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A Global Model of Very Long Term Economic Development

Diery Seck
Center for Research on Political Economy (CREPOL)

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1. Introduction

Judging by the amount of time and effort devoted to the task, modern Man has displayed an inordinate and relentless pursuit of improvement of his well-being, both to achieve it and to understand the factors that will help him in his quest. Current discrepancies in the level of economic welfare of humans around the planet are so striking as to become sources of concern for the physical survival of millions and threats to the security of a world facing deepening division. The challenging task of improving the fate of large sections of world population is now a collective goal for policymakers and scientists and the stakes are too high for success to be delayed. The key question being asked is: how to ensure a level of economic welfare for all the world population that is compatible with physical survival and a modern sense of human decency. The purpose of the present study is to examine the very long term factors that can help achieve that goal.

The study of human economic progress can be divided into several avenues of investigation. At the global level, authors have sought to describe the evolution of human societies either as they stood alone or in their interaction over time; Capra (1982), Diamond (1997), Fernandez-Armesto (2000), Gerschenkron (1982), Kennedy (1987), Maddison (2001, 2003), North (1981, 1990), North and Thomas (1973), Pointing (1991), Sass (1998), Tainter (1988) and Turchin (2003). Efforts were also made to identify ways in which societies could be more successful in ensuring their survival and economic development; Capra (1996), Diamond (2005), Malthus (1798), Marx (1857, 1867) and Smith (1776). These authors proposed methods for organizing society or to manage its natural resources.

Prescriptive models were proposed by a number of authors in their attempt to unravel and trigger the mechanics of economic growth as a way of attaining enhanced human welfare; Domar (1946, 1947), Harrod (1939), Hirschman (1971), Kuznets (1965, 1966, 1971), Lewis (1955), Lucas (1988), Mill (1848), Ricardo (1817), Robinson (1962), Rostow (1971), Schumpeter (1911) and Solow (1956). These theories were subjected to extensive empirical tests in respect of their capacity to generate economic growth, applicability to all the regions of the world, robustness to extraneous factors such as geography, ethnicity, religion, demographic characteristics, nature and strength of institutions and natural endowments; Barro (1991, 1997), Collier and Gunning (1999), Easterly (2002), Faye et al. (2004), Grier and Tullock (1989), Hall and Jones ((1999), Islam

(2003), Landes (1998), Levine and Renelt (1992), Limao and Venables (1999), MacKeller et al. (2000), Pritchett (1997), Sachs and Warner (1997a.b), Sala-i-Martin ((1997, 2002), Sala-i-Martin et al. (2004), World Bank (1993).

The abundance of literature on economic growth and development is marked by absence of consensus on the very key questions that it was tasked to address. There is no agreement on the determinants of economic growth; neither is there on the issue of economic convergence or even why some countries are rich and others poor. Some specific regions of the world, Sub-Saharan Africa chief among them, do not respond to any policy package and are sliding further behind despite constant efforts to help them grow. It is noteworthy that almost all the literature focuses on the impact of human action on nature and its intended developmental result. When nature's impact on development is studied, the issue is whether it constitutes a hurdle or a positive factor to policies that are typically of a very short term nature.

The present study seeks to examine the very long term process of economic development by focussing on the interaction between human economic welfare and factors that have been present, although possibly changing, over a time span of several millennia. It will provide an opportunity to study the impact of nature's action on human welfare rather than the opposite point of view of human action on nature. The very long time span of the study will also set the stage for insights into the link between economic theories and theories of natural evolution considering that the time dimension makes it possible to dispense with government and its policies and investigate the intimate interaction between Man and nature and its economic consequences over hundreds of generations.

The remainder of the paper is organized as follows. The next section discusses a number of age-old regularities that are related to human economic welfare. Then a conceptual model of very long term economic development is proposed, first in the case of the autarkic society, and later for the outward society. In each case a number of salient implications are presented. A few concluding comments constitute the final note.

Regularities in human welfare

In order to shed light on the millennial evolution of human welfare, the analysis uses a comparative approach to study the geographical and historical dimensions of development. To that end, it examines the evidence on the very long term history of economic growth of various and distinct parts of the world and seeks to uncover characteristics that are unchanging yet respectively peculiar to groups of societies with significantly different levels of affluence. The difficulty of measuring welfare across different societies over history cannot be overstated but the purpose of this study, the level of output measured in constant numeraire, is used even for communities that did not resort to currency for internal or external trade. This caveat underscores the need to appreciate the foregoing analysis in terms of magnitudes rather than pinpoint accuracy.

Three strands of regularities are investigated. The first one concerns the relative levels of wealth of various parts of the world and their evolution over the last two millennia. The question being addressed is: Have today's rich regions of the world always been rich, or richer than today's poor regions? And if all regions were initially at comparable levels of affluence, did today's rich parts of the world accelerate the pace of their development or did the poor regions stagnate or decline? And if so, when did that happen? Geographical location is the second regularity under study. Attention is paid to a possible link between the level of development of a region or country and its physical characteristics such as location on the world map, with its attendant climatic and natural resource endowment, and its ease of access to the broader world proxied by access to the sea. The third regularity concerns geo-climatic zones of the Earth and the extent to which their sizes and shapes can affect the welfare of human societies that reside in them.

