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The Fundamental Basis of Economic Developmental Pattern

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Abstract:

Many logical comparisons and arguments have been demonstrated to look for past and current, but not the future developmental pattern of human society. This paper argues that, governed by the Second Law of Thermodynamics, society is a living system which can theoretically live forever, or can revive again and again as long as our universe's entropy can increases without bound. Using a water tank model, the rising and falling mechanism of the living system functions like human society is described. This model is also used to explain some historical examples of the rise and mainly the fall of societies and countries. Finally, by using the growth pattern and model developed, the future economic development of human society is forecasted.

1. Introduction:

1.1 Brief Literature Review:

Ever since Malthusian growth model, worldwide economists have recognized the importance for looking for the development pattern of human society. In Solow's classic 1956 article, he began the study of economic growth by assuming a standard neoclassical production function with decreasing returns to capital and exogenous saving rate, population and technology growth rate. These exogenous variables determine the steady state level of income and capital per effective labor. As a main factor, human capital has been added into the model by previous research, including Edmund S. Phelps (1966), Karl Shell (1966), William D. Nordhaus (1969), Julian L. Simon (1986), Paul M. Romer (1990), Gene M. Grossman and Elhanan Helpman (1991), and Philippe Aghion and Peter Howitt (1992). Progress in empirical evidences has been made with respect to understanding differences in levels of income across countries by N. Gregory Mankiw et al. (1992) and Jonathan Eaton and Samuel S. Kortum (1999). A further improved panel data approach is done by Nazrul Islam (2003). These empirical papers support the augmented Solow model that includes accumulation of human and physical capital. Also, Charles Jones (2002) emphasizes the important contribution of the discovery of ideas by human capital toward the economy's long-run growth and developed a model involving creations of new ideas.

On the other hand, unified formal theoretical framework for addressing the biological basis of microeconomic behaviors has been attempted by some scholars. By looking at the empirical evidence from Ache people, Robson and Hillard Kaplan (2003) explain systematically the phenomenon that the human intelligence and longevity evolve together. They also found an interesting and reasonable pattern of productivity throughout the life of an individual. The productivity (Calories per day) increases slowly between age 0 to 18 and rapidly until 35. It then stays constant until 45, and starts to decline after that. There is a 17 years gap between the maximum point for physical strength and maximum productivity. This is explained as the somatic capital investment period (Robson and Kaplan, 2003.)

While microeconomic foundation has been widely applied in macroeconomic frontiers (David Andolfatto, 2004), it becomes very interesting to explore the deeper basis of human economic development, biological and even physically, at the macroeconomic scale by summing up the above cross-field rich fruits.

1.2 Tasks of the paper

Thomas Malthus's famous theory (1798), *Malthus Trap*, tells us the reason for the stagnation and slow growth pattern during the early stage of human society. After 1800AD, human society passed the critical technological mass and overcame the Malthus Trap. This leads to the rapid growth of productivity.

However, this is just an explanation for the growing period our society has already passed through, which has been modified by a large number of candidate growth models in the literature, there has been surprisingly little attention given to the future period. What will happen in the future? What will the whole economic growth pattern of human society look like from the beginning to the end, and what is the ultimate cause for this pattern? One apparent difficulty will be: we do not have any data and knowledge of future society. But it is said that future is the saddle of the past. Using theory from the study of biological processes, this paper will seek to adopt these theories to create new knowledge in the economical patterns of society.

In section 2 of this paper, both empirical and inductive methods will be used to prove that the similar growth pattern between an individual human case (Robson and Kaplan, 2003) and human society as a whole is not a simple analogy, but a reflection of fundamental laws of Nature. By looking at the trend of population growth rate in current and forecasted data, it is reasonable to assume that human society is at the end of its *teen age* (age 18) and that it will soon maximize its physical body—population growth rate will be zero, then after an expected time gap, it will enter its middle-aged period and its productivity growth rate (growth rate of GDP per capita) will also approach zero. A constant productivity and population period will inevitably arrive. This also fits the outcome and prediction of a simple, but useful, water tank model developed in Section 3 of the paper. In Section 4, some optimistic and pessimistic predictions will be given. Some suggestions and discussions of policies about whether it is possible, and how to attain good results and prevent bad ones, are also made. And Section 5 offers some concluding remarks.

2. The fundamental basis for society: macroeconomic development.

Why is our society what it is today: full of continuous, intelligent innovations, and increasing in population--a society enjoying high civilization and productivity. Considering that the basic unit of our society is the individual person, besides looking for causal effect and exogenous variables *outside* our society, one can obtain more useful and essential information by looking *inside* of society, and analyzing the endogenous variable and its basic unit—the individual human body. There may be a strong connection and similarities between the economic development of the whole human society and a single human's case.

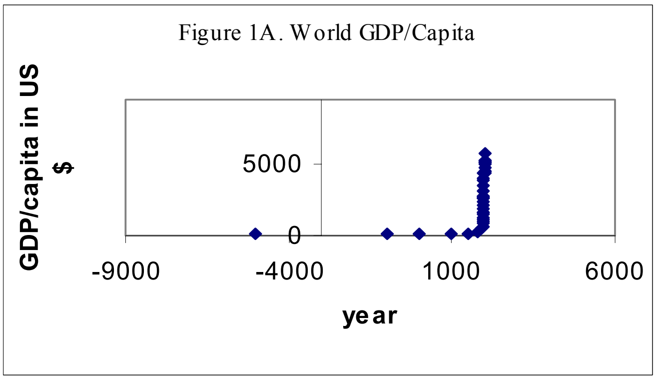
Figure 1A. World GDP/Capita

<u>*2.1 Empirical evidence*</u>

If we think of the whole society as a human body, and of each of its component cells as individual humans, then we can see that both society, represented by the human body (measured by population, *Figure 1B*), and productivity (measured

