Our Finite World
Exploring how oil limits affect the economy

Economic growth: How it works; how it fails; why wealth disparity occurs

Posted on December 8, 2015 by Gail Tverberg

Economists have put together models of how an economy works, but these models were developed years ago, when the world economy was far from limits. These models may have been reasonably adequate when they were developed, but there is increasing evidence that they don't work in an economy that is reaching limits. For example, my most recent post, "Why 'supply and demand' doesn't work for oil," showed that when the world is facing the rising cost of oil extraction, "supply and demand" doesn't work in the expected way.

In order to figure out what really does happen, we need to consider findings from a variety of different fields, including biology, physics, systems analysis, finance, and the study of past economic collapses. Since I started studying the situation in 2005, I have had the privilege of meeting many people who work in areas related to this problem.

My own background is in mathematics and actuarial science. Actuarial projections, such as those that underlie pensions and long term care policies, are one place where historical assumptions are not likely to be accurate, if an economy is reaching limits. Because of this connection to actuarial work, I have a particular interest in the problem.

How Other Species Grow

We know that other species don't amass wealth in the way humans do. However, the number of plants or animals of a given type can grow, at least within a range. Techniques that seem to be helpful for increasing the number of a given species include:

- **Natural selection.** With natural selection, all species have more offspring than needed to reproduce the parent. A species is able to continuously adapt to the changing environment because the best-adapted offspring tend to live.
- **Cooperation.** Individual cells within an organism cooperate in terms of the functions they perform. Cooperation also occurs among members of the same species, and among different species (symbiosis, parasites, hosts). In some cases, **division of labor** may occur (for example, bees, other social insects).
- **Use of tools**. Animals frequently use tools. Sometimes items such as rocks or logs are used directly. At other times, animals craft tools with their forepaws or beaks.

All species have specific needs of various kinds, including energy needs, water needs, mineral needs, and lack of pollution. They are in constant competition with both other members of the same species and with members of

other species to meet these needs. It is **individuals who can out-compete others in the resource battle** that survive. In some cases, animals find **hierarchical behavior** helpful in the competition for resources.

There are **various feedbacks that regulate the growth of a biological system**. For example, a person or animal eats, and later becomes hungry. Likewise, an animal drinks, and later becomes thirsty. Over the longer term, animals have a reserve of fat for times when food is scarce, and a small reserve of water. If they are not able to eat and drink within the required timeframe, they will die. Another feedback within the system regulates overuse of resources: if any kind of animal eats all of a type of plant or animal that it requires for food, it will not have food in the future.

Energy needs are one of the limiting factors, both for individual biological members of an ecosystem, and for the overall ecosystem. Energy systems need greater power (energy use per period of time) to out-compete one another. The Maximum Power Principle by Howard Odum says that biological systems will organize to increase power whenever system constraints allow.

Another way of viewing energy needs comes from the work of Ilya Prigogine, who studied how ordered structures, such as biological systems, can develop from disorder in a thermodynamically open system. Prigogine has called these ordered structures dissipative systems. These systems can temporarily exist as long as the system is held far from equilibrium by a continual flow of energy through the system. If the flow energy disappears, the biological system will die.

Using either Odum's or Prigogine's view, energy of the right type is essential for the growth of an overall ecosystem as well as for the continued health of its individual members.

How Humans Separated Themselves from Other Animals

Animals generally get energy from food. It stands to reason that if an animal has a unique way of obtaining additional energy to supplement the energy it gets from food, it will have an advantage over other animals. In fact, this approach seems to have been the secret to the growth of human populations.

Human population, plus the domesticated plants and animals of humans, now dominate the globe. Humans' path toward population growth seems to have started when early members of the species learned how to burn biomass in a controlled way. The burning of biomass had many benefits, including being able to keep warm, cook food and ward off predators. Cooking food was especially beneficial, because it allowed humans to use a wider range of foodstuffs. It also allowed bodies of humans to more easily get nutrition from food that was eaten. As a result, stomachs, jaws, and teeth could become smaller, and brains could become bigger, enabling more intelligence. The use of cooked food began long enough ago that our bodies are now adapted to the use of some cooked food.