1.1. Historical evolution of the wealth of world regions

In Table 1, Angus Maddison (2001) provides estimates of the growth domestic products (GDP) and average growth rates of GDP of various regions of the world during the entire modern era. The regions are organized in two groups to capture differences in geographical location and their modern day levels of development. During the first millennium, the ratio of wealth levels between the two groups of regions remained constant, Group B producing seven times as much as Group A. This is also reflected in their identical respective GDP growth rates for the same period. However, today's rich countries experienced a dramatic increase in their rate of growth,

which gave rise to catching up and ultimately overtaking of the other regions of the world. Indeed, between 1000 and 1820, Group A's GDP rose by an annual average of 0.32% while Group B regions increased their GDP by an annual average of 0.19%, which is 40% slower.

Table 1. Level and Rate of Growth of GDP, World and Major Regions, 0 – 1998 AD

	Billion 1990 International Dollars				Annual Average Compound Growth Rate		
Group A	0	1000	1820	1998	0-1000	1000-1820	1820-1998
Western Europe	11.1	10.2	163.7	6,961	-0.01	0.34	2.13
Western Offshoots	0.5	0.8	13.5	8,456	0.05	0.35	3.68
Japan	1.2	3.2	20.7	2,582	0.10	0.23	2.75
Sub-total group A	12.8	14.1	198.0	17,998	0.01	0.32	2.57
Group B							
Latin America	2.2	4.6	14.1	2,942	0.07	0.14	3.05
Eastern Europe & Former USSR	3.5	5.4	60.9	1,793	0.05	0.29	1.92
Asia (Excl. Japan)	77.0	78.9	390.5	9.953	0.00	0.20	1.84
Africa	7.0	13.7	31.0	1,039	0.07	0.10	1.99
Sub-total group B	89.7	102.7	496.5	15,727	0.01	0.19	1.96
World	102.5	116.8	694.4	33,726	0.01	0.22	2.21

Source: Angus Maddison, The World Economy: A Millennial Perspective, OECD, 2001, p.28.

To a large extent, the distribution of world income as we know it today was established almost 200 years ago and the two groups have diverged, rich regions accumulating wealth faster than poorer regions as evidenced by their respective growth rates for the period 1820 – 1998. Closer analysis also shows strong long term economic convergence between the various parts of the developed world, which cannot be said of the developing world because Latin America has outpaced Africa in each sub-period of Table 1. To illustrate historical divergence between rich and poor regions, consider that, according to Maddison (2001, p. 126) the spread of GDP per capita between these two regions has gone from 1 to 19 between 1000 and 1998. Pritchett (1997) conducted a comparison between the single richest country and the single poorest country and found a ratio of their respective per capita Gross National Products (GNP) to be 8.7 in 1870, 38.5 in 1960 and 45.2 in 1990.

Using World Development Indicators data from the World Bank, the average per capita GDP growth rates were computed for the 45 countries with the highest Human Development Index

(HDI) of the United Nations Development Programme (UNDP) in 2004 for the period 1966 to 2004. The same calculations were performed for the 45 countries with the lowest HDI, with ranks from 133 to 177. For the highest HDI ranking countries the mean of the averages was 2.48% with a standard deviation of 1.58% while for the lowest ranking countries the figures were 0.63% and 1.48% respectively. In other words, during the 38 year interval, the sampled rich countries increased their per capita income by 154% while for the poorer countries the increase was only 27%.

1.2. Geographical characteristics of rich and poor countries

Some of the most debated physical characteristics of historically poorer regions are reported in Table 2. Welfare is measured using UNDP's Human Development Index (HDI) for the year 2004. Two physical characteristics related to geographical location are cross tabulated with welfare: distance from the Equator in degrees and lack of direct access to the sea. For the sake of simplicity the first and last quartiles of country rankings of the HDI are reported in the table. This sub-sample includes the 45 top-ranked and the 45 bottom-ranked countries and represents half the countries of the HDI ranking. Countries are distributed among four geographical sub-regions based on the location of their capital cities. The sub-regions are divided in zones of 15 degrees of latitude starting from the Equator irrespective of the hemisphere in which countries are located.

Table 2. Human Development Index Rank, Latitude of Capital City and Access to Sea of Selected Countries

Geographical location		HDI rank quartile 1 1 – 45	HDI rank quartile 4 133 – 177
Distance from Equator (latitude) measured in degrees	45° – 60° +	1, 2, 4, 5, 6, 9, 10, 11, 12, 13, 14, 15, 16, 17, 21, 27, 30, 35, 37, 40, 41, 42, 44, 45	
	30° – 45°	3, 7, 8, 17, 19, 20, 22, 24, 26, 28, 29, 32, 36, 38, 43	134
	15° - 30°	22, 33, 39	135, 137, 138, 141, 143, 146, 148, 150, 151, 153, 154, 157, 165
	0° - 15°	25, 31, 34	133, 136, 139, 140, 142, 144, 145, 147, 148, 152, 155, 156, 158, 159, 160, 161, 162, 163, 164, 166, 167, 169, 170, 171, 172, 173, 174, 175, 176, 177
Landlocked		9, 13, 14, 30, 35, 42	133, 135, 138, 145, 146, 148, 151, 158, 165, 166, 169, 170, 171, 172, 174, 175, 177

NB. Countries are denoted by their UNDP's HDI ranks 2004. For clarity countries ranked 1 to 45 and 133 to 177 are included but countries ranked 46 to 132 are omitted. See list of ranked countries in Annex.

