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PRODUCTION THEORY AND PEAK OIL: COLLAPSE OR SUSTAINABILITY?

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1. The Historical Anthropology of Walrasian[1] Economics

All cultures are driven by "myths" that give meaning and purpose to their particular ways of living within social, biological and ecological constraints. Myths can be a unifying force that help drive a culture forward by unifying, consolidating, and streamlining patterns of behavior that help some societies gain an advantage over others. Myths can also outlive their usefulness and become a drag on the ability to adapt to changing conditions. It is the contention of this paper that the core myths of standard economic theory—economic man and perfect competition embodied in Walrasian general equilibrium theory—are an impediment to developing the kind of economic theories needed to guide the human species through the environmental and resource bottlenecks we face in the twenty-first century. The hope for the future is that new myths will evolve to meet this challenge.

A rich and fascinating literature in anthropology focuses on what might be called the "political cosmology" of economic theory. According to Marshall Sahlins (1996) the roots of Walrasian welfare economics lie deep in Western cosmology. At the core of traditional economic theory is a concept of human nature that casts behavior as devoid of social context, mechanically rational, and driven by an insatiable appetite for material possessions. Sahlins traces *Homo economicus* back to two ideas deeply embedded in Western cosmology. The first is the notion of "original sin", the idea that humans are doomed to eternal torment by their insatiable carnal appetites. The second is "natural order", the idea that the uncoordinated acts of isolated actors will lead to a harmonious equilibrium. The economic incarnation of this is that humans are cursed with a greedy and selfish nature but we can be redeemed by competitive markets whose teleological purpose is to transform individual greed into social harmony. Economic man is the original sinner, and the competitive market is his road to salvation.

Applbaum (1998, p. 336) argues that modern marketing techniques embody this cosmology of sin and salvation:

> Consumer free choice, like Christian free will, allows and enables us to transform ourselves, to transform our suffering and our needs. True, the marketplace can only

> offer a secular salvation, but this salvation is no trivial one; it makes life sufferable, even enjoyable… The logic is as follows: Insofar as free choice is about selecting how to satisfy needs, *needs* are transformed into *preferences*. A person is free to prefer; he is not free to need. A person is therefore no longer trapped by needs but transforms himself *into* them.

Economic man arose from the "noble savage" of Victorian England and the "original state of nature" where humans existed pure and free of the bounds of society. Hobbes wrote (1651, quoted in Bowles 1998, p. 75):

> [Let us] return again to the state of nature, and consider men as if but even now sprung out of the earth, and suddenly (like mushrooms), come full to maturity, without any kind of agreement with each other.

The Hobbesian fiction is the basis for the Robinson Crusoe economy where a single individual or a "representative agent" makes decisions about allocating scarce resources without reference to social or institutional context.

Although these myths were present in one form or another for hundreds of years they were not particularly dominant, nor did they drive human relationships and economic decisions the world over. The argument developed below is that the myths of standard economic analysis, salvation through material consumption and the growth of markets, the natural order of markets, unlimited growth, and independence from society and nature, came to prominence with the flood of abundant cheap energy in the nineteenth and twentieth centuries. Like the agricultural revolution before it, the fossil fuel revolution not only transformed the world's economy, it transformed human social systems all over the planet and the way humans relate to the rest of the natural world.

In terms of the energy return on the energy invested to obtain it (EROI) (Hall et al., 1992) fossil fuel is a unique energy source in human history that is unlikely to be easily replaced. Other sources of energy will surely be developed as fossil fuels are exhausted, but the energy bonanza of the last two hundred years or so is likely to be a one time occurrence. The transition to lower EROI energy sources will not only transform the human economy but also the value system supporting unlimited consumption and extravagant resource use. The glorification of greed was propelled by the frenzy of production that was the direct result of dumping seemingly unlimited energy into the market system. A new set of myths will evolve as the fossil fuel age winds down.

