Primary Energy Analysis: A New Approach beyond Extant Growth Theories

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Economic activities are inseparably correlated with energy conversion and consumption. All the economic processes must comprise a process of energy consumption as its material groundwork. There are several previous studies on the correlation of economic activities and energy consumption.

For example Reiner Künmel (Professor of the University of Würzburg in Germany) and his group have developed a new production function called "LINEX" consisting of the triple variables: capital, labor, and energy to replace the traditional Cobb-Douglas function. That is to say the quantities of capital, labor and energy were indexed to the starting year, and subsequent changes measured in percentage terms to make them comparable. Using this approach Künmel's group analysed the data for US, Japan and Germany over thirty-year period and they showed that their model produced 'predictions'of economic growth in the three countries that matched the actual outcomes very closely.('The Need to Reintegrate the Natural Sciences into Economics'"BioScience"August 2001 Vol. 51 No. 8)

Robert Ayres (Novartis Professor of Management and the Environment at the international business school INSEAD, France and Institute Scholar of at IIASA) and his co-authors studied an historical transition of thermodynamic efficiency in the major energy-consuming sectors: electric power systems, industrial processes, transportation, room heating, lighting and so on, and they introduced an index to measure useful work (thermodynamically available energy) in the economy. Then they fed their data into a model based on Reiner Künmel's LINEX function and theoretically estimated some GDPs to be expected from the model: the results are in good agreement with the empirical GDP of the U.S. or Japan for the entire twentieth century, without any readjustment.
 ' Accounting for Growth: The Role of Physical Works'"Working Papers" The Centre for Management of Environment Resources 2002

We appreciate their results to be sufficiently worthwhile in that they could successfully reproduced the GDP from the empirical data of capital, labor, and exergy and thus they have made the 'Solow Residual' term unnescessary for reproducing the empirical GDP.

However, we consider that their results call for a further study because both exergy and GDP are secondary, derived quantities.

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

We have compiled both the macro-economic data and the primary energy supply & consumption data. In reference to the previous studies, we have analyzed a possible correlation between the said two data.

In addition, by using the data of these data, we show that the economic value criteria can be converted to the "energy value" from the "monetary value". In this study, we defined as the "primary energy" includes the electric power that is generated using hydro and nuclear power or renewable method in addition to oil, coal, natural gas. In official statistics, national and international organizations have the same handling.

In this study, macro economic data that we directed to is the data of Input-Output tables. Input-Output tables estimate the Total Output. In this statistics, intermediate demand (=Intermediate Inputs) is estimated first, and Final Demand is added. Final Demand is equal to the Gross Value Added. The Gross Value Added is equivalent to the Gross Domestic Product in the System of National Account.

However, Total Output includes imports. In order to understand the true total output of a country, it is necessary to exclude imports minute. So as to distinguish Total Output, the total output excluding the imported minute, we call it the Whole Industrial Production (WIP). This WIP corresponds to the Primary Energy Supply. (Fig.1)

