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Geography, demography, and early development

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Abstract. This paper explores the role of geography in early development. It presents a model where the odds of survival are higher in geographically favorable regions. In such regions, higher life expectancy prompts parents to devote more of their resources to old-age consumption and enables them to invest relatively more in the quantity and quality of their offspring. Investment in education, together with population growth, helps geographically-favorable economies to attain high levels of a more educated population that is necessary for sustained economic growth. The empirical evidence is generally supportive of the view that geographic attributes influenced regional population levels in Europe and its colonial offshoots around 1500 A.D. and that they affected population levels and educational attainment in low-income countries of the 1990s.

JEL classification: J13, O11, O33

Key words: Human capital, demographic transition, growth

1. Introduction

This paper presents a simple theoretical framework that focuses on geography. It links population growth and early development to geographic characteristics and shows that geography affects economic development

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mostly indirectly–through its impact on households' demographic choices. Those choices, which entail the quantity and the quality of offspring, in turn, determine whether economies can sustain technological and economic progress.

The emphasis on geography in the context of early economic development and demographic change is warranted by two related findings: First, geographic characteristics were important in the emergence of agriculture and early development.[1] Second, economic development and demographic trends are related in the very long run.[2] Taken together these findings suggest that accounting for the role of geography in the early evolution of human societies could be important: by influencing the odds of survival and life expectancy in the initial stages of development, geographic characteristics have the potential to affect many household choices–including but not confined to those regarding the quantity and quality of offspring.

Using contemporary data covering low- and lower-middle income countries in 1994 as well as historic data on Western Europe and its colonial offshoots in 1500 A. D., I empirically verify that certain geographic attributes, such as latitude and terrain, help to explain population densities and educational attainment. Among the low- and lower-middle income countries in 1994, those which were located at higher latitudes, had milder temperatures and more diverse terrains had, in general, higher population densities and higher rates of educational attainment. I also find some evidence to suggest that terrain and temperatures exerted similar effects historically: among Western Europe and its colonial offshoots, those same variables help to explain which countries had higher population densities in 1500 A. D.

In the overlapping-generations model below, survival odds are influenced by geographic attributes. In geographically advantageous areas, individuals can survive longer periods compared to others who live in less hospitable regions. This in turn prompts parents to allocate more of their resources to old-age consumption and the quantity and quality of their offspring. In regions where geographical characteristics are more adverse, individuals struggle for survival.[3] These parents devote all of their limited resources to consumption and procreation. They do not invest in the education of their young. As a result, economies in geographically disadvantageous regions never escape the Malthusian trap: life expectancy and population growth stay low and mortality remains high.

In geographically favorable regions, however, a different story unfolds as higher survival odds allow parents to have more offspring that are also educated. Eventually, steady population growth and investment in education combine to provide the necessary conditions for sustained economic progress.

2. Related literature

This paper is related to the unified, long-run, growth models. Galor and Weil (2000) develop a framework that focuses primarily on the link between human capital accumulation and technological progress. In their model, economies eventually escape the Malthusian trap because of the scale effects of population size on technological progress.[4] Galor and Moav (2002) argue that the process of natural selection gives individuals who value the quality of their offspring relatively more a survival advantage. They then demonstrate that the emergence of mutations that value child quality more is sufficient to kick start a phase of demographic transition and economic development that is consistent with those observed in modern developed economies. The present effort differs from these papers by its emphasis on geographic characteristics as the driving force behind the patterns of demographic change during early development.[5] Goodfriend and McDermott (1995) emphasize, like I do here, the role of population growth in the process of early development. In a model with exogenous population growth, they show how economic development is first driven by a growing population, which generates increasing returns to specialization, and then by education and human capital accumulation, which leads to industrialization. The model I present below is similar to theirs because of the emphasis on population quantity and quality as important determinants of early development. What I present differs from their work because it emphasizes the role of geography in affecting early development.

The second theoretical strand to which this work is related examines how changes in mortality and the prevalence of epidemics influence demographic and economic transitions. For instance, Kalemli-Ozcan (2002) presents a model in which declining mortality enables parents to invest more in the education of their children and less in their numbers. This generates a strong link between mortality declines and economic growth. In a somewhat different vein, Lagerlof (2003) presents a model in which epidemic shocks fully account for the very long-run trends in demography and development. The model and the empirical analysis below is related to this strand because it links mortality change with economic development and demographic change. It differs from this strand primarily due to an emphasis on geography and early development.

Finally, this model is also related to empirical work that addresses how geographic characteristics impact economic performance. Gallup, Sachs, and Mellinger (1999) and Sachs (2000, 2001) find that location and climate have large effects on the level and growth of incomes per capita because they impact agricultural productivity, disease burdens, and transport costs.[6] Hall and Jones (1999) demonstrate how, while geographic location helps to account for a significant portion of the cross-country differences in output per worker, at least some of this might be due to the indirect role of geography in shaping institutions. Acemoglu et al. (2001, 2002) argue that the simple geography hypothesis, which suggests a direct link between climate and economic development, is inconsistent with available historical data. Their findings instead show that institutional differences help to explain most of the cross-country variation in incomes. What I present below differs from these papers because it emphasizes the role of geography in long-run population dynamics and early economic development.

3. The building blocks

The model rests on two key assumptions:

I) *Geographic characteristics affect survival odds*. In this model, the odds of survival (or mortality) are determined endogenously by geographic attributes. Specifically, I consider an overlapping generations model in which individuals could live up to three periods and there exists uncertainty about survival during the final old-age period.[7] This formulation has its analogs in other work. For example, a more discrete version of this approach has its precedents in models where consumption below a subsistence level leads to extinction. This is in fact the approach taken by Galor and Weil and Galor and Moav. Also there exists papers in which survival is modeled in similar fashion to the one presented below.[8]

According to this assumption, survival is low and mortality high if the climate is adverse and natural resources are scarce.[9] Indeed, Wrigley and Schofield (1989) find that mortality in England between 1541 and 1871 was increased by unusually cold temperatures in the winter and by extremely hot temperatures in the summer. Jones (1981) discusses that a hot and humid environment of human and animal diseases in Africa kept the rates of mortality high and the level of population down.

II) *Parents value both the quantity and quality of offspring*. Individuals in this model operate in the traditional Beckerian mold.[10] That is, household fertility is driven by a utility function that has as its arguments individuals' own consumption as well as the quantity and quality of their offspring. Given this Beckerian quality-quantity tradeoff and assumption (I), parents devote a larger fraction of their incomes to their children (either in the form of more or better educated offspring) if their self-survival odds are shorter.[11]

In the following section, I incorporate these assumptions into a simple dynamic model to demonstrate how geography could influence the demographics of population and educational attainment. In Sect. 5, I provide some empirical evidence that supports the role of geography in early development. In Sect. 6, I conclude.