2. The Abandonment of Production Theory and the Alchemy of the Walrasian System

The history of the transformation of economics in the late 1800s and early 1900s is well-documented (Hodgson, 2001; Hunt, 2002; Mirowski, 1989). The Classical economists—Smith, Ricardo, Malthus, Marx—recognized that production required unique physical inputs and took place within a particular kind of social organization. With the "marginalist revolution" of the 1870s, historical historical perspective was lost as the preferred starting point of analysis became a timeless equilibrium system within a field of forces. This paved the way for economics to become the "science of the allocation of scarce resources among alternative ends" (Robbins, 1935). The study of economic choice was reduced to examining the optimal exchange of a fixed amount of commodities. The whole scheme of static allocation was transferred wholesale from utility theory to production theory with no regard as to where productive inputs came from (Georgescu-Roegen, 1970). The study of economic production became the examination of the efficient allocation of a fixed collection of productive inputs. The origin of preferences or productive inputs was no longer of concern to economists.

The economic theory of the consumer is based on a model of human behavior, unsatisfactory as it is. Although not empirically based, the utility function begins with a series of assumptions about how consumers choose—a set of axioms conforming to the mathematical requirements of transitivity, independence, and the existence of indifference. The axioms of consumer choice provided a starting point for modern empirically-based critiques from behavioral economics and game theory which now dominate economic theory. It has proved so difficult to develop a critique of production theory precisely because there is no equivalent starting point to develop a theory of production. The rich historical explanations of economic production developed by the Classical economists were reduced to a "production function" such as the still widely used Cobb-Douglas function, Q = AF(K,L), where Q is output, K is capital, L is labor and A is technology. There is no theory at all behind this function except to say that "output requires inputs."[2] As is often the case with Walrasian theory, more is claimed from production functions than they can actually deliver. The fact that "output" requires "inputs" does not justify ignoring real time, assuming constant returns to scale, or assuming the near perfect substitutability that the Walrasian production function requires. Nor does it justify ignoring political power, market power, and social and economic history by assuming that competitive markets alone determine factor prices.

The fact that production requires specific and unique physical inputs is not compatible with the "equilibrium within a field of forces" model and over the course of the 20th century the categories "land" and "labor" were more or less banished from the theory of production. Every input became a kind of "capital" and the engine of economic growth became "technology", an amorphous concept more in tune with the abstraction "utility" than with the physical reality of production. Technology in the Walrasian system is a kind of magical force that can increase the productive power of the economy without limit. If one assumes that there are no diminishing returns to technology, then there is no need to worry about the scarcity of any particular productive input. Any particular scarcity can be overcome through substitution and by applying more technology. In the core Walrasian model, not only is utility independent of society and the biophysical world, so is production. Not only is the agent of consumption a "homogeneous globule of desire" (Veblen, 1907), that desire can be satisfied by a "homogenous globule of technology" independent of time and space.

There was nothing in the closed Walrasian system to account for the sudden increase in the ability to do work caused by the fossil fuel revolution. So something had to be invented to account for the seemingly magical increase in economic output beginning in the 1800s. That something was "technology". Like the alchemists of old who believed that a magical substance (philosopoher's stone or elixir) could make gold out of base metals, many Walrasian economists believe that technology has freed economic production from the need for the earth's natural resources.

3. Energy, EROI and the Industrial Economy

The alchemy of Walrasian economics has led economists to almost comically ignore physical reality. Two well-respected economists (William Nordhaus and Thomas Schelling), writing about the economic consequences of global warming, stated that since agriculture is less than 3% of U.S. GDP we can do without it and still have 97% of GDP left (Daly, 2000).[3] Since everything is substitutable we can eat SUVs or insurance policies without any noticeable loss of utility. The same argument is made by economists regarding energy. Since the petroleum industry represents only 1% of world economic output, or since energy represents only about 5% of production costs, or since energy cost as a percentage of GDP is declining, it is not important. This is like saying that since the human heart is only 5% of total body weight we can do without it. In the Walrasian system every item of consumption and every productive input are reduced to their monetary value and one dollar or euro is as good as another. This worldview has blinded economists to the fact that energy is one of the most critical factors in the history of humans on planet earth.

