How Energy Shapes the Economy

In the beginning, the Master Economist created the Economy. He created businesses large and small, consumers, governments with their regulation, and financial institutions of all types. And the Master Economist declared that the economy should grow. And it did grow, but only for a while. Then it stalled. Then He declared that stimulus of various types should fix it, and it did, for a while. Then He declared that if humans would just wait for a while, it would fix itself, but it wouldn't.

We all know that the foregoing isn't the real story about the economy, but what is the real story?

I think if we dig deeper, we discover that **energy** plays an all-powerful role, just as it does in the natural world in general.

Population: How Inadequate Energy Acts as a Limiting Factor

Human population is of course an important part of the economy. If population keeps growing, it helps the economy grow, because more consumers mean more demand. Can human population keep growing?

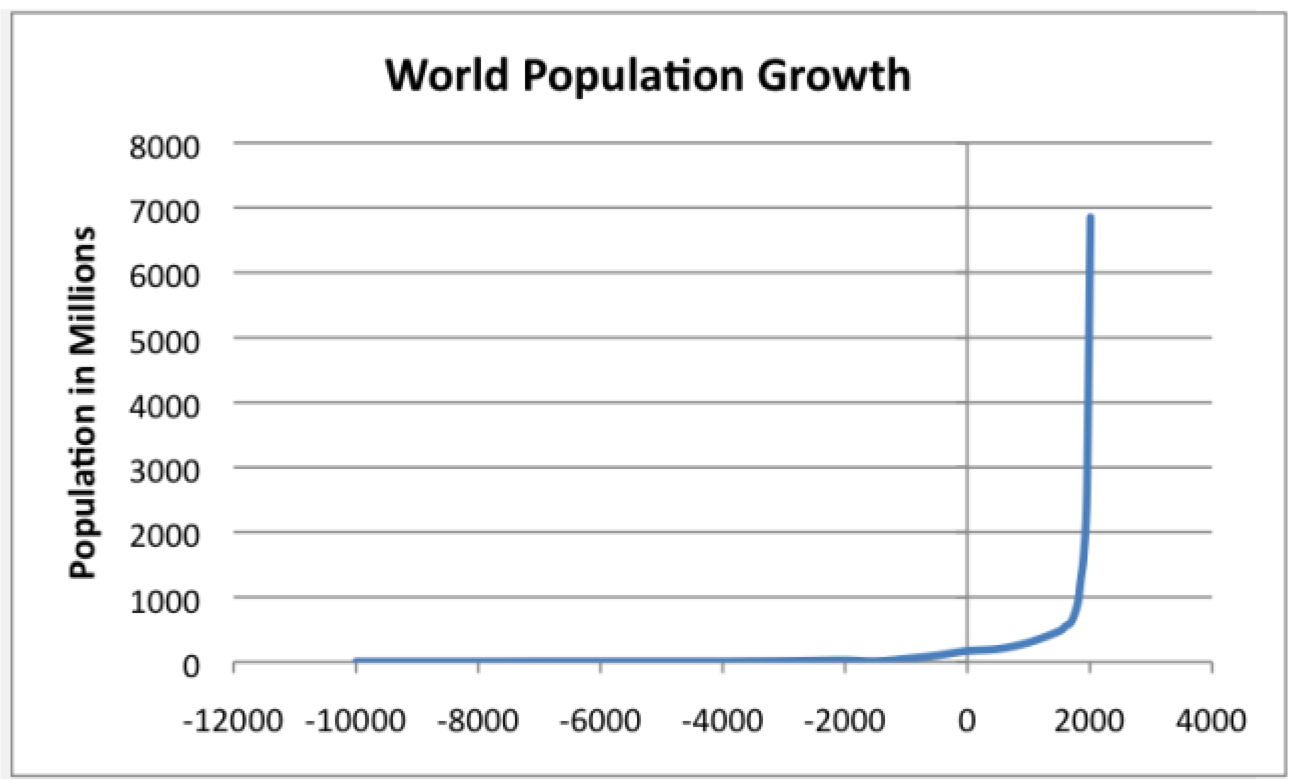

Figure 1. World Population Growth, based on summary data provided by US Census. Population growth became much more rapid after fossil fuels began adding to food supply, in the 1800s. Coal enabled much greater use of metal and glass, allowing changes which permitted horses to do more work on farms, and innovations such as electric light bulbs.

