The Oil Drum
DISCUSSIONS ABOUT ENERGY AND OUR FUTURE

"Tipping Point: Near-Term Systemic Implications of a Peak in Global Oil Production" -- Civilisation, the Economy, & Complexity

Posted by Gail the Actuary on April 3, 2010 - 8:48am
Topic: Economics/Finance
Tags: civilization, complexity, david korowicz, ecological economics, economics, feasta, risk/resilience network, 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. Last week we published the Summary of the paper. Today, we are publishing a section from the middle paper, talking about the dynamics of complex civilizations. It is because of the complexity and connectedness of our current economy that the failure of one part of the system is likely to lead to failure of another. --Gail

3.1 Civilisation, the Economy, & Complexity

This paper is concerned with humanity's impact on its environmental resource base, and the effect the resource base has on human welfare. What mediates between these is our complex civilisation[i].

The idea of civilisation has inspired intellectuals and propagandists for millenia, and it is not particularly helpful to enter the debate here. We shall define it broadly, and in a way that serves our purposes in the current context. Civilisation is firstly *a system*, a singular object that connects all its constituent elements together. The constituent are people, institutions, companies, and the products and services of human artifice. The connections are people, supply-chains and transport networks, telecommunications and information networks, financial and monetary systems, culture and forms of language. It has dimensions of space, in the momentary transmission of goods, images, money, and people across the globe. And it has dimensions of time as stored in libraries, education and institutional knowledge, the patterns of fields and city streets, ideas of who we are and why we do as we do. It also places, through its history and evolved structures, constraints on its future evolution.

Our particular *globalised civilisation* is one that has grown to connect almost every person on the planet. One is in some way part of it if you have heard of Barak Obama, seen a moving image, used money, or have or desire something made in a factory. There are very few people on the planet who are unconnected, most are more or less integrated. We can also look at this as our level of *system dependency*. Imagine if suddenly across the globe; all the advanced infrastructure of civilisation-banking, IT, communications systems, and supply-chains suddenly stopped working. For developed countries relying upon just-in-time delivery of food, digital money; and complex information systems, starvation and social breakdown could evolve rapidly. In developing countries the situation would not be much better. Only for the most remote tribes on the planet it would make little or no difference. Occasionally we get a glimpse of the issue as during the fuel depot blockades in the UK in 2000, when supermarkets emptied and the Home Secretary Jack Straw accused the blockaders of "threatening the lives of others and trying to put the whole of our economy and society at risk"[ii]. More recently, the collapse of Lehman Brothers helped precipitate a brief freeze in the financing of world trade as banks became afraid of perceived counter-party risks to Letters of Credit[iii]. The more we become part of the system the more we share its benefits and the more system dependent we become.

It is a cliché, though true, to say that civilisation has become more complex. We can understand complexity as involving the number of connections between people and institutions; the intensity of hierarchical networks, the number of products available, the extent and number of the supply-chain functions required to produce these products; the number of specialized occupations; the amount of effort that is required to manage and operate systems; the amount of information available, and the energy flows through the system. Here is a vivid description of one aspect of complexity by Eric Beinhocker who compares the number of distinct culturally produced artifacts produced by the Yanomamo tribe on the Orinoco River, and modern New Yorkers. The Yanomamo have a few hundred, the New Yorkers have in the order of tens of billions, and this wealth is a measure of complexity:

> To summarize 2.5 million years of economic history in brief: for a very, very long time not much happened; then all of a sudden all hell broke loose. It took 99.4% of economic history to reach the wealth levels of the Yanomamo, 0.59% to double that level by 1750, and then just 0.01% for global wealth to reach the level of the modern world.[iv]

Or we can look at it from the point of view of the supply-chains that are required to transform raw materials into products and services that criss-cross the globe. It is said that a modern car manufacturer has about 15,000 inputs to the manufacturing process. If each of those components was made by a supplier who put together on average 1500 components (10%), and each of those was put together by a supplier who put together 150 components, that makes over 3 billion interactions- and we have not included staff, plant, production lines, IT and financial systems. Nor are we at the end of the story here. For the car manufacturer would not exist were there not customers who could afford to buy a new car, which depends upon their economic outputs which are themselves dependent upon vast complex supply chains, and so on. Nor could these vast networks of exchange exist without transport, finance, and communications networks. And those networks would not be economically viable unless they were benefiting from the economies of scale shared with many other products and services. In this way we can start to see how intimately connected we are with one another across the planet, and why we see the global economy as a singular system.

