The Oil Drum
DISCUSSIONS ABOUT ENERGY AND OUR FUTURE

Tipping Point: Near-Term Systemic Implications of a Peak in Global Oil Production -- Collapse Dynamics

Posted by Gail the Actuary on April 14, 2010 - 8:33am
Topic: Supply/Production
Tags: collapse, collapse dynamics, david korowicz, economic collapse, feasta, globalised civilization, globalization, peak oil production, tipping point paper [list all tags]

Recently, a 55 page paper called Tipping Point: Near-Term Implications of a Peak in Global Oil Production (PDF warning) was published as the joint effort of two organizations: Feasta and The Risk/Resilience Network, with lead author David Korowicz. We have recently published two excerpts from that paper, which can be found at this link. This is a third excerpt.

4. Collapse Dynamics

4.1 The Dynamical State of Globalised Civilisation

The period since the end of the last ice age provided the large-scale stability in which human civilisation emerged. Climatic stability provided the opportunity for diverse human settlements to 'bed' down over generations. This formed the basis upon which knowledge, cultures, institutions, and infrastructures could build complexity and capability over generations without, by and large, having it shattered by extreme drought or flooding outside their capacity to adapt.

Recently, a 55 page paper called Tipping Point: Near-Term Implications of a Peak in Global Oil Production (PDF warning) was published as the joint effort of two organizations: Feasta and The Risk/Resilience Network, with lead author David Korowicz. We have recently published two excerpts from that paper, which can be found at this link. This is a third excerpt.

4. Collapse Dynamics

4.1 The Dynamical State of Globalised Civilisation

The period since the end of the last ice age provided the large-scale stability in which human civilisation emerged. Climatic stability provided the opportunity for diverse human settlements to 'bed' down over generations. This formed the basis upon which knowledge, cultures, institutions, and infrastructures could build complexity and capability over generations without, by and large, having it shattered by extreme drought or flooding outside their capacity to adapt.

Within this macro-climatic stability, is the medium-term stability that we referred to above, the period of globalising economic growth over the last century and a half. We tend to see the growth of this economy in terms of change. We can observe it through increasing energy and resource flows, population, material wealth, and as a general proxy, GWP [Gross World Product]. We could view this from another angle. We could say that the globalizing growth economy for the last one hundred and fifty years has been remarkably stable. It could have grown linearly by any percentage rate, declined exponentially, oscillated periodically, or swung chaotically, for example. What we see is a tendency to compound growth of a few percent per annum. And at this growth rate the system could evolve, unsurprisingly, at a rate we could adapt to.

This does not mean that there is not unpredictable fluctuations in the economy. However, the fluctuations are around a small additional percentage on the previous year's gross output. By magnitude we are roughly referring to $|^{\Delta GWP}/_{GWP}|$. Angus Maddison has estimated that GWP grew 0.32% per annum between 1500 and 1820; 0.94% (1820-1870); 2.12% (1870-1913); 1.82% (1913-1950); 4.9% (1950-1973); 3.17% (1973-2003), and 2.25% (1820-2003)[i]. Even through two world wars and the Great Depression in the most economically developed countries (1913-1950) growth remained positive and in a relatively narrow band. Figure 4 shows growth rates of the global economy in frequency bands over the last four decades, again the narrow band indicates system stability. Of course small differences in aggregate exponential growth can have major effects over time, but here we are concentrating upon the stability issue only.

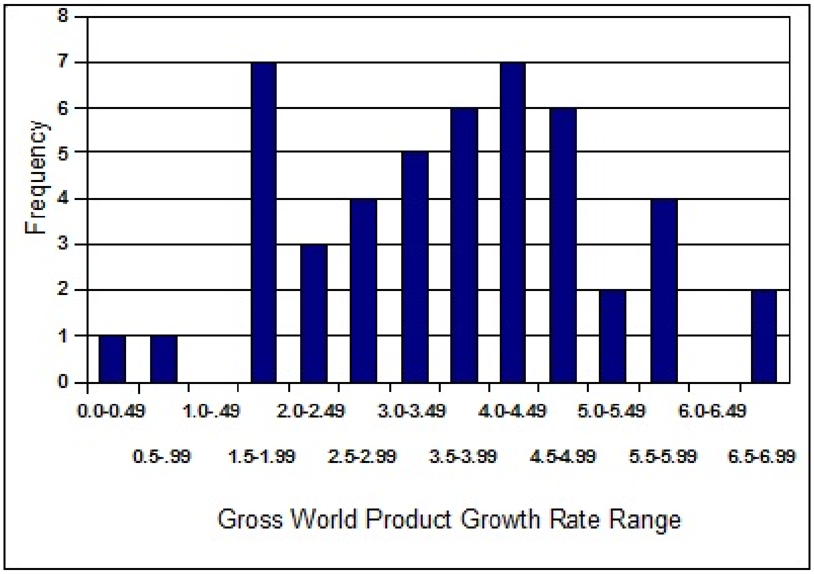

Figure 4: *Real GWP percentage change year on year 1961-2008. Source: Based upon World Bank data.*

Governments and populations are highly sensitive to even minor negative changes in growth. The constraints felt by governments and society in general arising from only a very small change in GDP growth should emphasize to us that our systems have adapted to this narrow range of stability, and the impact of moving outside it can provoke major stresses.