The answer seems to be no. Here we find that researchers have found an extremely important role for energy. The relationship they have found relates to any species, not just to *homo sapiens*.

Ecologists often talk about the existence of a natural cycle between predators and prey. The predators eat the prey that is available, but in time, the predators drop in number, as less food becomes available. When the population of predators drops, the prey is able to expand its population. In fact, Lotka and Volterra created a model that has been used to model a number of predator-prey relationships, including the wolf and moose population on Isle Royal National Park (Lotka) (Volterra) (Jost).

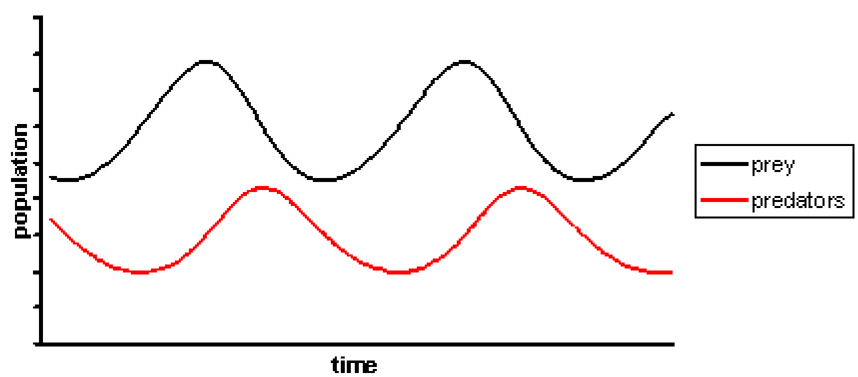

Figure 2. Lotka-Volterra Predator-Prey Model
Source: Wikipedia

Humans are now the dominant predator species on earth. Our numbers have grown from a relative handful in our earliest days to over 7 billion in 2012. Other species have had to contract in relationship to the advances man has made.

The United Nations is now forecasting a world population of over 9 billion in 2050, and over 10 billion in 2100 (United Nations). If this happens, the populations of other species will need to be pushed down to offset the growth in the human species. Eventually, this situation will reach a limit, since we need to eat other species, both plants and animals.

The situation is more complicated than Figure 2 suggests, because there are many species involved, and there are many other changes taking place—temperature of the sun is gradually changing, the earth's orbit around the sun varies, etc. Also, external energy, including fossil fuels and nuclear, is adding to total energy available to man. But the point remains: we cannot expect population growth to continue indefinitely.

The situation in Figure 2 is described as a predator-prey situation, but if we analyze the situation, it is really an energy situation as well, because prey is an **energy source to the predator**. Howard T. Odum has written extensively on this subject. Let me explain his view.

The Role of Energy in the Population of Species

Energy plays a major role in the balance between predators and prey. Natural systems, such as groups of plants and animals, arrange themselves to get the best possible use of**energy resources** available. All of us know that if there is a bare spot on our lawn, and enough sunlight and water, it is not long before some kinds of plants come along to fill the gap. Sunlight allows photosynthesis to take place, producing food for plants. If more sunlight is available, more plants will grow.

This tends to work with animals as well. Let's take the example of wolves that are predators of moose (mentioned above as being modeled using Lotka-Volterra equations). From the point of view of a wolf, a moose is a form of stored energy, since eating it provides calories that provide energy to the wolf. If at some point more moose become available to eat, then more offspring of wolves will be able to survive to adulthood, under survival of the fittest, so the wolf population will increase. As a result, the wolves get as much use as possible of the energy available to them.

Howard Odum, in *A Prosperous Way Down*, credits Lotka with discovering the fundamental energy law that underlies ecological systems, which Odum calls the *Maximum Power Concept* and rephrases as follows:

In the self-organization process, systems develop those parts, processes, and relationships that capture the most energy and use it with the best efficiency possible without reducing power.[1]

This means that ecosystems (and in fact, other self-organizing systems, such as economies), will gradually adapt to get the best use possible of the energy available to them. Ecosystems are "self-organizing" in that with the abundance of offspring of animals, and the abundance of seeds of plants, there are always offspring available to move into available niches with excess energy. There are other ways of making use of available energy—for example, selection of the fittest can lead to people with the right skin color being adapted to best using the intensity of the suns rays in their part of the globe.

