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Energy Products: Return on Investment is Already Too Low

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My major point when I gave my talk at the Fifth Biophysical Economics Conference at the University of Vermont was that our economy's overall energy return on investment is **already too low** to maintain the economic system we are accustomed to. That is why the US economy, and the economies of other developed nations, are showing signs of heading toward financial collapse. Both a PDF of my presentation and a podcast of the talk are available on Our Finite World, on a new page called Presentations/Podcasts.

My analysis is with respect to the feasibility of keeping our **current economic system** operating. It seems to me that the problems we are experiencing today–governments with inadequate funding, low economic growth, a financial system that cannot operate with "normal" interest rates, and stagnant to falling wages–are precisely the kinds of effects we might expect, if energy sources are providing an inadequate energy return for today's economy.

Commenters frequently remark that such-and-such an energy source has an Energy Return on Energy Invested (EROI) ratio of greater than 5:1, so must be a helpful addition to our current energy supply. My finding that the overall energy return is already too low seems to run counter to this belief. In this post, I will try to explain why this difference occurs. Part of the difference is that I am looking at what our current economy requires, not some theoretical low-level economy. Also, I don't think that it is really feasible to create a new economic system, based on lower EROI resources, because today's renewables are fossil-fuel based, and initially tend to **add to** fossil fuel use.

Adequate Return for All Elements Required for Energy Investment

In order to extract oil or create biofuels, or to make any other type of energy investment, at least four distinct elements described in Figure 1: (1) adequate payback on energy invested, (2) sufficient wages for humans, (3) sufficient credit availability and (4) sufficient funds for government services. If any of these is lacking, the whole system has a tendency to seize up.

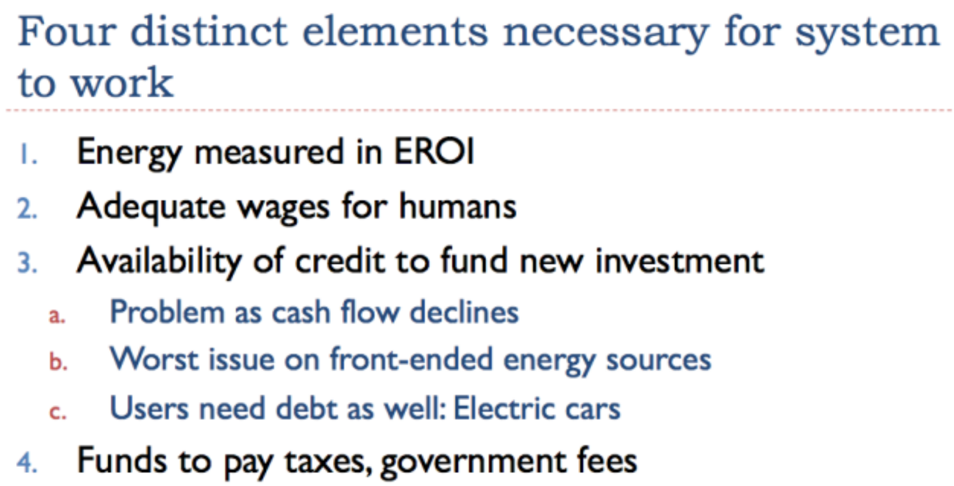

Figure 1. One sheet from Biophysical Economics Conference Presentation

EROI analyses tend to look primarily at the first item on the list, comparing "energy available to society" as the result of a given process to "energy required for extraction" (all in units of energy). While this comparison can be helpful for some purposes, it seems to me that we should also be looking at whether the **dollars collected** at the end-product level are sufficient to provide **an adequate financial return to meet the financial needs of all four areas** simultaneously.

My list of the four distinct elements necessary to enable energy extraction and to keep the economy functioning is really an abbreviated list. Clearly one needs other items, such as profits for businesses. In a sense, the whole world economy is an energy delivery system. This is why it is important to understand what the system needs to function properly.

What Happens as Oil Prices Rise

When oil prices rise, wages for humans seem to fall, or at least stagnate (Figure 2, below). The comparison shown uses US per capita wages, so takes into account changes in the proportion of people with jobs as well as the level of wages.