Sources: HDI from United Nations Development Program (UNDP) Report 2006, Online; Latitude of capital city and country access to sea from Google Earth, Online.

Twenty four out of 45 of the wealthy countries reported in Table 2 are located beyond the 45th parallel and only 6 have their capitals less than 30 degrees from the Equator. Among the 6 countries three are oil-exporting countries –Kuwait, Bahrain and Brunei- and the other three are marked by the strong influence of expatriates who brought their economic culture from original regions beyond the 30th parallel. Israel inherited the practices of Northern and Western Europe while the English influence is felt more in Barbados and Singapore and in their neighbouring island nations. Apart from Pakistan with a political capital, Islamabad, in the extreme north of its territory, on the 30th parallel, with the rest of the country stretching south of it, all the 45 least privileged countries are located less than 30 degrees from the Equator. In a way, the 30th parallel can be considered the geographical poverty line at the global level.

Of the 45 poorest countries 30 are within 15 degrees of the Equator and 17 are landlocked. The incidence of lack of access to the sea is 2.8 times higher among the poor countries than among the rich countries. Furthermore, with the exception of Switzerland, all the rich countries that are landlocked (Luxembourg, Austria, Hungary, Czech and Slovak republics) have been provinces of larger empires or kingdoms with access to the sea over the last few centuries. Their landlocked status is essentially an outcome of the world wars of the 20th century when they became independent nations carved out of the losing Austro-Hungarian Empire. Based on the frequencies depicted in Table 2, it can be observed that today's wealthy countries are predominantly located more than 45 degrees away from the Equator and that they have historically had direct access to the sea. In contrast, the poorest countries lie mostly less than 15 degrees from the Equator and almost 40% are landlocked.

1.3. Latitude and geo-climatic bands

Human quest for improved material welfare aims firstly at making use of the surrounding natural resources. Over the millennia, recourse to these resources to ensure sustenance, shelter and safety, has mobilized most of human energy. The need to secure constant and reliable supply of resources motivates development of technological knowledge that leads to a specific rate of extraction of natural resources, given the available body of knowledge. In other words, the specific physical circumstances of the natural environment may be considered the prime factor leading to the content of technological knowledge and its pace of change in the drive for welfare improvement. But what are the contours of that knowledge?

The physical characteristics of a given geographical area include a degree of homogeneity among the indigenous species/varieties to which extractive technological knowledge applies. This knowledge results from past human investment and is utilized in an area that is most profitable in the quest for welfare, the same geo-climatic band. A geo-climatic band is understood as geographic space that has largely similar or highly compatible physical features such as terrain, soil and climate, and provides a habitat suitable for long lasting occupation by flora and fauna that would not thrive in areas with different characteristics. For instance, the artic regions, rainforest regions or deserts can be considered distinct geo-climatic bands. These very characteristics play a crucial role in the shape and extension of geo-climatic bands. Indeed, similar climatic and soil conditions are more likely to be found along the same latitude even across large bodies of water. As a result, geo-climatic bands tend to be narrow but rather long

along the same parallel and can be likened to ellipses. However, due to the variety of weather systems around the planet, two separate geo-climatic bands need not have the same height across parallels even when lying between the same longitudes.[1]

Given the climatic characteristics of regions on different latitudes, it can be hypothesized that geo-climatic bands located in the zone delineated by the 45th and 60th parallels are more elongated and thus have higher eccentricity than geo-climatic bands lying near the Equator or the Poles.[2] As a result, a shorter travel distance along the same longitude is required to reach a different geo-climatic band from the center of a band located in the 45-60 degree zone than from the center of a band located near the Equator.

Figure 1 illustrates some of the characteristics of geo-climatic bands. It depicts areas that are original habitats for wild varieties that are precursors of cultivated plants in Africa. These crops constitute a large proportion of the food crops in modern day Sub-Saharan Africa and cover mostly the sub-tropical area between 5 and 15 degrees north. They represent several varieties of millet indigenous to the dry Sahel region and a few other plants located in the more humid zones south of the Sahel. The main feature of these ellipsoidal areas is their pronounced elongation along the same parallel and their narrow expanse up the same longitude. Teff, a variety of millet indigenous to Ethiopia's high plateau that is cooler and stretches from south-west to north-east is the only exception to the typical shape of crop areas in this region. The entire zone that runs from Senegal in the west to Ethiopia in the east could be considered a geo-climatic band, bearing in mind that, although single crops do not cover all the area, all the longitudes are home to one or several native crops.

