Literature Review about Mainstream Economics and Biophysical Economics

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Keywords: Mainstream Economics, Biophysical Economics, Energy Economics.

Abstract. The history of human culture can be viewed as the progressive development of new energy source and their associated conversion technologies. For example, the invention of steam engines and internal combustion engines, led to the substitution of coal and oil for animal power and firewood as the main sources of energy, and eventually led to the industrial revolution. As results, these developments increased the economic and life quality. There are so much study indicates that there is a strong correlation between energy and economic growth. The role of energy in the economic system has come in for much discussion. For now, some debate still continues about the relationship between energy and economic growth from different perspective.

Mainstream Economics about Relationship between Energy and Economic Growth

Energy Quantity Perspective

Most study of energy quantity via relationship between energy production perspective or energy consumption perspective and economic growth. These two perspectives represent two main stream energy econometric analyses of relationship between energy quantity and economic growth.

Some impressive array of studies focuses on establishing the causal links between energy consumption and economic growth. Such studies have been conducted since the two important seminal papers of Adams and Miovic[1], Kraft and Kraft[2]. Energy is one of important inputs for the development of industries and economic growth. The importance of energy as an essential ingredient to life on earth is well established in the physical sciences both in terms of biological energy and as a primary enabler of industrialization [3]. The energy-economy link is often omitted from economic growth formulations, such as the Solow model, for which the production function [3]. Kraft. J. and Kraft. A. [4] is the first use of Sims Test to analyze the relationship between energy consumption and economic growth, they found that the U.S. had a one-way causal relationship from GNP to energy consumption between 1947 and 1974. However, Eden [5] stated that the causal relationship from GNP to energy consumption could only be found by using monthly data in the U.S. from 1947 to 1979. Nachane [6] based on the Engle-Granger co-integration method, a large number of annual data on energy consumption and economic growth in 11 developing countries and 5 developed countries were studied, and it was found that the economic growth rate indeed had a co-integration relationship with energy consumption. In studies of developing countries in Asia, Asafu Adjaye [7] found that there is a one-way causal relationship between energy consumption and economic growth in populous Indonesia and India, while energy consumption and economic growth in Thailand and the Philippines, both countries with relatively small population but rapid development, are mutually causal.

Besides, another studies analysis internal compliance relationship between energy consumption and economic growth based on econometric method applied and casualty test. Therefore, the internal compliance relationship between energy consumption and economic growth becomes the problem that the researchers should study and attach great attention to [8]. Florian and Victor [8]
summarized these studies envisaged and systematically tested four assumptions: A relation of cause-and-effect running from energy to economic growth, causal relation running from economic growth to energy, feedback hypothesis between energy and economic growth, the absence of any causal relation between energy and economic growth.

However, the fundamental problem is that a generation of mainstream macroeconomic theorists has come to accept a theory that has an error at its very core: economic theories can no longer regard resources as “free gifts” [9-11]. Resources are clearly limited no matter what energy type it is, fossil fuels or renewable, no exception. Most studies apply well to periods with large and growing energy supplies and relatively low energy production costs. Sometimes this assumption is useful but does not consistent with the actual situation. Assume gross energy extraction/capture does not sufficiently increase due to environment constraints, technology constraints (Betz limit), land cover and land use constraints or fossil fuel production peaks (reserves limits), the increases in indirect and direct energy inputs in energy production not only increased energy output but also will eventually lead to a reduction in energy used at end of use.

When realized the improper assumption about “free gifts”. Some pioneer scientist connection between limited natural resources with population, economic, environment or society or all of this. Hotelling’s [12] publication said that that these products are now too cheap for the good of future generations, that they are being selfishly exploited at too rapid a rate. publication of Limits to Growth [13] sparked sustainable development because of limited natural resources depletion. M. King Hubbert [14] used graphical methods to construct a logistic curve for oil production in the lower 48 States of the USA [15]. Hubbert came up with conception about “peak oil” and proposed a bell-shaped curve to represent the rate of oil production with time, under the assumption that the production rate will be zero at the onset of production and again zero when the reserves are exhausted, then other researchers expand this concept to “peak fossil fuels” [15].

