Primary Energy Analysis: A New Approach beyond Extant Growth Theories

- Growth of what? Degrowth of What?

What is the Real Economic Substance that is to expand, stagnate, or shrink? It should be, beyond the GDP, *the Whole Industrial Production (WIP)* standing for all kinds of real economic activities, where the WIP comprises both the intermediate and the added value sectors of the inter-industrial relations table (IIRT) while the GDP represents only the latter.

Every economic activity, or, every term of the IIRT needs some suitable energy input and, vice versa, every part of energy consumption takes place for a certain economic purpose.

Therefore it is the very WIP, not the GDP alone, that absorbs the total Primary Energy Supply (PES) to a domestic economy; and it is the total PES or its industrial conversion that drives the whole (Domestic) Industrial Production (WIP) of a country, whereby causing all the environmental liability due to the economy.

Thus we have come to an assumptive conclusion that the WIP, rather than the GDP, is the best available indicator to show the real scale (magnitude) of an economy. Let us certify this proposition in reference to the IIRT (=the Inputs-Outputs Table) of which the structure is illustrated in Fig. 1.

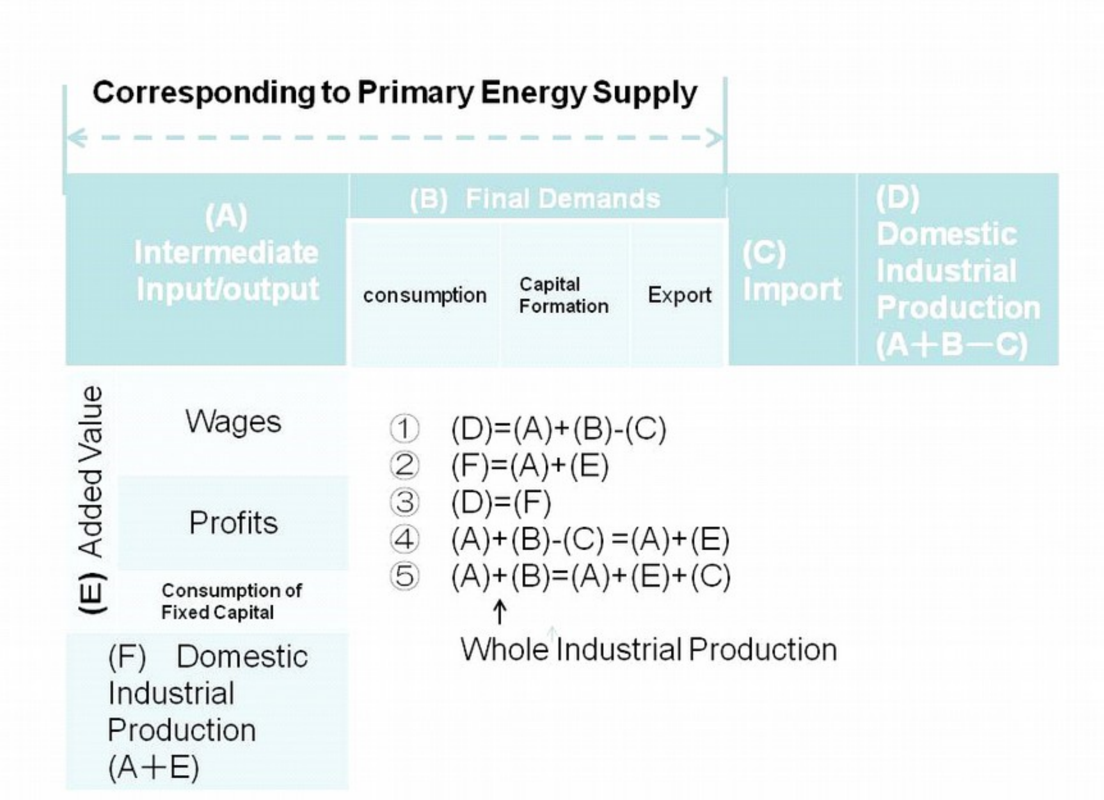

Fig.1 Schematic diagram to illustrate a structure of the Inter-Industrial Relations Table

The 'Whole Industrial Production' corresponds to the sum of the intermediate inputs/outputs and the final demands, while the so called GDP represents only added value sector of the WIP.