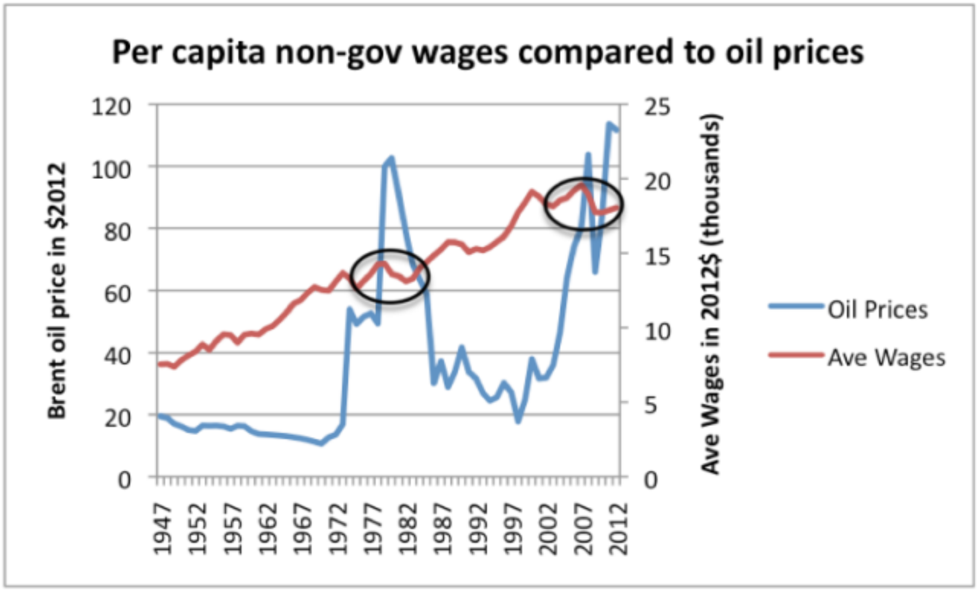

Figure 2. High oil prices are associated with depressed wages. Oil price through 2011 from BP's 2012 Statistical Review of World Energy, updated to 2012 using EIA data and CPI-Urban from BLS. Average wages calculated by dividing Private Industry wages from US BEA Table 2.1 by US population, and bringing to 2012 cost level using CPI-Urban.

In fact, if we analyze Figure 2, we see that virtually all of the rise in US wages came in periods when oil prices were below $30 per barrel, in inflation-adjusted terms. The reason why the drop in wages happens at higher per-barrel levels is related to the drop in corporate profits that can be expected if oil prices rise, and businesses fail to respond. Let me explain this further with Figure 3, below.

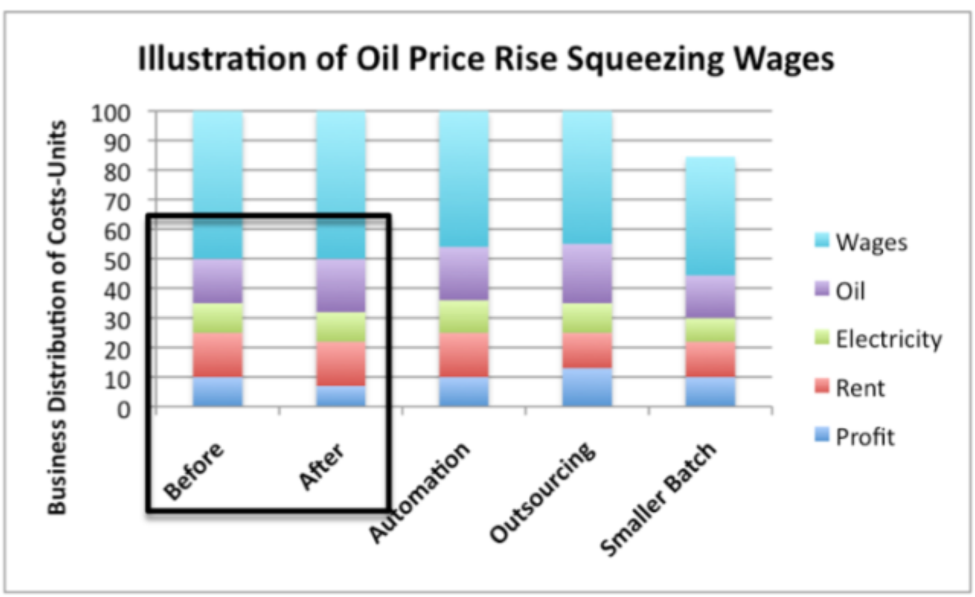

Figure 3. Illustration by author of ways oil price rise could squeeze wages. Amounts illustrative, not based on averages.