Beginning about 10,000 years ago early agricultural technology harnessed flows of solar energy in the form of animal muscle power, water, wind, and wood. With the widespread use of wood for fuel humans began to tap into stocks of solar energy rather than relying solely on flows. The use of stocks of energy made it possible to capture ever larger amounts of energy per capita with smaller amounts of effort. Wood, wind and water power fueled the industrial revolution which began in the early 1700s. In the 1800s ancient solar energy—fossil hydrocarbons in the form of coal—rapidly became the fuel of choice. During the twentieth century petroleum and natural gas replaced coal as the dominant fuel. Each step in the history of energy use has been characterized by an increasing flexibility and substitutability of the dominant fuel type. Each step has also locked human society into particular belief systems, power relationships, and technological infrastructures.

Today, most of the physical work in the world's economy is done by the fossil fuels oil, gas, and coal. The increase in the ability to do work that came with fossil fuel is almost incomprehensible. One barrel of oil contains the energy equivalent of 25,000 person hours of labor. The total energy used by today's human population is the equivalent of the amount of work done by 280 billion people (Price, 1995). It is as if every person on the planet had about 50 "energy slaves" working for them (Price, 1995). In the early 1900s, agricultural production was done by men with teams of horses, sometimes as many as 20 pulling huge plows and combines. During the winter these horses had to be fed and taken care of using food and land that could have gone to human use (Youngquist, 1999). Today, fossil fuel energy makes it possible to run agricultural machines, produce fertilizer and pesticides to increase production, and cheaply transport crops to distant markets. And machines do not have to be fed when they are not working. By 1930 almost all the mechanical work done on U.S. farms came from fossil fuels. For grain production in the U.S., labor input per acre has been reduced over the last century from about 500 hours to 4 hours (Pimentel et al.,1999).

In the first half of the twentieth century oil was so easy to obtain that the energy return on investment was about 100:1 (Hall et al.,1992). By contrast, the EROI for coal is about 10 at the mine mouth and it is much more difficult to transport, its extraction more labor intensive and its environmental effects much more serious. An important characteristic of high EROI systems is that they tend to decline steeply after such a resource has been tapped. Tainter et al. (2003) argue that systems characterized by steep resource gradients have characteristics making them more vulnerable to overshoot and collapse. High gain and low gain systems are depicted in Figure 1. According to Tainter et al. (2003), systems with steep resource gradients (high gain systems) exhibit these characteristics (1) large differences exist between the state of the resource before and after its use, (2) resources are likely to be used profligately, (3) high gain systems are perturbed only by the most extreme environmental disruptions, and (4) high-gain systems self-organize around the exploited resource. All these characteristics apply to the current fossil fuel economy.

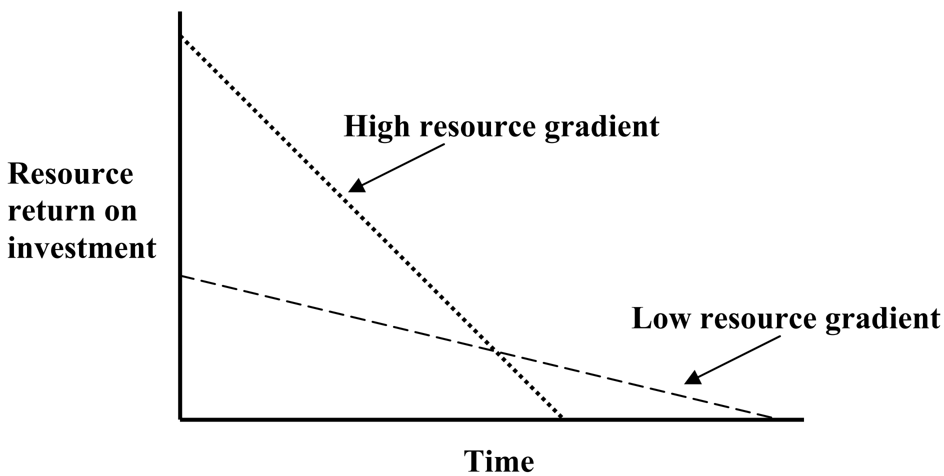

Figure 1. High and low resource gain systems

The qualitative difference between energy sources, so important in the unfolding of human history, is ignored in standard economics. Figures 2 and 3 below show the extent to which conventional economic accounting masks the true physical nature of the U.S. economy. It reduces human welfare to the monetary value of economic output, and it reduces the physical nature of production to the monetary value of inputs as in Figure 2. Inputs and output bear no relation to any physical reality. They are reduced to financial measures (money) which are uniform, substitutable, and can be reduced to a self-perpetuating circular flow system.