4.2 Tipping Points in Complex Systems

Despite the diversity of complex systems, from markets to ecosystems to crowd behavior- there are remarkable similarities. For most of the time such systems are stable. However, many complex systems have critical thresholds, called tipping points, when the system shifts abruptly from one state to another. This has been studied in many systems including market crashes, abrupt climate change, fisheries collapse, and asthma attacks. Despite the complexity and number of parameters within such systems, the meta-state of the system may often be dependent on just one or two key state variables[ii].

Recent research has indicated that as systems approach a tipping point they begin to share common behavioral features, irrespective of the particular type of system[iii]. This unity between the dynamics of disparate systems gives us a formalism through which to describe the dynamical state of globalised civilisation, via its proxy measure of GWP, and its major state variable, energy flow.

We are particularly interested in the class of transitions called catastrophic bifurcations where once the tipping point has been passed, a series of positive feedbacks drive the system to a contrasting state. Such ideas have become popularised in discussions of climate change. For example, as the climate warms it drives up emissions of methane from the arctic tundra, which drives further climate change, which leads to further exponential growth in emissions. This could trigger other tipping points such as a die-off in the Amazon, itself driving further emissions. Such positive feedbacks could mean that whatever humanity does would no longer matter as its impact would be swamped by the acceleration of much larger scale processes.

Figure 5 shows how the system state responds to a change in conditions. The state of a system could represent the size of a fish population, or the level of biodiversity in a forest, while the conditions could represent nutrient loading or temperature (both effectively energy vectors). The continuous line represents a stable equilibrium, the dotted one an unstable one. In a stable equilibrium, the state of the system can be maintained once the condition is maintained. In Figures a) and b) we see two different responses of a stable system under changing conditions. In the first, a given change in conditions has a proportional effect on the system state; in the latter, the state is highly sensitive to a change in conditions. In c) and d) the system is said to be close to a catastrophic bifurcation. In both of these cases there is an unstable region, where there is a range of system states that cannot be maintained. If a system state is in an unstable regime, it is dynamically driven to another available stable state. If one is close to a tipping point at a catastrophic bifurcation, the slightest change in the condition can cause a collapse to a new state as in c), or a small perturbation can drive the system over the boundary as in d).