4. The economy

4.1. production

Consider an overlapping generations economy in which real economic activity extends over an infinite discrete time. In every period, the economy produces a single homogenous good using efficiency units of labor. The supply of aggregate efficiency units of labor is determined by the size of the work force and the human capital of each worker. Let Y_t^j denote the aggregate output at time t of an economy located in geographic region j. Then,

$$Y_t^j = AH_t^j, \tag{1}$$

where A represents the exogenously given static level of technology and where H_t^j is the efficiency units of labor supply.[12,13]

The labor market is competitive and human capital is paid its marginal product:[14]

$$\bar{w} = A. \tag{2}$$

4.2. Individuals

Individuals, who are identical, live for up to three periods in overlapping generations. All individuals survive youth and young adulthood but only some live to become old. There is uncertainty about who reaches old age, but a favorable geography–one that is, presumably, milder in climate, exacts lower disease burden costs, and more hospitable to agricultural production–improves the odds of survival. Each individual has a single parent and is endowed with a unit of time in every period. When young, a member of generation $t-1$ consumes a fraction of her parent's time. This time requirement increases with the child's education level. In the second period of life, t, the individual is a young adult. During this period she works, consumes, and procreates, allocating her time between employment and child rearing. In the final old-age period, $t+1$, the individual retires and consumes if she survives to live that long.

4.2.1. Preferences and budget constraints

Individuals' preferences are defined over their expected consumption and the quantity and quality of their children.[15] Resources that are devoted to improving genetic survival–via quantity and/or quality investment in the offspring–reduce the availability of resources for consumption. Let c_t and c_{t+1} respectively denote the consumption of a member of generation $t-1$ in young adulthood and old age. And let n_t and h_{t+1} respectively denote the number of her children and their average human capital level. Preferences of this individual are represented by the following inter-temporal utility function:

$$U_j^{t-1} = u(c_t) + \alpha p_j u(c_{t+1}) + (1+p_j)[\beta u(n_t) + (1-\beta)u(\bar{w}h_{t+1})], \tag{3}$$

where $\alpha, \beta \in (0, 1)$ and where the utility function $u(.)$ satisfies the neoclassical restrictions, with $\forall\, x \equiv c_t, c_{t+1}, n_t, e_{t+1} > 0, u'(x) > 0, u''(x) < 0, \lim_{x\to 0} u'(x) = \infty$, and $\lim_{x\to\infty} u'(x) = 0$. In (3), the parameter β measures the value associated with the number of offspring relative to average quality as measured by future income, and p_j, $0 \leq p_j \leq 1$, denotes the probability of surviving young adulthood in geographic region j.[16] This probability depends on how favorable the geographic characteristics of the economy are. Let G_j denote the relevant geographic attributes of the economy j. Then, by assumption, $p_j = p(G_j)$, with $p' > 0$, $p'' < 0$, $p(0) = 0$, $p(\infty) = \bar{p} \leq 1$, $\lim_{G\to 0} p'(G_j) = \infty$, and $\lim_{G\to\infty} p'(G_j) = 0$. Note that the life expectancy of all individuals in this economy equals $2 + p_j$.

Following the standard Beckerian model of household fertility, individuals decide the optimal number of their children and the education level of each subject to a budget constraint that reflects the allocation of time between work and child rearing. To formalize, let e_{t+1} denote the education level of each child, and let τ^n and τ^e respectively denote the time costs of rearing a child and educating one for a unit of time. Then, for a member of generation $t-1$, $n_t(\tau^n + \tau^e e_{t+1})$ denotes the total time cost of child rearing and education.

Given that a member of generation $t-1$ works in the following period and possesses h_t efficiency units of labor at that time, her income is equal to $\bar{w}h_t = Ah_t \equiv I_t$. She allocates this potential income among current consumption, saving for future consumption and child rearing and education. Thus, she faces the following budget constraint:

$$Ah_t n_t(\tau^n + \tau^e e_{t+1}) + c_t + S_t \leq Ah_t \equiv I_t \tag{4}$$

where S_t denotes the individual's amount of saving in period t.[17]

4.2.2. Population size and education

The size of the working population at time $t+1$, L_{t+1}, is given by

$$L_{t+1} = n_t L_t, \tag{5}$$

where L_t is the working population in period t, n_t is the number of children per parent, and $n_t - 1$, is the growth rate of the working population.[18] The size of the population at time 0, L_0, is given historically.

In order to employ a relatively simple human capital accumulation process, I assume that each person's human capital is determined in the following specific way:

$$h_{t+1} = \phi(e_{t+1}), \tag{6}$$

where $\forall e_{t+1} \geq 0$, $\phi(e_{t+1}) > 0, \phi' > 0$, $\phi'' < 0$, $\phi(0) = \tilde{h} > 0$, and $\lim_{e_{t+1} \to 0} \phi'(e_{t+1}) < \infty$.

4.2.3. Geography, life expectancy, and the quantity-quality tradeoff

Members of generation $t-1$ maximize (3) by choosing the number and education of their offspring, and their own optimal consumption pattern. Substituting equations (2), (4), and (6) into (3), and expressing the amount of saving, S_t, as a fraction of total potential income (i.e., $S_t = s_t A h_t$), the problem of a representative individual can be written as follows:

$$\{n_t, e_{t+1}, s_t\} = argmax \left\{ \begin{array}{l} u[I_t(1 - n_t(\tau^n + \tau^e e_{t+1}) - s_t)] \\ +\ \alpha p_j u(s_t I_t) + \beta(1 + p_j) u(n_t) \\ +\ (1 - \beta)(1 + p_j) u[A\phi(e_{t+1})] \end{array} \right\} \tag{7}$$

subject to $(n_t, e_{t+1}, s_t) \geq 0$.

The first-order conditions with respect to each of the arguments, n_t, e_{t+1}, s_t, are respectively given by the following:

$$\begin{aligned} &\frac{u'(n_t)}{u'(c_t)} - \frac{(\tau^n + \tau^e e_{t+1}) I_t}{\beta[1 + p(G_j)]} \leq 0 \\ &\frac{u'[\phi(e_{t+1})]\phi'(e_{t+1})}{u'(c_t)} - \frac{\tau^e n_t I_t}{(1 - \beta)[1 + p(G_j)]A} \leq 0 \\ &\frac{u'(c_{t+1})}{u'(c_t)} - \frac{1}{\alpha p(G_j)} \leq 0 \end{aligned} \tag{8}$$

Functional form assumptions imply that interior solutions exist for the optimal number of children, n_t, and the share of total income earmarked for second period consumption, s_t. That is not the case, however, with respect to optimal education, e_{t+1}. More specifically, there exists low enough values of the geographic characteristics, G_j, for which the odds of survival are relatively low. For such values, the optimal amount of education per child equals zero.[19] For other values, an interior solution exists for all control variables.