Cultivation of the same plants requires similar implements and one can imagine that little or no change in the technology has been introduced over several centuries in many areas given the absence of significant change in climatic and soil conditions, land tenure system, average farm size, social organization and slow rate of economic progress. This illustrative example on Africa would also apply to other regions of the world, most likely with other indigenous plants and geo-climatic conditions.

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[1] For the sake of simplicity, the shape of geo-climatic bands is approximated by ellipses rather than polygons that have more diversity in their shapes.

[2] Eccentricity measures the degree of elongation of an ellipse. Its formula is given by $\varepsilon = \sqrt{1 - \frac{b^2}{a^2}}$ where a is the semimajor axis and b is the semiminor axis of the ellipse, and ε denotes its eccentricity.

The strong and historically consistent regularities examined above are most likely related to the causes of human economic development and could provide a better understanding of the current distribution of world incomes across world regions and help predict the future welfare of societies. The purpose of the theoretical model is to uncover links between millennial physical characteristics of these regions and their level of development over time , which can help shed some light on the very long term determinants of human economic development and their possible relevance today.

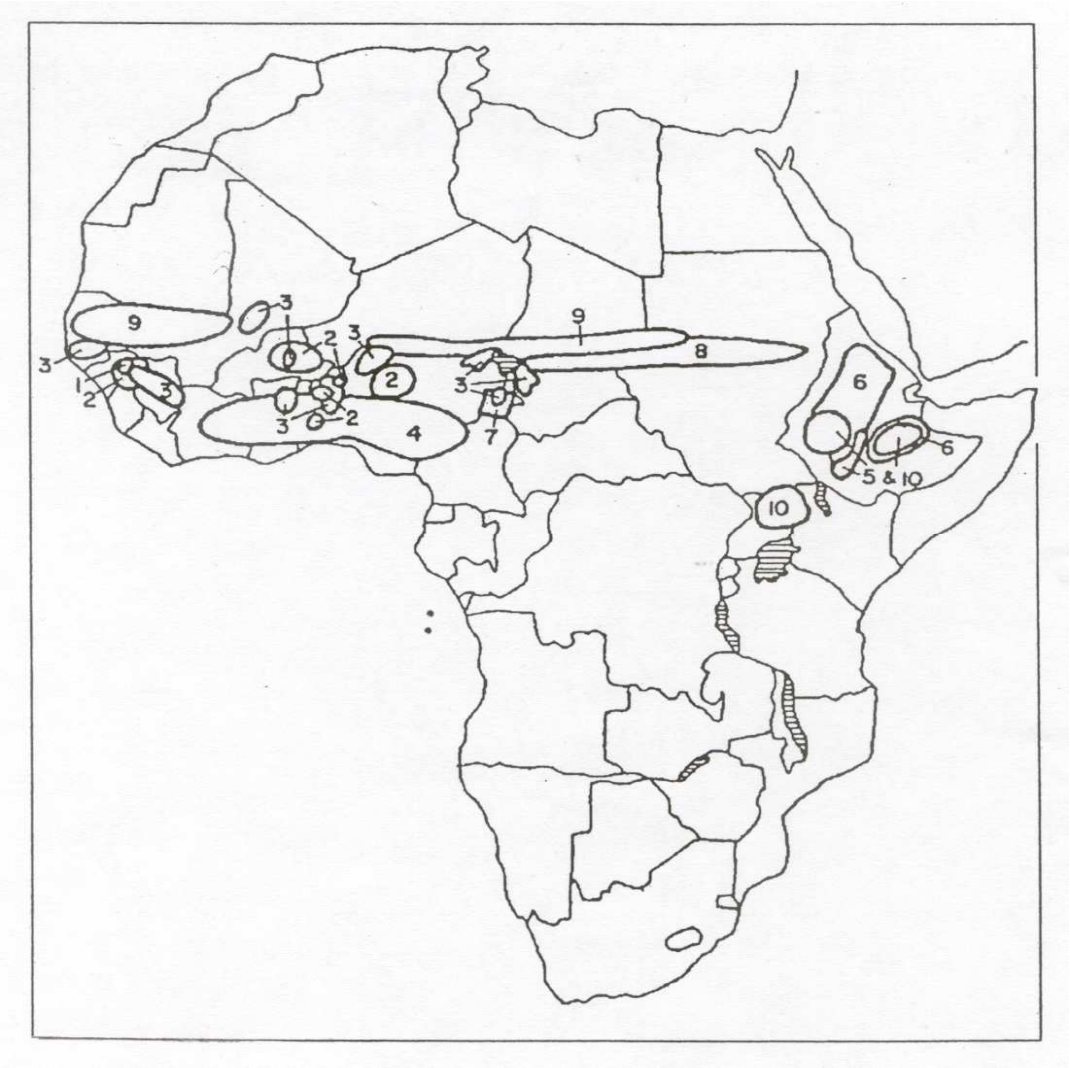

Figure 1: Distribution of areas of precursors of wild plants currently cultivated in Africa
1: Guinea millet, 2: While and black fonio, 3: African rice, 4: White Yam, 5: Wild banana and Niger plant, 6: Teff, 7: Bambara groundnut and Ground bean, 8: Sorghum, 9: Pearl millet, 10: Finger millet. Source: L'Afrique Depuis les Débuts de la Production de Nourriture Jusqu'à il y'a Environ 5000 Ans, in Histoire de l'Humanité, Chap. 40, Editions UNESCO, Carte 44, p. 997.