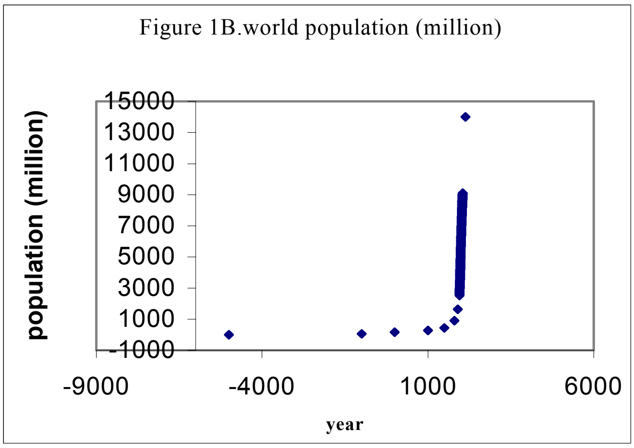
Figure 1B.world population (million)

by GDP per Capita, *Figure 1A*[1]) grow very slowly before age 16 (the corresponding year is 1800AD). Both the representative human body and productivity then enter developing period and increases rapidly after 1800AD.

Thomas Malthus (1798) explains that human economic development was relatively slow before its developing period (pre-industry period). This is because after new inventions, human living standards increased. This leads to the growth of population. Fast rates of population growth increases natural resource scarcity, lower productivity, and reduce people's living standards. As a result, the population growth rate drops. This is the famous "Malthus Trap". However, human society was able to get out of the Malthus gap after the Industrial Revolution, and to start a rapid growth period. How can this be explained? Galor et al (2002) examine economic growth from the stand point of Natural Selection and extend Malthus's idea by setting up a mathematical model, showing that the preference between child quantity and quality is the "trigger of the take off from stagnation to sustained economic growth". It turns out that, even under the shadow of two world wars, human population and productivity increased much faster than before: the total amount of social treasure created within the latter half of the Twenty Century is larger than the total amount of all previous human production (Galor et al, 2002)

Figure 1A shows the growth pattern of world productivity from the beginning of human society 11000 years ago to 2003 AD. This looks very similar to the early stage of an individual human's productivity measured by Calories per day. (Robson and Kaplan, 2003, pp.154.) This suggests that the economic development of the whole human society shares a high degree of similarity with a single human's productivity development pattern. If this hypothesis is true, one can determine what stage human society is in now by using empirical evidence, and can therefore predict the direction of the world's economic development with comparison to an individual person's pattern.

2.2 The analogy between human body and society development pattern

However, the main concern of this paper is this: is this similarity just analogy? Does it release any intuitive truth? The individual human's economic development (productivity) is parallel in timing with the whole society's economic development because the individual human is a component of the

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[1] Source: Fig. 1A and 1B are from United Nation's website http://unstats.un.org/unsd/snaama/selectionquick.htm

society, and they both share similar growth pattern. Let us explore whether they share the same fundamental basis and if so, what it is .

2.2.I The finite increasing entropy in a limited system

According to the Second Law of thermodynamics, the disorder of the universe, measured by entropy, is continual. As a result, an isolated system will diverge from order to disorder such as the decline of a life or society. Society operates similarly—if we assume it as an isolated living system (at least in the short run), its entropy is guaranteed to increase and therefore its ending cannot be prevented. We therefore have a universal theorem:

THEOREM 1: An entropy system that belongs to an isolated limited universe always has a beginning and an ending. (Please see the proof in Appendix A)

However, a system can be open, too. A system that is *open* can use disordered raw materials outside the system to produce orderly structures in which to live, develop, and converge from disorder to order. Such is the developing period of a human body and human society. As open systems, they will always evolve towards more complex forms (See James Walker 2000, pp. 599-600). If the system is differentially closed and open, we will define it as a living system, such as the system J in a limited isolated universe in the proof of Theorem 1, it will have a growth stage, where it functions as an open system, and maturation and aging stage where it functions more as a closed system. The process of human body shows an Up-Flat-Down (UFD) pattern as Robson and Kaplan's demonstration (2003).

So why is the individual person's development pattern a UFD pattern? An individual person's body and, accordingly, his productivity keep growing when he is open to the surrounding environment. He accepts new nutrition and knowledge so that his body cells and productivity keep growing. After his body reaches the maximum physical strength at age 18, he keeps accumulating somatic capital and, therefore, will not reach productivity maximum until age 35. Then a relatively stable stage occurs, keeping at maximum productivity level. However, after 50, the un-renewable parts, such as brain cells, and the depreciation of the organs show the power of constraint. These parts bring down the productivity and body condition even though other parts are still open, renewing and accepting somatic capital. Such is the metabolic process.

The same argument can be applied to human society's development pattern because human society is also a living system with entropy increasing and decreasing at the same time. This means that there are some parts open and renewable, and other parts isolated and non-renewable. Initially, the productivity and population—like body cells—grow slowly through absorbing energy and experience from the surrounding environment. Then, after adequate knowledge and experience are accumulates, it grows very fast with continuous new innovations. After the population reaches its maximum, the society keeps metabolizing knowledge and experience. As a result, productivity will reach its maximum later on. However, society and the knowledge logic system are not perfect, they will have constraints for understanding deeper knowledge. For example, the famous "Uncertain Principle" in quantum physics says that we can either have very precise measurements of a particle's momentum or position, it is impossible to get both of them measured precisely. This is because we study micro world as macro observers with macro world knowledge. All other physics laws are built based on that, and there is no way to get rid of such constraint (at least in modern physics). Consequently, the constraint factor dominates, and productivity, therefore, will start to decline.