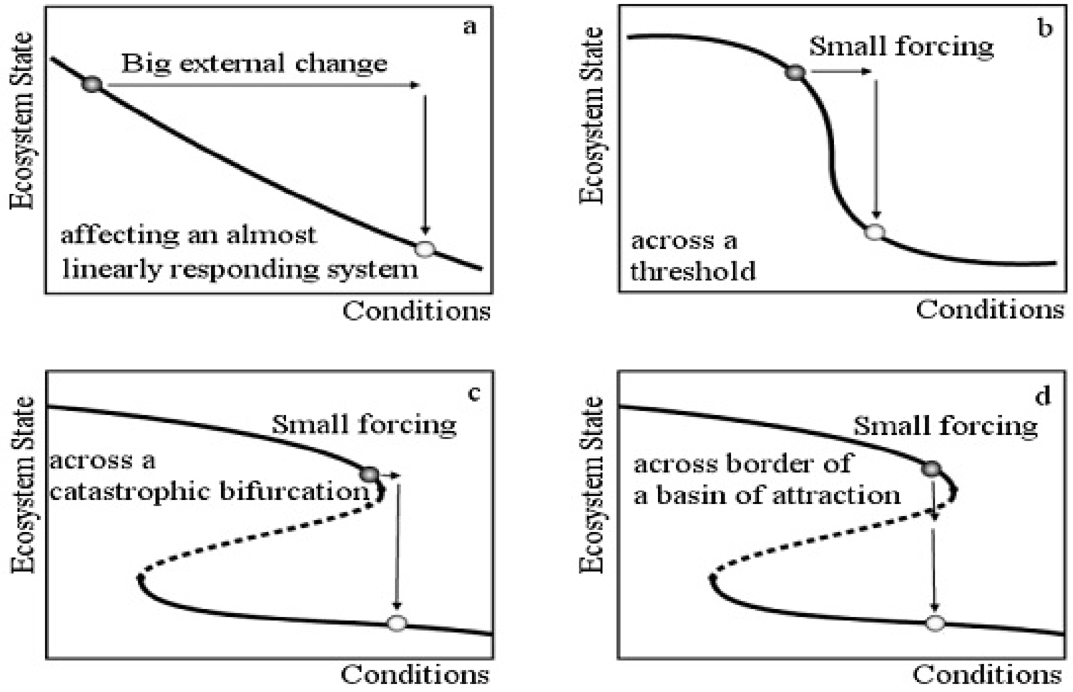

Figure 5: *The state of a system responds to a change in conditions. The continuous line represents a stable equilibria. In a) a change in conditions drives an approximately linear*

response in the systems state, unlike b) where a threshold is crossed and the relationship becomes very sensitive. The fold bifurcation (c,d) has three equliibra for the same condition, but one represented by the dotted line is unstable. That means that there is a range of system states which are dynamically unstable to any condition[iv]

5. Three Peak Energy-Economy Models

5.1 Introduction

While discussions of peak oil have begun to enter the policy arena, and while it is generally acknowledged that it would have a major impact upon the economy, the discussion is often fragmented and lacking in a broad system synthesis. In general, discussion tends to focus on the direct uses of oil, and sometimes its effect on a country's balance of payments. Where economic impact studies of peak oil have been done, they are based upon the direct decline curve assumption such as the 4see model by Arup for the UK Peak Oil Task Force Report[v]. Nel and Cooper have used the decline curve assumption and accounted for EROI and peak coal and gas to look at the economic implications[vi]. The latter authors show a smooth decline in GDP but acknowledge that their modelling assumptions include that the financial markets must remain functional, state legitimacy remains intact, and international law prevails.

In most cases there is an intuitive assumption or mental model of what the effects of peaking oil production will mean economically and socially. In order to clarify our discussion, and introduce some working concepts, we will look at three models.

These should not be considered in isolation. In a very broad and general fashion we might consider that the *linear decline* model is valid for small energy constraints that have a very small effect on the overall magnitude of real GWP and level of complexity. This merges into a *oscillating decline* phase which cause larger perturbations in GWP/Complexity level. Finally, tipping points are crossed that rapidly cause a severe *collapse* in GWP/Complexity.

Finally, we note that what we are trying to do is clarify peak energy-civilisation dynamics and identify the major structural drivers in the process. The real world is more unknowable than can ever be engaged with here.

5.2 Linear Decline

Intuitively we tend to assume that most phenomena respond proportionately to some causation. This is mostly true. A change in price proportionately changes demand; an increase in population proportionately increases food demand; and increase in cars leads to a proportional increase in emissions.

Most commonly, there are two associated assumptions relating to the energy-economy relationship post-peak. The first is the Decline Curve Assumption. Thus oil production is withdrawn from the economy at between 2 and 3% p.a. The second element is that there is an approximately linear relationship between the oil production decline and economic decline. The combination of these assumptions is that the global economy declines in the form of the slope of the downward projection curve.

Thus we see the price of oil rise as oil becomes scarcer. Having less energy constrains economic activity. Bit by bit we become poorer; there is less and less discretionary consumption. The rising prices force more localized production and consumption, and there is growing de-globalisation.

Jobs lost in the areas serving today's discretionary needs are over time deployed in food and agriculture, producing with more direct human effort and skill many of the essentials of life.

In such a case a longish period of adaptation is assumed in which gradually declining oil production and resulting oil price increases cause recession, hardship and cause some shocks, but also initiate a major move into renewable energy, efficiency investments, and societal adaptation. New energy production that was once too expensive becomes viable. The general operability of familiar systems and institutions is assumed, or they change slowly.

Even where the linear decline model is valid, it would be difficult to adapt. Consider a country's budget in energy terms, with some amount for health, business operations, agriculture, operations, education, and investment. As total energy available declined, less and less energy would be available in each sector. Because we discount the future (we favour short-term benefits), and the discount rate rises in economic stress, the ability to maintain investment in renewable energy would become increasingly difficult. In essence, there would be a choice between keeping some functionality in a crumbling health service, and stalling rising employment a little; or accepting job losses and a health crisis in return for a small energy return per annum in the future.

