Economic Stimulus for Constraint

how we came to promote productivity & growth to slow resource depletion

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Scientist, HDS systems design science, 680 Ft. Washington Ave. New York NY 10040

w: **www.synapse9.com** e: **eco@synapse9.com** t: 212-795-4844

Abstract: It seems possible that something very fundamental goes wrong with complex human societies as they mature. Social networks of every kind may develop their own socially constructed realities from information that is ever more removed from real experience and observation. We won't argue that thesis here, essentially that the fundamental cause of societal breakdown for complex human societies is that they naturally lead to an information age, leaving every social network to form their own separate and increasingly detached reality. We'll just discuss the systems science needed to recapture the ability to observe change in the natural world given cases that give that appearance. We focus on the remarkably clear example of a modern day worldwide 'scientific' belief system and relied on social policy that departs entirely from simple direct observation, commonly discussed as "Jevons' Paradox". The world economy simply does not behave in the least like economic efficiency would reduce economic externalities. We'll discuss the basic evidence, how to read it closely to discover the systems of the natural world at work producing it, and a new paradigm of natural systems science that allows one to do original research based on direct observation of complex natural systems without reliance on a preceding social construct for how they work.

Beginning an inquiry from an unexplained but clear observation is somewhat like beginning with "the proof" and then searching for the theory it demonstrates, doing systems science as detective work. The goal is building a narrative from clearly answerable questions, letting "just the facts" speak for themselves as it develops, for suggesting other well founded and productive questions. A way to start such narratives is presented, starting from the conservation of energy, the natural boundary for a net-energy system and the auto-catalytic process by which it needs to develop.

KEYWORDS: efficiency effect, Jevons, whole systems, whole effects, costs, productivity, growth, language gaps, scientific methods, sustainability science, natural systems

The Curious Use of Stimulus for Constraint

how we came to promote productivity & growth to slow resource depletion

1. Introduction

By all counts the sustainability policy and science community should be in turmoil, due to strong evidence of steadily growing energy use and resource depletion despite parallel growth in efficiency savings, promoted for the reverse effect. The historic trends (Figure 1) show them regularly growing together. Curiously the subject does not even come up in the discussions of sustainability. Only rarely do articles appear in the popular press such as the New Yorker (Owen 2010), and the New York Times seems never to have had an article mentioning it.

What makes it a difficult subject to write about, and to follow, is it concerns how languages are themselves self-organized systems, that define their own subjects, and may be fooled by how other systems also define themselves independently, with quite different appearance inside and out. Just thinking about it calls for some way of imagining, not a "ghost in the machine", but an implied hidden "machine in the ghost", to imaging a world full of self-organized worlds, needing some common reference to communicate at all. For the world as a whole, it's very clear that both energy use and efficiency savings have been steadily growing, implying however it works there is some kind of machine behind the data doing that. The troubling question is whether a persistent belief in the opposite, to save the world's resources, is as deep rooted a cultural mistake as whatever causes successful complex human societies to be so short lived in the past (Tainter 1972). Here the view is that it might possibly, but it would then also be a way for us to see it. So this paper is a discussion of the kind of science needed to look and see.

2. The puzzle of environmental systems

Part of the question is why so many people wouldn't recognize increasing energy use along with energy savings as challenging their belief in the opposite, as lack of discussion about it attests. It appears to be that languages themselves are environmental systems, constructing their version of the world, by mutual agreement on the terms, a world unto themselves. Nature builds all kinds of systems much the same way, organized from inside, with a cellular design of parts that primarily relate to each other, like organisms as well as businesses too. How they work inside is hidden from view. As all systems develop their own internal organization for their own needs, languages may not include lots of terms for how the world's other systems work. It allows each language to develop a privately designed interior, with specialized languages perhaps not connecting to each other at all if people like. From a natural science view the acceleration of resource use with economic efficiency has been studied for over 125 years (Jevons 1885). Despite enormous economic importance and consequences given belief in the opposite, bridges have not emerged to connect popular opinion and the direct observations of science.