Regardless of whether an interior solution exists for education, e_{t+1}, (8) demonstrates the impact of a favorable geography on optimal choices of fertility, education, and saving: by generating higher survival probability, $p(G_j)$, and extending the expected lifetime, a friendly geography lowers the effective discount rate on all kinds of future consumption. In a Beckerian framework, the latter includes, in addition to old-age consumption, c_{t+1}, the quantity and quality of offspring, n_t and h_{t+1}, as well.

The first-order conditions given by (8), together with the budget constraint in (4), fully determine the optimal values of fertility, n_t^*, education, e_{t+1}^*, and saving, s_t^*. In particular, they are all non-decreasing functions of per capita income, I_t, and geographic endowment, G_j:

$$n_t^* = n(I_t, G_j),$$

$$e_{t+1}^* = e(I_t, G_j), \tag{9}$$

and,

$$s_t^* = s(I_t, G_j),$$

Proposition 1 $\forall\ h_t,\ G_j\ >\ 0,$

(i) $\partial n_t^*/\partial I_t > 0$ and $\partial n_t^*/\partial G_j\ >\ 0;$

(ii) $\partial e_{t+1}^*/\partial I_t \geq 0$ and $\partial e_{t+1}^*/\partial G_j \geq 0;$

(iii) $\partial s_t^*/\partial I_t > 0$ and $\partial s_t^*/\partial G_j\ >\ 0.$

Proof: Follows immediately from applying the implicit function theorem to the first-order conditions defined by (8).

5. Empirical evidence

As noted in the preceding section, this model suggests that favorable geographic characteristics should lead to higher population densities and more knowledge accumulation–most certainly in the early phases of development. In this section, I test this hypothesis using two different datasets: one for the low-income countries of the 1990s, and another for Western Europe and its colonial offshoots in 1000 A. D. and in 1500 A. D. The first sample, by selection, includes only those countries that have not yet become developed (and excludes those that might have become industrialized due to other factors despite their unfavorable geographic attributes).[20] Thus, this sample should help to reveal the impact of geography on the levels of population and educational attainment during early development.[21] Similarly, historic data on Europe and its colonial offshoots prior to the Industrial Revolution should also reflect any impact geographic attributes might have had on countries, some of which that have become industrialized since then.[22]

The empirical estimates of the effect of geographic attributes on various characteristics of early development, like population density, educational attainment, or urbanization, are obtained by estimating the following equation with cross-country data:

$$DEV_{j,t} = \beta_0 + \beta_1 G_j + \beta_2 X_{j,t-1} + \upsilon_{j,t}, \tag{10}$$

where $DEV_{j,t}$ is the dependent variable potentially influenced by geography (more on which below), G_j is a vector of regional geographic attributes, X_{t-1} are additional control variables that may help to explain $DEV_{j,t}$, and $\upsilon_{i,t}$ is the variability in $DEV_{j,t}$ not explained by the regressors. I assume that $\upsilon_{i,t}$ is uncorrelated with the regressors and is distributed normally with a mean of zero and a variance of $\sigma^2_{i,t}$.[23]

For each country, both sets of data include the following independent G_j variables: Latitude, $LATITUDE_j$, terrain, $TERRAIN_j$, measures of average annual temperature, $TEMP_j$, average morning humidity, $HUMID_j$, and two interaction terms for latitude and terrain and average temperature and humidity.[24] The control variables in $X_{j,t-1}$ include regional\continental dummies for Africa, East Asia, Central and Latin America, the Middle East, $AFRICA_j$, $ASIA_j$, LAM_j, $MEAST_j$, respectively. For the contemporary data, they also include an additional dummy for oil exporting countries, OIL_j, and the log of the level of per capita income, $LNGDPCAP_j$.[25]

The dependent variables, $DEV_{j,t}$, are population density, $PDENSE_{j,t}$, average years of schooling, $SCHOOL_{j,t}$, and rates of urbanization, $URBAN_{j,t}$.[26] Population density data are available for both the contemporary and the historic data. Thus, for both datasets, I use the independent variables to predict population density, $PDENSE_{j,t}$. Educational attainment data are only available for the contemporary data, and I use them to explore the role of geographic characteristics in average years of schooling, $SCHOOL_{j,t}$. Finally, rates of urbanization have been demonstrated to be highly correlated with early development.[27] For the historic data on Europe and its colonial offshoots, urbanization rates are available for as early as 1000 A. D. and I use them to examine the impact of geography on urbanization, $URBAN_{j,t}$.

With the exception of *TERRAIN* and *URBAN*, all these variables are self-explanatory. *TERRAIN* is a binary dummy variable. It is based on an index that ranges from 0 to 4.[28] The index attains a value of zero if the landscape is mostly sandy deserts or desert plains with low coastal regions; one if it is mostly coastal lowlands with desert plateaus or coastal plains with swamps; two if the landscape is diverse, ranging from flat plains or gently rolling hills to plains, plateaus and deltas; three if the terrain is mostly mountains and hills with small plains, high plateaus, and deltas; and four if the landscape is mostly rugged mountains. For our purposes here, it is important to note that the most favorable attributes are covered by terrain codes 2 and 3. Consequently, the dummy *TERRAIN* attains a value of one if the underlying code is a 2 or a 3 and zero otherwise. *URBAN* is defined as the share of the total population that lives in urban areas, the latter which is usually defined as residential areas with a population of 20,000 or more. As noted above, the urbanization rate is positively related to per-capita income.

Given that geographic attributes change little, if at all, over very long periods of time, empirical issues arising from reverse causality is not of major concern. They are applicable with respect to per-capita income, *LNGDPCAP*, which is only available for contemporary data. To focus attention on the link from per capita income to population density and educational attainment, I use a lagged value of per capita income, studying the relationship between per capita income in 1960 and population density and educational attainment in 1994.

The data are from a variety of sources. For both sets, the geography variables are from Parker (1997). For the first dataset, which covers the low-income countries of the 1990s, the population density data are from Parker, average years of schooling are from the *World Development Indicators* of the World Bank, and per-capita incomes are from the Penn World Tables. For the second dataset on Western Europe and its colonial offshoots, the 1000 A. D. urbanization measures and the 1500 A. D. population density variables (with the exception of those for Western Europe) are borrowed from Acemoglu et al. (2002), who in turn derive them from data provided by Chandler (1987) and McEvedy and Jones (1978). Those for Western Europe are derived from McEvedy and Jones and the *CIA World Fact Book*.[29] Table 1 presents summary statistics of the key variables in the empirical analysis.

