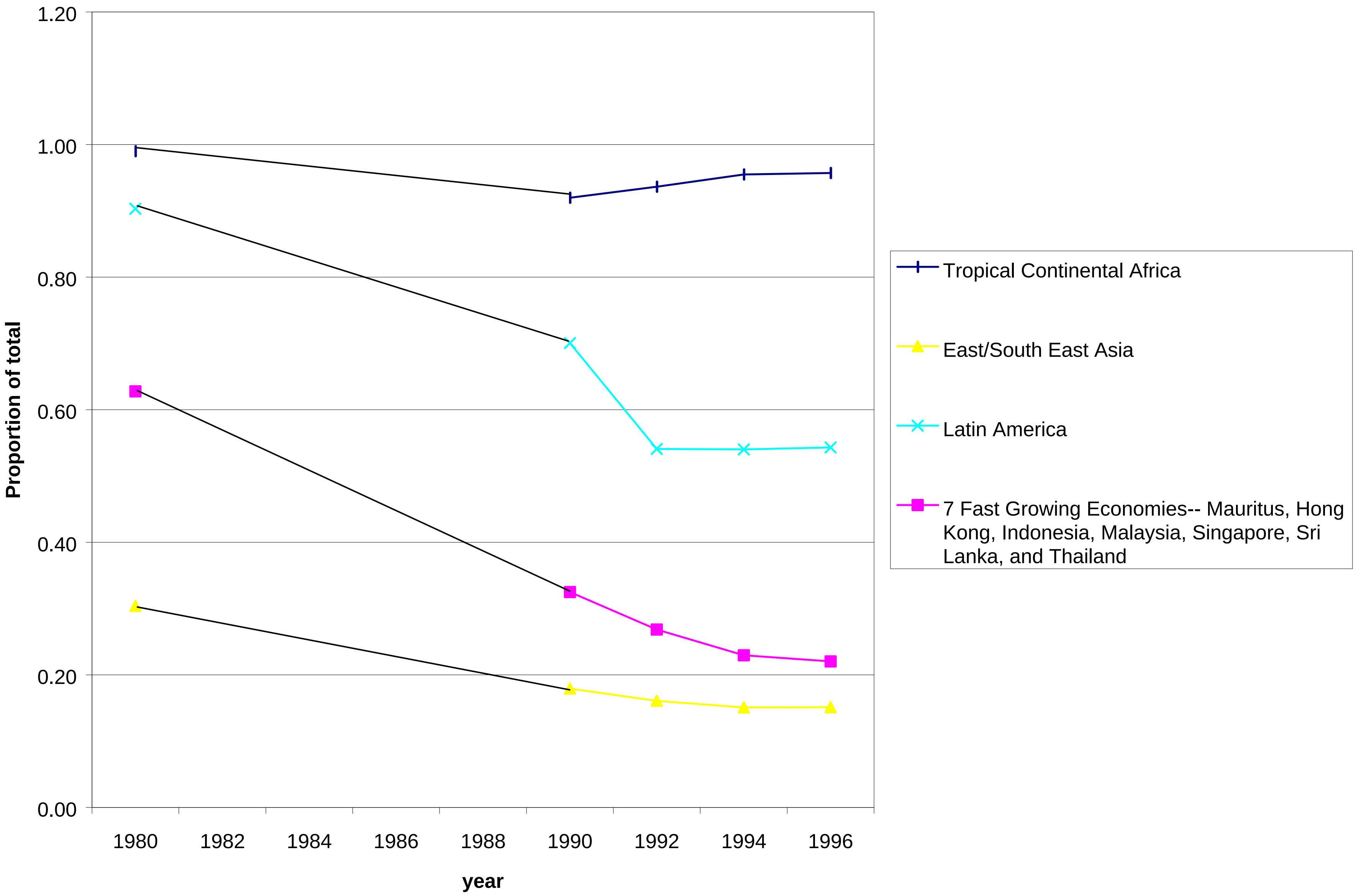
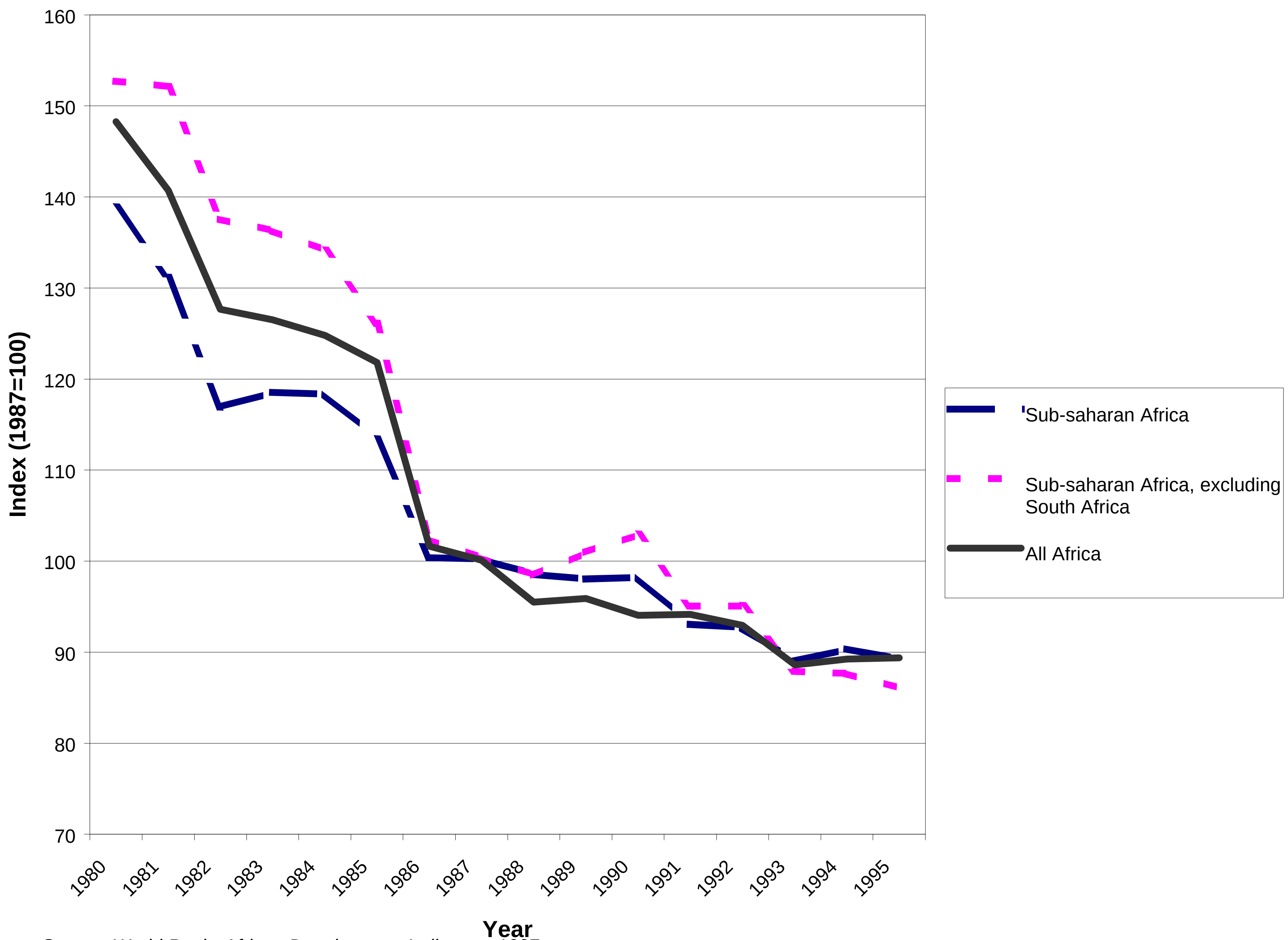


Figure 9. Terms of Trade



Source: World Bank, *African Development Indicators* 1997