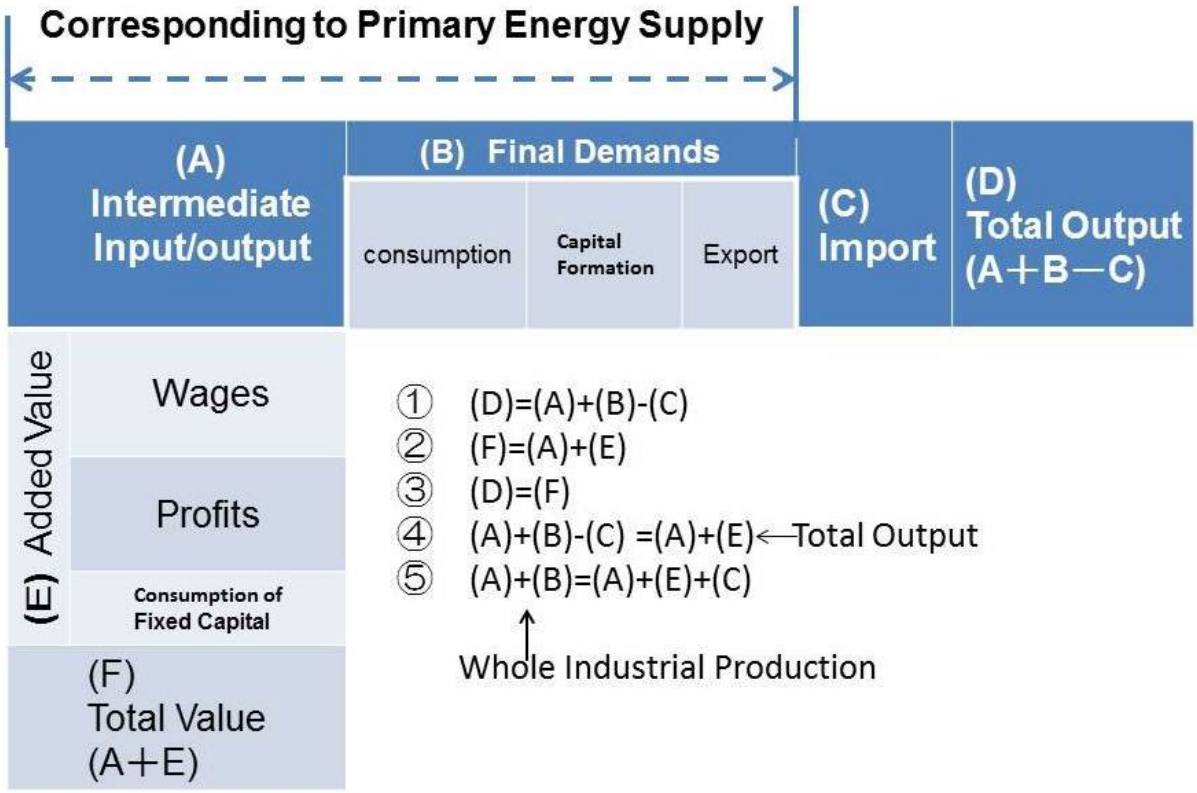

Fig.1 Schematic diagram to illustrate a structure of the Inter-Industrial Relations Table
The 'Whole Industrial Production' corresponds to the sum of the intermediate inputs/outputs and the final demands, while the so called GDP represents only added value sector of the WIP.

2. Historical comparison of the Primary Energy Supply and the Whole Industrial Production of Japan

To begin with, let us show the historical changes of Japan's PES, WIP, and GDP in Fig.2 and table 1. The PES to Japan made an extraordinary expansion from the early 1950s to 1973, the year of the First Oil Crisis, from ca. 60 million to ca. 400 million TOE (Tons of Oil Equivalent), resulting in ca. 6.5 times rise in the two decades. On the contrary, Japan's PES has been limited to around 500 million TOE for four decades after 1973.

The WIP of Japan (in terms of nominal yen), on the other hand, began to make a very rapid rise after a time lag of ten years or so to the rise of PES. This time lag, we consider, had been an intrinsic result 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. As is shown in Fig. 2, the stunning rise of the PES suddenly and entirely ceased at the First Oil Crisis in 1973.

On the contrary, Japan's WIP had survived this oil shock and successfully continued to rise for ca. twenty years, further prolonging the time lag against the PES rising. However, the WIP of Japan seems to have dissipated all its growth potential: gradually during the financial/fiscal bubble in the late 1980s and then precipitously at the bubble burst 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.