3. A global model of very long term economic development

Very long term economic development is defined as improvement in human welfare measured by three factors: sustenance, shelter and safety. The variable shelter includes housing and clothing while safety measures protection from any source of danger to the human body: disease, accident and violence. Psychological and community-related considerations are omitted because they are context-sensitive and undergo major changes over time, which makes them less relevant over very long periods. Proper formulation of a model of very long term economic development is predicated on identification of relevant factors that are equally long lasting. This requirement is rather restrictive because it implies exclusion of economic policy variables that are typically considered to have an effect on economic development. The exclusion may even extend to the existence of government because one can conceive of economic development as a process that neither requires government action, nor logically leads to its very creation or existence.

What the analysis is left to start with is human action and its interaction with the physical characteristics of its environment because economic development is primarily material and therefore organizes Man's impact on nature's resources. In order to account for very long term economic development, the model will first focus on the case of autarkic societies to examine the sources and pace of development. Then the more complete case of outward societies will be addressed with an attempt at explaining phenomena such as economic convergence, divergence, the direction of migration and the economic implications of the geographical direction of regional integration schemes.

3.1. The autarkic society

Consider the Earth's sphere depicted in a map partitioned into S zones across longitudes and S zones down the latitudes. The centers of the S x S geographical areas can be presented in matrix formulation as follows:

$$G_W = \begin{bmatrix} G_{1,1} & G_{1,2} & . & G_{1,S} \\ G_{2,1} & G_{2,2} & . & G_{2,S} \\ . & . & . & . \\ G_{S,1} & G_{S,2} & . & G_{S,S} \end{bmatrix}$$

Where $G_{i,j}$ denotes the geographical area whose center is located on the latitude numbered i and longitude numbered j. If S is sufficiently large, the whole area $G_{i,j}$ is homogeneous enough to be part of a single geo-climatic band.

Each area $G_{i,j}$ is assumed to have a set of natural resources $N_{i,j}$ on which human technomical asset applies to extract economic output $Q_{i,j}$. An area's technomical asset is the productive capacity, technological, demographic, cultural and institutional, that is used by human action to generate economic output. Henceforth, it is termed techknowledge, for the sake of brevity. Using the same matrix formulation, we have:

$$N_W = \begin{bmatrix} N_{1,1} & N_{1,2} & . & N_{1,S} \\ N_{2,1} & N_{2,2} & . & N_{2,S} \\ . & . & . & . \\ N_{S,1} & N_{S,2} & . & N_{S,S} \end{bmatrix}; \qquad K_W = \begin{bmatrix} K_{1,1} & K_{1,2} & . & K_{1,S} \\ K_{2,1} & K_{2,2} & . & K_{2,S} \\ . & . & . & . \\ K_{S,1} & K_{S,2} & . & K_{S,S} \end{bmatrix}$$

Where $N_{i,j}$ is the stock of natural resources available in geographical area $G_{i,j}$, and $K_{i,j}$ is the level of techknowledge of area $G_{i,j}$.[3]

For any area $G_{i,j}$, i = 1 to S, economic output is given by:

$$Q_{i,j} = N_{i,j} K_{i,j} \qquad (1)$$

For any longitude j, j = 1 to S, total economic output is given by:

$$Q_j = \sum_{i=1}^{S} N_{i,j} K_{i,j} \qquad (2)$$

[3] The two quantities $N_{i,j}$ and $K_{i,j}$ are two vectors that can be represented as follows: $N_{ij} = (n_1, n_2, \ldots, n_T)$ and $K_{ij} = (k_1, k_2, \ldots, k_T)$. The elements of $N_{i,j}$ constitute different types of natural resources that contribute to the technomical production function while the elements of $K_{i,j}$ are the corresponding types of techknowledge needed to extract the natural resources and secure human welfare.

For any latitude i, i = 1 to S, total economic output is given by:

$$Q_i = \sum_{j=1}^{S} N_{i,j} K_{i,j} \qquad (3)$$

The world economic output is given by

$$Q_w = \sum_{i=1}^{S} Q_i \qquad = \qquad \sum_{j=1}^{S} Q_j \qquad (4)$$

and the elements of Q_w can be presented in matrix form as follows:

$$Q_W = \begin{bmatrix} Q_{1,1} & Q_{1,2} & . & Q_{1,S} \\ Q_{2,1} & Q_{2,2} & . & Q_{2,S} \\ . & . & . & . \\ Q_{S,1} & Q_{S,2} & . & Q_{S,S} \end{bmatrix}$$

<u>The technomical consumption function</u>

The following assumptions are made.