It should now be clear that the developmental pattern at the individual's level and the whole society's level has a high degree of analogy. Also, it seems we cannot say that they are cause-and-effect relationship. Instead, their developmental patterns are analogous because they have similar causes: they both function like living systems, with entropy increasing and decreasing at the same time; the differences are influenced by details alone. *The biological basis for an individual human's developmental pattern as a living system is the metabolism of his body, while the fundamental basis for the whole human society's development as a living system is the nature of human knowledge systems determined by logic, and limited by the way we are learning and the constraint that we cannot renew knowledge and innovation forever.*

2.2. II The infinite increasing entropy in an unlimited system

A natural question arises at this point. If every individual person must have an ending (die mostly before 150 years old no matter how strong he is), then why do human not distinct? Instead, human society develops from generation to generation. If every society must have an ending (destruct mostly within a few hundred years) why we still have so many young countries around the world? If every living system must have an ending (stars burn out within a few billion years), why there are still billions of stars in the sky?

Modern physics provide us a possible explanation. With the help of Hubble Telescope, our universe has been approved to be expending as an unlimited system. Therefore, its entropy S is increasing unbound with the Second Law of Thermodynamics still valid[2]. So living systems can develop and grow to lower level entropy as long as it has a chance to use disordered raw materials outside the system to produce orderly structures in which to live, develop, and converge from disorder to order, keeping its entropy not decreasing.

THEOREM 2: *An entropy system that belongs to an unlimited universe does not necessary have an ending. (Please see the proof in Appendix A)*

So theoretically, our human society as a living system can exist for ever as long as we can keep our society's entropy not increasing as a whole as long as we can have continuous innovation and knowledge creations.

2.3 A bit more

To go a bit further, one can ask this: why must the entropy in our universe increase? Physicists suggest that it is because the initial condition at the time of Big Bang chose the increasing entropy by chance. This phenomenon, which is also called the "Un-reversible Time Arrow," leads to un-reversible thermodynamic arrow, and therefore an un-reversible biological arrow, moving the universe toward greater disorder (See Zhongshu Yang 1996, pp. 134-6). We can call the above explanations the "Physics Basis", the deepest foundation for our society's economic development pattern.

3. The Water Tank Model

It would be very helpful if there was a mathematical model which could describe the properties of human society as a living system with entropy increasing and decreasing at the same time. This process can be illustrated by an isolated water tank full of salt water with inflow and outflow salt water of different concentration. (See William E. Boyce and Richard C. Diprima's book

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[2] If not, the Universe will end up "Heat Death", which is already proved to be impossible in modern physics.

"Elementary Differential Equations", pp. 51) Therefore, the variations in the amount of innovation (new inventions and theories, etc) are due solely to the inflow and outflow innovations per capita.

3.1 A model with population growth

Assume the population N grows as a function of time t with its growth rate $n > 0$. Each economy is populated by N_t identical agents. To keep it simple, the number of agents in each economy grows over time at the common and constant exogenous rate n: $N(t) = N_0 \cdot e^{nt}$, $N_0 > 0$.

Let the annual birthrate be $r_1 > 0$ and mortality be $r_2 > 0$, so the number of births is equal to $N \cdot r_1$ *and the number of deaths is equal to* $N \cdot r_2$, *and* $n = r_1 - r_2 > 0$. Assume each innovation is a numeraire good, so the amount of innovation can be measured as dollars and related to productivity (GDP). The initial amount of innovation in the original population is I_0, which is worth $\$I_0$. Each year, the newborn population $N(t) \cdot r_1$ brings in i innovations per capita to the society, while the deaths per year take away some amount of unused or inadaptable or depreciated innovations. For example, petroleum was discovered to be combustible about a thousand years ago in China, but petroleum and its related inventions are not widely used until recent century, that is why we can say the innovations related to petroleum flew out (or was wasted) human society at that time and did not come back until 20 century. Let the total amount of innovations in the society be a function of time: $I(t)$. So the innovations per capita in the society at time *t* are equal to $I(t) / N(t)$. The rate of change of innovations in the society is $\partial I / \partial t$. This is equivalent to the difference between the rates at which innovations enter and leave the system. The rate at which new innovations enter the society is the amount of new innovations per capita i times the population inflow rate $N(t) \cdot r_1$, and is equal to $i \cdot N(t) \cdot r_1$. To find out the rate at which new innovations leave the society, we need to multiply the innovations per capita in the society at time t by the rate of outflow population $N(t) \cdot r_2$. Consequently, the rate at which innovations leave the society is $N(t) \cdot r_2 \cdot [\, I(t) / N(t) \,] = I(t) \cdot r_2$.

We now have a first order differential equation describing the human society:

(1a) $\partial I / \partial t = i \cdot N(t) \cdot r_1 - I(t) \cdot r_2 = i \cdot r_1 \cdot N_0 \cdot e^{nt} - I(t) \cdot r_2$,

Subject to the initial condition is:

(2) $I(t{=}0) = I_0$.

If we plug in $n = r_1 - r_2$, the final solution for (1) is

(5a) $I(t) = (I_0 - iN_0)\, e^{-r2\, t} + iN_0 \cdot e^{n\, t}$ [3]

Equation (5a) can be rewritten in terms of innovations per person $s = I/N$ as:

(6a) $s(t) = s_0 e^{-r1t} + i(1 - ie^{-r1t})$ The term $i(1 - ie^{-r1t})$ gives the amount of innovations per person in the society due to the action of the flow processes, while the term $s_0 e^{-r1t}$ is the portion of the initial innovations per person that remains at time t.