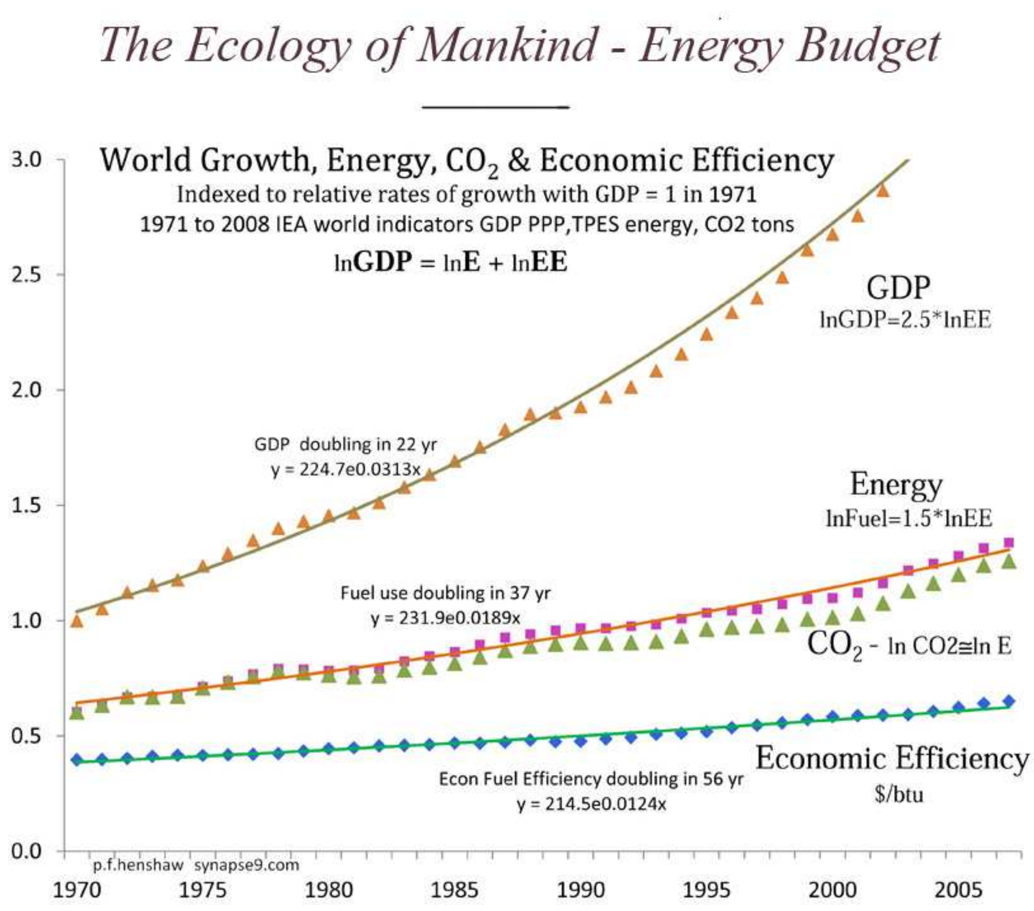


Figure 1 World GDP, Energy and Economic Efficiency. IEA data 1971-2007: GDP (2000$ PPP) indexed to 1971, Purchased Fuels (TPES in Quad btu's), Economic Efficiency ($/btu) scaled by relative growth rates to GDP

Considered as a problem of participatory intervention in nature, for people with different explanations based on different points of view, Gerald Midgley et al. (2007) offer a general way to evaluate the methods used. The problem arises frequently for determining the value of efforts taken by communities of stakeholders, each with different perceptions, to achieve systemic change in complex environments. The normal self-evaluation method relies on the assumptions of the participants, using measures of outcomes, the commitment of participants, the reputed value of the method used or the importance of the objective. Midgley's approach is to first make a functional assessment of how the participants are to be engagement in the learning process first, before considering outcomes. That helps determine if it could be effective as a working system in its own right first, in a rather simple way, not unlike a medical team goes through a check list of things that are easy to forget. It asks whether the method fits 1) the circumstance, 2)the ability of the people and 3)the purpose, i.e. whether the engagement process would work as functional system in itself. That evaluates the how the parts of the intervention work together before asking how they would work as a unit on the world.

Some of what one needs for learning how to change a complexly self-organized world, shared by people with different views, is a way to build bridges between their views. The hard part is having those bridges of communication also match natural relationships within the system that connects them. It's very easy to think what someone else says about a complex subject is what the listener assumes, but miss the real intent. The approach to that here is to use an intentional learning process, one of going back and forth between the different cultural views and the observable features of the working physical systems of the environment beyond our view. Meanings for the word "efficiency" seem to apply differently in different contexts, but assumed to be universal in this case, and so needing to be stretched and diversified to fit the natural form of the world as yet beyond view.