With the use of fire to burn biomass, humans could better "win" in the competition against other species, allowing the number of humans to increase. In this way, **humans could, to some extent, circumvent**

natural selection. From the point of the individual who could live longer, or whose children could live to maturity, this was a benefit. Unfortunately, it had at least two drawbacks:

1. While animal populations tended to become increasingly adapted to a changing environment through natural selection, humans tend not to become better adapted, because of the high survival rate that results from more adequate food supplies and better healthcare. Humans might eventually find themselves becoming less well adapted: more overweight, or having more physical disabilities, or having more of a tendency toward diabetes.
2. Without a natural limit to population, the quantity of resources per person tends to decline over time. For example, such a tendency tends to lead to less farmland per person. This would be a problem if techniques remained the same. Thus, rising population tends to lead to constant pressure to raise output (more food per arable acre or technological advancements that allow the economy to "do more with less").

How Humans Have Been Able to Meet the Challenge of Rising Population Relative to Resources

Humans were able to meet the challenge of rising population by taking the techniques many animals use, as described above, and raising them to new levels. The fact that humans figured out how to burn biomass, and later would learn to harness other kinds of energy, gave humans many capabilities that other animals did not have.

- **Co-operation with other humans** became possible, through a variety of mechanisms (learning of language with our bigger brains, development of financial systems to facilitate trade). Even as hunter-gatherers, researchers have found that economies of scale (enabled by co-operation) allowed greater food gathering per hectare. Division of labor allowed some specialization, even in very early days (gathering, fishing, hunting).
- **Humans have been able to domesticate many kinds of plants and animals.** Generally, the relationship with other species is a symbiotic relationship–the animals gain the benefit of a steady food supply and protection from predators, so their population can increase. Chosen plants have little competition from "weeds," thanks to the protection humans provide. As a result, they can flourish whether or not they would be competitive with other plants and predators in the wild.
- **Humans have been able to take the idea of making and using tools to an extreme level.** Humans first started by using fire to sharpen rocks. With the sharpened rocks, they could make new devices such as boats, and they could make spears to help kill animals for food. Tools could be used for planting the seeds they wanted to grow, so they did not have to live with the mixture of plants nature provided. We don't think of roads, pipelines, and lines for transmitting electricity as tools, but as a practical matter, they also provide functions similar to those of tools. The many chemicals humans use, such as herbicides, insecticides, and antibiotics, also act in way similar to tools. The many objects that humans create to make life "better" (houses, cars, dishwashers, prepared foods, cosmetics) might in some very broad sense be considered tools as well. Some tools might be considered "capital," when used to create additional goods and services.

- **Humans created businesses and governments to enable better organization, including division of labor and hierarchical behavior.** A single person can create a simple tool, just as an animal can. But there are economies of scale, such as when many devices of a particular kind can be made, or when some individuals learn specialized skills that enable them to perform particular tasks better. As mentioned previously, even in the days of hunter-gatherers, there were economies of scale, if a larger group of workers could be organized so that specialization could take place.
- **Financial systems and changing systems of laws and regulations** provide additional structure to the system, telling businesses and customers how much of a given product is required at a given time, and at what prices. In animals, appetite and thirst determine how important obtaining food and water are at a given point in time. Financial systems provide a somewhat similar role for an economy, but the financial system doesn't operate within as constrained a system as hunger and thirst. As a result, the financial system can give strange signals, including prices that at times fall below the cost of extraction.
- **Humans have tended to put resources of many kinds (arable land, land for homes and businesses, fresh water, mineral resources) under the control of governments.** Governments then authorize particular individuals and business to use this land, under various arrangements ("ownership," leases, or authorized temporary usage). Governments often collect taxes for use of the resources. The practice is in some ways similar to the use of territoriality by animals, but it can have the opposite result. With animals, territoriality is used to prevent crowding, and can act to prevent overuse of shared resources. With human economies, ownership or temporary use permits can lead to a government sanctioned way of depleting resources, and thus, over time, can lead to a higher cost of resource extraction.

Physicist François Roddier has described individual human economies as another type of dissipative structure, not too different from biological systems, such as plants, animals, and ecosystems. If this is true, an adequate supply of energy is absolutely essential for the growth of the world economy.

We know that there is a very close tie between energy use and the growth of the world economy. Energy consumption has recently been dropping (Figure 1), suggesting that the world is heading into recession again. The Wall Street Journal indicates that a junk bond selloff also points in the direction of a likely recession in the not-too-distant future.