The graph of (5a) is shown in Figure 2A1. I (t) is convex increasing unboundedly because the first order condition $\partial I / \partial t = r_2(iN_0 - I_0)\, e^{-r2t} + (r_1+r_2)\, iN_0 \cdot e^{(r1+r2)\,t} > 0$ and second order condition $\partial^2 I / \partial t^2 = r_2^2(I_0 - iN_0)\, e^{-r2\,t} + (r_1+r_2)^2 iN_0 \cdot e^{(r1+r2)\,t} > 0$ under very weak assumptions: $r_2 > 0$ and $I_0 > iN_0$. This implies that if r_2 and i are constant, the path of I (t) will keep increasing as t goes to infinity.

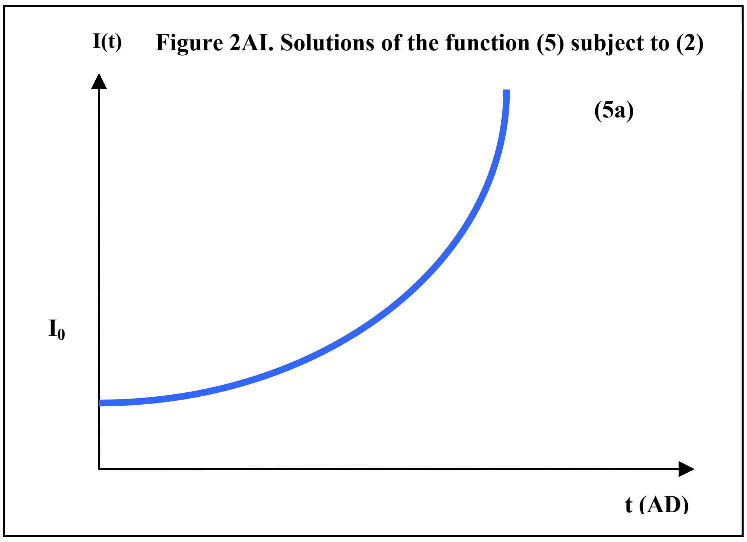

Figure 2AI. Solutions of the function (5) subject to (2)

The graph of (6a) is shown in Figure 2A2. It shows that the actual path of the function depends on the value of $\$I_0$ and $i \cdot N$. The first order condition $\partial s / \partial t = -r_1 (s_0 - i)\, e^{-r1t}$ and second order condition $\partial^2 s / \partial t^2 = r1^2 (s_0 - i)\, e^{-r1t}$ *imply that if* I_0 and $i \cdot N_0$ are constant, the path of $I(t)$ will converge to *i* as *t* goes to infinity. This makes perfect sense and is straight forward, because eventually the innovations originally in the society will be replaced by the innovations flowing in, whose new innovations per capita is *i*.

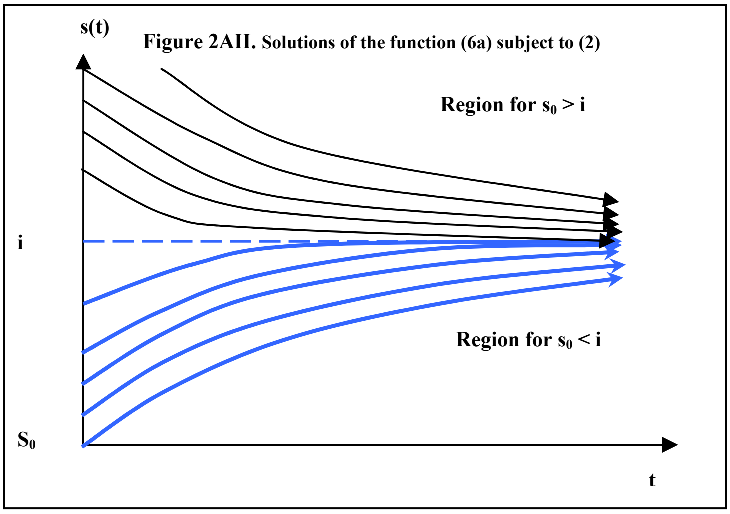

Figure 2AII. Solutions of the function (6a) subject to (2)

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[3] *Please see the proof in Appendix A*

Consistent with the outcome of my equation, inflow of new innovation will be equivalent to the outflow ones after a long period of time.

If we rearrange the terms in Equation (6a), we get:

(7a) $s(t) = (s_0 - i)\, e^{-r1t} + i$

This tells us when the initial innovation per capita s_0 is smaller than the inflow of new innovations per capita *i*, the society is in its developing stage, its path is upward sloping, its innovations per capita *i* and the entropy is decreasing because the "open" factor is the dominant factor in the social living system. If, on the other hand, the initial innovation per capita s_0 is larger than the inflow of new innovations per capita i, then the society is in its declining stage, its path is downward sloping, and entropy is increasing because the closed factor is now the dominant factor. The relation between I (t) and s (t) is just like the relation between output Y(K) and output per capita y(k) in Solow Model.

3.2 When population growth is constant

In some situations, like the recent years and most likely the near future, the population *N* of the society is constant (about 6.5 billion). In other words, this means that the annual birthrate and mortality are the same. I will call this rate: *r/ year*. The number of newborns is equal to the number of deaths per year, so the number of births and deaths are both equivalent to $N \cdot r$. Then the first order differential equation becomes:

(1b) $\partial I / \partial t = i \cdot N \cdot r - I(t) \cdot r$ subject to the initial condition (2).

This equation (1) can be solved as:

(5b) $I(t) = i \cdot N(1 - e^{-rt}) + I_0 \cdot e^{-rt}$ or in terms of innovation per person s = I/N as:

(6b) $s(t) = s_0 e^{-r1t} + i(1 - ie^{-r1t})$

In this case, both I (t) and s (t) have similar pattern as Fig 2AII. The intuition is, when population becomes constant in the steady state, the inflow innovations are just equal to the outflow ones, so both the total amount of $I^* = i N$ and per capita form $s^* = i$ are constant.