1. Regions with more diversity in the climatic conditions of their seasons face higher seasonality in weather conditions and in the availability of natural resources.
2. The stocks of natural resources and of techknowledge grow at natural rates that are specific to each geo-climatic band.
3. At any given time t, the level of techknowledge is a given parameter.
4. At any given time t, the stock of natural resources is a given parameter.

For the autarkic society, the consumption function is also the production function. It is formulated as follows. From Eq. (1) we have

$Q_{i,j,t} = N_{ij,t} K_{ij,t}$

Further, for any period t, we have:

$N_{ij,t} = (p_1 + q) N_{ij,t-1}$ (5)

p_1 = Natural rate of increase of natural resources.

q = Net impact of human action on natural resource (regeneration-extraction).

$p_1, q > \text{or} < 0$

We also have :

$$K_{ij,t} = p_2 K_{ij,t-1} + n\,|N_{ij,t} - N_{ij\,t-1}| \qquad (6)$$

p_2 = Rate of increase of the stock of techknowledge for period t-1.

n = Rate at which variations in the stock of natural resources are transformed into new techknowledge.

$p_2 > \text{or} < 1, \quad n \geq 0.$

The speed of variation in the stock of natural resources depends on the combined impact of its natural rate of growth, p_1, and the rate of net human extraction of natural resources.[4] From Eq. (6) one can infer that societies that experience larger variations in the stock of their natural resources will draw more new knowledge from their natural environment than societies with little or no variability in their natural resource endowment. The reason is that variations in the stock of natural resources provide relevant information that creates a new incentive to adapt and gives rise to new combinations of techknowledge and natural resources resulting in innovation. Given that in Eq. (6) $K_{ij,t-1}$ can be written as an autoregressive function of previous variations in the stock of natural resources, it follows that these variations are the main source of human techknowledge. In the main, over long periods of time N_{ij} is not a constraint for human welfare because of the low demographic pressure on natural resources in most regions of the world and the effectiveness of historical population regulators such as war, famine, disease and migration.

It is noteworthy that Eq.(6) is consistent with the theory of evolution proposed by Darwin (1859) because it allows for a process of adaptation for sustainable welfare attainment through its two arguments. Sustainable welfare is achieved through the transmission of knowledge from one generation to the next, which is captured by $p_2 K_{ij,t-1}$. It is also secured by the capacity to learn from and adapt to, changes in the level of natural resources available, $n\,|N_{ij,t} - N_{ij\,t-1}|$. Faced

[4] The model proposed here captures Diamond's (2005) argument on the need for human societies to manage their natural resources sensibly to avoid collapse and ensure physical survival and sustainable economic success.

with the same extent of changes in the level of natural resources, societies that have a higher capacity to adapt, captured by the parameter n, increase their techknowledge more and secure a higher level of production, thus of welfare, than less adaptive societies. Conversely, an environment that is characterized by little or no change in its natural resource endowment will trigger little or no human adaptation or economic progress.

What are the implications of the autarchic model? First, in geographic areas that have little or no variations in their stock of natural resources, change in techknowledge results mainly from new observation including study of known natural phenomena or by accident because
$n\,|N_{ij,t} - N_{ij,t-1}| \cong 0$.

As a result, given that knowledge is cumulative, if two regions acquire it at different rates, over a long period, they will experience different paces of progress owing to their different levels of techknowledge, thus of productive efficiency. To illustrate, if for example one region benefits from knowledge that increases its production by a mere one tenth of one percent annually compared to another region, everything else kept equal, the first region will be 10.5% richer than the other over a period of 100 years, 64.8% over 500 years and 172 % richer over 1000 years. It was shown earlier that the 45 countries with the highest rankings in UNDP's Human Development Index have recorded an average growth rate of their per capita GDP of 2.48% during the period 1966 through 2004, while for the 45 countries with the lowest Index, the figure is 0.63%. If these figures are extrapolated over a period of merely 100 years, the first group will have an average per capita GDP that is 11.6 times its current level. The figure will only be 1.9 times for the poorest countries.

Second, a higher rate of knowledge acquisition may lead to non linear, thus exponential improvement in the production function because of a more active innovation process. Consider eq. (5) that portrays the level of natural resources as determined by their natural rate of increase, p_1 , and by net human impact on them, q. Parameter q can serve as a channel for increased production through productivity gains or discovery of new welfare-enhancing uses of natural resources that reduce their rate of depletion or the cost of accessing them.

The proposed formulation of the technomical production function has an implication on the direction of human migration. From eq. (6), it can be argued that, techknowledge being based on a cumulative process of learning from the natural environment, human relocation would be optimal where already acquired technowledge is used to secure immediate welfare. This is best achieved in areas similar to the point of origin with respect to natural resources and their ease of extraction. As was discussed earlier, geo-climatic bands have highly similar natural resource endowments and an ellipsoidal shape elongated along the latitude. Figure 1 is an illustration of the shape of possible geo-climatic bands for parts of Africa. Therefore, it can be concluded that human migration that is not constrained by immediate danger or insurmountable physical barriers would tend to be along the latitude, in other words in an east-west direction, rather that along the longitude.