Capital \$11,933 → **Labor \$27,843 →**	**The (unexplained)** **Production Process** **Q = A•F(K,L)**	**→ GDP \$3,776**

Figure 2. The paper economy (U.S. per capita inputs and output 2005)

When the economy is shown as a biophysical system a quite different picture emerges. A shown in Figure 3, the amount of energy and raw materials going through the economy is absolutely staggering. To support the economic activity of just one person in the U.S. requires 2500 kilograms of petroleum, 3000 kilos of coal, 140,000 kilos of water and so on. The economic process degrades these low entropy resources into 89,000 kilos of CO2, 29 kilos of particulate matter, 84 kilos of sulfur oxides and so on, per person (Hall).

Oil 2,500 Kg **Coal 3,000 Kg** **Gas 2,000 Kg** **Water 140,000 Kg** **Iron 186 Kg** **Rock 81,000 Kg**	→	**The Biophysical Economy** (One person)	→	**CO_2 89,000 Kg** **Particulates 29 Kg** **SOx 84 Kg** **NOx 80 Kg** **Erosion** **Biodiversity loss etc.**

Figure 3. The Biophysical Economy: Throughput per Person

The extravagant use of natural resources in the industrial economy is made possible by cheap energy. Fossil fuel in the contemporary economic system is a "limitative input" (Georgescu-Roegen, 1935), that is, an input whose use is both a necessary and sufficient condition for increasing output. It is the increase in energy per capita that drove the development of the technologically complex industrial economy. Energy has been the driving force behind the phenomenal increase in economic output in the past century (Ayres and Warr, 2005). And there is reason to believe that the impending decline in per capita energy use will reduce economic output and the human population, and thus the pressure of our species on the rest of the planet.

Low gain systems, according to Tainter et al. (2003) have very different characteristics than high gain systems. Among other things, the difference in a resource before and after its use tends to be less pronounced, resource capture tends to be more extensive, resource use requires more aggregation and a higher degree of organization, and low gain systems are more susceptible to fluctuations. Some of these characteristics may be positive during and after the coming energy gradient transition, while others are likely to be negative. Renewable energy is low gradient and much more dispersed which should diffuse the power of the energy cartels now dominating the public sphere. On the other hand, sources like biofuels, wind and hydropower will be much more susceptible to the effects of climate change. If the transition to a low gradient system is fairly smooth the effects on human society and the rest of the biosphere could be quite positive.

4. Peak Oil and the end of fossil fuels may save the human species

The idea of cultural determinism has never been popular. People like to think our species is in control of its own destiny (White, 1948). But when one looks at energy and human civilization it appears to be almost a mechanical system. Inject energy into human societies and predictable things happen. Since energy is a limitative input, as its per capita use increases, population increases and so does the use of all other resources (land, minerals, water, forests). Social systems and belief systems evolve to justify and facilitate further exploitation. As per capita energy use exploded in the 1900s the mythology of unlimited growth and consumption flourished. Cheap, abundant fossil fuel caused the current human domination of planet Earth.

Almost all the environmental problems we face, global warming, acid rain, groundwater and stream pollution from agricultural runoff, air pollution, species extinction from loss of habitat, and so on, can be traced to the extravagant use of fossil fuels (Hall et al., 2003). While it is true that non-renewable resources can cause considerable damage (Tainter et al., 2003), as fossil fuel use winds down the human population will decline substantially and this cannot help but reduce human pressure on the environment.