Although Hubbert [16] was one of the pioneers to gather empirical data of energy in order to make predictions on future energy availability, which means energy production. But Hubbert didn’t further analysis correlation between energy availability with economic growth, he criticizes neoclassic economics for its lack of a biophysical basis [17]. Hubbert [18] stated: “quantity GNP is a monetary bookkeeping entity. It obeys the laws of money. It can be expanded or diminished, created or destroyed, but it does not obey the laws of physics”.

Odum [19] argued that energy was the source of economic value. This means wherever a dollar flow existed in the economy, there was a requirement for an energy flow in the opposite direction. If we think relationship between energy and economic growth in Odum’s perspective, it seems to illustrate something: increasing GNP leads to economic require more goods and service eventually consume more energy. But it has been based on abundant resource reserves. William P. Nel [3] was cognizant of depletion of fossil fuels after production reached peak of life cycle, and scarcity of fossil fuels will have increased energy produce costs eventually impact economic growth. William P. Nel [3] says: “when we take long-term structural scarcity in energy supplies into account, energy cost for obtaining the energy is needed to measure the energy constraint to economic growth.” Lutz [20] stated that due to the price-inelasticity of oil demand the oil supply shortage leads to a sharp increase in oil prices, with high effects on GDP comparable to the magnitude of the global financial crises. Kerschner [21] has similar theory about shortage oil will leads to price goes high and effects on economic growth. Additionally, Lutz [20] further study result shows that oil exporting countries benefit from high oil prices, whereas oil importing countries are negatively affected. For example, energy production has positive effect on the economic growth of Iran [22].

**Energy Price Perspective**

The relationship between energy price (usually the oil price) and the macroeconomy has been debated since the early 1980s when the first oil crisis occurred and global recessions followed [23]. Hamilton [24] was the pioneer of study on the correlation between energy prices and economic growth since World War II. From then on, more excellent researchers and more sophisticated methods are required to evaluate the energy price–economic growth relation.
Paul Cashin [25] based on Global VGR model study on oil price fluctuations have different effects on oil importers and oil exporters between 1979-2011, under the scenarios of supply driven a shortage of oil is good for exporters but bad for importers, and vice versa under the scenarios of demand driven. When demand is driven, almost all countries at risk from long-term inflation, rising interest rates and falling stock prices. Kilian and Vigfusson [26] found no evidence in support of the impulse responses of economic factors to oil shocks are asymmetric. But An [27] found that results in this paper are opposite to the findings of Kilian and Vigfusson [26] and the relationship between higher and lower oil prices and macroeconomy is asymmetric (this relationship may be different in different countries).

Biophysical Economics about Relationship between Energy and Economic Growth

In addition to the perspective about price and quantity, there are another perspective about energy quality called biophysical economics. Biophysical economics is characterized by a wide range of analysts from diverse fields who use basic ecological and thermodynamic principles to analyze the economic process [28].

The history of biophysical thought is traced from the 18th-century Physiocrats, its first principle that natural resources, and fertile agricultural productivity in particular, were the source of material wealth. Physiocrats most important principle is “Natural Law”, and it is objective laws that do not depend on people's subjective will. Quesnay [29] defined it is physical law. It's different from social law, natural law without absolute construction force and people can accept or deny it by their own will. Quesnay argued that Natural Law operated independent of human free will, and that if humans accurately deduced the 'proper' economic behavior implied by Natural Law, social welfare would be maximized. Although Physiocratism had many limitations at that time, but it is the first time to analyze physical productivity of the extractive sectors, and especially the surplus produced by agriculture which was called net product.

The human civilization was originated from naturally, use nature resources propels human society unceasing progress. Physiocrats rise and fall in decades (1750-1770) in Europe inspired economists take nature resources especially energy seriously. Many physical and life scientists realized that those nature resources follow the nature laws had enormous implications for economic production. For example, the study on the relationship between the periodic activity of sunspot and economic cycle is the earliest understanding of the periodic fluctuation of economic activity. Periodic changes in sunspots affect climate change on earth, hampering agriculture (particularly in food production and prices) and ultimately affecting the entire economy.