The remarkable thing about such a complex economy is that it works. Each day I buy bread. The person who sold me that bread need not know from whom the wheat was bought, who manufactured the mixer, or who provided export credit insurance for the bulk wheat shipment. The person who delivered the bread to the shop did not need to know who refined his diesel, who invented the polymer for his gasket, or if I personally have money to pay for bread. The steel company did not know that a small manufacturer of bread mixers would use its product, nor cared where its investment came from. The process required to simply give me tasty and affordable bread, required, depending on the system boundaries, millions, even hundreds of millions of people acting in a coherent manner.

Yet in all this there was no organizer. The complexity of understanding, designing, and managing such a system is far beyond human and computer assisted abilities. We say such systems are self-organised, just like the formation of birds in flight, and the patterns of walkers down a city street. Self-organisation can be a feature of all complex adaptive systems, as opposed to 'just' complex systems such as a watch. Birds do not 'agree' together that arrow shapes make good sense aerodynamically, and then work out who flies where. Each bird simply adapts to its local environment and path of least effort, with some innate sense of hierarchy for the lead bird, and what emerges is a macro-structure without intentional design (readers will notice the same non-teleological explanations within evolutionary biology).

Our globalised civilisation has evolved and operates as a complex adaptive system. From each person, company or institution, with common and distinctive histories, playing their own part in their own niche, and interacting together through cultural and structural channels, the global system emerges.

What ties our globalised civilisation together is the global economy. It is to our civilisation what blood and the central nervous system is to our body. The economy allows the exchange of goods and services across the globe. And the more system dependent we are, the more we rely upon the global economy.

If one side of the global economy is goods and services, the other side is money. Money has no intrinsic value, it is a piece of paper or charged capacitors in an integrated circuit. It represents not wealth, but a claim on wealth (money is not the house or food we can buy with it). Across the globe we exchange something intrinsically valuable for something intrinsically useless. This only works if we all play the game, governments mandate legal tender, and monetary stability and trust is maintained. The hyper-inflation in Weimar Germany and in today's Zimbabwe shows what happens when trust is lost.

One of the great virtues of the global economy is that factories may fail and links in a supply chain can break down, but the economy can quickly adapt to fulfilling that need elsewhere or finding a substitute. This is a measure of the adaptive capacity within the globalised economy, and is a natural feature of such a de-localised and networked complex adaptive system. But it is true only within a certain context. There are common platforms or 'hub infrastructure' that maintain the operation of the global economy and the operational fabric, without which they would collapse. Principle among them are the the monetary and financial system, accessible energy flows, and the integrated infrastructures of information technology, electricity generation, and transport.

We can make an analogy here with another complex adaptive system, the human body. Hub infrastructure for the human body would include blood circulation (heart), the signaling and information (central nervous system), and the respiratory system. If any of these fail, we die. However our body can self-repair cuts and light trauma, and can survive quite major local damage (limb loss). If the local damage is significant enough (or death by a thousand cuts), the body can fail. So collapse (death) can result from hub failure or significant general system damage. We tend to find that final collapse is driven by the interactions of these elements (death caused by heart or respiratory failure caused by trauma).

This current integrated complexity was not always so. We have adapted so well to its changes, and its changes have been in general so stable, that we are often oblivious to its ties. Imagine if all the integrated circuits introduced within the last 10 or even five years should stop working. Financial systems, the grid, and supply-chains would fail. Our just-in-time food systems would soon leave the cupboard bare, and our inability to carry out financial transactions would ensure it remained so, real starvation could appear in the most advanced (system dependent) economies. The question poses itself, how can something introduced only in the last five or ten years cause such chaos if removed, after all we were fine just ten years ago? Even just consider the consequences of losing the mobile phone network. Our most basic functioning has become, almost by stealth, more and more entwined with rapid turnover technologies, the complex supply-chains that carry our needs and labours across the planet, and the financial and monetary systems that hold them all together.