5.3 Oscillating Decline

In this model, constrained or declining oil production leads to an escalation in oil (plus other energy and food) prices. But economies cannot pay this price for a number of reasons. Firstly, it adds to energy and food price inflation, which are the most non-discretionary purchases. This means discretionary spending declines, from which follows job losses, business closures, and reduced purchasing power. The decline in economic activity leads to a fall in energy demand and a fall in its price. Secondly, for a country that is a net importer of energy, the money sent abroad to pay for energy is lost to the economy, unless that country exports goods of equivalent value. This will drive deflation, cut production, and reduce energy demand and prices. Thirdly, it would increase the trade deficits of a country already struggling with growing indebtedness, and add to the cost of new debt and debt servicing.

Falling and volatile energy prices mean new production is harder to bring on stream, while the marginal cost of new energy rises and credit financing becomes more difficult. It would also mean that the cost of maintaining existing energy infrastructure (gas pipelines, refineries etc) would be higher, thus laying the foundations for further reductions in production capability.

In such an energy constrained environment, one would also expect a rise in geo-political risks to supply. This could be bi-lateral arrangements between countries to secure oil (or food). Such agreements would tend to reduce the amount of oil available on the open market. Energy constraints would also increase the inherent vulnerability to highly asymmetric price/supply shocks from state/non-state military action, extreme weather events, or other so-called black swan events.

When oil prices fall below what can be supplied above the marginal cost of production and delivery, and oil price is what can be afforded in the context of decreased purchasing power, then energy for growth is again available. Of course local and national differences (for example energy import dependence, export of key production such as food) can be expected to shift how regions fare in the recession and in their general ability to pick up again. Growth then might be assumed to kick off again, focusing maybe on more ‘sustainable’ production and consumption.

However, as growth returns, the purchasing power of the economy will not be able to return to where it was before. Oil production will be limited by natural decline and lack of investment, and entropic decay of infrastructure will reduce the supply-demand price point further. Again higher oil, food and energy prices would then drive another recession.

In the oscillating decline model: economic activity increases→energy prices rise→a recession occurs→energy prices fall→economic activity picks up again but to a lower bound set by declining oil production. In this model the economy oscillates to a lower and lower level of activity. From our discussion about the origins of the current recession, we see this process has already begun.

5.4 Systemic Collapse

This model draws on ideas from the general dynamics of complex systems and networks, and tends to see our civilisation as a single complex adaptive system by virtue of its connectedness and integration. Indeed the concept of globalization is about integration with a common singular network.

We associate systemic collapse of civilisation with a catastrophic bifurcation. The state of civilisation at a time is by necessity dependent upon the state of the globalised economy. The state of the global economy is dependent on the infrastructure that integrates the operational fabric. The state of the globalised economy may be parameterized by GWP, which implies a level of complexity. And GWP (and complexity) is absolutely dependent upon energy flows.

To argue that civilisation is on the cusp of a collapse, we need to be able to show that there are tipping points that, once passed, drive the system rapidly towards another contrasting state through a process of positive feedback that may in turn drive other feedback processes. We need to also demonstrate that it is a catastrophic bifurcation in which the state of the globalised economy is driven through an unstable regime where the strength of the feedback processes is greater than any stabilizing process. It acknowledges that there may be an early period of oscillating decline, but that once major structural components (international finance, techno-sphere) drop or ‘freeze’ out, irreversible collapse must occur.

In the new post-collapse equilibrium state we would expect a collapse in material wealth and productivity, enforced localization/ de-globalisation, and collapse in the complexity as compared with before, as an expression of the reduced energy flows.

The collapses in the Roman Empire occurred over centuries; collapse of the Greenland Viking settlements in decades. We suggest a hypothesis here that the speed of collapse is a function of the level of integration, coupling, and the key operational speeds of the systems that support the stability of the pre-collapse state. For us, that includes the behavioral change in financial markets, food flow rates, and replacement lifetime of key components in infrastructure. In discussing the feedback processes in the next chapter we will see processes are indeed fast.

References

[i]Maddison A (2007) *Contours of the World Economy 1-2030AD*. Page 81 Oxford Univ. Press.

[ii]Scheffer, M. (2009) *Critical Transitions in Nature and Society*. Princeton Univ. Press.

[iii]Scheffer, M et al.(2009) *Early-warning signals for critical transitions*. Nature Vol 461 3 Sept.

[iv] http://www.stockholmresilience.org/download/18.1fe8f33123572b59ab8000166...

[v] *The Oil Crunch: A Wake-up Call for the UK Economy*.(2010) Second Report of the UK Industry Taskforce on Peak Oil and Energy Security. http://peakoiltaskforce.net/wp-content/uploads/2010/02/final-report-uk-i...

[vi] Nel, W, and Cooper, C. (2009) *Implications of Fossil Fuel Constraints on Economic Growth and Global Warming*. Energy Policy 37 166-180.