Both popular and professional languages develop as independent worldviews, in isolation from each other, and omit features of the environment hidden from their view. As a physical ecology, the world of knowledge is an "economy of ideas" composed of diverse kinds of independent cells with complementary roles, somewhat like the ecosystem of an organism or market economy. One thing it also has like other natural cellular systems is an identifiable boundary, and an energy budget, of some kind. So by Midgley's test, what you'd want for intervening in the circumstance of threatening contradictions between views of what efficiency does, is people prepared to explore the complementary roles of language cells with different explanations and the natural system beyond view, to discover meaningful options as a first response to the threat.

One of the first questions then is "whose language to use" if all languages are to be brought into question? Clearly it's a matter of both keeping that question in mind as people do have a hard time understanding things in any language but their own, and looking for the common language of the system being studied itself. How ideas are organized and physical systems are organized probably can't be the same. The two do both have something like "universal story lines", with language being developed around narratives and physical systems built around the assembly and decay of ways to use energy.

The basis for connecting natural systems with their energy budgets is a formal method for defining them as working units of the environment with natural physical boundaries enclosing their working parts. That making them individually identifiable physical subjects of science, called Systems Energy Assessment (Henshaw et al. 2011). That paper also exposes one of the most troubling aspects of using science to study environmental systems, the tendency of science to represent nature as a theory based on its information, instead of as whole networks of implicit parts needed to perform observed behavior. The trouble is that for business energy information it appears that nominally 80% of the energy uses required for businesses to operate don't leave traceable energy use records. Most of the costs of business are for paying people to use machines of one kind or another, to deliver the product of their "know how". Both what particular know-how is used, and the environmental cost of paying people to deliver it, are largely untraceable. The same seems to be true of other energetic systems in nature, that the animating parts leave no informative trace. The process of growth itself leaves no record except implicitly having occurred if there is a product, and the record of the process disappears. That natural gap in our information naturally exposes the scientific method to significant error in describing energetic systems, while also exposing some fascinating features of the natural world to be explored.

3. The method

The method used to explore the working design of environmental systems amounts to shifting ones attention back and forth between different natural features and ways of describing and accounting for energy use. That takes an exploratory approach, and time to digest, being as much an appreciation of missing information as it is finding reliable patterns in carefully collected data. How complex self-organized systems are designed is naturally internal and hidden from view, by their self-organization, so learning about what is hidden from view is about expanding your questions rather than narrowing down your answers.

One way to generate systemic questions is with by finding periods of growth or decay in either a theoretical model of a system or in the observed behavior of a physical subject. It represent periods of regular proportional change that prompt you to look for how the implicit system will change. As described in Models Learning Change(Henshaw 2010b), whether for growth or decay for an organism, an economy or a culture, such periods implicitly identify emergent phenomena, for a local network of energetic processes, identifiable their natural boundary, resource uses and products, that are implicitly temporary and trigger systemic change in themselves as they turn into something else, as is the general pattern if growth and decay. Things like the energetic processes of gestation in the womb are as hard to individually observe as the energetic processes of thought, but you can see the exterior forms, and sometimes deduce strong predictions that what appears to be a regular pattern will change, and be prompted to discover as much as you can about what and how.

Investors like George Soros (2011) regularly use this method, understanding that positive feedback identifies a system that will become unstable and be followed by negative feedback, that might original from some invisible source. It gives the impression of being clairvoyant, thought is far from it, only being observant about what to anticipate will happen for dynamic natural systems. Organizational development in both social and scientific cultures has many of the same characteristics, occurring within an observably bounded network, displaying accumulative progressions reflecting change throughout the community, with emergent features that start small and accumulatively bigger steps that, replaced by successively smaller ones, for the system as a whole. In an economy, innovation and adaptive change is occurring everywhere at the same time, but the emergence of each new product type or technology follows that pattern, being experimented with in an naturally emerging network of innovators and adapters.

The starting point of this line of investigation is often not a "problem", but a question, some evidence that nature is doing something rather simply for which there seems to be no cause. That might even be thought of as the original idea of science, looking for things nature does simply that we can turn into simple answers. In using evidently systemic behavior to help raise questions about the implicitly unstable working processes of nature doing it, is a bit unusual for the scientific method. As done here the aim is not to use physics to help write equations for complex energetic systems, but to help generate good questions allowing you to anticipate and explore them, as a "detective naturalist" would. In the broad family of systems sciences it falls more within the group of learning and practice methods than within the group of mathematical modeling methods (Henshaw 2010a).

4. The history of Jevons' Paradox debate

The discussion of how economic efficiency affects resource use is part of the larger discussion about the environmental effects of the economy, various sciences and policy communities. For the effect Jevons first noticed, like many of the other issues, active debate has come in flurries that die down with many questions left unresolved. As different approaches came up with different explanations, none have been really persuasive. Unable to be persuasive, conflicting views have needed to be treated as legitimate (Madlenera & Alcot 2009) finding a lack of definitive evidence or reasoning as an end of discussion.