- Primary Energy Supply and Economic Processes: How do they correlate?

Therefore Ecological Economics must first analyze the correlation *between the PES and the WIP* because it is only the latter that calls for the full demand to the PES and causes all the resultant environmental consequences (including the global warming).

To begin with, let us show the historical changes of Japan's PES, WIP, and GDP in Fig.2. The PES for Japan made an extraordinary development from the early 1950s to 1973, the year of the First Oil Crisis, from ca. 60 million to near 400 million TOE (Tons of Oil Equivalent), which means about 6.5 times rise in the two decades. On the contrary Japan's PES has been limited under, near, or just over 500 million TOE for four decades after 1973.

The WIP of Japan (in terms of nominal yen), on the other hand, entered into the steeply rising stage with a marked delay of ten years or so against the PES rising. This delay, we consider, must have been an intrinsic manifestation of the structural correlation between the PES rise and the WIP rise. In other words, the preceding (rapid) expansion of the PES is considered to have been an essential prerequisite for the rapid WIP growth in the post-war Japan. Then followed the delayed but long enduring growth of Japan's WIP in 1960s, '70s, and '80s (the WIP growth survived the Oil Shocks in '70s!).

'90 Bust

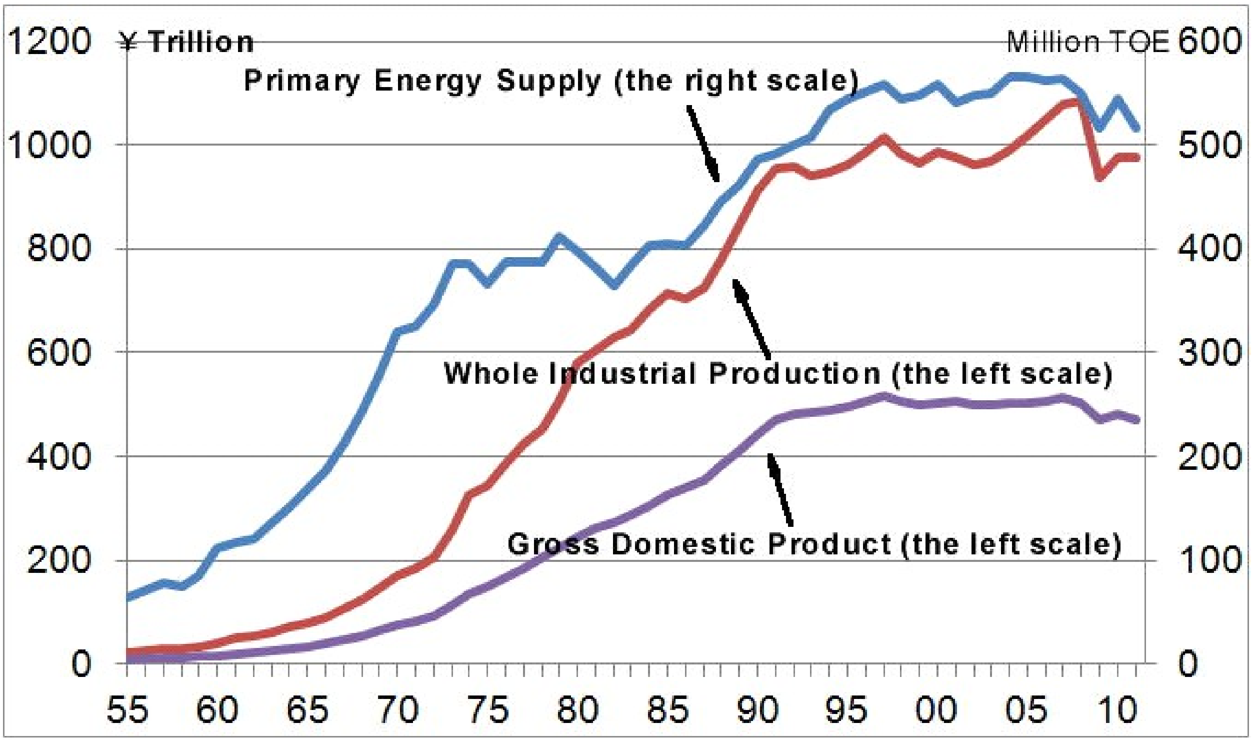

Fig.2 The total Primary Energy Supply, the Whole Industrial Production, and the Gross Domestic Product of Japan for 1955-2011