3.3 Some examples

This model can be illustrated by the following historical examples in economic development:

EXAMPLE 1:

When there are one-time, short-lived shocks to the original population's innovations, the amount of innovations inside the society *jumps* greatly. For example, to help the development of human society, Mother Nature kindly blessed Britain with Adam Smith who had the intelligence and intuition to set up the foundation of Economics at time $t_1 \approx 1776AD$. However, because this is just a short-term positive shock, with few supporting shocks, the new innovations per capita is still i_0^{uk} . This brings up the original path of s_0^{uk} (t, s_0^{uk}) to s_0^{uk} (t, $s_0^{uk'}$) as one time shocks can only speed up the society's innovations in the short run[4], In the long run, the equilibrium level will still be approached. The growth path therefore has a ladder shape (See Figure 2B).

In a case where there are continuous shocks to innovations, for example, when America became independent from the British Colony Empire at time $t_2 \approx$ 1783AD and its social structure changed to the modern capitalist system, the inflow of new innovations per capita to the American *increased* from i_0^{us} to i_1^{us}, and their innovation path *shifted* up from s_0^{us} (t, s_0^{us}) to s_1^{us} (t, s_1^{us}). The long run equilibrium level increased to i_1^{us}, which was higher than Britain's i_0^{uk}. Even in the short run, the America's innovation level is still lower than the Britain's *level.* True to prediction, in about 1910 AD (point A), the American productivity caught up with the British productivity. The British productivity path has one jump in 1776AD then is continuous to approach to i_0^{uk}, while as the

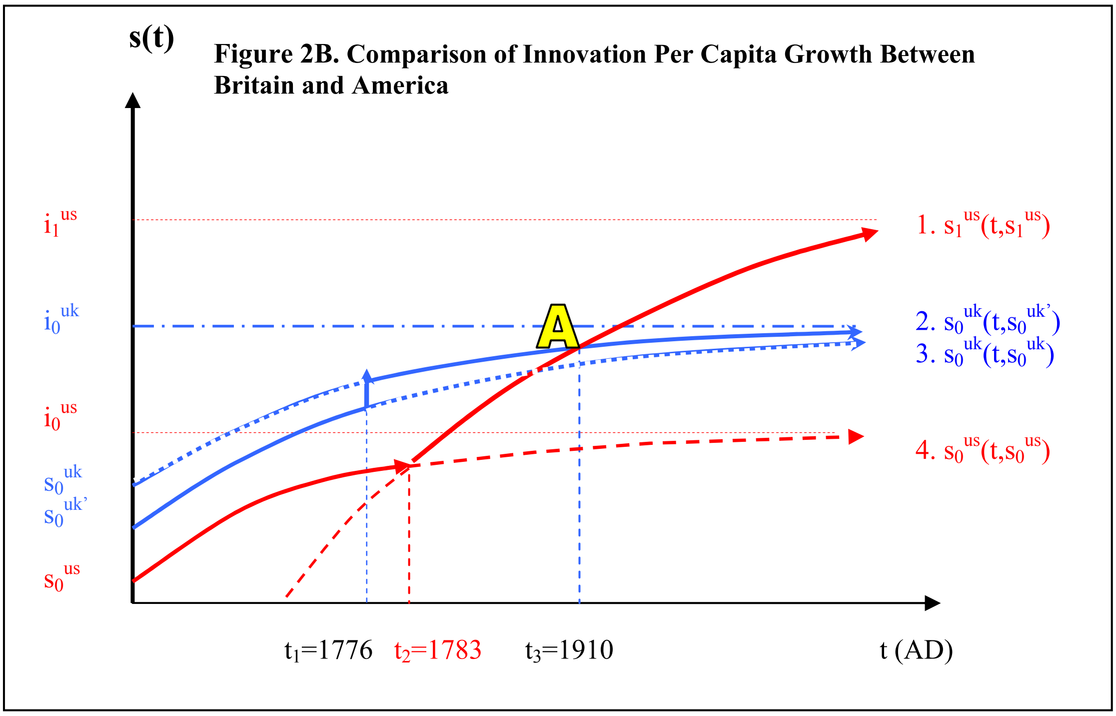
Figure 2B. Comparison of Innovation Per Capita Growth Between Britain and America

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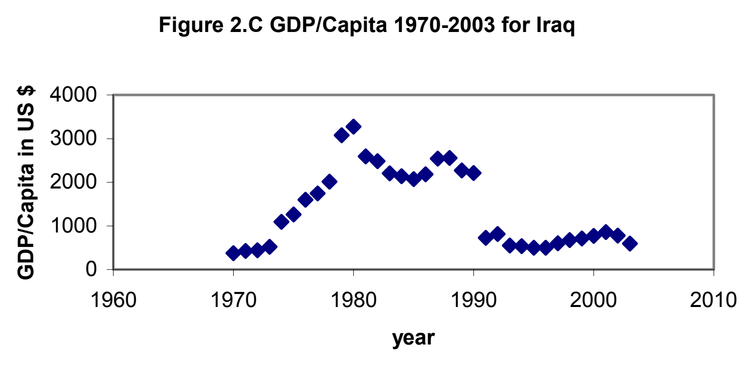
[4] Mathematically speaking, the path function is changed from s_0^{uk} (t, s_0^{uk}) to $s_0^{u\,k}$ (t, $s_0^{uk'}$), with the initial value changed from s_0^{uk} to $s_0^{uk'}$, but the limit i_0^{uk} is the same as t goes to infinite.

American productivity path has one kink point in 1783 AD and then is continuous to approach to i_1^{us}. (See Figure 2B)

What if there are negative shocks to a living system? Example 2 is given to illustrate how the declining stage and downward sloping path occurs. (Question: Does the EU enlargement / integration help Europe increase i ?)