Part of why the discussions have been unresolved is how professional languages treat their theory as their subject, and may not notice contradictory interpretations of the same physical thing. Economists have long considered efficiency in the use of factors of economic production to be synonymous with growth and expansion, for example (Abramovitz 1973). It's not quite clear how economists have also give the reverse advice to the environmental and policy communities wanting to use efficiency to reduce polluting resource use and depletion, that the wide spectrum of public policies for efficiency are publically advocated for. How the two groups simply "speak a different language" may come from economists considering unintended impacts as "externalities" to the economy, and not part of their theory, while. It gets confusing, if there is no common subject for people using the same terminology to refer to, agreeing on things the both understand quite differently. In any case, both groups seem to act as if whether local efficiency has directly additive effects is the pervasive assumption (Tainter, 2008) and is accepted without study, evidently seeming to fit fine with however each community has developed its own views. The association between efficiency and savings seems to have emerged as a new idea in the 1970's, to become quite popular (Google, 2011, Figure 2)

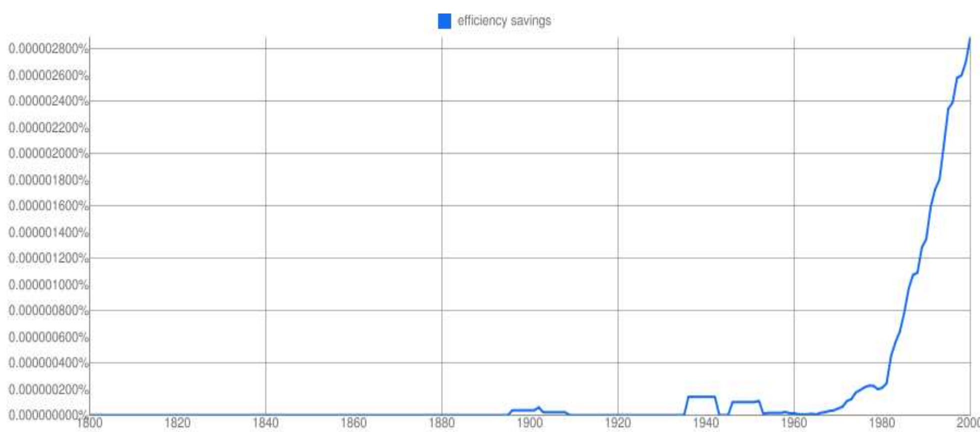


Figure 2

Use of "efficiency savings" in books scanned by Google from 1800 to 2000

Stanley Jevons' frame of reference was as a physical scientist with many interests, whose work on economics contributed considerably to the foundations of modern economics. His finding 125 years ago was that improving steam engine efficiency accelerated the depletion of England's coal reserves. He describing it as a general principle that efficiency stimulated growth and increased resource use (Jevons 1885). Similar conclusions by modern scientists, also considering the economy as a physical system, began appearing more recently, Brookes (1979), Khazzoom (1980,

1987) Greenhalgh (1990), Saunders (1992), Hall (2004, 2007), Alcott (2005), Herring (2006), Polimeni et al. (2008), Madlenera and Alcot (2009) and Henshaw (2009). Both the long standing view of one of the founders of economic science, Jeavons, and the numerous complaints of modern scientists who study economies as physical systems, have gone unmentioned and unexamined in the popular press and in policy debates. It is indeed a little mysterious.

The modern scientific debate over whether efficiency causes accumulative savings to reduce energy use or to stimulate growth began after Len Brooks (1979) raised the contradiction implied and J Khazzoom (1980, 1987) expanded on it. The tendency for the growth effect to dominate the savings effect was named the "Khazzoom-Brookes" postulate by Saunders (1984) initiating an occasionally vigorous debate summarized by Herring (1999). Whether local energy efficiency might reduce energy use locally, but increase energy use globally was vigorously disputed by environmentalists Michael Grubb (1990) and Amory Lovins (1988) among others, and with various flurries of discussion since, has continued to be advanced to become a world consensus sustainability policy, while being left resolved.

Imagining the economy

5. The common view for individuals - the economy's atoms

The main thing both sides could agree on seems to be what became called the "rebound effect". That's the idea that efficiency improvement won't have quite as big an effect as it might, by reducing energy demand with the effect of somewhat increasing supply and demand by others, a strictly linear effect with no growth multiplier (Herring & Cleveland 2008). As Herring says in that article to explain the indecisiveness "This debate is difficult to resolve, as it is with all macroeconomic arguments, since we cannot conduct such (economic) experiments on society". The curious assumption contained in that is that the question is one of theory and debate, and not observation. One may wish to have a theory to explain it, certainly, but the evidence of the historical record in Figure 1 itself is clear evidence that energy uses are growing at the same time as energy savings from efficiency.