Figure 3 is a bit complicated. What happens initially when oil prices rise, is illustrated in the black box at the left. What happens is that the business' profits fall, because oil is used as one of the inputs used in manufacturing and transportation. If the cost of oil rises and the sales price of the product remains unchanged, the company's profits are likely to fall. Additionally, there may be some reduction in demand for the product, because the discretionary income of consumers is reduced because of rising oil prices. Clearly, the business will want to fix its business model, so that it can again make an adequate profit.

There are three ways that a business can bring its profits back to a satisfactory level, illustrated in the last three columns of Figure 3. They are

- **Automation.** Human energy is the most expensive type of energy a business can employ, because wages to paid to humans to do a given process (such as putting a label on a jar) are far higher than the cost of an electricity-based process to perform the same procedure. Thus, if a firm can substitute electrical or oil energy for human energy, its cost of production will be lower, and profits can be improved. Of course, workers will be laid off in the process, reducing total wages paid.
- **Outsourcing to a Country with Lower Costs.** If part of the production cost can be moved to a country where wage costs are lower, this will reduce the cost of manufacturing the product, and allow the business to offset (partially or fully) the impact of rising oil prices. Of course, this will again lead to less US employment of workers.
- **Make a Smaller Batch.** If neither of the above options work, another possibility is to cut back production across the board. Even if oil prices rise, there are still some consumers who can afford the higher prices. If a business can cut back in the size of its operations (for example, close unprofitable branches or fly fewer airplanes), it can cut back on outgo of many types: rent, energy products used, and wages. With reduced output, the company may be able to make an adequate profit by selling only to those who can afford the higher price.

In all three instances, an attempt to fix corporate profits leads to a squeeze on human wages–the highest cost source of energy services that there is. This seems to be Nature's attempt way of rebalancing the system, toward lower-cost energy sources.

If we look at the other elements shown in Figure 1, we see that they have been under pressure recently as well. The **availability of credit to fund new energy investment** is enabled by profits that are sufficiently high that they can withstand interest charges incurred in the payback of debt. Debt use is also enabled by growth, since if profits will be higher in the future, it makes sense to delay funding until the future. In recent years, central governments have seen a need to put interest rates at artificially low levels, in order to encourage borrowing. To me, this is a sign that the credit portion of the system is also under pressure.

Government's ability to fund its own needs has been under severe stress as well. Part of the problem comes from the inability of workers to pay adequate taxes, because their wages are lower. Part of the problem comes from a need for governments to pay out more in benefits, such as disability income, unemployment, and food stamps. The part that gets most stressed is the **debt portion of government funding**. This really represents the intersection of two different areas mentioned in Figure 1: (3) Adequacy of credit availability and

(4) Funding for government services.

The constellation of energy problems we are now experiencing seems to me to be precisely what might be expected, if energy return is now, on average, already too low.

The Role of Energy Extraction in this Squeeze

When any energy producer decides to produce energy of a given type (say oil or uranium), the energy producer will look for the resource that can be extracted at lowest cost to the producer.

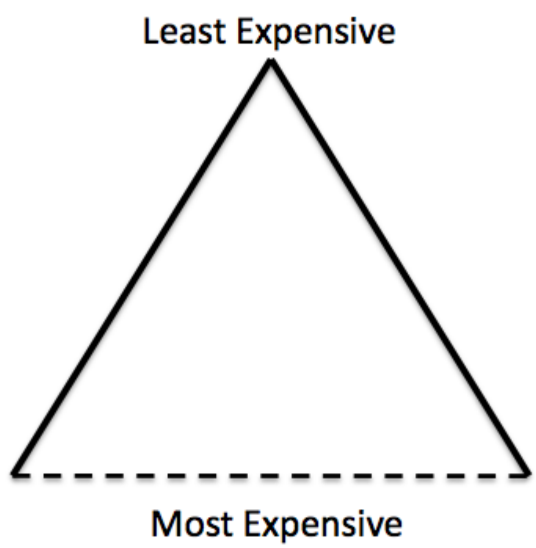

Figure 4. Resource triangle, with dotted line indicating uncertain financial cut-off.