Japan’s Primary Energy Supply is entirely dependent on import: the governmental statistics count nuclear energy as domestic (self-supporting) but in fact all the uranium comes from overseas. The most rapid growth of The total Primary Energy Supply took place in 1955-1973 while that of the Whole Industrial Production, in 1967-1992: and the Gross Domestic Product has always been sharing about one half of the WIP.

As is shown in Fig. 2, the stunning rise of the PES suddenly and entirely ceased at the First Oil Crisis. On the contrary, the rise of the WIP had a marked delay of ca. ten years against that of the PES but retained its tenacity for ca. twenty five years, clearly beyond the Oil Shocks in 1970s.

However, the WIP of Japan seems to have dissipated all its growth potential during the financial/fiscal bubble in the late 1980s and at the precipitous bust of 1990. This chart clearly shows that the dual but time-sequent expansions of the PES and the WIP should be a one-off (monocarpic, so to say) historical process. Japan’s once brilliant growth of the PES-WIP pair must have ended forever.

- The advent of the world-wide stagnation since 2008 as compared with Japan

Since Japan’s bubble burst of 1990-91, there have been enforced all-out, rather frantic, economic policies to bolster up Japan’s long obsolete economy, *all entirely in vain*. None of remedial policies taken by the successive administrations, or proposed by Keynesians, monetarists, market-fundamentalists, pragmatic economists, or whatever conceivable speculators, could ever have been effectual. In fact the successive governments funneled extraordinary fiscal funds into the nation’s economy, which have piled up to 1000 trillion yen, or roughly 10 trillion dollars by 2012, all without any visible effects on the nation’s economy.

The last to come is the “sink or swim” speculation by the Abe Administration and the Bank of Japan. However, this final attempt to terminate Japan’s decades lasting deflation has an intrinsic self-contradiction: its core policy, the targeted inflation, is taking place actually in the form of a cost-push inflation instead of a demand-pull one. In fact, serious price hike has occurred for imported fuels, mineral materials, and foods in inverse proportion to the serious yen devaluation since the fall of 2013, which is seriously to erode people’s disposable incomes in concert with the consumption tax rise (to come in April 2014).

In the meantime, the US and EU suddenly came to crash into the composite bubble burst on real estates and financial securities, in several cases, accompanying sovereign risks: thus the US and EU finally turned out to have gone onto Japan’s trajectory two decades belatedly. The age of secular stagnation has set in for the US, EU, other OECD countries, and newly developing economies (including BRICs) whose exports are to be absorbed by the OECD countries.

Japan’s economy, submerged in much prolonged slump, has often been ridiculed or sometimes pitied by the world outside of Japan. However, since the financial/realty bubble bursts in US and EU in 2008-09, the OECD economies are barely bolstered by the unprecedented Quantitative Ease (QE) of the central banks; also, the so called Emerging Markets including BRICs turned out to be heavily dependent on the QE of FBR, ECB, and BoJ (the Bank of Japan). Even a fairly mild squeeze in the FRB's QE by 10 billion dollars per month, i.e. from $ 85T to $ 75T (FOMC decision in Dec. 2013) caused a trembling repercussion on newly developing regions like South America, India, Indonesia, Turk etc. And the next step, $ 10T squeeze from $ 75T to $ 65T per month was enforced in late Jan. 2014, which again shook the world market.