3.2 The Evolution of the Global Economy

For most people living before the late medieval period, sustenance and welfare depended upon one's own efforts and those of one's close community. In such a context, abundant harvests could co-exist with nearby famine[v] From a general welfare point of view there was a production and a distribution problem.

The central problem of distribution was firstly that money was a small part of the local economy, as most communities were largely self-sufficient. Secondly, there were very rudimentary transport links, and actual communication between towns may have been infrequent and haphazard. This meant that there was neither a proper signaling mechanism to indicate shortages, a tradable store of value, nor a trade and transport system to facilitate the resource redistribution. Rural villages could find themselves vulnerable to harvest failure (from flooding say), which was the bedrock asset of community welfare, and therefore they had to bear all the risk locally. The risk could be partially managed by storage and storage technology, but the ability to store for a rainy day also meant that there needed to be surplus production. But investing in increasing production tends to require surpluses, traded inputs and knowledge from elsewhere.

One of the great advantages of a growing interconnectedness between regions, and more trade with money was that localised risks could be shared over the whole network of regions. Surpluses could be sold to where prices were highest in the network, and the money received in return would hold its value better than the stored grain prone to rot or rodents. Distributing surpluses across the network was also the most efficient use of resources. What economists now call comparative advantage meant that more specialised roles could be performed in the network than in a similar number of isolated regions or towns with greater efficiency. This meant new products and services could be developed, especially ones that relied on diverse sub-components. This promoted further efficiency, increased wealth, surpluses, capital and a growing knowledge and technical base. Now increased investment in future wealth could be more ambitious in building the size of the network (through assimilation, integration and conquest) and its levels of integration (bridges, markets, and guilds).

There are push-pull drivers of growth; in human behavior; in population growth; in the need to maintain existing infrastructure and wealth against entropic decay; in the need to employ those displaced by technology; in the response to new problems arising; and in the need to service debt that forms the basis of our economic system. The process of economic growth and complexity has been self-re-enforcing. The growth in the size of the networks of exchange, the level of complexity, the economic efficiencies all provide a basis for further growth. Growing complexity provides the basis for developing even more complex integration. In aggregate, as the operational fabric evolves in complexity it provides the basis to build more complex solutions.

We are problem solvers, arising from our basic needs, status anxiety, and our responses to the new challenges a dynamic environment presents. That could be simple such as getting a bus or making bread; or it could be complex, putting in a renewable energy infrastructure say. We tend to exploit the easiest and least costly solutions first. We pick the lowest hanging fruit, or the easiest extractable oil first. As problems are solved new ones tend to require more complex solutions. Our ability to solve problems is limited by the range of possible solutions available to us, *the solution space*. The extent of the solution space is limited by knowledge and culture; the operational fabric at a time; and the available energetic, material, and economic resources available to us. It is also shaped by the interactions with the myriad other interacting agents such as people and institutions, and because all may be increasingly complex, they may re-enforce growing complexity as they co-evolve together.

As new technologies and business models (solutions or sets of solutions) emerge they co-adapt and co-evolve with what is already present. Their adoption and spread through wider networks will be dependent upon the efficiencies they provide in terms of lower costs and new market opportunities. One of the principle ways of gaining overall efficiency is by letting individual parts of the system share the costs of transactions by sharing common platforms (information networks, supply chains, financial systems), and integrating more. Thus there is a re-enforcing trend of benefits for those who build the platform and the users of the platform, which grows as the number of users grow. In time the scale of the system becomes a barrier to a diversity of alternative systems as the upfront cost and the embedded economies of scale become a greater barrier to new entrants, this being more true for more complex hub infrastructure. Here we are not necessarily associating lack of system diversity with corporate monopolies. There is quite vigorous competition between mobile phone service providers-but they share common platforms and co-integrate with electricity networks and the monetary system, for example.