Energy Use by Humans

Energy plays an important role for each of us as humans, just as it does for other species in ecosystems. The most obvious use for energy is in the food that we eat. Some of the energy we use is embedded energy—that is energy from the past that has been used to make something that we use today. The stored energy can be human energy, as in the energy it would take to shear wool from a sheep, make it into yarn, and knit a sweater from it. Stored energy can also be from other sources. For example, it takes a great deal of energy to extract and refine metals. It also takes a great deal of energy to make today's concrete.

One type of stored energy comes in the form of education (Odum). Education is available because the student's labor is not needed in the workforce to create the food and other goods that he consumes while being educated. Education requires that teachers attend school themselves for many years, meaning that teachers must somehow be supported by the energy of the rest of society both during their own education and while they are teaching students.

Education also involves the concentration of knowledge in the form of books and on the Internet. All of this requires energy. Books require energy to support the people taking time to write the books, to physically make the books, and to transport them to the location where they are read. The Internet requires electrical energy. Even thinking requires energy. The human brain uses a disproportionate share of man's energy, up to 20% of the energy used by humans (Swaminathan). The people with the highest education tend to receive higher salaries than others, indicating that this form of embedded energy is highly valued by society.

The Role of Energy in Numbers and Types of Businesses and Governments

Businesses, governments, and consumers form another self-organizing system, not unlike ecological systems (Odum). This system has gradually arisen over many years, and adapts itself as conditions change. The financial system is the part of the self-organizing system that keeps track of the energy costs of the system (as well as other costs), and pushes the whole system toward the lowest cost approach to creating goods and services. Businesses tend to succeed or fail in ways that make the most productive use of energy resources, according to the rules set out by the system.

Let's consider a small-scale example of a potential addition to this self-organized system. An entrepreneur decides to plant a field of turnips. In this case, part of the energy for the business comes from the sun, and part of the energy comes from the labor of the entrepreneur. The calories the entrepreneur eats provide energy for his labor. The entrepreneur's education represents another form of stored energy, affecting his success. If the entrepreneur buys fertilizer, it is an energy input as well, since energy was required to make and transport the fertilizer to the location where it is used.

Part of the energy used by the entrepreneur may come from mechanical equipment that was made in the past using heat energy, and part from fuels that power that equipment. If purchased energy is scarce, and because of this, high-priced, the entrepreneur will have to charge a higher price for turnips he sells in order to cover his costs. The entrepreneur has a much greater chance of success in selling his turnips to customers if energy is low-priced rather than high-priced because many more customers will be able to afford turnips at $1.00 pound than at $4.00 pound. So it is the price of goods, which is tied to energy costs, that helps determine both which goods are sold and which businesses will succeed. High energy cost tend to lead to business failures.

Governments, too, use energy, and fit in with the same self-organizing system as businesses. The type of government requiring the least amount of energy is one run by a single person, perhaps a king or dictator. In order to support the king, the economy needs to have enough spare energy (in the form of food) available so that the king or dictator doesn't himself need to work to grow food. It is also helpful if there is excess energy generated by society to provide clothing, a home, heat for the home, and the many other things that the king or dictator expects to own.

More complicated governments require more energy. A government of elected officials requires not only the excess energy from society to feed and clothe the elected officials, it also requires the energy to build the buildings where polling takes place, and the energy for officials to travel to the location of the government offices. The offices themselves also require energy, both for their construction and their maintenance. If energy supply is constricted, the price of energy is likely to be higher, and thus the cost of government will be higher. Taxes will need to be raised. If there is a sufficient energy surplus elsewhere to afford these higher taxes, these higher taxes may be acceptable to taxpayers. If not, some government officials may need to be laid off, to balance the (energy) budget.

What Happens When Energy is Deficient?
Something has to "give," when there is not enough energy.