There seem to be two good reasons for a natural bias toward believing that local efficiencies generally reduce resource use. For one, reducing resource use is often the immediate object and purpose of being more efficient. Projecting that effect to the whole economy is no more difficult than other ways people habitually project personal experiences to the rest of the world, though those are as often mistaken too. The second reason is that when used to improve methods in a work place, efficiencies are very profitable and rewarding. So, they both save resources on one hand and create more resources as a reward on the other. One might easily not think of questioning a sure formula for success like that. How it adds up for the whole system, however, is that one of those two effects is a constraint and the other a stimulus. Without a whole system view you might simply never have the "perverse" thought that the stimulus effect might dominate.

6. The typical view for business – The economy's cells

The approach here starts from the clear evidence of how the world economic system has behaved, by observation, to begin a scientific inquiry with physical evidence of an active environmental system lacking a theory.

Everyone generally benefits from being efficient, and using less to achieve the same things or get more done for the same work, both at home and in business. Businesses all concentrate effort and investment on improving their efficiency. We're quite aware of the personal benefits and rewards of efficiency, but tend not to directly see the way it gives businesses competitive advantages in the marketplace or makes workers able to do more with what they have to see how to conserve their effort and resource use in a smart way. Product designers and office managers look for the special combinations of design features that make products easier to make, cheaper to sell, and provide better service, to create popular products. It expands a business's market share while increasing earnings faster that costs, the heart of the economic growth process. Those market forces are visible to individuals when they are shopping and comparing the offerings available, or noticing trends in what is advertised.

At home if you insulate your home and reduce your fuel bill, consider what happens for the household as a business. It does reduce your energy consumption for heating or cooling. There's a local "rebound effect" when your reduced demand for fuel use encouraging others to buy more, but it's small (Herring &Cleveland 2008). The larger reverse effect comes from the profit from it, how being efficient gives you more money to spend. Profitable efficiencies give you profit, giving you added choices for what you can spend on, just like in a business, and if you invest the new income or free time in creating even more efficiencies, well that's a learning process feedback loop that can grow. How people use their increased incomes tends to be to do more of everything they want to do, and a big part of that is self-improvement. When people are young they may use extra money partly for investing in their careers or businesses. When they're older it may be investing in their children and living comfortably themselves. Historically, that ongoing generational learning process of self-improvement is what makes people eager to take part in the economic growth process.

Businesses and investors, of course, take the effort to learn how to use profits to create profits very seriously, always following a business plan to find the next "big account", "great design" or "killer app" that will drive their success another step, creating a flood of new wealth. The most powerful new ways to satisfy an old need with a new product for a lower price are inventions. They often could never have been done before, and involve some key innovation, like connecting a wheel to an axle, and so making something really marvelously efficient for the cost. It can release a flood of other things that can suddenly be done that couldn't before. It has the effect for the economy of removing a bottleneck from a channel, or creating a bridge where there none was before.

There are also environmental opportunities that have this same effect of creating new capabilities and unleashing a flood of money and resource uses that investors look for too. Some anecdotal examples help fill out the picture:

1. *Greater fuel efficiency lets you drive further (York, 2006) making commuting more affordable so people can live further apart and in bigger homes.*
2. *Computer designed architecture makes it easier to replicate designs so fewer people can build more buildings at less cost and further expand development.*
3. *Water saving appliances let developers build larger sub-divisions and drip irrigation creates larger farming communities in the desert (Fountain, 2008).*

Investors use their profits to look for those opportunities. While consumer preferences do drive market choices, it's the vision of investors in creating market offerings to lead the consumer that is more often in the lead in finding new ways to deliver value. In any case it's ultimately an investor decision what developments to fund, making that the direct steering mechanism for selecting the directions in which the economy as a whole will evolve, using its profits to send it in new directions.

The kinds of efficiencies investors as well as consumers don't seem to generally use or look for are ones that will cost them more or let them accomplish less, i.e. invest in efficiencies without a profit. It is more efficient for a farmer to rotate their crops, for example, reducing the outside non-renewable resources they will need. Their profit margins in an economy where everyone else is cutting corners may not allow them to do that, though. When economies actually do have to shrink due to foreign competition or financial failures, and need to shift from efficiencies for productivity to efficiencies for conservation, they may be forced to look for ways to live well with less income and actually reduce their level of consumption. But mostly, people seem to look for efficiencies that let them do more of something else, and use those increased choices with the intent to profit from them.