This however can lay the basis for systemic vulnerability. That is, if our IT platform failed so too would our financial, knowledge and energy systems. Conversely if our financial system collapsed, it would not take long for our IT and supply-chains to collapse. The UK based Institute of Civil Engineers acknowledges that the complex relationships between co-dependent critical infrastructure is not understood[vi]. Our operational systems are not isolated from the wider economy either. Because of the expense of infrastructure and the continual need for replacement of components, a large number of economically connected people and economies of scale are necessary to provide their operational viability. What has helped make such systems viable is that they are being cross-subsidized throughout the whole economy. The resource required to build and maintain critical complex infrastructure demands that we buy games consoles, send superfluous text messages, and watch YouTube.

The growth of civilisation has costs, and as it grows, costs rise. The biggest driver of environmental destruction is the growth process itself. Rising soil and aquifer depletion, collapsed fisheries, deforestation, greenhouse gas emissions, and polluted groundwater are just some of the consequences of the requirement for continuous flows for the maintenance and growth in GDP. There are also the costs of complexity itself. As systems become more complex there are growing costs associated with managing and operating the systems and the investment in educating people who will work in more specialised roles.

Joseph Tainter has argued that declining marginal returns on growing complexity provide the context in which previous civilisations have collapsed[vii]. The benefits of rising complexity are finally outweighed by the rising costs. But problems still arise, and a society no longer can respond to those problems in the traditional way-increasingly complex solutions. It becomes locked into established processes and infrastructures but is less able to recover from shocks or adapt to change, it loses resilience.

3.3 Evolution of Science & Technology

The assumption that science and technology will automatically respond to meet the challenges we face has become an article of faith. It is related to our conceptions of 'progress', and its power and potential may be asserted with authority by anyone. In discussions of sustainability, science and technology is often invoked as the *deus* ex machina destined to fill the looming gaps between our demands and the earth's ability to supply them. In this sense it may act as a collective charm wielded to chase away the anxiety induced by glimpses of our civilisation's precariousness. The following section attempts to locate science and technology within the evolutionary and material conditions of our economy. We also wish to illuminate a little more why high technology infrastructure is vulnerable.

Science & Technology Suffer from Declining Marginal Returns

In 1897 J.J. Thompson discovered the electron, then the cutting edge of physics, all on a laboratory bench. The understanding of this particle laid the foundation for the digital infrastructure upon which much of the world relies. Today it requires a 27km underground tunnel, 1,600 27 tonne superconducting magnets cooled to less than 2 degrees above absolute zero, and the direct involvement of over 10,000 scientists and engineers to find (possibly) today's cutting-edge particle, the Higgs boson. In the 1920s, Alexander Fleming discovered penicillin, with a huge benefit to human welfare, for a cost of about €20,000. Today it costs hundreds of millions to develop minor variations on existing drugs that do little for human welfare.

Science and technology are an exercise in problem solving. As generalised knowledge is established early on in the history of a discipline, the work that remains to be done becomes increasingly specialised. The problems become more difficult to solve, are more costly, and progress in smaller increments. Increasing investments in research yield declining marginal return[viii]. We see this in the growing size of research groups, levels of specialisation, and the knowledge burden[ix].

The conclusion is that further research and development is likely to be more resource intensive, yet on average give smaller returns to society. For a society trying to undergo an energy transformation, this means that more and more of possibly declining energy available to society must be devoted to research and development, but with less likelihood of significant breakthroughs.

The Most Advanced Technology is the Most Resource Intensive

Because new technologies tend to be solutions to more complex problems, are built using high technology components, and have relied upon the continually upgrading operational fabric; they tend to be more resource intensive. We can see this in the evolution of key manufacturing processes over the last century where one analysis shows a six order of magnitude increase in the energy and resource intensiveness per unit mass of processed materials. This was driven by the desire for smaller and more precise devices and products[x]. A 2 gram 32 MB DRAM chip would now be considered archaic, but it required 1700g of resources to fabricate, one expects that contemporary Very Large Scale Integration (VLSI) chips require vastly more resources[xi]. While popular focus tends to be on the direct energy used by final goods, it is the embodied energy and material resources that is staggering[xii].