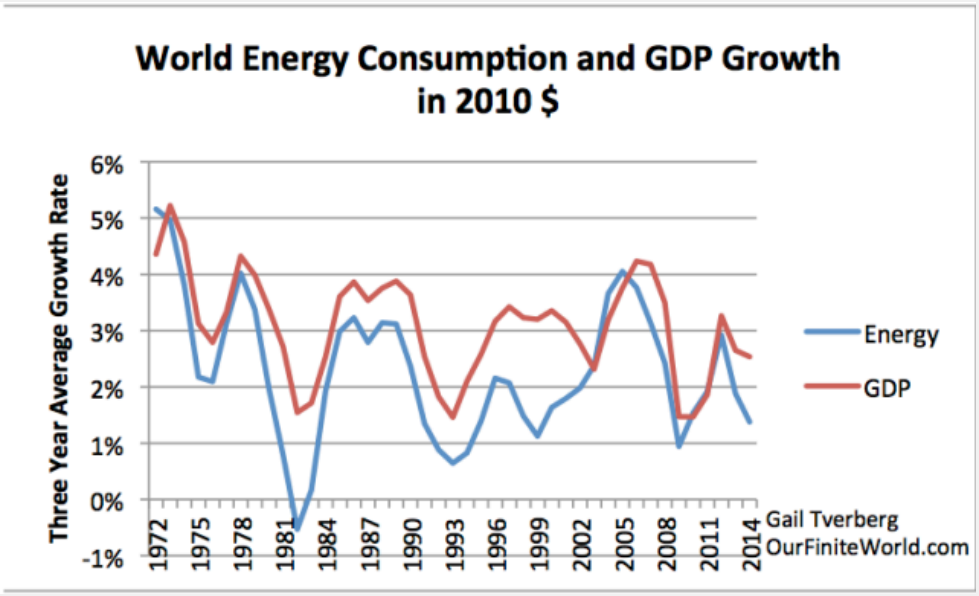

Figure 1. Three year average growth rate in world energy consumption and in GDP. World energy consumption based on BP Review of World Energy, 2015 data; real GDP from USDA in 2010$.

What Goes Wrong as Economic Growth Approaches Limits?

We know that in the past, many economies have collapsed. In fact, if Roddier is correct about economies being dissipative structures, then we know that economies cannot be expected to last forever. Economies will tend to run into energy limits, and these energy limits will ultimately bring them down.

The symptoms that occur when economies run into energy limits are not intuitively obvious. The following are some of the things that generally go wrong:

Item 1. A slowdown in economic growth.

Research by Turchin and Nefedov regarding historical collapses shows that growth tended to start in an economy when a group of people discovered a new energy-related resource. For example, a piece of land might be cleared to allow more arable land, or existing arable land might be irrigated. At first, these new resources allowed economies to grow rapidly for many years. Once the population grew to match the new carrying capacity of the land, economies tended to hit a period of "stagflation" for another period, say 50 or 60 years. Eventually "collapse" occurred, typically over a period of 20 or more years.

Today's world economy seems to be following a similar pattern. The world started using coal in quantity in the early 1800s. This helped ramp up economic growth above a baseline of less than 1% per year. A second larger ramp up in economic growth occurred about the time of World War II, as oil began to be put to greater use (Figure 2).