This world-wide stagnation, however, seems to moderately correspond to the present PES saturation (Hubbert peak) or near saturation. In fact, if a PES-intensive growth as seen in Japan's 1960s or China's 1990s and 2000s begin in large-population regions like India, South Asia, South America, Africa etc. or recur in China, it will raise PE price immediately and mercilessly until the global PE demand subsides. Now no oil or gas fields will be able to bear a further PES surge on a global scale.

- A theoretical, semi-quantitative analysis on the growth/degrowth problem of the world economy

4.1 Mathematical notes on the logistic function (LF)

The logistic function (LF) is an S-shaped curve (sigmoid) to show an asymptotic approach to a limit (see Fig.##). Its normalized form *q(t)* can be written as

$$q(t) = \{\tanh(t)+1\}/2=\{1+\exp(-t)\}^{-1}$$

The first derivative of LF (i.e. LFD1), i.e. a slope of the LF, is a bell-shaped curve with a fairly broad peak at the center (t=0) and a left and a right tail diminishing to zero at their ends: LFD1 is written as

$$\mathrm{d}q(t)/\mathrm{d}t =(\mathrm{d}/\mathrm{d}t) \{\tanh(t)+1\}/2=(\mathrm{d}/\mathrm{d}t)\{1+\exp(-t)\}^{-1}= \mathrm{cosech}^2(t)/2$$

And the second derivative of LF (i.e. LFD2) means the rate of change in LFD1 and forms a hill-and-dale shaped curve with a peak and a dip, rather narrow in contrast to that of LFD1, both lying near the center: LFD2 is written as

$$\mathrm{d}^2q(t)/\mathrm{d}t^{\,2}=(\mathrm{d}^2/\mathrm{d}t^2)\{\tanh(t)+1\}/2=(\mathrm{d}^2/\mathrm{d}t^2) \{1+\exp(-t)\}^{-1}= -\tanh(t)\mathrm{sech}^2(t)$$