A deficiency in solar energy would likely cause the world to get colder. Crops would fail, prices would rise, and the problem of low solar energy would affect both the natural world, and the economy consisting of businesses, governments, consumers, and financial institutions. The last time this was a major issue was during the Little Ice Age. The biggest impact seems to have been during the 1600s. I show in The Long-Term Tie Between Energy Supply, Population, and the Economy that this seems to have been the case.

What happens when energy supply such as wood, coal, oil or natural gas is constrained?

Unfortunately, we are getting a chance to find out. There is considerable evidence that oil, our largest and most flexible source of energy, is now encountering supply issues. Oil price in 2012 is more than three times the price it was ten years ago, in inflation-adjusted prices.

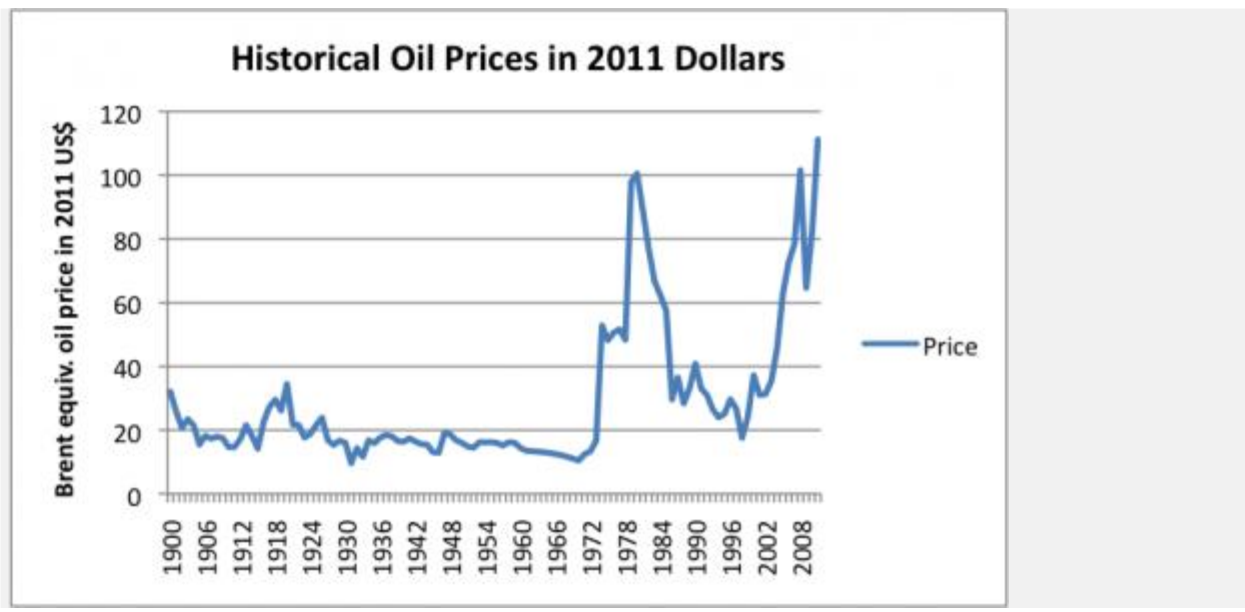

Figure 3. Historical inflation adjusted oil price per barrel, (Brent equivalent in 2011$), based on amounts shown in BP's 2012 Statistical Review of World Energy.

It is during the time that prices have been high (indicating short supply) that the world has been suffering from recession. This is precisely the impact one would expect, if energy is closely tied to the economy. Adequate supply would be reflected in low price. When it is not, the economy of countries, especially of oil importers, tends to go into recession. We will discuss this more in future posts.

Figure 3 shows that there was a previous time, in the 1970s and early 1980s, when oil prices were very high in inflation adjusted terms. This was the time shortly after the United States discovered that its own oil supply was decreasing rapidly (Figure 4).