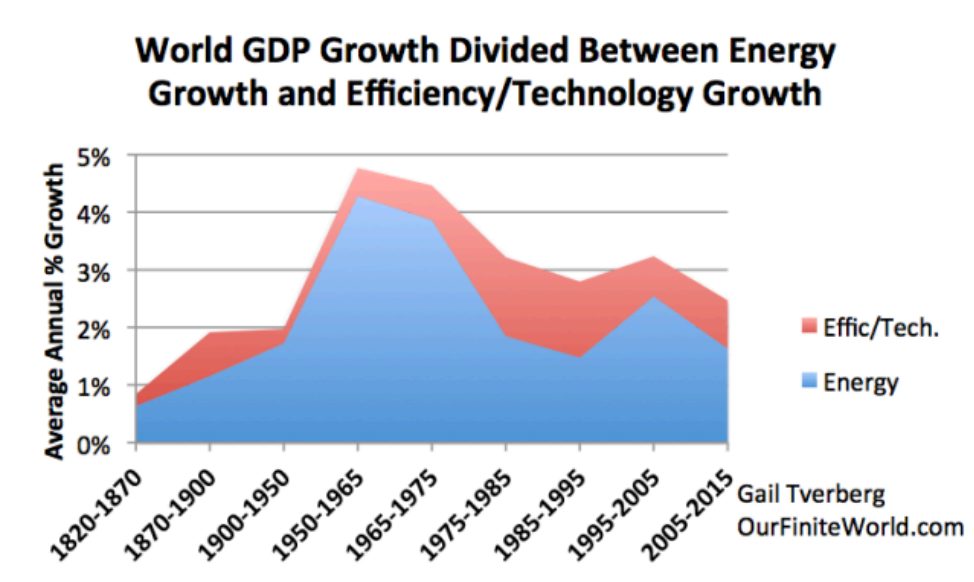

Figure 2. World GDP growth compared to world energy consumption growth for selected time periods since 1820. World real GDP trends for 1975 to present are based on USDA real GDP data in 2010$ for 1975 and subsequent. (Estimated by author for 2015.) GDP estimates for prior to 1975 are based on Maddison project updates as of 2013. Growth in the use of energy products is based on a combination of data from Appendix A data from Vaclav Smil's Energy Transitions: History, Requirements and Prospects together with BP Statistical Review of World Energy 2015 for 1965 and subsequent.

Worldwide, the economic growth rate hit a high point in the 1950 to 1965 period, and since then has trended downward. Figure 2 indicates that in all periods analyzed, the increase in energy consumption accounts for the majority of economic growth.

Since 2001, when China joined the World Trade Organization, world economic growth has been supported by economic growth in China. This growth was made possible by China's rapid growth in coal consumption (Figure 3).

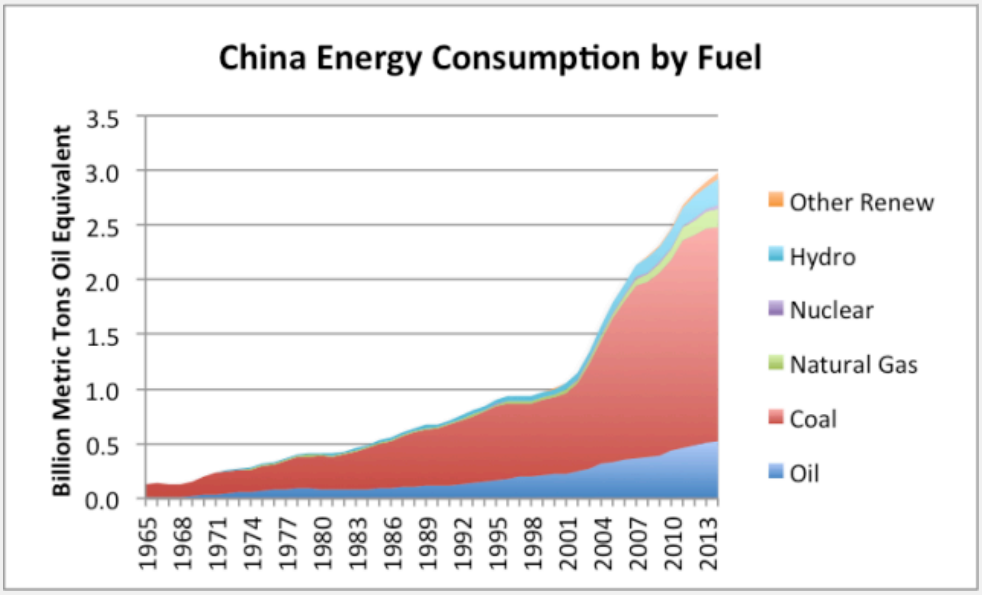

Figure 3. China's energy consumption by fuel, based on data of BP Statistical Review of World Energy 2015.

China's growth in energy consumption, particularly coal consumption, is now slowing. Its economy is slowing at the same time, so its leadership in world economic growth is now being lost. There is no new major source of cheap energy coming online. This is a major reason why *world* economic growth is slowing.