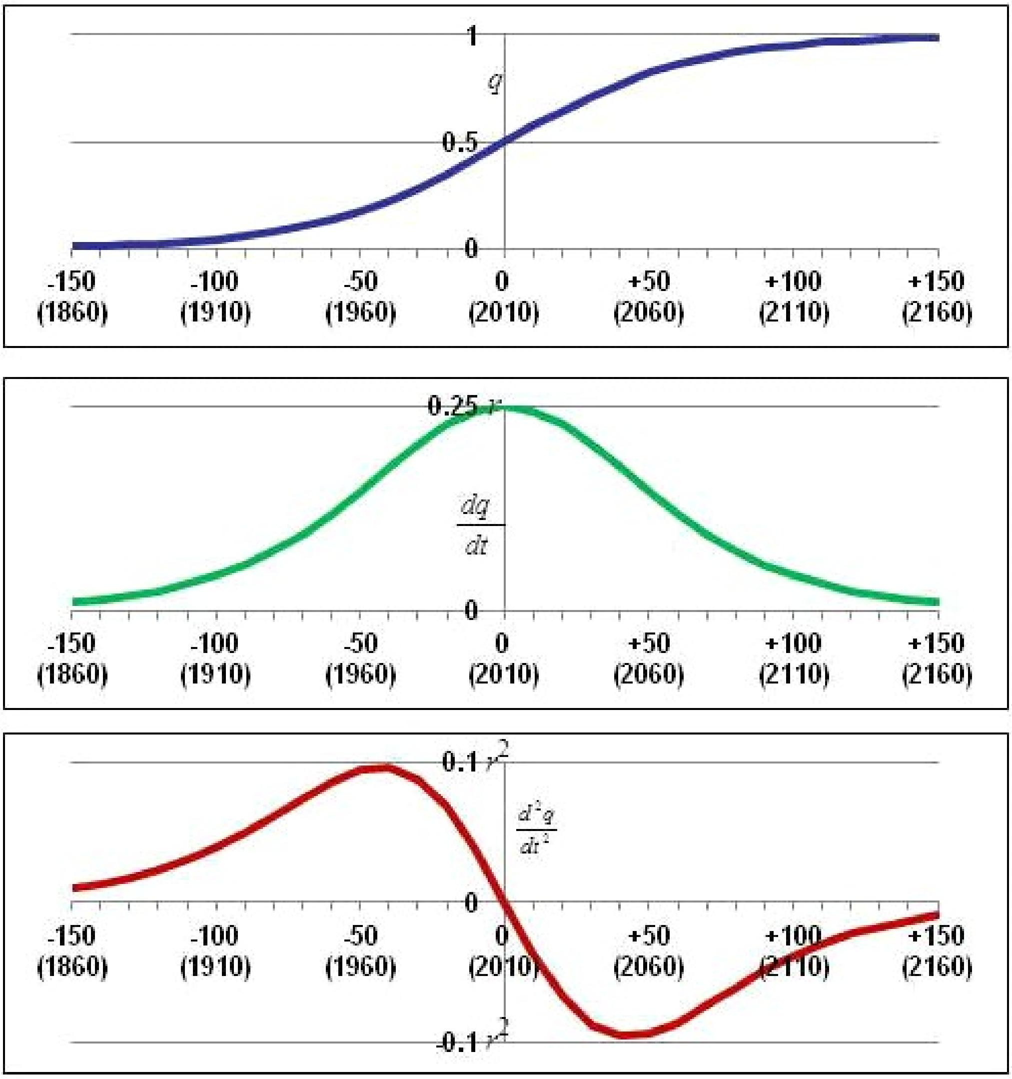

Fig. 3 Logistic function with its first and second derivatives

The uppermost curve stands for the logistic function; the middle, for its first derivative; and the lowest, for its second derivative. The vertical scale is normalized to 1.0 while the horizontal scale is an arbitrarily adjusted historical years that might roughly represent the world fossil fuel reserve and the Hubbert curve for the world primary energy supply with a hypothetical peak at 2010.

The LF theory has two very important applications: the first is for dealing with exhaustible resources and the second, with renewable resources, where the former can be named as Mill-Jevons-Hubbert Framework: MJHF (1) and the latter, as Malthus- Verhulst Framework: MVF (2). To be remarked is that the variable *t* and the function *q*(*t*) should have entirely different implications according as in the MJHF or in the MVF.

4.2 Mill-Jevons-Hubbert Framework for exhaustible resources

In the first case (MJHF), the variable *t* represents an historical time; and the value of LF *q*(*t*), a cumulative extraction or consumption of exhaustible resources (more precisely, economically recoverable reserves). Further, the first derivative of LF (LFD1) corresponds to an annual yield, which must change year by year under external conditions.

This function is often called as “Hubbert curve” because M. King Hubbert (1956) is the first who *intentionally* applied this logistic analysis to a problem of exhaustible resources, in fact, of the US oil reserve depletion. He was able to *successfully* predict ‘the peak oil’ of the US mainland to occur in 1970, against which fierce and full fury arguments were hurled by growth-oriented (great majority) economists. Recently, however, the peak oil of the Middle East countries and, hence, of the whole world have come into affirmative arguments.

In the history of economic thoughts, the depletion problem of underground resources has traditionally been a grave Pandora’s Box to all economists. Only few thinkers dared to confront this problem. Among them was J. S. Mill (1848, 1871): he came to recognize that the Law of Diminishing Returns (LDR) must hold in the mining industry as well as in, or rather, more relentlessly than in the agriculture. His remark on this problem shows that he had clearly discerned the LDR *for renewable resources* (e.g. forestry) and that *for exhaustible ones* (e.g. a coal mine).

This distinction is essentially important in dealing with limitation to the growth, or restrictions imposed on the industrial civilization in general. W. S. Jevons (1865) published “*The Coal Question*” and revealed that all the British industries had been entirely dependent on the domestic coal and that economically recoverable coal in Britain is restricted and on the way to depletion. Although his estimation on the coal reserve might have been too tight, his recognition on the exhaustibility and the way of depletion seems essentially to have been of the same kind as that of Hubbert.