7. Connecting with the outside view – the whole

The most direct evidence that improving efficiency throughout the economy is connected to our steadily growing energy use is Figure 1. It shows 35 years of inflation adjusted IEA world GDP data corrected for national differences in purchasing power , total purchased Energy use, and the ratio of GDP generated for the energy use (GDP/Energy), the Economic Efficiency, along with the CO_2 produced by economic energy use, growing at the same pace as energy use. The four curves move together, as if part of one process. Each changes in fairly smooth constant proportion to each other. These graphs are each indexed, setting the scale of GDP to 1.0 in 1971, and scaling the others in proportion to their growth rates, so Energy use and CO_2 is indexed to .60 in 1971 and Economic Efficiency to .40 in 1971. The relation between the growth rates of GDP and Energy use to Economic Efficiency are shown as linear equations. Energy use grew 1.5 times as fast, and GDP 2.5 times as fast. Those rates correspond to world GDP steady doubling every 22 years, energy use every 37 years, and efficiency every 56 years. That GDP grows faster than Energy use shows that the economy was finding efficiencies that let it do more with less, at a rate equal to the increasing Energy Efficiency, doubling every 56 years. That the Energy use is growing faster than the Economic Efficiency implies that its stimulus effect for expanding the economy is stronger than its conservation effect.

The inverse of the rising Economic Efficiency (EE), in $/btu, is the declining Energy Intensity (EI), in btu/$ (curve not shown). That is a measure of the conservation effect of efficiency improvement by itself, reducing the energy needed to make a dollar of GDP. GDP increases by 2.5 times the rate of increasing EE, and Energy use only 1.5 times.

$$\text{GDP increases: } dGDP = 2.5\ dEE \qquad (1)$$

$$\text{and energy use less: } dE = 1.5 dEE \qquad (2)$$

$$\text{So the difference in change rates: } dGDP - dE = (2.5\text{-}1.5)\ EE = 1.0EE \qquad (3)$$

So an improvement in EE (of say 10%) will result in 2.5 times that amount of GDP increase (and so 25%) and 1.5 times the energy use (or 15%). So instead of reducing energy use 10% energy use increases 15% = 25% difference. So the conservation effect is the 10% and the stimulus effect the 25%, 2.5 times the size.

$$\text{Conservation factor} = 1.0\text{, is economic Stimulus} = 2.5 \qquad (4)$$

$$\text{for net energy use stimulus} = 1.5 \qquad (5)$$

These are simply direct implications of the growth rates, and the task is to discover what they mean. It does not explain all the questions you would have, but just says that however people are learning to improve their lives the stimulus effect of the efficiency gains is 2.5 times the conservation effect.

8. *Reading the curves*

Growth & development curves are a direct reflection of the complex process taking place, but may not prompt any image of what is really happening, Why it's hard to see what's happening… is that what's happening is located inside the system that is evolving. So thinking of them as learning curves for that system, rather than size curves, shifts your attention from an outside to an inside view. It helps transform the evidence into a rich question that, with a little effort, will help you build an image of what's happening that will begin to connect to your personal awareness as being part of it. What really tells you that the curves are evidence of a complex system is how very simply the complex world of people they describe appears to behave as a whole. As history curves of accumulative change for one system, each one shows the effect of small changes in how things work becoming the foundation for successively larger changes, for money, for energy/CO2, and for the efficiency/productivity ratio that implicitly represents the development of organization for turning energy into money. In the current phase of development each curve displays steps of change building up fairly regularly to be followed by bigger steps, *in near constant proportion* to prior ones. That constant rate of proportional change indicates that there is an established system for changing the system. You could see the curves as a stop action movie, like for "sky cam" shots of a construction site, turning the complex animation of the whole into a movie.

It's also the simplicity of the curves that makes them seem easy to explain, and for that to stifle our questions about the remarkably dramatic processes taking place to produce them. It might help you take notice and try to see now to connect them with your experience to understand that economic growth curves are actually the tell-tale signs of the creation of new forms of human ecology erupting all around you. It's one of the most obvious features of nature, that growth is how things begin, but somehow it's quite uncommon for people to associate outside evidence of growth with what is happening inside. If our minds were to appreciate what growth curves seem to actually represent taking place in nature, the feeling we'd get tracing our eyes along a growth curve would be first a quiet and then increasingly intense sense of excitement of anticipation. Growth processes of one kind or another appear to be at the heart of how things in nature begin, and making change "eventful". It's not just economies, ecologies and organisms that begin with periods of increasingly rapid invention. It's the source of the eventfulness of pop culture crazes, cloud bursts and lightning bolts too, as well as the eventfulness of gestation and birth, and the eventful waves of new technology that wait to occur till someone has assembled their critical elements.