Item 2. Increased use of debt, with less and less productivity of that debt in terms of increased goods and services produced.

Another finding of Turchin and Nefedov is that the use of debt tended to increase in the stagflation period. Since growth was lower in this period, it is clear that the use of debt was becoming less productive.

If we look at the world situation today, we find a similar situation. More and more debt is being used, but that debt is becoming less productive in terms of the amount of GDP being provided. In fact, this pattern of falling productivity of debt seems to have been taking place since the early 1970s, when the price of oil rose above $20 per barrel (in 2014$). It is doubtful that that economic growth can occur if the price of oil is above $20 per barrel, without debt spiraling ever upward as a percentage of GDP. It is supplemental energy that allows the economy to function. If the price of energy is too high, it becomes unaffordable, and economic growth slows.

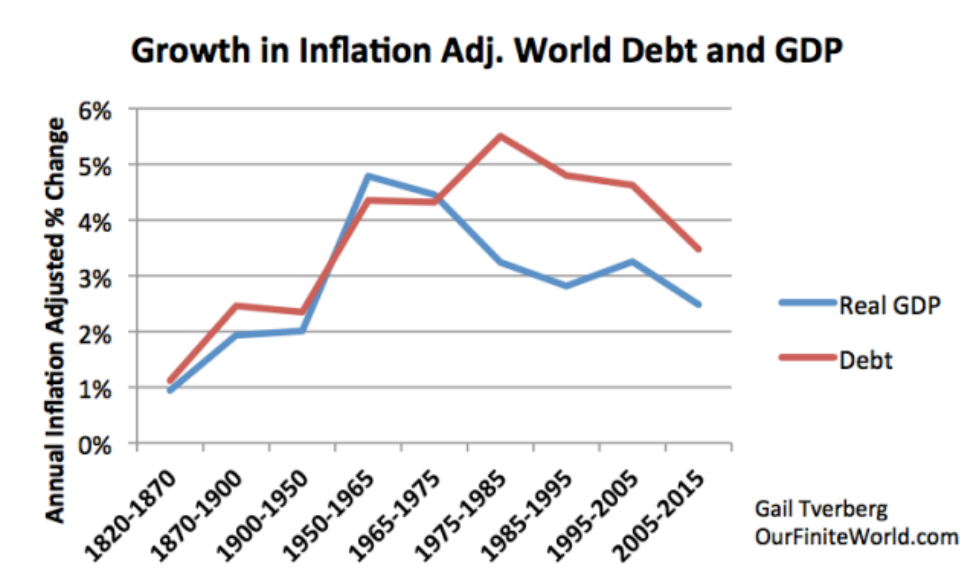

Figure 4. Worldwide average inflation-adjusted annual growth rates in debt and GDP, for selected time periods. See author's post on debt for explanation of methodology.

China has been using debt to fund its recent expansion. There is evidence that it, too, is encountering falling productivity of additional debt.

We mentioned that appetite controls how much an animal eats. Debt helps control demand for energy products, and in fact, for products of all kinds in the economy. Appetite is different from debt as a regulator of demand.

For one thing, debt can be used for an almost unlimited number of purposes, whether or not these purposes have any real possibility of adding GDP to the economy. (This is especially true if interest rates are close to 0%, or even negative.) There are few controls on debt. Governments have discovered that in some instances, debt stimulates an economy. Because of this, governments have tended to be very liberal in encouraging growth in debt. Often, when a debtor is near default, this problem is hidden by extending the term of the loan and pretending that no problem exists.

With respect to biological organisms, energy is often stored up as fat and used later when there is a shortfall of energy. This is the opposite of the way financing for human "tools" generally works. Here financing is often obtained when a tool is put into operation, with the hope that the new tool will pay back its worth, plus interest, over the life of the tool. Much debt doesn't even have such a purpose; sometimes it is used simply to make an expensive object easier to purchase, or to give a young person (perhaps with poor grades) an opportunity to attend college. When debt has such poor regulation, we cannot expect it to work as reliably as biological mechanisms in feeding back information regarding true "demand" through the price system.

Item 3. Increased disparity of wages; non-elite workers earning less.