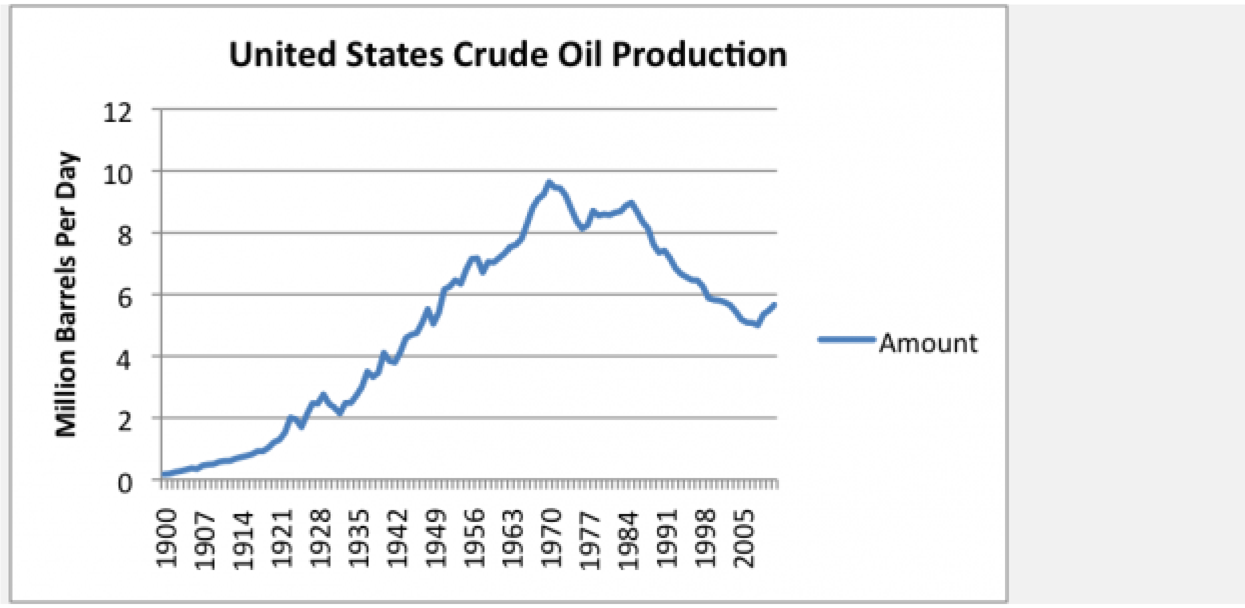

Figure 4. US crude oil production based on data of the US Energy Information Administration.

After United States oil production began decreasing in 1970, a huge amount of effort was put into finding more oil supplies, increasing efficiency, and converting oil use to other types of energy use. There was considerable success in these areas. The second "bump" in Figure 4 reflects the addition of oil from Alaska, something that is now in decline also. Oil uses that could be easily switched to another fuel were switched away. For example, where oil had been used to create electricity, new generation using nuclear or coal was built. In the case of oil for home heating, the switch was often made to natural gas. Cars became smaller and more energy-efficient during this period.

It might be noted that the period of high oil prices in the mid 1970s and early 1980s was also a time of recession. Economist James Hamilton has shown that 10 out of 11 US recessions since World War II were associated with oil price spikes (Hamilton, 2011). He has also shown that there appears be a direct connection between the price run-up of 2007-08, cutbacks in consumer consumption and spending on purchases of domestic automobiles, and the economic slowdown of 2007 – 2008 (Hamilton, 2009).

The run-up in oil prices in the past few years seems to be related to a combination of (a) world oil supply that is not growing very rapidly, and (b) increasing demand from developing economies, such as China and India, and (c) higher production costs for oil, because much of the inexpensive to extract oil has already been extracted.

There is a great deal more that could be said about these issues, but I will save this information for later. I will make a couple of observations, however:

1. The United States has not been very successful in increasing its oil production, in spite of improved technology. The right hand side of the graph in Figure 4 is higher than what it would have been because of opening areas to drilling in the Gulf of Mexico, new technology, and enhanced oil recovery methods. But current production still lies far below the 1970 peak of oil production.

2. The government has not been forthright in telling us about this problem. Science textbooks don't generally discuss this issue, nor do history books. Some things are embarrassing. This seems to be one of them.

Footnote:

[1] Power is the rate at which energy is used. For example, a 100 watt light bulb uses more energy per unit of time than a 50 watt bulb, so has more power. Any organism has a rate at which it uses energy. For example, we may eat 2200 calories a day. This quote is just saying that the rate at which organisms use energy is considered in this self-organization process.

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