Initially, production starts where costs are most affordable–not much energy is required for extraction; governments involved do not require too high taxes; and the cost of human labor is not too high. The producer may need debt financing, and this must also be available, at an affordable cost.

For example, easy-to-extract oil located in the US that could be extracted very simply in the early days of extraction (say before 1900), was very inexpensive to extract, and would be near the top of the triangle. Tight oil from the Bakken and bitumen from Canada would be examples of higher cost types of oil, located lower in the triangle.

As the least expensive energy is extracted, later producers wishing to extract energy must often settle for higher cost extraction. In some cases, technology advancements can help bring costs back down again. In others, such as recent oil extraction, the higher costs are firmly in place. Higher sales prices available in the market place enable production "lower in the triangle." The catch is that these higher oil prices lead to stresses in other systems: human employment, government funding, and ability for credit markets to work normally.

What Is Happening on an Overall Basis

Man has used external energy for a very long time, to raise his standard of living. Man started over 1,000,000 years ago with the burning of biomass, to keep himself warm, to cook food, and for use in hunting. Gradually, man added other sources of energy. All of these sources of energy allowed man to accomplish more in a given day. As a result of these greater accomplishments, man's standard of living rose–he could have clothes, food which had been cooked, sharper tools, and heat when it was cold.

Over time, man added additional sources of energy, eventually including coal and oil. These additional sources of energy allowed man to leverage his own limited ability to do work, using his own energy. Goods created using external energy tended to be less expensive than those made with only human energy, allowing prices to drop, and wages to go farther. Food became more available and cheaper, allowing population to rise. Money was also available for public health, allowing more babies to live to maturity.

What happened in the early 2000s was a sharp "bend" in the system. Instead of goods becoming increasingly inexpensive, they started becoming relatively more expensive relative to the earnings of the common man. For example, the price of metals, used in many kinds of goods started becoming more expensive.

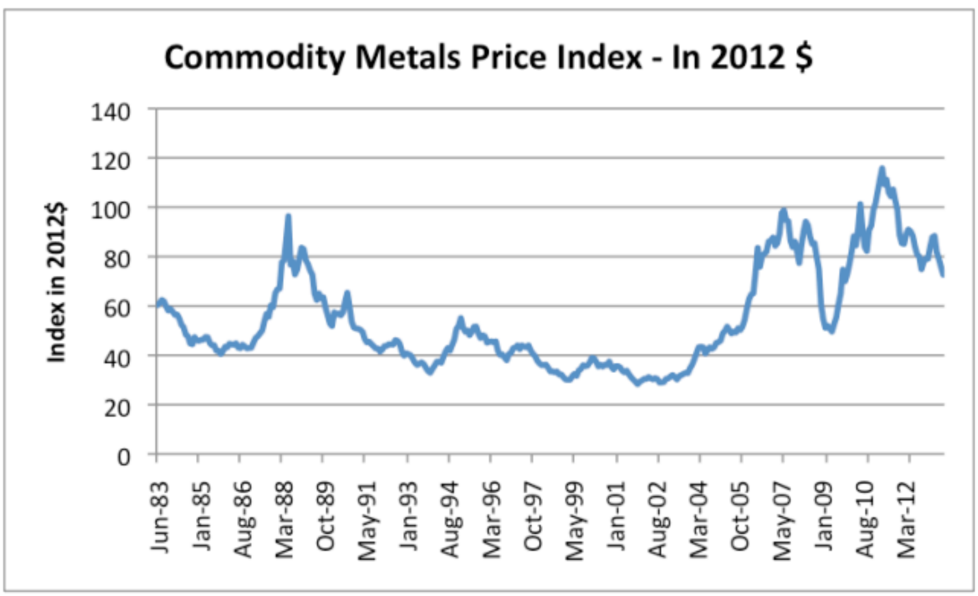

Figure 5. Commodity Metals Price Index from the International Monetary Fund, adjusted by the US CPI-Urban to 2012 price levels. Commodity Metals include Copper, Aluminum, Iron Ore, Tin, Nickel, Zinc, Lead, and Uranium.