Table 2 shows how geographic characteristics impact population density in the lowest-income countries of the world today. [As in all tables that follow, columns (1)-(3) show estimates with robust errors, and (4)–(6) the results from robust regressions that correct for outlier biases.] Under most specifications using this sample, *TERRAIN* and *LATITUDE* enter positively and statistically significantly, and their interaction, *LATTER*, enters negatively and significantly. Together, these results suggest that the positive impact of the terrain (latitude) declines as latitude (terrain) increases. The impact of *LATITUDE* and *TERRAIN* on population density is quite large: a ten degree higher latitude leads to an average of 20 more people per square kilometer, an increase in density of roughly 15 %. And an increase from zero to one in the terrain code is associated with an increase of roughly 60 people per square kilometer, an increase in density of over 50 %.

As seen in the robust errors specification in column (2) and the robust regression results in (6), warmer temperatures yield a significant and positive impact on population density in the low-income countries, although the positive impact of a warmer climate dissipates with increases in the average temperature. As shown, *TEMP* is significant and positive in both specifications and $TEMP^2$ is significant and negative (with the coefficient on *TEMP* dominating that on $TEMP^2$ by an important order of magnitude). Note also that, while the regional/continental dummies are significant in some cases (like the negative and significant African dummy and the positive and significant East Asian dummy), per-capita income in 1960, *LNGDPCAP*, had in general no significant effect on population densities in 1994. These results, as well as those that follow, are robust to the exclusion of any combinations of the additional control variables like regional/continental dummies and income per capita. They are also robust to the inclusion of additional variables such as the cumulative share of total world mineral resources, openness (as measured by the total share of exports and imports in GDP), and a dummy variable for whether the country is landlocked.

According to our model, there should exist a positive relationship between educational attainment and favorable geographic attributes as well. Years of schooling data is scarce for the lowest-income countries (it exists for only 14 out of 60 of the countries in the sample). However, data on secondary school enrollment rates are more widely available for this sample and I rely on this alternative data here.[30] Table 3 shows tests of the prediction that geographic attributes should affect secondary school enrollment rates. As shown in

Table 1. Descriptive statistics and the correlation matrix

n = 60	*Mean*	*Std. Dev.*	*The Correlation Matrix, 1994*						
			PDENSE	*SCHOOL*	*LATITUDE*	*TERRAIN*	*TEMP*	*HUMID*	*LNGDPCAP*
PDENSE	88.8	128.2	1	–	–	–	–	–	–
SCHOOL	7.1	3.5	0.303	1	–	–	–	–	–
LATITUDE	18.0	13.7	0.674	.725	1	–	–	–	–
TERRAIN	0.667	0.475	0.209	.216	−.063	1	–	–	–
TEMP	21.8	7.4	0.020	−.717	−.863	−.149	1	–	–
HUMID	66.0	18.4	−.104	.603	.010	0.309	−.177	1	–

n = 14	*Mean*	*Std. Dev.*	*The Correlation Matrix, 1000 A. D. and 1500 A. D.*					
			PDENSE	*URBAN*	*LATITUDE*	*TERRAIN*	*TEMP*	*HUMID*
PDENSE	6.61	16.3	1	–	–	–	–	–
URBAN	3.95	3.93	0.140	1	–	–	–	–
LATITUDE	20.9	13.3	0.134	−0.368	1	–	–	–
TERRAIN	0.738	0.445	−0.323	0.215	0.061	1	–	–
TEMP	21.5	5.78	0.185	0.287	−0.540	−0.322	1	–
HUMID	73.4	15.1	−0.511	0.239	0.355	0.267	0.071	1

Table 2. Regressions for low-income countries, 1994

	Dependent variable: POPULATION DENSITY, 1994 (Person/Square km.)					
	Robust errors			Robust regressions		
	(1)	(2)	(3)	(4)	(5)	(6)
$LATITUDE_j$	2.08 (2.09)	–	2.75 (3.37)	3.01^{*} (1.01)	–	3.40^{*} (1.03)
$TERRAIN_j$	78.7^{*} (33.6)	–	88.05^{*} (36.24)	50.9^{*} (18.82)	–	48.9^{*} (17.18)
$LATITUDE_j * TER_j$	-4.0^{**} (2.48)	–	−3.61 (2.76)	-3.43^{*} (.998)	–	-2.83^{*} (.849)
$TEMP_j$	–	24.1^{**} (14.3)	19.02 (15.99)	–	2.03 (5.71)	7.51^{***} (4.97)
$HUMID_j$	–	9.0^{***} (5.92)	9.03 (7.48)	–	−.337 (2.96)	−3.13 (2.59)
$HUMID_j * TEMP_j$	–	−.185 (.174)	−.138 (.161)	–	.045 (.075)	−.035 (.066)
$TEMP_j^2$	–	$-.24^{**}$ (.145)	−.146 (.161)	–	$-.133^{**}$ (.080)	$-.113^{***}$ (.069)
$HUMID_j^2$	–	−.039 (.030)	−.049 (.038)	–	−.006 (.016)	.014 (.014)
$AFRICA_j$	-51.4^{***} (35.6)	−51.4 (40.1)	−52.5 (36.3)	−13 (15.3)	−14.7 (15.0)	−16.4 (14.5)
$ASIA_j$	117^{*} (55.2)	97.8^{**} (49.9)	120.0^{*} (39.9)	160^{*} (25.2)	162^{*} (24.8)	170.8^{*} (23.6)
LAM_j	-84.0^{*} (28.8)	-71.0^{*} (29.6)	-126.4^{*} (61.4)	−28.8 (42.9)	−24.6 (44.1)	−18.7 (44.2)
$MEAST_j$	232.4 (210)	265.1 (214)	277^{***} (179)	51.0 (42.9)	14.9 (33.5)	35.2 (32.4)
$LNGDPCAP_j$	−2.55 (18.9)	−.223 (17.8)	.029 (.036)	11^{***} (7.13)	10.05 (7.29)	−.014 (.016)
No. of obs.	60	60	60	59	58	59
R^2	.33	.42	.47	–	–	–

Note: *, ** and *** respectively denote significance at the 5%, 10% and 15% levels. The variables LLOCK and MINERAL not included as they were not significant under any specification.