Item 3 is another problem that Turchin and Nefedov encountered in reviewing economies that collapsed. One of the reasons for the increased disparity of wages is the increased need for hierarchical relationships if an economy wants to work around a shortfall in goods and services by adding new "tools". Businesses and governments need to grow larger if they are to accommodate these more complex processes. In such a case, the natural tendency is for these organizations to become more hierarchical in nature. Also, if there is growth, followed by a temporary need to shrink back, the cutbacks are likely to come disproportionately from the lower ranks of workers, reinforcing the hierarchical structure.

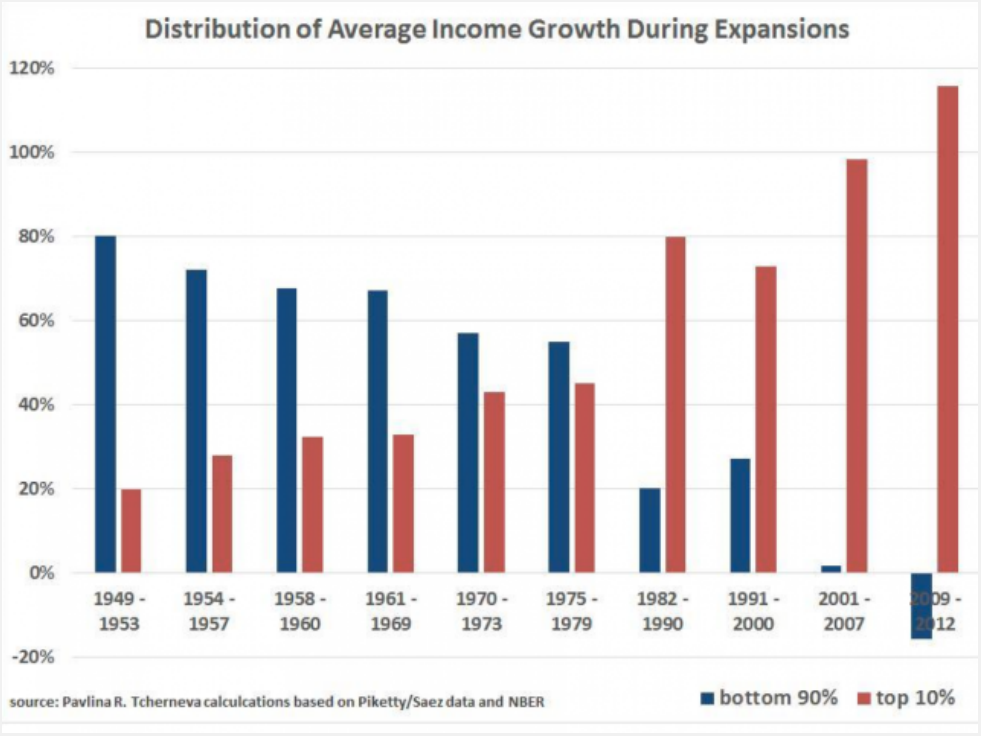

Figure 5. Chart by Pavlina Tscherneva, in Reorienting Fiscal Policy, as reprinted by the Washington Post.

Funding arrangements for the new "tools" to work around shortages add to the hierarchical behavior. Typically, businesses must expand to fund the development of the new tools. This expansion may be funded by debt, or by stock programs. Regardless of which approach is used for funding, the programs tend to funnel an increasing share of the wealth of the economy to the wealthier members of the economy. This happens because interest payments and dividend payments both go disproportionately to benefit those who are already high up on the wealth hierarchy.

Furthermore, the inherent problem of fewer resources per person is not really solved, so an increasingly large share of jobs become "service" jobs, using only a small quantity of energy products, but also providing little true benefit to the economy. The wages for these jobs are thus low. The addition of these low-paid jobs to the economy further reinforces the hierarchical nature of the system.

In a sense, what is happening is that the economy as a whole is growing very little in output of goods and services. An ever-larger share of the output is going to the wealthier members of the economy, because of increased hierarchical behavior and because of growth in debt and dividend payments. Non-elite members of the economy find their wages falling in inflation adjusted terms, because, in a sense, the productivity of their labor as leveraged by a falling amount of energy resources is gradually contracting, rather than increasing. It becomes increasingly difficult for the low-paid members of the economy to "pay the wages" of the high-paid members of the economy, so overall demand for goods and services tends to contract. As a result, the increasingly hierarchical behavior of the economy pushes the economy even more toward contraction.