EXAMPLE 2:

Figure 2C[5] represents the productivity (in terms of innovations per person) development path for Iraq between 1970 and 2003 under the rule of Saddam Hussein. From 1970 to early 1980s, the developing period for Iraq's productivity was dominated by the increasing effect of entropy. There was a jump in 1975, probably due to the one-time, positive shock of the Oil Shock. This brought up Iraq's original path of $s(t, s_0)$ to s (t, s_1)[6]. Another bigger one -time shock occurred from 1979-1980. This was probably because Iraq was preparing the war against Iran, and its economy was stimulated by the increase of military expenditure. Both shocks caused little change to the inflow of new innovations per capita i_0. After the breakout of the Iraq-Iran War, its new inflow of innovations per capita dropped from i_0 to i_1. Even though there were some positive one-time shocks during the mid 1980s, probably because of the secret support from the US government, Iraq's innovation path *shifted* down from $s(t, i_0)$ to $s(t, i_1)$. That means their long run equilibrium level decreases from i_0 to i_1. When Saddam started the Gulf War in 1990 soon after the Iraq-Iran War, he prompted another continuous negative shock. This drew down the long -run equilibrium level even further to i_2, which is very close to zero. As a result, 1980 to 2003 is the declining period for the Saddam's Iraq Empire, and it experienced its "death" in 2003. This is a period dominated by the increasing effect of entropy.



3.4 Discussion

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[5] Source: Fig. 2C is from United Nation's website http://unstats.un.org/unsd/snaama/selectionquick.htm

[6] In this example, s(t) can be treated as GDP per capita y(t) in Solow Model.

The water tank model treats the inflow rate of innovation as the dynamic force for our society's economic growth. This is in the same spirit as the human capital model by Jones (2002): Long-run growth is driven by the discovery of new ideas throughout the world. Growth in the world's stock of useful knowledge is ultimately tied to growth in world research effort. But the advantage here is, unlike the classic neoclassical growth models, we do not concern whether the agents are over lapping generation and infinite life, the form of the production function is not important as well. Rather, the inflow-outflow dynamic mechanism is adequate to describe the development pattern, and very suitable to describe macro economy development. With the focus on innovation (human capital) mainly, a steady state i can also be solved through solving a differential equation.

It also suggests that the long run productivity level does NOT depend on the endowed resource and innovations-- which are determined by one time shocks-- but rather on the acquired innovation rate determined by continuous shocks, similar to the Solow Model.

4. Predictions using the Water Tank Model.

Figure 3.A World population growth rate

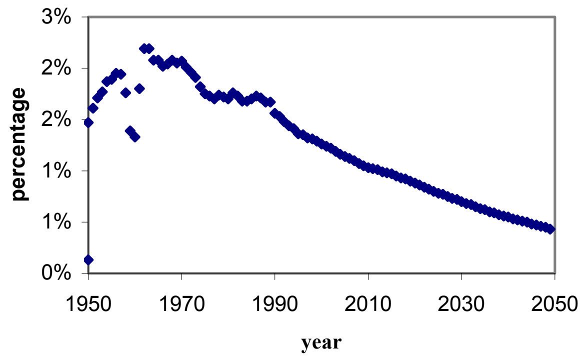
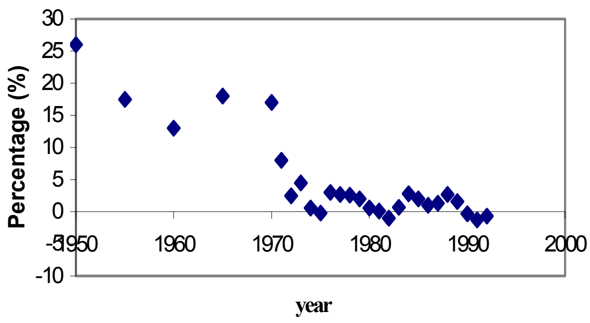


Figure 3.B Growth rate of GDP/Capita(1950-1992)

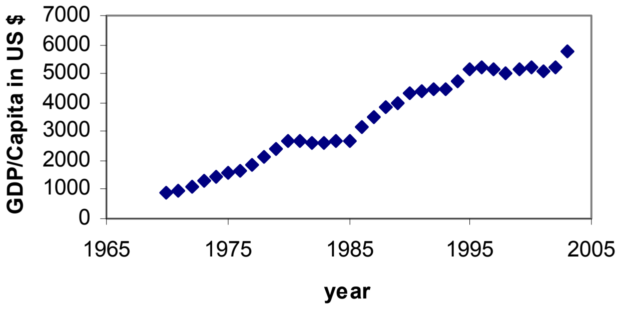


Innovation is in positive proportion to the productivity level, measured by GDP per capita. Let GDP per capita be g, then there will a relationship $s(t) = c \cdot g(t)$ (7) where c is a transformation constant, which can be estimated using the empirical estimation method with statistical new innovation per capita data . Then plugging in (1) and solving for *g (t),* we will have a very similar equation to (6). This means that the whole society's economical development pattern can be described by the water tank model. Based on comparisons to other living systems, the properties of the human society's economic growth, such as the periodic patterns, can be obtained. By using empirical evidences, we can know what stage we are in now, and can therefore predict the direction of the world's economic development with comparison to an individual person's pattern. That is, though we cannot predict shocks in the future, but we can describe particular development patterns given different assumptions.