Table 3. Regressions for low-income countries, 1994

	Dependent variable: SECONDARY SCHOOL ENROLLMENT RATES, 1994 (Average years of male educational attainment)					
	Robust Errors			Robust Regressions		
	(1)	(2)	(3)	(4)	(5)	(6)
$LATITUDE_j$	−.013 (.024)	–	−.018 (.025)	008 (.009)	–	.001 (.012)
$TERRAIN_j$	−.214 (.707)	–	−.211 (.725)	.503* (.182)	–	.541* (.194)
$LATITUDE_j * TER_j$	−.011 (.020)	–	−.012 (.018)	−.030* (.009)	–	−.030* (.010)
$TEMP_j$	–	.024 (.080)	−.004 (.076)	–	.071 (.060)	.005 (.055)
$HUMID_j$	–	−.001 (.035)	.001 (.034)	–	−.020 (.032)	−.019 (.029)
$HUMID_j * TEMP_j$	–	.0003 (.001)	.0004 (.001)	–	−.001 (.001)	−.0002 (.0007)
$TEMP_j^2$	–	−.0003 (.001)	−.001 (.001)	–	−.001 (.001)	−.0005 (.0008)
$HUMID_j^2$	–	−.0001 (.0003)	−.0001 (.0003)	–	.0002*** (.0001)	.0001 (.0002)
$AFRICA_j$	.310 (.341)	.476 (.463)	.296 (.393)	.012 (.147)	.052 (.158)	−.575 (.988)
$ASIA_j$	−.030 (.338)	.123 (.312)	−.100 (.362)	−.048 (.240)	−.077 (.264)	2.13 (.170)
LAM_j	.060 (.171)	.018 (.216)	.067 (.181)	−.044 (.419)	.179 (.470)	1.23 (1.27)
$MEAST_j$	−.139 (.213)	.062 (.350)	−.233 (.209)	−.226 (.269)	−.174 (.299)	.998 (1.25)
$LNGDPCAP_j$	.293 (.209)	.270 (.271)	.350 (.267)	.097*** (.064)	.016 (.078)	.0001 (.0004)
No. of obs.	60	60	60	60	60	60
R^2	.13	.09	.14	–	–	–

Note: *, ** and *** respectively denote significance at the 5%, 10% and 15% levels.

columns (4) and (6), *TERRAIN* positively and statistically significantly impacts secondary school enrollment rates. The effect of *TERRAIN* on school enrollment is very large: for instance, geographic regions where the terrain is more favorable have more than double the school enrollment rates compared to regions where the terrain is not favorable.[31]

Tables 4 and 5 show the results generated with the second dataset, that on Western Europe and its colonial offshoots in 1000 A. D. and 1500 A. D. respectively. As shown in columns (1) and (3) of Table 4, *TERRAIN* had a positive and significant effect on rates of urbanization in 1000 A. D. although this effect seems to be driven by some outliers. In Table 5, I repeat this exercise using population density data from 1500 A. D. The results are mixed. On the one hand, the effect of *TERRAIN* on population density levels in 1500 A. D. does not seem to be robust (where it is either insignificant or significant with opposite signs in different specifications). On the other hand, geographic regions with warmer temperatures seem to have generated higher population densities historically: the coefficient on *TEMP* is significant and positive in two specifications (just like they are in Table 2).

I also examined whether geographic characteristics can help to explain *modern* as well as *early* economic development. To test this idea, I expanded the contemporary dataset, which covers the low-income countries in 1994, to include all countries. This exercise generated 175 observations. Then, I tested whether the selected geographic attributes, *LATITUDE*, *TERRAIN TEMP*, and *HUMID*, help to explain population density, *PDENSE*, and educational attainment, *SCHOOL*.

Table 6 shows the impact of geographic attributes on population densities for all countries in the broadened sample. The results with this sample are consistent with those reported in Table 2: *LATITUDE* and *TERRAIN* positively impact population densities. Interestingly, however, the positive and statistically significant effects of both *LATITUDE* and *TERRAIN* attain with the robust regression specification. And when significant and positive, as they are in column (6), the coefficients on *LATITUDE* and *TERRAIN* are about a third to a half smaller than the coefficients in Table 2. Further, the aggregate explanatory power of all the independent variables is much weaker according to the fit of the models as measured by R^2. Thus, based on a comparison of the results in Table 2 and Table 6, it is reasonable to conclude that the effect of the selected geographic attributes on population densities are most relevant for early development (when per-capita incomes are much lower).

Table 7 presents the estimation results with years of schooling, *SCHOOL*, as the dependent variable and using this whole sample. Again, these results do indicate a statistically significant, positive, and robust effect of *LATITUDE* and *TERRAIN* on years of schooling. Accordingly, we can conclude that the impact of geographic attributes on educational attainment seems to persist for longer phases than that of geography on population. There is a reasonable, but admittedly speculative, explanation for why the impact of geography on schooling persists while that of geography on population density does not: technological advances in health care in the last century had a profound impact on mortality and life expectancy in all but the poorest countries in the world. If in addition technological progress had a greater and earlier effect on health than on educational attainment, one would expect the effect of geography on population dynamics (but not so much education)

Table 4. Regressions for Western Europe and its colonical offshoots, 1000 A.D

	Dependent variable: URBANIZATION, 1000 A.D. (Percentage of Population Living in Urban Areas)					
	Robust errors			Robust regressions		
	(1)	(2)	(3)	(4)	(5)	(6)
$LATITUDE_j$	−0.040(0.125)	–	−0.010(0.126)	−0.063(0.113)	–	−0.043(0.156)
$TERRAIN_j$	5.15***(3.27)	–	6.20**(3.40)	5.11(3.87)	–	6.22(4.65)
$LATITUDE_j$*$TER._j$	−0.152(0.114)	–	−0.151(0.127)	−0.149(0.150)	–	−0.140(0.179)
$TEMP_j$	–	0.834(1.29)	0.761(1.36)	–	0.747(2.08)	0.655(1.95)
$HUMID_j$	–	0.172(0.402)	0.284(0.341)	–	0.096(0.610)	0.288(0.583)
$HUMID_j$* TEMP_j	–	−0.007(0.017)	−0.006(0.015)	–	−0.005(0.022)	−0.005(0.020)
$TEMP_j^2$	–		−0.001(0.015)	–	−0.001(0.026)	−0.0006(0.025)
$HUMID_j^2$	–		−0.001(0.002)	–	−0.0002(0.003)	−0.002(0.003)
$AFRICA_J$	−0.117(2.74)	−1.51(3.71)	−3.11(3.78)	0.147(2.94)	−0.147(4.50)	−3.21(4.25)
$ASIA_j$	−4.13**(2.43)	−3.86(3.02)	−6.14(3.23)	−4.37***(2.89)	−4.25(4.00)	−6.69**(3.92)
LAM_j	−3.15(2.78)	−.368(2.59)	−4.80(3.54)	−3.17(3.21)	−0.448(4.04)	−4.81(4.33)
No.of obs.	34	34	34	34	34	34
R^2	0.33	0.26	0.40	–	–	–

Note: *, ** and *** respectively denote significance at the 5%, 10% and 15% levels. The variables LLOCK, and MINERAL, not included as they were not significant under any specification.