It should be remarked that the Hubbert peak or the maximum of LFD1 does not mean the onset of the absolute (physical) depletion of the underground resources but rather notifies the beginning of decrease in profitably extractable resources. This peak also corresponds to a manifestation of the *LDR for exhaustible resources*, as was mentioned by Mill. The LDR in the MJHF directly concerns with a now hot issue of EROIE (the Energy Return on Invested Energy) to be defined as the ratio of {the energy output} divided by {the energy input} (invested energy).

The maximum of the EROIE is ca. 100:1 or even more but can be achieved only as spontaneous gushing forth of oil or gas on an open plain. This condition was fulfilled on Texas Oil Fields in 1930s or on Saudi Oil Fields until 1970s. Nowadays, there are no such excellent oil fields. The world is now plunged into the convulsions of EROIE deterioration in general. All the second best energy sources available have much lower EROIE and much higher environmental risk, as seen in deep-sea oil fields, nuclear power, wind power, solar cells etc. Moreover the world might be on the verge of ‘cliff’ like fall of EROIE as proved by Tim Morgan (2013).

As for the second derivative (LFD2) of the LF, it is nothing but the slope of the Hubbert curve (=annual yield curve) and represents the rate of growth (or of degrowth, after the Hubbert peak period), cf. Fig.3. This function provides very significant information on the growth potential of economic systems. Before the Hubbert peak, LFD2 remains positive, however, goes through three periods: an increasing, an around-summit, and a decreasing stages in succession.

In the first stage, the LFD2 is increasing, which means that the growth rate itself is growing. During this period, the WIP (or the whole industrial activities) can enjoy an accelerating expansion *no matter whether* ‘the growth-oriented policy’ is adequate or not; *whether* ‘the economic growth theory’ is true or not; or *whether* ‘the business cycle' is favorable or not. This was just the case in the US, the EU area, and Japan at 1960s or in China at 1990s.

During the second stage, the WIP (real economic substance) would keep a plateau state for a decade or so, often boosted by various financial bubbles, as was the case in Japan and the US at 1980s. Later, this period would usually be remembered as 'the Belle Epoque' of the nation and often become not only a target of nostalgia but also an economic landmark to win back. However, it is this period that intensely dissipates the primary energies then provided under advantageous conditions and, thereby, prepares the third stage.

In the third stage, the growth rate LFD2 can still keep itself in positive, however, cannot avoid decline any longer, whether be it rapid or slow. The WIP along with the GDP remains rather stagnant and the fruit of dwindling growth would be fully collected by 'the richest 1%', leaving ordinary people in distress of unemployment, wage cutting, or indebtedness. Japan resides in this stage since 1990; and the US and EU seem to have reached this stage in the late 2000s.

Since the Lehman shock in September 2008, the FBR and other major central banks has pumped enormous financial funds into the staggering world economy and that at virtually zero interest rate. Yet the growth rate of the OECD economy is hardly recovered *no matter which* 'growth-oriented policy' may be adopted; *which* 'economic growth theory' may be mobilized; or *which* phase may occur in the business cycle. This was just the case in the US, the EU area since 2008, and in Japan since 1990.

All the problems mentioned above occur slightly before or just at the Hubbert peak. What would take place if the world economy would enter into post-peak stage?

4.3 Malthus-Verhulst Framework for renewable resources

In the second case (MVF), the value of LF $q(t)$ should represent an extant biomass (population) such as forests, tunas in the oceans, or agricultural products; and the variable t, whole metabolic inputs (e.g. solar rays, water, mineral nutrients etc.) to sustain the concerned biomass. In this case, contrastively to the first case (MJHF), the bell-shaped curve FLD1 represents the *reproductive capacity* (rate of renewal) of the biomass or the other renewable resources in concern and generally *time-independent*.

Therefore, an annual yield not greater than this curve is *sustainable*: even the peak of this curve is within the sustainable capacity and the peak is called as *Maximum Sustainable Yield* (MSY). This MSY, however, is very sensitive to the environmental circumstances. A possible environmental degradation might seriously impair the reproducibility (renewability) of the living resources and lower the MSY. And in case the annual yield exceeds the MSY, i.e. excessive exploitation takes place, the biomass stock concerned will suffer a sharp decrease or even eradication. Thus a Malthus-Verhulst type limit to the growth is much less rigid than a Mill-Jevons-Hubbert type limit, yet the former requires most careful maintenance.