4.1 The Optimistic Predictions and "Bright Economics" With OptimisticAssumptions

From the analysis and figures in Section 2, it becomes apparent that population and productivity (measured by GDP per capita) grows very slowly before 1800AD. It then enters a fast developing period, and both its population and productivity increase rapidly after 1800AD. This is the developing period dominated by the increasing effect of entropy. However, our earth has become very crowded; in 2000AD, the world's population has passed six billion. Controlling the growth of population has become a key task around the world. The population base is so large that even a small percentage increase is a lot. Nevertheless, *Figure 3A* [7]shows that the growth rate of population has been declining since the 1960s, and predictions have been made that population growth rate will approach zero between 2040 and 2130. The total population of the world at that time is predicted to be between eight to thirteen billion (The Futurist, 1990) due to resource constraint. This is a strong indication that our society's "body" will reach its physical maximum in the near future. Robson and Kaplan (2003) point out that, after the physical strength of a human body is reached at age 18, there is a 17 years time gap before the maximum productivity level is reached. In other words, it is reasonable to think that human society's productivity will still keep increasing after the population stops growing. But, from the empirical data in *Figure 3B* [8], the growth rate of GDP per capita shows a clear exponential declining trend towards zero, and it is very possible that this growth rate will reach approximately zero more or less at the same time as the population growth rate in the near future, which is very puzzling. Jones (2002) suggests using balanced growth path theory to explain this. And,

Figure 3.C World GDP/Capita 1970-2003



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[7] Source: Fig. 3A are from Kramer (1993) and DeLong (http://www.j-bradford-delong.net/).

[8] Source: Fig. 3B is from Joshua S. Goldstein et al (1997).

most of the economists agree the world GDP per capita is along its downward trend, even others argue that there is still uncertainty. But this well-known productivity slowdown is supported by a number of stylized facts. Even the productivity does not slow down now like other economists argue, the trend of the productivity path is approaching i_0 in the coming future.

If we have a closer look at the data for productivity measured by GDP per capita between 1970 and 2003 (*Figure 3C*[9]), an interesting ladder shaped growth path can be found, which is explained by the Water Tank model developed in Section 3. This ladder pattern is likely due to numerous one-time shocks within short time periods rather than to continuous shocks, which have one kink point and then a continuous path. *Figure 3C* shows that there were one-time shocks between 1976-78(the Oil Shock), 1985-90(the crash of Soviet Union and ending of Cold War) and 1993-94(IT innovation). Note that the jump in 1980s is larger than the other two. So, if only multiple one-time shocks occur in the future, we should predict that both productivity and population will reach their maximum level (the limit) almost at the same time and soon. On the other hand, it is also possible that our society's productivity level will shift to a new level due to continuous shocks, because unlike human body which must have an ending (die) due to the internal constraint, the society can get rid of this necessary ending by continuous renewing its knowledge. This will lead to an exponential trend of productivity increase after a kink turning point in 20xxAD, the periodic law of which can be estimated by using econometric data and tools. Possible causes include the war against terrorism, the changing ideologies of our society, and the "Fourth Industrial Revolution" lead by the IT industry, the effect of which has not been observed yet. Following this the exponential decreasing trend for the growth rate of productivity will turn upwards thereafter, and productivity will keep increasing after the maximum level of population is reached. What's more, based on Theorem 2, theoretically, a living system can live and keep prosperous forever. A large number of candidate growth models in previous literature describing this developing process have been published, I will therefore summarize them as "Bright Economics".

4.2 The "Pessimistic" Predictions and "Dark Economics" With Pessimistic Assumptions

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[9] Source: Fig. 3C is from United Nation's website http://unstats.un.org/unsd/snaama/selectionquick.htm

According to the water tank model, a living system which is differentially closed and open will have a developing stage where an increase in entropy dominates and--after the peak--a declining stage where a decrease in entropy dominates. This is comparable to the growth, maturation, and aging of the human body and the rise and fall of the Iraq Empire. There is no doubt that human society will enter its middle age in the near future: its body--population and productivity will stop growing, remaining at peak level from then on. The question then becomes this: how long will this *golden period* last? What is waiting for us after that? The optimists will likely console us not to worry too much about the analogical pattern because Man's hidden ability will be stimulated when needed. Aren't we still prosperous after the World War, they will ask? But my main concern is this: *no matter what kind of stage we are now*, *we are firstly living systems, we must follow the Second Law of Thermodynamic*. Even the most powerful man will pass away within two hundred years and, as our human society is a living system, even the most prosperous empire will fall. Disasters and periods of wealth or peace are governed by Mother Nature which can not be prevented. The studies on the falling stage of economic systems are called "Dark Economics". But again based on Theorem 2, theoretically, a living system can revive like phoenix, as long as it can keep its entropy not decreasing by increasing the entropy outside, or in a society's case, keep having new innovations. This theory can be used to argue against those who predict that our society will decline for sure due to the constraint of the amount and time of researchers.[10] For example, after the fall of Hussein Empire, Iraq gains its new life with its GDP per capita increased greatly in 2004.

This tells us that all we really can do is to promote the discoveries of new ideas, or to reduce the outflow rate of innovations and prevent the waste of new ideas.[11] For example, the government can use more policies to encourage innovations in our society, such as building more schools. If our society and economy are hit by a bad shock unfortunately, all we can do is to help make our society develop and recover faster after disasters, using our intelligence. All we can do is to prepare adequate reserves, to keep a clear mind, to do more research to gain a better understanding of Nature, and to cross our fingers and hope for the best. (Extension: What policies should EU apply in 21th Century?)

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[10] Jones (2002) argues that at most the entire labor force can be devoted to producing ideas, and at most individuals can spend their entire lives accumulating human capital due to upper bound imposed by nature.

[11] Many historical examples can be found. For example, economists did not recognized Ramsey model's (1928) importance until Cass and Koopmans' work (1965).