Carnot [30], Clausius [31] and other scantiest formalized the laws of thermodynamics. Cleveland stated that Carnot's steam engine experiments demonstrated the relevance of the Second Law of Thermodynamics of economics, namely, how much 'useful work' could be obtained from an energy transformation. Podolinsky's [32] biophysical analysis led him to conclude that ultimate limits to economic growth lay in thermodynamic, physical and ecological laws. Cleveland argued that Podolinsky's work now widely used by biophysical analysts: modeling labor productivity as a function of the quantity of energy used to subsidize the efforts of labor [33]; and the importance of the energy surplus or net energy yielded by an energy supply process [34-36]. Frederick Soddy [37], a Nobel laureate in chemistry, who applied the laws of thermodynamics to analysis economic systems has conclude that economic wealth has biophysical laws as first principles because the whole energy for sustained human life comes from nature and this inanimate energy follow the basic physical principles. In the meantime, Soddy [38] argue that bank shouldn’t create debt based on 'will of the mind' because debt is a purely imaginary mathematical quantity with no physical dimension, debts possibly would outstrip wealth lead the banking system to collapse. Lotka [39] proposed a hypothesis for human development that mankind has been unconsciously following the laws of nature in the pursuit of energy, and nature selection tend to preserve and increase the numbers of those organisms that maximize the total energy flux through their system.
Since 1950’s, the biophysical economics research more focus on the relationship between energy quality and the economic growth. Cottrell [40] emphasized good energy quality should supply abundant ‘surplus energy’, the difference between the energy delivered by a process and the energy invested in the delivery process, and good energy quality had more efficiency to subsidize the efforts of labor and the productivity of labor. Odum [41] combine Lotka’s hypothesis and Darwinian’s theory as general biophysical law called ‘maximum power principle’: maximization of useful work obtained from energy conversion is the criteria for natural selection. Odum [19] also given definition of energy quality: relative ability of the economy to use different fuels to produce economic output per heat equivalent burned. Costanza [42] used the term embodied energy to described ‘per heat equivalent burned’ which is direct energy (real energy) and indirect energy (capital and labor inputs) used to produce a good or service.

Not all primary energy carriers can be delivered to the end user because energy-producing industries use energy during its production. Campbell [43] argue that A comprehensive evaluation should focus not only on energy resources but also on both the energy input that is part of the energy production process and the net energy contribution to this process, particularly the impact of its size on the economic system. Hall [36] found that the surplus energy delivered by the U.S. petroleum industry declined from more than 100 kcal of fuel delivered per kcal of energy invested in the 1930s to about 10-20 kcal returned per kcal invested by 1980. Hall and Cleveland [44] first publication that used the method Energy return on energy invested (EROI) to calculate the energy returned to the economy and society compared to the energy required to obtain that energy. It is calculated as energy outputs divided by energy inputs used in the same production process. The units of EROI are either dimensionless or maybe Joules per Joule, Calories per Calorie, barrels per barrel etc. EROI might be considered a measure of ‘surplus energy’ also called ‘net energy’.

Conclusion

In recent years, many researchers and public officials have shown considerable interest in EROI. After years of effort some general law well acknowledged by Biophysical economics researches based on EROI theory. These general laws are summarized following but is not limited to:

1. Dale [45] proposed a dynamic equation to describe the EROI of fossil fuel initially increases before reaching some point of production, until reaches its maximum value and begins to decline, eventually dropping to less than the break-even limit represented by an EROI value of 1:1.

2. Dale [45] point that there are two factors that will influence EROI function: technology and physical limited.

3. As EROI decline, the proportion of net energy in total energy decreases exponentially. Mearns [46] have discussed this relationship and noted a declining relationship between gross and net energy.

4. Lambert [47] and Hall [48] constructed a “Pyramid of Energetic Needs” model similar to the famous Maslow demand curve. Humans must first meet their physiological needs and then important psychological needs, but low EROI energy system can’t afford human psychological needs. Lambert [47] found that nations with HDI (human development index) levels greater than 0.949 have higher national EROIsoc values and lower energy use per capita than other countries.

5. There is a minimum EROI that a society must attain from its energy exploitation to support continued economic activity and social function. Quoting from Hall: “Think of society dependent upon one energy resource. If the EROI for this oil was 1.1:1 one could pump the oil out of the ground and look at it. If the children were to be educated you would need perhaps 9 or 10:1, have health care 12:1, have arts in their life maybe 14:1 and so on.”

6. According to the Bashmakov [49], growing overall economic productivity requires a better quality of energy services. Energy transition always from low quality energy to high quality energy. Combine energy quality definition so high EROI value energy is necessary for economic growth.
References