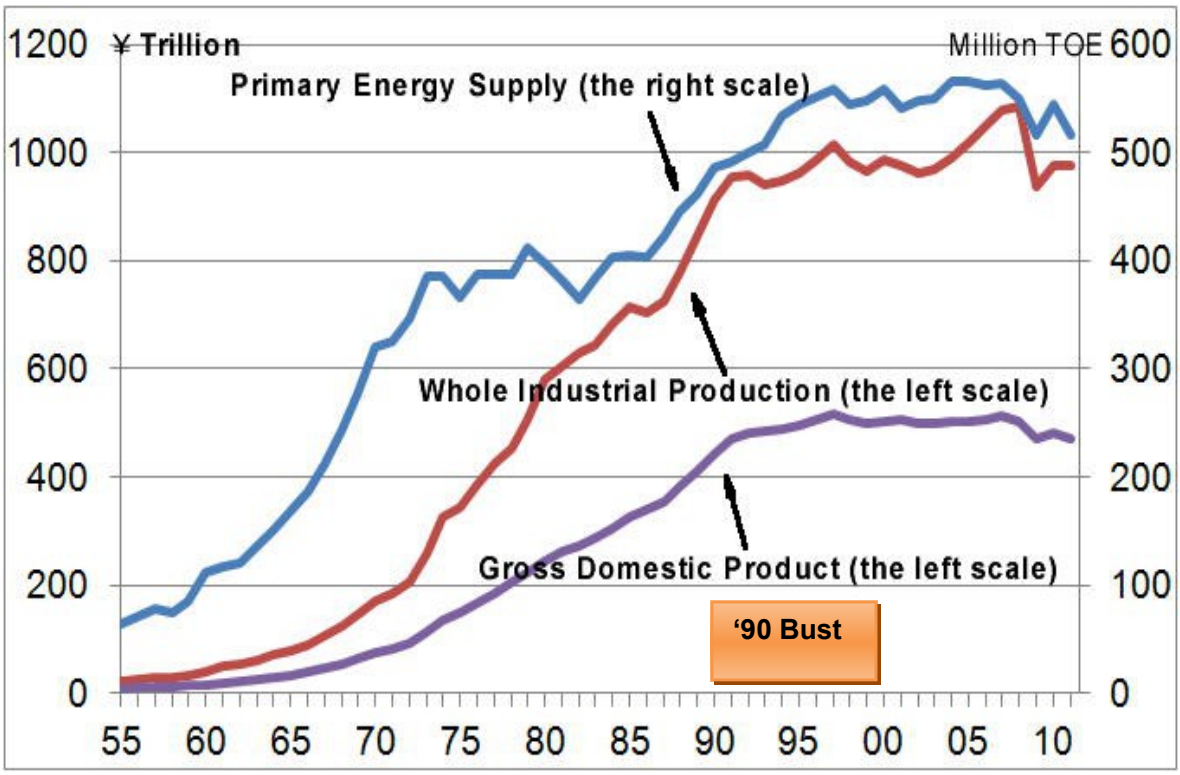

Fig.2 The total Primary Energy Supply, the Whole Industrial Production, and the Gross Domestic Product of Japan for 1955-2011

Item	Unit	1955	1965	1973	1985	1990	2000	2011
Primary Energy Supply	Million TOE	64.1	152	358	393	486	559	516
Whole Industrial Production	Trillion Yen	20.7	76.8	259	713	912	987	976
Gross Domestic Product	Trillion Yen	8.4	32.9	113	325	473	503	471
WIP/PES	Thousand Yen/TOE	320	510	720	1,810	1,880	1,770	1,890
PES/WIP	TOE/Million Yen	3.10	1.98	1.38	0.55	0.53	0.57	0.53

Table 1 The Historical Changes of Japan's PES, WIP, and GDP

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.

3. Conversion from Monetary Value to Energy-Content Value

We think as follows. The PES expresses the total energy used for all the economic production per year. On the other hand, the WIP expresses the total monetary value of economic production per year. The former, PES, views all the economic activities in terms of energy. The latter, WIP, views the same process on monetary evaluation. Therefore, we can recognize a proper correspondence between the PES and the WIP. Further, it is possible to convert each other through an appropriate "conversion rate".

We adopt the "conversion rate" to the energy unit price (WIP / PES) and the specific energy consumption (PES / WIP).

4. Estimates of the energy content value by industrial sector

It is noteworthy that the PES can break down to the ES for each industrial sector according to its share in the WIP by the use of the appropriate conversion rate. The ES by sector will be of great importance in estimating the socio-economic and environmental sustainability because they can provide information on future ES requirements by industrial sector. For example urban infrastructures, accompanied by their inevitable degradation, will need not

only fiscal provisions.

5. Conclusion

Thus if we can successfully derive a consistent conversion rate between PES and WIP for each economy, and can analyze the nation's economy in terms of energy-content value, then we can deal with the economic processes neutrally from various disturbances like the currency exchange rate fluctuations, time-dependent value alterations due to inflation etc. Therefore, this approach will contain an extensive applicability comparative study of the multinational economies, long term analysis of a national economy along with necessary estimation of inevitable degradation of social-capitals and infrastructures and of energy-material requirements needed for their replacements, renewals, etc.