Table 5. Regressions for Western Europe and its colonical offshoots, 1500 A.D

	Dependent variable: POPULATION DENSITY, 1500 A. D. (Person/Square km.)					
	Robust errors			Robust regressions		
	(1)	(2)	(3)	(4)	(5)	(6)
$LATITUDE_j$	0.769 (0.613)	–	0.581 (0.524)	−0.003 (0.022)	–	−0.218* (0.082)
$TERRAIN_j$	9.43 (10.86)	–	11.39 (12.32)	1.32* (0.649)	–	−7.07 (2.16)
$LATITUDE_J$*TER.$_j$	−0.879 (0.732)	–	−0.832 (0.707)	−0.40*** (0.027)	–	0.205 (0.003)
$TEMP_j$	–	5.05*** (2.76)	3.85 (4.00)	–	0.587 (0.583)	2.86* (0.996)
$HUMID_j$	–	1.03 (0.965)	1.09 (1.04)	–	0.874* (0.161)	0.141 (0.270)
$HUMID_j$* TEMP$_j$	–	−0.081* (0.030)	−0.085 (0.045)	–	−0.009*** (0.006)	−0.045 (0.010)
$TEMP_j^2$	–	0.035 (0.044)	0.070 (0.062)	–	0.004 (0.007)	0.019*** (0.12)
$HUMID_j^2$	–	0.003 (0.005)	0.003 (0.004)	–	0.007* (0.001)	0.005* (0.001)
$AFRICA_J$	19.24 (14.06)	18.19 (15.35)	19.80 (15.02)	7.11* (.527)	7.79* (1.17)	9.21* (1.96)
$ASIA_j$	1.40 (6.70)	−2.14 (9.05)	−2.41 (5.97)	−0.844** (0.473)	−0.395 (0.979)	2.71*** (1.71)
LAM_j	−6.18 (6.22)	−5.09 (9.06)	−5.09 (6.08)	−0.550 (0.492)	0.420 (0.957)	1.14 (1.71)
No.of obs.	42	42	42	4	4	4
R^2	0.35	0.48	0.55	–	–	–

Note: *, ** and *** respectively denote significance at the 5%, 10% and 15% levels. The variables *LLOCK* and *MINERAL* not included as they were not significant under any specification.

Table 6. Regressions for All Countries, 1994

	Dependent Variable: POPULATION DENSITY,1994 (Person/Square km.)					
	Robust Errors			Robust Regressions		
	(1)	(2)	(3)	(4)	(5)	(6)
$LATITUDE_j$	−27.60 (25.79)	–	−18.49 (28.64)	0.296 (0.480)	–	1.37** (0.741)
$TERRAIN_j$	−454.82 (548.8)	–	−378.3 (576.2)	25.27*** (17.20)	–	16.17* (8.12)
$LATITUDE_j$*$\mathrm{TER.}_j$	−4.16 (13.56)	–	−7.49 (14.58)	−0.341 (0.539)	–	−0.142 (0.247)
$TEMP_j$	–	186.8 (138.6)	151.0 (125.2)	–	15.32* (4.61)	17.31* (4.95)
$HUMID_j$	–	85.91** (48.36)	75.86** (47.2)	–	6.65* (2.47)	7.93* (2.67)
$HUMID_j$*TEMP_j	–	−0.331 (0.674)	−0.062 (0.805)	–	−0.116* (0.050)	−0.134* (0.055)
$TEMP^2{}_j$	–	−2.97 (2.46)	−3.57 (2.87)	–	−0.211* (0.073)	−0.190* (0.079)
$HUMID^2{}_j$	–	−0.638* (0.327)	−0.634* (0.327)	–	−0.029** (0.015)	−0.035* (0.17)
$AFRICA_j$	−666.4 (626.3)	−517.5 (544.4)	−587.6 (606.1)	−29.07* (14.48)	−32.28* (14.05)	−32.06* (15.21)
$ASIA_j$	67.93 (846.4)	211.9 (794.9)	137.7 (834.6)	114.7* (19.56)	111.8* (19.03)	133.3* (20.4)
LAM_j	−860.9 (676.1)	−803.2 (670.2)	−870.1** (705.9)	−40.55* (15.92)	−56.56* (14.86)	−58.96* (16.71)
$MEAST_j$	−702.4 (535.6)	−677.5 (502.8)	−808.3 (590.3)	−13.21 (15.29)	−1.17 (16.41)	4.84 (17.53)
$LNGDPCAP_j$	315.8* (156.8)	283.6* (136.0)	315.2* (151.6)	1.29 (4.11)	−1.28 (3.91)	−2.11 (4.65)
No.of obs.	175	175	175	175	175	175
R^2	0.06	0.06	0.07	–	–	–

Table 7. Regressions for All Countries, 1994

	Dependent Variable YEARS OF SCHOOLING, 1994 (Average Years of Male Educational Accttainment)					
	Robust Errors			Robust Regressions		
	(1)	(2)	(3)	(4)	(5)	(6)
$LATITUDE_j$	0.077* (0.022)	–	0.082*(0.032)	0.078* (0.024)	–	0.103* (0.034)
$TERRAIN_j$	1.94* (0.956)	–	0.717 (0.790)	1.81* (0.796)	–	0.038 (0.456)
$LATITUDE_j$*TER.$_j$	−0.046* (0.023)	–	−0.024 (0.022)	−0.042** (0.023)	–	−0.004 (0.012)
$TEMP_j$	–	−0.301 (0.222)	−0.223 (0.246)	–	−0.264 (0.263)	−0.025 (0.231)
$HUMID_j$	–	−0.221* (0.111)	−0.253* (0.099)	–	−0.247* (0.101)	−0.292* (0.092)
$HUMID_j$*TEMP$_j$	–	0.005* (0.002)	0.005* (0.002)	–	0.005* (0.002)	0.006* (0.002)
$TEMP^2{}_j$	–	−0.005 (0.004)	−0.005 (0.005)	–	−0.006 (0.004)	−0.011* (0.004)
$HUMID^2{}_j$	–	0.001** (0.0007)	0.001* (0.0006)	–	0.0013* (0.0006)	0.0015* (0.0006)
$AFRICA_j$	0.709 (0.715)	0.165 (0.694)	0.471 (0.634)	0.856 (0.680)	0.046 (0.716)	0.462 (0.635)
$ASIA_j$	1.44 (1.12)	0.709 (0.982)	1.27 (0.920)	1.74* (0.837)	0.619 (0.843)	1.48** (0.765)
LAM_j	1.08** (0.639)	0.650 (0.624)	1.04** (0.631)	1.29** (0.691)	0.456 (0.719)	0.836 (0.668)
$MEAST_j$	−0.792*** (0.536)	−0.815 (0.799)	−0.591 (0.596)	−0.835 (0.587)	−1.03*** (0.675)	−0.793 (0.602)
$LNGDPCAP_j$	1.63* (0.205)	1.56* (0.157)	1.38* (1.97)	1.67 (0.205)	1.57* (0.207)	1.34* (0.203)
No.of obs.	71	71	71	71	71	71
R^2	0.83	0.84	0.84	–	–	–

to be diluted by that of technological advances on health and mortality over time.[32]

6. Conclusion

During most of its history, humankind struggled for survival. This struggle was all the more brutal where nature was not relatively cooperative. To what extent did the fate of human societies depend on nature?