Malthus (1798) has been often notorious for his 'limit to growth' concept and his assumption or anticipation on atrocious ways of population control. However, if once we replace his idea on population control into a more rational family planning, his theory is considered to be still effectual. In fact, China has long continued a population control policy, implicitly according to Malthusian theory, to be a rational policy choice for the future of China and, also, of the rest of the world. In contrast, India has been desperately endeavoring, in vain, to introduce family planning and, in concert, to guarantee the right to sexual equality.

To tell the truth, however, Malthus-Verhulst Framework (MVF) is not an “application” but is rather a prototype of the logistic function as was formulated by Verhulst (1845).

Yet, nowadays, the agriculture is so heavily dependent on fossil fuels. Therefore, the MVF may not be able to retain its proper independence but will have to be subject to MJHF.

- Invalidation of traditional growth theories and an urgent necessity of post-peak approach

Let us review the trend of the world energy supply (corresponding to the global WIP) and the world population. It is clear that world population and the primary energy supply made a drastic upturn at near 1960 owing to the then affluent supply of cheap oil and gas. Now this advantage is lost forever during the following half century. Meanwhile all the growth-oriented theories had been compiled before 1960 and therefore have now fallen doubly obsolete.

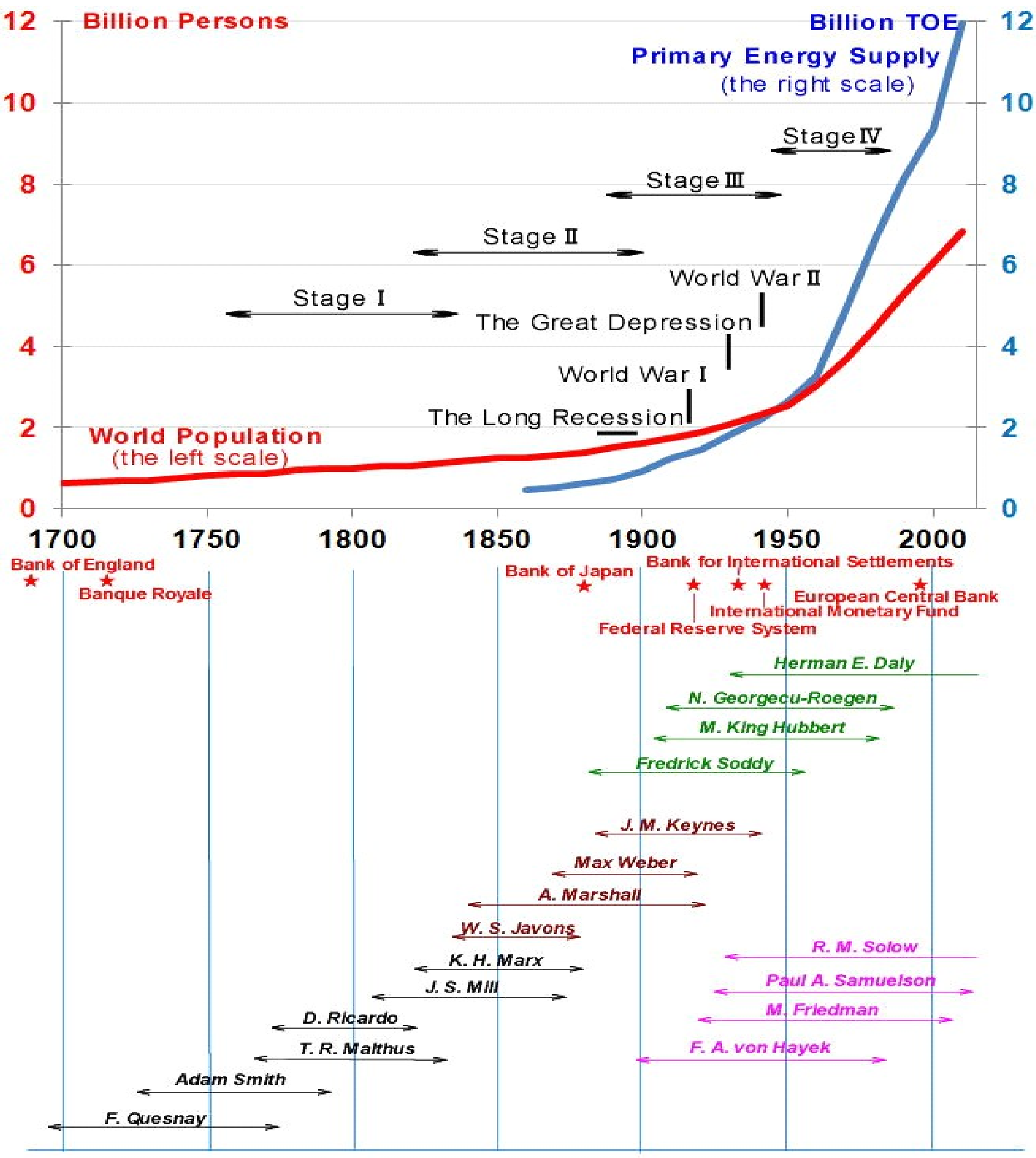

Fig.4 The world population and the world primary energy supply appended by the lives of major economists and the major events concerning major center banks.

All the growth-oriented economic thoughts were compiled much before the Hubbert peak. Therefore, it is no wonder that recent Hubbert-type restrictions have invalidated all the mainstream economics. In the upper chart, Stage 1 represents the Industrial Revolution in UK; Stage 2, the I.R. in Continental Europe, the US, and Japan; Stage 3, classical heavy-chemical industrialization; and Stage 4, the post-war global growth.