The growth phenomenon as the emergence of new form even appears to fit the description of the rapid "inflation period" from which the universe itself apparently emerged as well, the beginning of time that physicists describe as occurring in some small fraction of a second. That seeming contradiction points to another general characteristic and particular fascination with growth processes. That they appear to start by inventing themselves, from some bare seed of the pattern that eventually develops that can never be found. As for an organism that develops from a single fertilized cell, both the single cell and the event of its fertilization occur at a scale so small it is generally impossible to identify or confirm, but implicitly required.

It may actually be the smoothness of the curves that tells the most about what is going on inside the system. It shows "liquidity" as the system efficiently allocates resources and distributes stresses so that it can operate as a whole. Liquidity in the behavior of systems shows that the parts are responsive to each other. For learning systems that means they are actively learning how to make the best use of each other strengths and cover each other's weaknesses, just how markets work when they work as they are supposed to. It indicates resources and talents are being steadily matched and reallocated in response to emerging differences in supply and productivity.

That markets intended to maximize individual profit margins would have this effect is surprising, but only in that it's what's supposed to happen, and seems to. If you look at these same ratios for different companies or different countries you don't find them all the same at all. You only see it for the system as a whole. How the data is collected is critical too, of course. This evidence of the "invisible hand" of the marketplace of how vastly complex systems can behave as a whole is of how the separate parts remain in constant communication. I also call that property "ESP", for "Equal Stress Principle" to suggest the internal balancing that distributes needs and opportunities of all the parts as a form of constant communication. It's also referred to as "homeostasis", referring to the tendency of systems to "remember" their home state adaptively return to it.

In a recent study of national economic accounts, GDP, energy use and efficiency for each vary in scale and rates of change widely (Hall, 2007; Gupta, 2009). Considering that the global data is so smooth the apparent reason for irregularity in national accounts is that it displays how the world market mechanism is being efficient in allocating its resources to equalize imbalances and so optimize the growth of the whole. How independent parts coordinate to move together in complementary ways works in practice is a little like walking, with the step of each foot leaves an opening for the other. That kind of coordination is another hallmark of systems generally, one of the things it means to be "part of a system" and relying on the responsiveness of the other parts.

9. The fine detail

The fine detail in the growth curves (Figure 3) shows alternating phases of speeding up and slowing down in economies that we are all personally familiar with. It is likely that short periods of acceleration and deceleration in global rates of growth correspond in some way to widespread recessions and booms. It is beyond the scope of this paper to investigate that, but the details do speak of how the whole system works. The changing rates of efficiency improvement can be seen to be 180° out of phase with the periods of changing rates of energy use. The periods of rapid efficiency improvement correspond to less rapid increase in energy use. Each trend moves by what you might call leaps and pauses, going back and forth as if taking alternating steps in one process, further confirming that they are both part of the same process.