Item 4. Increased difficulty in obtaining adequate funding for government programs.

Governments operate on the surpluses of an economy. As an economy finds itself in a squeeze (job loss, more workers with lower wages, fewer goods and services being produced), governments find themselves increasingly called upon to deal with these problems. Governments may need larger armies to try to obtain resources elsewhere, or they may be needed to build a public works project (like a dam, to get more water and hydroelectric power), or they may need to make transfer payments to displaced workers. Here again, Turchin and Nefedov found governmental funding to be one of the problems of economies reaching limits.

Energy products are unique in that their *value to society* can be quite different from their *cost of extraction*. A third value, which may be different from either of the first two values, is the *selling price* of the energy product. When the cost of producing energy products is low, the wide difference between the *value to society* and the *cost of extraction* can be used to fund government programs and to raise the wages of workers. In fact, this difference seems to be a primary reason why economic growth occurs. (This difference is not recognized by most economists.)

As the *cost of extraction* of energy products rises, the difference between the *value to society* and the *cost of extraction* falls, because the value to society is pretty close to fixed (except for changes taking place because of energy efficiency changes), based on how far a barrel of oil can move a truck or how many British thermal units of energy it can provide. As the cost of energy extraction rises, it becomes increasingly difficult to obtain enough tax revenue, either from taxing energy products directly, or from taxing wages. Wages tend to reflect the energy consumption required to support each job because supplemental energy acts to leverage the abilities of workers, and thus improves their productivity.

Energy *selling prices* may behave in a strange manner, as an economy increasingly reaches limits. Falling prices redistribute what gain is available, so that energy importers get more, while energy exporters get less. Of course, the problem we are now seeing is that oil exporting countries are having difficulty obtaining sufficient revenue for their programs.

Debt is different this time

This time truly is different. We should have learned from past experience that debt tends not to be very permanent; it often defaults. We should therefore expect huge periods of debt defaults, and we should expect to need frequent debt jubilees. Economist Michael Hudson reports that the structure of debt was very different in the past (Killing the Host or excerpt). In early times, he found that by far the major creditors were the temples and palaces of Bronze Age Mesopotamia, not private individuals acting on their own. Because of the top-down nature of the debt, it was easy for the temples and palaces to forgive debt and restore balance to the social structure.

Now, especially since World War II, there is a new belief in the permanency of debt, and about its suitability for funding insurance companies, banks, and pension plans. The rise in economic growth after World War II was

important in this new belief in permanency, because without economic growth, it is extremely difficult to pay back debt with interest, unless debt is used for a truly productive purpose. (See also Figures 2 and 4, above)

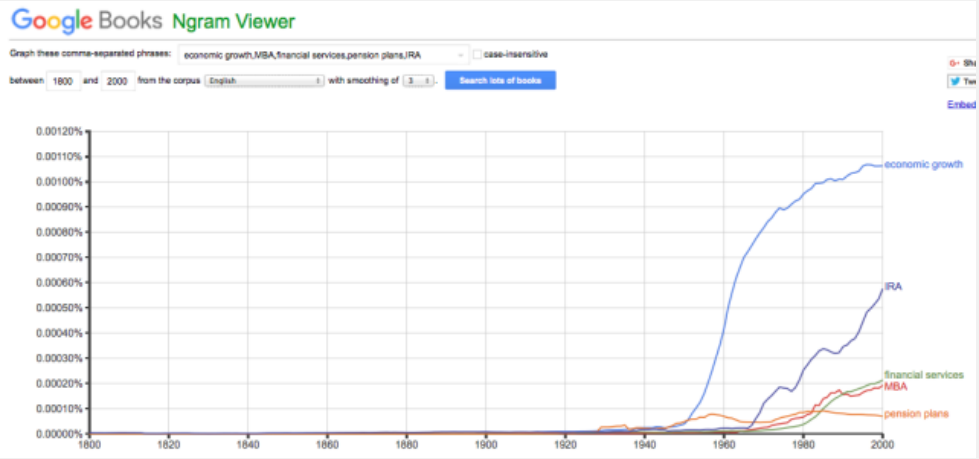

Figure 6. Ngram showing frequency of words over a period of years, by Google searches of a large number of books. Words searched from top to bottom are "economic growth, IRA, financial services, MBA, and pension plans."