Here to be remarked is that the mainstream economists would always regard *technological innovations* as Deus ex Machina, or a cure-all Elixir. But this is not the case because the *effects of science and technology* are strictly finite despite that *their progress* may be infinite. Technology *cannot create* a single atom or even an electron. It *can only convert* already given (extant) energy and materials. Therefore, it is closely restricted by the laws of thermodynamics and qualities and abundance of raw materials.

In conclusion, the present global stagnation is considered to be an inevitable result due to multiple restrictions concerned with the Hubbert peak of fossil fuels and other underground resources. This is the ultimate reason that all the growth policies in the world remain just invalid. A new approach is necessary to confront this problem: its first step is to correctly analyze the energy/material aspects of the economy.

References

Jevons (1865): "The Coal Question An Inquiry Concerning the Progress of the Nation, and the Probable Exhaustion of Our Coal-Mines" by William Stanley Jevons (1865)

Hubbert(1956): "NUCLEAR ENERGY AND THE FOSSIL FUELS" by M. KING HUBBERT, PUBLICATION No. 95, SHELL DEVELOPMENT COMPANY, JUNE 1956 To be published in Drilling and Production Practice (1956) , American Petroleum Institute

Malthus(1798): "An Essay on the Principle of Population" by Thomas Robert Malthus (1798) Oxford World's Classics reprint: xxix Chronology. Edition Used: London: Macmillan and Co., 1866. (Second edition, revised) First Published: 1865.

Mill(1848, 1871): "The Principles of Political Economy: with some of their applications to social philosophy" by John Stuart Mill, John W. Parker (1848), "The Principle of Political Economy" (1871), Part 1 chapter 12, section 3.

Morgan(2013): "*Life After Growth*" by Tim Morgan, Harriman House Ltd, Hampshire, UK (2013), Chapter 6.

Verhulst(1845): "Recherches mathématiques sur la loi d'accroissement de la population [Mathematical Researches into the Law of Population Growth Increase]" by Pierre-François Verhulst, Nouveaux Mémoires de l'Académie Royale des Sciences et Belles-Lettres de Bruxelles 18: 1–42(1845)

Keywords: Energy, Interindustrial-Table, Peak-Oil, GDP, Growth