3.2. The outward society

The outward society expands its access to natural resources by reaching areas that are beyond its habitat, without establishing permanent settlement in them. It is different from the trading society because its extraction of foreign-based natural resources is not compensated by surrender of goods or services to the human group that resides in the foreign area. The outward society secures its welfare by producing and consuming from natural resources extracted partly in the home area and partly from the foreign area. It does not trade. Its production function, which is also its consumption function, is formulated as follows:

$$Q_{ij,t} = \mathrm{N}_{\mathrm{ij,t}}\, K_{ij,t} + N_{F,t}\,(K_{ij,t} - C_{F,t}) \qquad (7)$$

$N_{F,t}$ is the level of natural resources available to the home production function and located in the foreign area.

$C_{F,t}$ = Cost of transporting the natural resources extracted in the foreign area and processed at home.

Eq. (7) is a general formulation of Eq. (1), the case of the autarkic society, because the first argument is the same and describes the behaviour of such a society. The second argument of (7) captures the increase in welfare that results from outwardness given that added production is achieved by applying home techknowledge to foreign-based natural resources. The incentive for outwardness is positive if the second argument is positive which presupposes that the gain

from applying the home techknowledge, $K_{ij,t}$, on a unit of foreign-based natural resources, is higher than the cost of transporting it to the home area, $C_{F,t}$.

The formulation of the technomical production function of the trading society is different from that of the outward society but identical to that of the autarkic society, considering that over long periods of time, exports equal imports. What differs is the composition of what is consumed because the welfare of the trading society is based on consumption of homemade and foreign-based production. The foreign-made component is equal to the portion of the homemade production that is used to acquire foreign production for consumption. In this sense, trade can be understood as extraction of natural resources by proxy. Indeed, foreign producers use their own techknowledge to produce the imported component of the home society's consumption thanks to their superior production function in the extraction of their own natural resources. In other words, Eq. (7) does not apply for the trading society but describes the behaviour of the outward society.

To a large extent, the incentive for outwardness depends on $C_{F,t}$ the cost of transport of natural resources. This cost is a function of the level of techknowledge available to a society and used to lower the cost of transport, and the physical characteristics of its environment. Arguably, travel is cheaper on a flat terrain than across a rugged landscape or a dense forest, and even cheaper on water. Therefore, large bodies of water coupled with capacity for long haul sailing provide opportunities to lower the cost of transport, thus increase the incentive for outwardness, as shown in (7).[5]

What are the implications of the outward society model? The foregoing analysis has underscored natural resources as a key long term determinant of the level of techknowledge of a society. It follows that even under autarky, societies that are on the same latitude may lie on similar or comparable geo-climatic bands and, as a result, accumulate knowledge that is comparable or with highly similar characteristics. Therefore, natural resources, being similar on

[5] It is noteworthy that past land-based empires that dominated the world, such as the Mongols, the Arab-Islamic empire and the empire of Alexander, praised the horse as the instrument of their success. But the horse was effective in warfare but not in the transport of merchandise. Conversely, many societies that achieved significant economic success, especially in the Western world, symbolized their economic achievement by adopting the sailing ship in their insignia.

the same latitude, tend to yield comparable production given the proximity of the techknowledge that is applied to extract them. In the absence of superiority of the techknowledge of a society compared to that of another society on the same latitude or bio-climatic band, the pattern of the trading society may prevail over that of the outward society, given the cost of transport of natural resources depicted in (7). Consequently, over the very long term, trade along the latitude is expected to dominate trade along the longitude. In this instance, trade is predominantly on substitutable goods, and is justified more by the need to weather the impact of adverse variations in natural resources located at home on human welfare or the human desire for some variety in consumption of familiar goods.

It was indicated earlier that geo-climatic bands have an ellipsoidal shape that lies on the latitude. It is then possible for the outward society to travel across bands lying on different latitudes and extract natural resources in different natural environments at a cost lower than would be the case if it travelled across longitudes but on its latitude. If the outward society has access to the sea, the cost of travel becomes even lower and allows for more distant voyages and gives rise to a higher level of welfare. Furthermore, the non-substitutability of the natural resources located on different latitudes and the production that results from their extraction result in welfare enhancement, as opposed to welfare preservation, and thus, lead to a stronger process of wealth creation for the outward society, than if extraction is along the latitude.

The analysis gives insights on economic convergence between countries of different levels of development. Considering the low variability of income levels between countries on the same latitude, there seems to be a process of reversion to the mean income of the latitude, rather than convergence, for countries lying on the same geo-climatic band. This may explain the first regularity observed earlier regarding the clustering of rich countries on a narrow band of latitudes and that of poor countries which are all closer to the Equator. In other words, while individual countries such as Singapore, Taiwan, Hong Kong and a few oil-exporting countries were able to catch-up with advanced countries economically in the last few decades, the historical evidence and the model proposed do not support the thesis of economic convergence

as a self-implementing process that happens inevitably.[6] Instead, it seems that deliberate and consistent human action was its main cause, which lends credence to the significant role that shorter term policies can play in improving welfare. What seems to be observed is a process of economic divergence that is accelerating in view of the statistical trends observed over the last 50 years. Considering that the wealth ranking of countries has not changed significantly over the last 200 years, turning divergence into convergence can be expected to be challenging and protracted.