The Ngram chart above, showing the frequency of word searches for "economic growth, IRA (Individual Retirement Accounts), financial services, MBA (Master of Business Administration), and pension plans" indicates that economic growth was essentially a new concept after World War II. Once it became clear that the economy could grow, financial services began to grow, as did the training of MBAs. Pension plans grew at first, but once companies with pension programs found that it was difficult to keep them adequately funded, there was a shift to IRAs. With IRAs, employees are expected to fund their own retirements, generally using a combination of stock and debt purchases.

Now that debt is "reused" and integrated into the economy, it becomes much more difficult to forgive. We have a situation where insurance companies, banks, and pension plans are all tied together. They all depend on the current economic growth paradigm, including use of debt with interest, continued dividend plans, and rising stock market prices. We have a major problem if widespread debt defaults start.

Demographic Bubble

The other problem we are up against, making government funding even more difficult than it would otherwise be, is the retirement of the baby boomers, born soon after World War II. This by itself would be a problem for maintaining adequate government funding. When it is added to multiple other problems, including bailing out banks, insurance companies, and pension plans if there are debt defaults, the demographic bubble leaves us in much worse shape than economies that reached limits in the past.

Note that *High Energy Prices* Are Not on the List of Expected Problems

The idea that as we approach limits, we should expect ever-higher energy prices, is simply not true. It should be

viewed as a superstition, or as an erroneous understanding of our current situation, based on a poor model of energy supply and demand. Turchin and Nefedov found evidence of spiking food prices, perhaps similar to the spiking we saw in energy prices as we approached the peak in prices in 2008. But with wages of non-elite workers falling too low, especially on an after-tax basis, it was hard for prices to continue to spike.

The idea that collapse can come from low prices, rather than high, is something that is not obvious, unless a person thinks through the situation carefully. Prices seem to be primarily influenced by two factors:

(1) **Wages of non-elite workers.** These wages are important because there is such a large number of them. If their wages are high enough, they buy homes, cars, and other products that are big users of commodities, both when they are made, and as they are operated.

(2) **Increases or decreases in the amount of debt outstanding.** If debt defaults start to rise, it is very easy for growth in the quantity of debt outstanding to slow, or even to fall. In such a case, low commodity prices, rather than high, become a problem. As economic growth slows, we should expect more debt defaults, not fewer. There is also a limit to how high Debt/GDP ratios can rise before many suspect that the world economy functions much like a Ponzi Scheme.

Mark Twain wrote, "It ain't what you know that gets you in trouble. It's what you know for sure, that just ain't so." This is especially a problem for academic researchers who depend on the precedents of past academic papers. A researcher may have come to a conclusion years ago, based on a narrow set of research that didn't cover today's conditions. The belief can get carried forward endlessly, even though it isn't really true in today's situation.

If we are going to figure out the real answer to how the economy operates, we need to look closely at indications from many areas of research. Such an approach can allow us to see the situation in a broader context and thus "weed out" firmly held beliefs that aren't really true.

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About Gail Tverberg

My name is Gail Tverberg. I am an actuary interested in finite world issues - oil depletion, natural gas depletion, water shortages, and climate change. Oil limits look very different from what most expect, with high prices leading to recession, and low prices leading to inadequate supply.

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Fast Eddy *says:*

December 21, 2015 at 9:51 am

I take this as a sign…. a sign that there are higher powers at work…. that they are standing by to save us when BAU blows up…

Either than or David Copperfield is in China

http://www.liveleak.com/view?i=c6b_1448604412

doomphd *says:*

December 21, 2015 at 12:11 pm

the guy crossing the street was a Jedi knight?

Matthew Krajcik *says:*

December 21, 2015 at 1:11 pm

The big heavy truck on the far right was dragging a steel cable. No supernatural forces needed.

Fast Eddy *says:*

December 22, 2015 at 1:11 pm

Even The Rich Are Cutting Back – Swiss Watch Exports Continue Collapse Despite Price Cuts

http://www.zerohedge.com/news/2015-12-22/even-rich-are-cutting-back-swiss-watch-exports-continue-collapse-despite-price-cuts