In this paper, I present a simple dynamic model that focuses on geography in the very long run. The model links demographic transition to geography and shows that geography affects the economy mostly indirectly via its impact on demographics. The reason is that, by affecting the odds of survival, geographic characteristics influence household decisions–including those related to the quantity and quality of children. And the latter in turn determine whether economies can sustain economic progress.

The empirical evidence for Western Europe and its colonial offshoots in 1500 A. D. and those for the low-income countries of the 1990s generally supports the idea that geographic attributes influence population levels and educational attainment. The effects of latitude and terrain on population dynamics and early development are statistically significant and robust: among the low-income countries today, those with higher latitude and more diverse terrains have higher population densities and education levels. And among Western Europe and its colonial offshoots, average temperatures (controlling for humidity) help to explain which countries had higher population densities in 1500 A. D.

Endnotes

[1] For instance, McNeill (1998, p. 67) claims that the reason why Africa remained backward in the development of agriculture compared to temperate lands is that the latter exacted much lower costs in terms of exposure to disease.

[2] See, for example, Galor and Weil (2000) and Galor and Moav (2002).

[3] Another indirect channel through which geography could potentially manifest itself in the demographic makeup of regions is migration. Although the model here abstracts from the idea that geographic characteristics might generate migration across the regions, the incorporation of such an endogenous mechanism would serve to further propagate the indirect effects of geography on demographic and economic changes. Such a modification could also help to explain the long-run patterns of human migration.

[4] While the primary emphasis of Galor and Weil is on the scale effect of population size on technological progress, their model too incorporates the impact of geographic attributes on the survival odds of the offspring (and the role of the latter in the take-off to a Malthusian regime). The theoretical distinction of the model below is that geographic attributes influence adult survival (which in turn affects individuals' inter-temporal resource allocation).

[5] As noted above, the emphasis here is on the role of geograpic attributes in early economic development. In that vein, the simple model described above does not contain dynamic elements that would generate a demographic transition phase–during which both population levels and per capita incomes rose–as well as a take-off phase to sustained economic growth–during which rising per capita income levels are associated with lower fertility and higher educational attainment. These features could easily be incorporated into the model discussed below without altering its main conclusions.

[6] See also Masters and McMillan (2001) and Olsson and Hibbs (forthcoming) for further empirical support.

[7] There are at least two alternative specifications of survival probability. First, one could assume that geographic characteristics influence survival indirectly by making survival endogenous in

consumption. Then, in determining the optimal consumption pattern and the amount of resources devoted to their children, individuals would have to take into account not only the marginal utility of consumption but also the marginal effect of consumption on their own survival. This specification would yield qualitative results that would be similar to what is below. Second, while I abstract from child mortality and focus on adult mortality only, the model could be extended to include child mortality without altering significantly the qualitative nature of the main results.

[8] See, for example, Grossman and Mendoza (2000).

[9] This, of course, is associated with the ‘‘positive check’’ on population growth identified by Malthus. He envisaged two sets of relationships that might serve to keep a population in balance with its economic resources. In both cases, an increase in population exerts pressure on food prices and lowers real incomes. Positive check operates through increases in mortality, and the preventive check manifests itself in lower nuptiality and fertility. Refer to Wrigley and Schofield (1989, pp. 458-466) for more details.

[10] See Becker (1981).

[11] The basic premise here is that children are normal goods that individuals get to enjoy adulthood. Improvements in life expectancy induce individuals to allocate a larger share of their incomes to the consumption of goods that they get to enjoy in their adulthood. In a related vein, Kalemli-Ozcan and Weil (2001) employ a similar approach to highlight how improvements in life expectancy could account for the emergence of life-cycle saving in advanced economies.

[12] In what I present below, I assume that geographic attributes do not directly influence production. I adopt this formulation to demonstrate the importance of the indirect mechanisms through which geography can influence the early evolution of an economy. That noted, including geographic characteristics directly in the production technology would serve to propagate the effects I present below.

[13] For simplicity of notation, I will supress the geography superscript j hereafter unless the discussion warrrants its inclusion.

[14] By assuming there are constant returns to human capital, the model abstracts from how changes in the level of population might influence wage rates. In fact, the negative link between the size of the labor force and wage rates provided the main channel through which the positive and preventive Malthusian checks operated (see footnote 9). The model presented here could be easily extended to ensure that population shocks lead to changes in the real wage rate, and therefore, that short-run deviations from the subsistence equilibrium self-correct in the medium run. However, the main point I emphasize here is this: despite the fact that places with good geographic attributes would have dense populations that could somewhat offset the impact of a favorable geography, they would still be places where population densities reach some threshold level first. This would in turn enable such geographically-favorable places to take off on a path of sustained growth earlier than other locales with more unfavorable geographic attributes.

[15] As Galor and Moav (2002) demonstrate, the explicit formulation of the quantitiy-quality tradeoff in parents’ utility specification has evolutionary foundations.

[16] Note that both the number and the average human capital level of an individuals’ offspring do not change during adulthood. Hence, $n_{t+1}^{t-1} = n_t^{t-1}$ and$h_{t+2}^{t+1} = h_{t+1}^{t+1}$.

[17] I assume that there exists a costless storage technology that allows individuals to transfer part of their current potential consumption to the future.

[18] Note that, at any given time t, total population equals $[1 + n_t + p_j/n_{t-1}]L_t$ This suggests that total population would equal $3L_t$ if the growth rate of population was zero and the odds of survival were one.

[19] This is driven by the assumption that $\phi(0) = \tilde{h} > 0$ and $\lim_{e_{t+1} \to 0} \phi'(e_{t+1}) < \infty$

[20] According to the World Bank classifications, the list of low-income countries in 1994 included Afghanistan, Albania, Armenia, Angola, Azerbeijan, Bangladesh, Benin, Bhutan, Bosnia and Herzegovina, Burkina Faso, Burundi, Cote d’Ivoire, Cambodia, Cameroon, Central African Republic, Chad, China, Comoros, Congo, Equatorial Guinea, Eritrea, Ethiopia, Gambia, Georgia, Ghana, Haiti, Honduras, India, Kenya, Kyrgyz Republic, Liberia, Madagascar, Malawi, Mali, Mauritania, Mongolia, Mozambique, Myanmar, Nepal, Nicaragua, Niger, Nigeria, Pakistan, Rwanda, Senegal, Sierra Leone, Somalia, Sri Lanka, Sudan, Tajikistan, Tanzania, Togo, Uganda, Vietnam, Yemen, Zaire, Zambia, Zimbabwe.