There seem to be two reasons for this: (1) In the early 2000s, oil prices started rising (Figure 2, above), and these higher prices started exerting an upward force on the price of goods. At the same time, (2) globalization took off, providing downward pressure on wages. The result was that suddenly, workers found it harder to keep a job, and even when they were working, wages were stagnant.

It seems to me that prior to the early 2000s, part of what buoyed up the system was the large difference between:

A. The cost of extracting a barrel of oil

B. The value of that barrel of oil to society as a whole, in terms of additional human productivity, and hence additional goods and services that barrel of oil could provide.

As oil prices rose, this difference started disappearing, and its benefit to the world economy started going away. The government became increasingly stressed, trying to provide for the many people without jobs while tax revenue lagged. Slower economic growth made the debt system increasingly fragile. The economy was gradually transformed from one which provided perpetual growth, to one where citizens were becoming poorer and poorer. This pushed the economy in the direction of collapse. Research documented in the book Secular Cycles by Turchin and Nefedov shows that in past collapses, the inability of governments to collect sufficient taxes from populations that were becoming increasingly poor (due to more population relative to resources) was a primary contributing factor in these collapses. The problems that the US and other developed countries are having in collecting enough taxes to balance their budgets, without continuing to add debt, are documentation that this issue is again a problem today. Greece and Spain are having particular problems in this regard.

A More Complete List of Inputs that Need Adequate Returns

My original list was

1. Energy counted in EROI calculation–mostly fossil fuels, sometimes biomass used as a fuel
2. Human labor
3. Credit system
4. Cost of government

To this we probably need to add:

1. Profits for corporations involved in these processes
2. Rent for land used in the process – this cost would be highest in biofuel operations.
3. Costs to prevent pollution, and mitigate its effects – not charged currently, except as mandated by law
4. Compensation for mineral depletion and degradation of soil. Degradation of soil would likely be an issue for biofuels.
5. Energy not counted in EROI calculations. This is mostly "free energy" such as solar, wind, and wave energy, but can include energy which is of limited quantity, such as biomass energy.

Given the diversity of items in this list, it is not clear that simply keeping EROI above some specified target such as 5:1 is likely to provide enough "margin" to cover the financial return needed to properly fund all of these elements. Also, because the need for government services tends to increase over time as the system gets more stressed, if there is an EROI threshold, it needs to increase over time.

It might also be noted that the amounts paid for government services are surprisingly high for fossil fuels. Barry Rodgers gave some figures regarding "government take" (including lease fees as well as other taxes and fees) in the May 2013 Oil and Gas Journal. According to his figures, the average government take associated with an $80 barrel of US tight oil is $33.29 per barrel. This compares to capital expenditures of $22.60 a barrel, and operating expenditures of $7.50 a barrel. If we are to leave fossil fuels, we would need to get along without the government services funded by these fees, or we would need to find a different source of government funding.

Source of the EROI 5:1 Threshold

To my knowledge, no one has directly proven that a 5:1 threshold is sufficient for an energy source to be helpful to an economy. The study that is often referred to is the 2009 paper, What is the Minimum EROI that a Sustainable Society Must Have? (Free for download), by Charles A. S. Hall, Steven Balogh, and David Murphy. This paper analyzes how much energy needs to provided by oil and coal, if the energy provided by those fuels is to be sufficient to pay not just for the energy used in its own extraction, but also for the energy required for pipeline and truck or train transportation to its destination of use. The conclusion of that paper was that in order to include these energy transportation costs for oil or coal, an EROI of at least 3:1 was needed.

Clearly this figure is not high enough to cover all costs of using the fuels, including the energy costs to build devices that actually use the fuels, such as private passenger cars, electrical power plants and transmission lines, and devices to use electricity, such as refrigerators. The ratio required would probably need to be higher for harder-to-transport fuels, such as natural gas and ethanol. The ratio would also need to include the energy cost of schools, if there are to be engineers to design all of these devices, and factory workers who can read basic instructions. If the cost of government in general were added, the cost would be higher yet. One could theoretically add other systems as well, such as the cost of maintaining the financial system.

The way I understood the 5:1 ratio was that it was more or less a lower bound, below which even looking at an energy product did not make sense. Given the diversity of what is needed to support the current economy, the small increment between 3 and 5 is probably not enough–the minimum ratio probably needs to be much higher. The ratio also seems to need to change for different fuels, with many quite a bit higher.