Yet the high-tech products we use (computers say), require the networks, telecoms infrastructure, software, and the computer use of others to realise their value. Which in turn depends upon an even vaster infrastructure. So in a way, asking about the resource requirements of your computer is akin to asking about the resource requirements for your finger, it make sense only if you assume the rest of the body is well resourced.

Finally, we note for completeness that rising energetic and material costs from growing complexity (more specifically energy flows per unit mass) is just what we would expect from thermodynamic principles.

The Most Advanced Technology Has the Most Complex Supply-Chain Dependencies

The more complex a product and production process the more tightly integrated it is into the global economy. There are far more direct and indirect links in the supply-chains upon which they are dependent. Its production process is also dependent upon the inputs of more specialized suppliers with fewer substitutes. Let us consider the integrated circuit as our standard-bearer of technological complexity. Intel, who supply 90% of the processors in personal computers relies upon high-tech research-led companies providing sophisticated optical and metrology systems, control electronics, and a vast array of specialty chemicals. Those companies rely upon further sophisticated inputs with few substitutes. High-tech is less geographically mobile, relies upon very specialised staff and institutional knowledge, and generally will have a very large sunk cost in the operations and plant. Thus we can say that the more technologically advanced a process the greater risk it faces from supply-chain breakdown, just like the old rhyme:

> For want of a nail the shoe was lost.
>
> For want of a shoe the horse was lost.
>
> For want of a horse the rider was lost.
>
> For want of a rider the battle was lost.
>
> For want of a battle the kingdom was lost.
>
> And all for the want of a horseshoe nail.

Because of the complexity of chip manufacture no company has the knowledge to build an integrated circuit (IC) 'from the ground up', that is, by starting with the raw elements to build all the production and operation systems, and process inputs. Many companies have co-adapted and co-evolved together, so that the knowledge of fabrication and the tools of fabrication, and the tools of those tools is really an IC-ecosystem knowledge, which itself is co-dependent on the global economy.

References:

[i] Korowicz, D. *Things Fall Apart: Some thoughts on complexity, supply-chains, infrastructure, and collapse dynamics*. ASPO/ The Oil Drum 'Peak Summit', Perugia, Italy (2009). Gives an overview of some of the issues discussed here. At www.theoildrum.com/node/5633

[ii] Jack Straw BBC News. 4 November 2000.

[iii] Here we are referring to the 95% drop in the Baltic Dry Shipping Index. See www.globaleconomicanalysis.blogspot.com/2008/10/baltic-dry-shipping-collapses.html.

[iv] Beinhocker, E. *The Origin of Wealth: Evolution, Complexity, and the Radical Remaking of Economics*. Rh Business Books (2005).

[v] Blanning, T. *The Pursuit of Glory* (2007). Describes harvest failures and famines in Scotland and the north of England at the end of the 17th Century, in which some regions were saved the worst by canal networks. Page 53.

[vi] *State of the Nation: Defending Critical Infrastructure*. Institute of Civil Engineers (2009).

[vii] Tainter, J.A.(1988) *The Collapse of Complex Societies*. Cambridge Univ. Press.

[viii] Tainter J. (1996) *Complexity, Problem Solving, and Sustainable Societies*. Getting Down to Earth: Practical Applications of Ecological Economics. Island Press.

[ix] Jones, B. *The Burden of Knowledge and the Death of the Rennaissance Man: Is Innovation Getting Harder?* Review of Economic Studies 76(1) (2009)

[x] Gutowski T. *et. al. Thermodynamic Analysis of Resources Used in Manufacturing Processes*. Environ. Sci. Technol. 43(5) pp1584-1590 (2009).

[xi] Williams. E, Ayres. R.U, Heller. M. *The 1.7 kilogram Microchip: Energy and Material Use in the Production of Semiconductor Devices*. Environ. Sci. Technol. 36, 5504-5510.(2002)

[xii] De Decker, K. (2009) *The Monster Footprint of Digital Technology*. Low-tech Magazine July.