[21] At the end of this section, I also explore what the impact of geography was on *all* countries in the 1990s to test whether geographic attributes can help to explain *modern* demographic changes as well.

[22] For the historic data, I confine attention to this subset because, together with Western Europe, it comprises countries for which Acemoglu et al. (2002) demonstrate that institutions–but not geography–played a role in their economic development since the 19th century. In addition to aggregated data for Western Europe, this sample includes 41 observations for Argentina, Algeria, Australia, Bangladesh, Belize, Bolivia, Brazil, Canada, Chile, Colombia, Cost Rica, Dominican Republic, Ecuador, Egypt, El Salvador, Guatamala, Guyana, Hong Kong, Honduras, Haiti, Indonesia, India, Jamaica, Laos, Sri Lanka, Morocco, Mexico, Malaysia, Nicaragua, New Zealand, Pakistan, Panama, Peru, the Philippines, Paraguay, Singapore, Tunisia, Uruguay, the United States, Venezuela, and Vietnam.

[23] In addition to adopting this assumption on the distribution of errors because of its intuitive appeal for cross-country data, I confirmed it with a Cook-Weisberg test for heteroscedasticity.

[24] An alternative to *TERRAIN* involves utilizing the amount of arable land. The latter would more directly capture the extent to which the land mass is amenable to agriculture. However, using this alternative variable would generate endoegenity problems that do not exist when *TERRAIN* is used instead. Nonetheless, in alternative empirical specifications where arable land was used as a subsitute for *TERRAIN* results were generally similar in nature to what I present below.

[25] I include per-capita GDP as one of the regressors on two accounts. First, during the process of early development, there is a potential for a Malthusian link between income and fertility. Second, under most generalized utility specifications, there exists a relationship between household income and the quantity-quality tradeoff (see, for instance, Galor and Weil, 2000). This noted, the empirical results I present below are robust to excluding *LNGDPCAP* from the empirical estimates.

[26] While, population density may not be a good measure of modern development, as shown in Kremer (1993), it is a good measure of early development historically.

[27] See, for example, Acemoglu et al. (2002). For the exact methodology of calculations, see also Chandler (1987).

[28] Source: Parker (1997).

[29] http://www.odci.gov/cia/publications/factbook.

[30] Alternatively, I have experimented with expanding the sample to cover the lowest- as well as the lower-middle income countries according to the World Bank classifications. That way, I was able to generate 43 observations using the average years of schooling data. The results I generated with that sample were roughly in line with those reported in Table 3.

[31] It is important to note that, while the results presented in Tables 3 and 7 are consistent with the idea that geographic attributes influence educational attainment, they are also in line with other alternative theories. For example, it could well be that, at unhealthy locations, parents invest less in the education of their offspring (and more in their numbers) because the life expectancy of the children–and not the parents–is low (see Kalemli-Ozcan, 2002).

[32] There are both empirical and theoretical underpinnings of such a mechanism. Goldin and Katz (1998), for example, find evidence that the technology-skill complementarity originated with the shift in manufacturing to batch and continuous-process methods, as well as the adoption of electricity motors. All of those occured in the 1890s and beyond–well after life expectancy began to rise dramatically in the late-18th and early-19th centuries due to better nutrition (see McNeill, 1998). Acemoglu (1998) presents a model in which the direction of technical change is determined endogenously according to the fraction of skilled (or educated) workers in the economy. Thus, his approach provides a theoretical basis for which to believe that the effects of the technology-skill complementarity becomes more pronounced later during the development process.

References

Acemoglu D (1998) Why Do New Technologies Complement Skills? Directed Technical Change and Wage Inequality. *Quarterly Journal of Economics* 113(4): 1055–89

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

Acemoglu D, Johnson S, Robinson J (2002) Reversal of Fortune: Geography and Institutions in the Making of the Modern World Income Distribution. *Quarterly Journal of Economics* 117: 1231–94

Becker GS (1981) *A Treatise on the Family*. Harvard University Press, Cambridge, MA

Chandler T (1987) *Four Thousand Years of Urban Growth: An Historical Census*. St. David's University Press, New York

Gallup JL, Sachs JD, Mellinger AD (1999) Geography and Economic Development. Harvard Institute for International Development, CAER II Discussion Paper No: 39 (March)

Galor O, Moav O (2002) Natural Selection and the Origin of economic Growth. *Quarterly Journal of Economics* 117(November): 1133–91

Galor O, Weil DN (2000) Population, Technology and Growth: From the Malthusian Regime to the Demographic Transition. *American Economic Review* 90(4): 806–28

Goldin C, Katz LF (1998) The Origins of Technology-Skill Complementarity. *Quarterly Journal of Economics* 113(June): 683–732

Goodfriend M, McDermott J (1995) Early Development. *American Economic Review* 85(1): 116–33

Grossman HI, Mendoza J (2000) Scarcity and Conflict. Brown University Working Paper No: 1999-19

Hall RE, Jones CI (1999) Why Do Some Countries Produce So Much More Output Per Worker Than Others? *Quarterly Journal of Economics* 114(February): 83–116

Jones EL (1981) *The European Miracle*. Cambridge University Press, Cambridge

Kalemli-Ozcan S, Weil DN (2001) Mortality Change, the Uncertainty Effect and Retirement. NBER Working Paper Series, No. 8742

Kalemli-Ozcan S (2002) Does Mortaility Decline Promote Economic Growth? *Journal of Economic Growth* 7(4): 411–39

Kremer M (1993) Population Growth and Technological Change: 1,000,000 B.C. to 1990. *Quarterly Journal of Economics* 108(August): 681–716

Lagerlof N (2003) From Malthus to Modern Growth: Can Epidemics Explain the Three Regimes? *International Economic Review* 44(March): 755–777

Masters WA, McMillan MS (2001) Climate and Scale in Economic Growth. *Journal of Economic Growth* 6(3): 167–86

McEvedy C, Jones R (1978) *Atlas of World Population History*. Facts on File, New York

McNeill W (1998) *Plagues and Peoples*. Anchor Books/Doubleday, New York

Olsson O, Hibbs, DA Jr. (forthcoming) Biogeography and Long-Run Economic Development. *European Economic Review*

Parker PM (1997) *National Cultures of the World: A Statistical Reference*. Greenwood Press, Connecticut

Sachs JD (2000) Notes on a New Sociology of Economic Development. In: Harrison LE, Huntington SP (ed) *Culture Matters: How Values Shape Human Progress*. Basic Books, New York 29–43

Sachs JD (2001) Tropical Underdevelopment. NBER Working Paper Series No: 8119

Wrigley EA, Schofield RS (1989) *The Population History of England, 1541–1871: A Reconstruction*. Cambridge University Press, Cambridge