Given the enormous amount of rent accruing to the extraction and sale of fossil fuels, it seems inevitable that almost all of the coal, natural gas, and petroleum in the ground will be found and used. But the physical amount of available fossil fuel energy will certainly decline. It is inconceivable that the figure in Figure 3 of 7500 Kg per person per year of fossil fuel can be maintained. There is nothing on the horizon to make up for this impending shortfall. Whatever energy systems come along will have to be based on a combination of biofuels and solar power, two sources of energy which time-limited flows, not "stocks" that can be used at any desired rate (Georgescu-Roegen, 1984). Biofuels depend on how much can be grown in a season and this can vary substantially from year to year. Solar power although abundant, is diffuse and its rate of use is also constrained. Fusion power seems to be out of the question for both technological and economic reasons. Other far out suggestions from technological utopians such as massive solar energy lasers in space or finding energy resources on other planets (Easterbrook, 2005) not even worth talking about. Energy use per capita will continue to decline. What are the implications of this?

Just as the massive injection of energy brought forth a frenzy of production and an ideology to support extravagant consumption, it seems likely that an opposite reaction will happen as per capita energy use declines. If energy is indeed a limitative factor, then the use of other resources will decline as the EROI, population, and total energy use falls. Other social and belief systems will eventually evolve in the context of the new limits on human exploitation of the planet. This has happened many times before in human history (Diamond, 2005). The handful of human systems that made a smooth transition (Tikopia for example) were those that let the system adjust and worked within the new limits. Those many societies that collapsed (Easter Island for example) were the ones who tried to maintain or even reinforce the outdated patterns of behavior.

Given the power of the fossil fuel cabal, the multinational corporations with their ideology of expansion and exploitation, their military power, and control of the media, it is likely that the West will follow the path of Easter Island. Those in power will do anything they can to keep the energy flowing including using all the remaining coal, massively subsidizing nuclear power and ethanol, and undertaking more military adventures to secure the remaining stocks of petroleum.

Nothing is on the horizon to replace fossil fuel. Whatever energy system comes along will have to be based on a combination of biofuels and solar power, two sources of energy which are not "stocks" that can be used at any desired rate (Georgescu-Roegen, 1984). Biofuels depend on how much can be grown in a season, solar power although abundant, is diffuse. Of course these were the sources of power for most of the time since agriculture some 10,000 years ago and for most of that time most human societies were basically slave systems run by politico-religious tyrants. The modern drift toward religious fanaticism, new age mysticism, and post modern dismissal of reason and logic is not encouraging. But if there is a ray of optimism regarding the future human prospect, it is that the current system of social and environmental exploitation, based on a frenzy of growth of production and consumption, will come to an end.

Footnotes

1. Following Bowles & Gintis (2000), Colander (2000) and others, I use the term "Walrasian" to refer to the general equilibrium model based on self-interested exogenous preferences and complete and costless contracting. The field of economics is changing so rapidly that the more widely used term "neoclassical" no longer represents the monolithic core it once did. Many who call themselves "neoclassical" do not accept the core Walrasian assumptions.

2. For example, Samuelson states: "Until the laws of thermodynamics are repealed, I shall continue to relate outputs to inputs—i.e. to believe in production functions. Until factors cease to have their rewards determined by bidding in quasi-competitive markets, I shall adhere to (generalized) neoclassical approximations in which relative factor supplies are important in explaining their market remunerations." (Samuelson 1972, p. 174).

3. Quotes by well-known economists on climate change and agriculture: "Agriculture, the part of the economy that is sensitive to climates change accounts for just 3% of national output. That means there is no way to get a very large effect on the U.S. economy." (William Nordhaus). "If net output of agriculture fell by 50% by the end of the next century this is only a 1.5% cut in GNP" (Wilfred Beckerman). "Agriculture is practically the only sector of the economy affected by climate, and it contributes only a small percentage, 3% in the United States, of national income. If agricultural productivity were drastically reduced by climate change, the cost of living would rise by 1 or 2%, and at a time when per capita income will likely have doubled." (Thomas Schelling, Nobel Prize recipient in 2005). These distinguished economists could only have made such transparently stupid statements because their minds are totally enveloped by Walrasian general equilibrium and marginal analysis. See the discussion and sources of the quotes in Daly (2000).

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