The foregoing analysis also sheds some light on the implication of regional integration depending on the relative geographic positions of its members. A union of countries lying on the same latitude may serve to reduce the deviations of the national incomes of its members from the group trend by way of remedial or preventive mechanisms thereby primarily preserving the level of welfare already obtained and ensuring economic progress as a second priority. Conversely, a union that spreads North-South across geo-climatic bands is prone to give rise to welfare enhancement through wealth creation, especially if it makes extensive use of sea travel. Adequate resolution of the issue of distribution of the wealth that is created determines the number of beneficiaries from the union and, consequently, the longevity of the union itself. In summary, it can be hypothesized that the three factors that may affect the chances of success of a regional union as a wealth-enhancing arrangement are membership that runs extensively across the latitudes and less across the longitudes, pre-eminence of sea transport and a redistributive mechanism that ensures long term voluntary membership.

Conclusion

Empirical evidence shows that today's rich regions have outpaced poorer regions for several centuries and keep surpassing them economically. It also shows that rich countries are predominantly located beyond the 30th parallel while most underdeveloped countries are less than 30 degrees from the Equator and a significant percentage of them are also land-locked. The Earth is characterized by geo-climatic bands that have specific natural resource endowments and are eccentric along their respective latitudes. The study has sought to examine the

[6] The definition of economic convergence used here refers to the process by which poorer countries achieve higher rates of economic growth than richer countries which will, over time, result in an increasingly smaller difference in the levels of economic development of the two groups.

persistence of these regularities and their relevance to the analysis of very long term economic development. The autarkic version of the model shows that the techknowledge that is applied by human action to extract natural resources in pursuit of material welfare is adaptive to variations in the availability of natural resources, which prompts different paces of economic progress across regions. The elongation of the geo-climatic bands along the latitudes makes acquired techkowledge easier to apply in foreign regions on the same latitude. Therefore, dominant migratory flows will tend to be along the same or nearer latitude rather than along the same longitude.

The outward society, which is different from the trading society, benefits from the eccentricity of geo-climatic bands by reaching geographic areas with different natural resource endowments more easily by travelling across the latitudes than across the longitudes. The incentive for welfare-enhancing outwardness depends on the cost of transport of natural resources which is minimized by sea travel. The relative similarity of technomical production functions of areas on the same latitude makes trade a preferred means of exchange between societies located in the same geo-climatic band while outward extraction is more likely when natural resources are located on a different band. The model does not support economic convergence as a natural or historical process; instead it underscores a tendency from different regions to diverge economically unless adequate and protracted remedial shorter term policies are implemented.

The analysis shows that regional integration may serve different purposes depending on the geographical alignment of its membership. A union lying predominantly on the same latitude will help reduce deviations of its members' incomes through some form of insurance or prevention, and provide a degree of diversity in the consumption of production that is specific to the geo-climatic band of its members. Conversely, a union that spans across latitudes will give rise for more welfare-enhancing extraction of natural resources, especially if it makes extensive use of sea travel and adopts a mechanism of wealth redistribution that secures long term voluntary membership.

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Appendix 1. UNDP's Human Development Index ranks of countries reported in Table 2

HDI Rank	Country	HDI Rank	Country
1.	Norway	133	Laos
2.	Iceland	134	Pakistan
3	Australia	135	Bhutan
4	Ireland	136	Ghana
5	Sweden	137	Bangladesh
6	Canada	138	Nepal
7	Japan	139	Papua New Guinea
8	United States	140	Congo
9	Switzerland	141	Sudan
10	Netherlands	142	Timor-Leste
11	Finland	143	Madagascar
12	Belgium	144	Cameroon
13	Luxembourg	145	Uganda
14	Austria	146	Swaziland
15	Denmark	147	Togo
16	France	148	Lesotho
17	United Kingdom	149	Djibouti
18	Italy	150	Yemen
19	Spain	151	Zimbabwe
20	New Zealand	152	Kenya
21	Germany	153	Mauritania
22	Israel	154	Haiti
23	Hong Kong	155	Gambia
24	Greece	156	Senegal
25	Singapore	157	Eritrea
26	Korea, Rep. of	158	Rwanda
27	Slovenia	159	Nigeria
28	Portugal	160	Guinea
29	Cyprus	161	Angola
30	Czech Republic	162	Tanzania
31	Barbados	163	Benin
32	Malta	164	Côte d'Ivoire
33	Kuwait	165	Zambia
34	Brunei Darussalam	166	Malawi
35	Hungary	167	Congo Dem. Rep.
36	Argentina	168	Mozambique
37	Poland	169	Burundi
38	Chile	170	Ethiopia
39	Bahrain	171	Chad
40	Estonia	172	Central African Republic
41	Lithuania	173	Guinea Bissau
42	Slovakia	174	Burkina Faso
43	Uruguay	175	Mali
44	Croatia	176	Sierra Leone
45	Latvia	177	Niger