5. Conclusions and Prospects

The exploration in this paper for the basis of human society's economic pattern has reached the physical level. The main purpose of the paper is NOT to argue what we are today and what we will be tomorrow. It is open for debate. E.g. Jones (2002) argues that our economy is far from its steady state, which is similar to my opinion. Rather, this paper presents and calibrates BOTH the developing and declining period's mechanism through a new model of economic growth. Regardless of whether the perceived conclusions are accurate, this research study will probably prove useful for future analyses, as few studies describing the dark side of economic development (declining period) are attempted. By studying the "Dark Economics", we can have a more complete view about the process of development and know how to prevent and get out of the dark side.

One method for approaching economic pattern analysis suggested by this paper is to look inside the researching object such as human society for details by standing outside and applying fundamental laws. For example, physicists will use the "Conservation of Momentum" for anything. In a similar way, the Second Law of Thermodynamics can be applied to the study of development pattern.

Further more, the water tank model introduced in Section 3 explains how a living system works governed by both the conservation and thermodynamics laws. Using this simple model as a guide, more complicated models can be developed in the future. For example, one can think of the amount of population *growth rate n*, or the birth r_1 and death rate r_2, and the inflow new innovation per capita i/person as functions of time, then the equation (1) becomes:

$$\partial I / \partial t = i(t) \cdot N(t) \cdot r_1(t) - I(t) \cdot r_2(t). \qquad (7)$$

As long as these functions are given, one can always find the solution for $I(t)$ and arrive at more realistic patterns.[12] The model can also be applied to other living systems, such as individual humans, firms, countries, and nations with different variables. It can also be used to analyze historical examples to deduce general rules. To learn from failures of living systems (for example, the fall of Iraq or the extinction of species) is very important to Mankind, because extinctions can be very fast

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[12] Gary Becker (1990) has discussed the relationship between fertility rate and economic growth. Kremer (1993) shows that the population growth rate exponentially increasing before 1970, then linearly decreases after that.

and sudden, and play as a menace to human society. The water tank model can also serve to forecast the future: it tells us that the main factors for the rising and falling of human society are continuous new innovations. Therefore, future researches should focus on how to facilitate the developing period, prolong the prosperous periods, and recover from the declining period by stimulating the new innovations rate.

APPENDIX A:

PROOF OF THEORM 1:

PROOF: Assume the Second Law of thermodynamics is universally true. If a universe is isolated and limited, there must exist a maximum entropy level S* per system such that the universe's unit entropy will not increase any more after S* is reached. At the beginning, the universe's entropy is $S_0 < S^*$. When $t > t_0$, the total amount of the initial entropy of the universe S_0 is increasing as time t passes until it reaches its maximum level S*. This requires $\forall t \in R$, $\exists\ \partial S/\partial t > 0$. Assume there exists a living system J which belongs to the universe and J is without an ending (that means its final $s<S^*$), its initial entropy level is $s_0 < S^*$. So $\forall t \in R$, it is always true that $s < S^*$. This requires $\forall t \in t_1$, $\exists\ \partial s/\partial t \leq 0$. Assume at time t_1, all parts of the universe reach S* except J. Then S stops increasing if $\partial s/\partial t \leq 0$ because J is now the only place the universe can get entropy from. That means the total amount of the universe's entropy S is NOT increasing as time t passes because it cannot get more entropy from J. But this violates the Second Law of thermodynamics that S will keep increasing if $S < S^*$. So J must have an ending with final entropy $s = S^* > s_0$ so that the whole system reaches S* at the end (dies).

PROOF OF THEORM 2:

Similar to Theorem 1, if a universe is unlimited, there does not exist a bounding level of entropy such that the universe's entropy will stop increase. Then the living system J which belongs to the universe and J can possibly use disordered raw materials outside the system to produce orderly structures in which to live, develop, and converge from disorder to order, keeping its entropy not decreasing for ever. So $\forall t \in R$, $\exists\ \partial s/\partial t \leq 0$.

PROOF OF EQUTION (5a)

To solve the first order differential equation describing the human society:

(1a) $\partial I / \partial t = i \cdot N(t) \cdot r_1 - I(t) \cdot r_2 = \; = i \cdot r_1 \cdot N_0 \cdot e^{nt} - I(t) \cdot r_2$,

Subject to the initial condition:

(2) $I\,(t=0) = I_0$.

Since (1a) is not an exact form, I will times e^{r2t} on both sides of (1a), and let

(3) $M\,(t, I) = \Psi t = I r_2 e^{r2t} - i r_1 N_0 e^{(n+r2)\,t}$, (4) $N\,(t, I) = \Psi_I = e^{r2t}$

After rearrangement and plugging n + r2 = r1, we have:

(4) $\Psi = \int \Psi_t dt + h(I) = I\,e^{r2\,t} - i\,N_0 e^{r1t} + h(I)$

=> $\Psi_I = e^{r2\,t} + h'(I) = e^{r2t}$ => $h(\,I\,) = c_1$.

=> $\Psi = I e^{r2\,t} - i N_0 e^{r1t} = c$ = > (5) $I = c e^{-r2t} + i N_0 e^{nt}$.

When $I_0 = I\,(t=0) = c + iN_0$ => $c = I_0 - iN_0$

Plug in (5) = > (5a) $I\,(t) = (I_0 - iN_0)\,e^{-r2t} + iN_0 \cdot e^{nt}$

APPENDIX B: DATA

The data used in this paper are taken from several different sources. Many of the sources are now available online.

1) Data of Fig. 1A, Fig 3.C World GDP/Capita and Figure 2.C GDP/Capita for Iraq is from United Nation's website: http://unstats.un.org/unsd/snaama/selectionquick.htm

2) Fig 1B world population and Fig 3.A are from Kramer (1993) and DeLong (http://www.j-bradford-delong.net/).

3) Fig. 3B is from Joshua S. Goldstein; Xiaoming Huang; Burcu Akan.
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