The Add-On Problem for Fossil Fuel Based Renewables

With renewables made using fossil fuels, such as hydroelectric, wind turbines, solar PV, and ethanol, the only way anyone can calculate EROI factors is as **add-ons to our current fossil fuel system**. These renewables depend on the fossil fuel system for their initial manufacture, for their maintenance, and for the upkeep of all the systems that allow the economy to function. There is no way that these fuels can power the whole system, based on what we know today, within the next hundred years. Thus, any EROI factor is misleading if viewed as the possibility what might happen if these fuels were to attempt to operate on a stand-alone basis. The system simply wouldn't work–it would collapse.

A related issue is the front-ended nature of the fossil fuels used in creating most of today's renewables. People today think of "financing" any new investment, with easy payments over a period of years. The catch (as Tom Murphy pointed out in his BPE talk) is that **Nature Doesn't Do Financing**. Nature demands up-front payment in terms of any fossil fuels used. Thus, if we build a huge new hydroelectric dam, such as the Three Gorges Dam in China, the fossil fuels required to make the concrete and to move huge amounts of soil come at the beginning of the project. This is also true if we make a huge number of solar panels. The saving we get are all only theoretical, and will take place **only if** we are actually able reduce the use of other fossil fuel energy sources in the future, because of the energy from the PV panels or other new renewable.

In nearly all cases, adding renewables requires **increasing** fossil fuel use for this reason. We could, in theory, reduce fossil fuel use elsewhere, to try to cover the greater fossil fuel use to add renewables, but this would mean cutting industries and jobs currently using the fuel, something that many find objectionable. Several readers have suggested that we could greatly ramp-up solar PV. Yes, we could, but we would have to greatly ramp up fossil fuel usage (mostly coal in China, if current manufacturing approaches are used) to create these panels. Any future savings would be theoretical, depending on how long we keep the new system operating, and how much fossil fuel energy consumption is actually reduced as a result of the new panels.

Conclusions

At this point, the foregoing analysis suggests that products created using today's oil and other energy products are not producing an adequate financial return to cover wages, interest expense, and necessary taxes. If EROI plays a major role in determining financial returns, EROI on average is already too low for many developed economies.

It is convenient to think that an economy can keep adding lower and lower EROI resources, but at some point, a "stop" signal starts appearing. I would argue that the issues we are seeing in many sectors of the economy are clear indicators that such a threshold is already being reached. An economy in which the wages of the common worker are buying less and less is an economy in trouble. I talk in another post (Energy and the Economy–Basic Principles and Feedback Loops) about the fact that economic growth seems to be the result of one set of feedbacks. As the price of oil rises and related changes take place, these feedbacks change from economic growth to economic contraction. It is these feedbacks that we are already having problems with.

One can argue that EROI has nothing to do with these issues. But if this is the case, what is the point it analyzing it in the first place? We clearly need to understand when an economy is giving us "stop" signals with respect to increasingly low quality energy inputs. If EROI is not helpful in this regard, perhaps we need to be looking at other indicators.

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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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242 Responses to *Energy Products: Return on Investment is Already Too Low*

timl2k11 *says:*
June 24, 2013 at 11:09 pm

Very interesting. I was reading an article on Bloomberg that talked about how the biggest players in US shale, by their own metrics, have not yet been able to turn a profit. It would be interesting to see a graph that shows not just total US crude output (which appears to be rising), but net energy. It would seem that oil shale is not even worth extracting from the ground.

Danilo *says:*
June 25, 2013 at 6:55 am

I agree, According to Joseph Tainter, Sustainability is a function of solving problems. It takes resources to solve problems. We need more and more resources to be sustainable.
So Gail is factually demonstrating what J. Tainter is explaining

Gail Tverberg *says:*
June 25, 2013 at 2:36 pm

Yes, it takes resources to solve problems. Tainter talks about the problems leading to increased complexity. As a practical matter, it is the government that is called on to solve problems. Also, this increased complexity has a cost–more programs, more employees, and so forth. So it is the government that gets to be the one that cannot pay its bills, when there are not enough resources.

Gail Tverberg *says:*
June 25, 2013 at 11:07 am

Interesting! Do you have a link to the Bloomberg article?