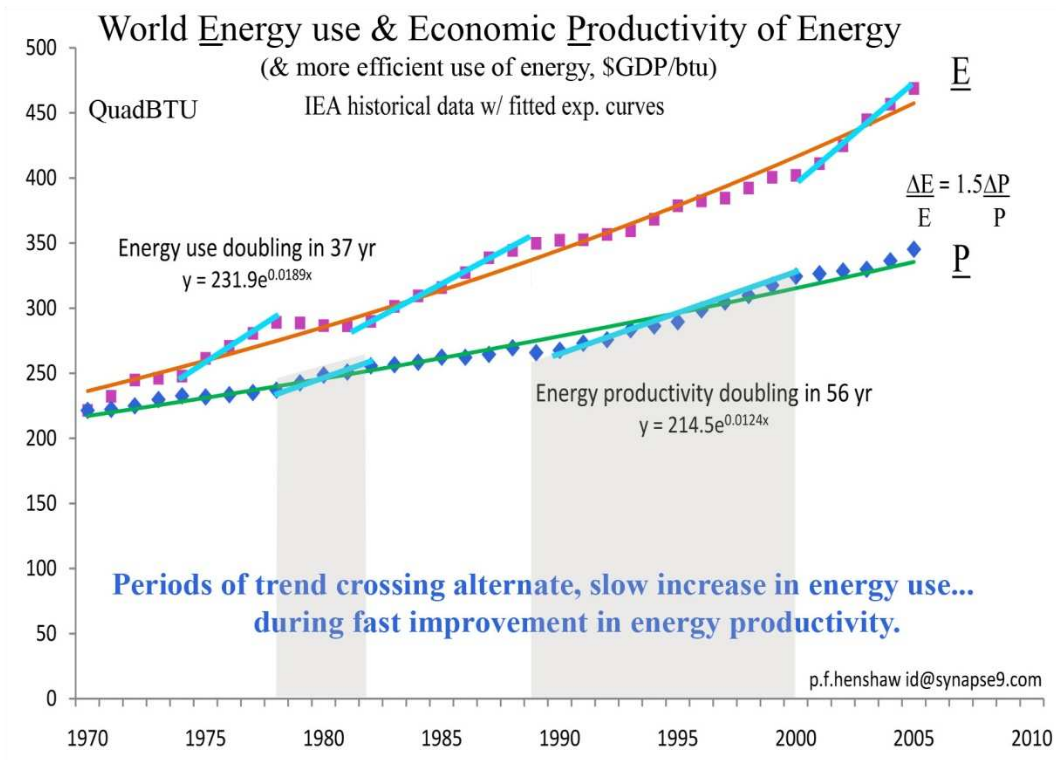


Figure 3

Alternating periods of faster energy use and productivity increase. Data as shown in Figure 1, but indexed to 1971 value of Energy Use, and "Economic Efficiency" data called "Energy Productivity" ($/btu)

The pattern would be quite logical if pauses in growth an rapid efficiency improvement were times when inefficient parts of the economy were being discarded, as more efficient one were being introduces, and that occurring in waves. A "learning cycle" of taking a new idea to its limit, to then pause to improve on them, would describe growth as repeatedly pausing to reorganize and retool for faster growth. One could see the alternating expanding and reorganizing process either as suggesting there are no limits to growth, or that learning is constantly running into them, and needing to "rethink" as it changes direction. It adds to the impression of the economy itself as a learning system, with systematic learning processes, to see the close coordination of its learning parts.

So in summary, this gives a nice image of the economy "inching along" as it explores its changing world looking for better and better ways to do things. That seems to be the reason the stimulus effect of efficiency is greater than the conservation effect.

We focus our time and effort on learning to do things more efficiently to improve our lives. People appear to be so unaware of how it happens that their efficiency improvement locally is done to leverage more resource uses elsewhere, the profitability of having the invisible effect is enough to convince them it has the opposite effect.

Section I. Theory and discussion

10. Budget boundaries for natural systems

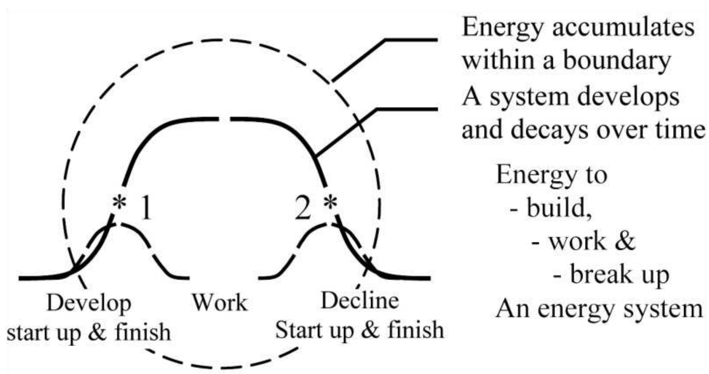
Energy budgets are a way to use the universally connected uses of energy to connect the disconnected cultural ideologies and languages that arise from our many differing views. Businesses regularly use that approach with monetary budgets too. In a business it helps connect the rather differing world views of all their many departments, design, marketing, public relations, production, etc. It helps the parts coordinate their essential contributions to see that one monetary dimension of the effect any choice makes on the prosperity of the whole, treating money as information. Energy budgets serve the same combination of purposes, defining limits and helping inform the parts how to coordinate. Budgets account for a conserved measure of exchange, something not created or destroyed in being exchanged, and a boundary across which the information or material is passed "in" or "out". Money isn't exchanged with nature, but is used as information about energy use choices, for directing and communicating the physical processes of the economy. So energy can be accounted as entering and leaving the economy by its connection to the choices made to do use it, and energy budgets interpreted as the physical meaning of financial decisions.

Budgets show what's inside the accounting boundary as a result of what's crossing the boundary, raising questions about what's available outside and happening either inside or out. The arithmetic is about the same for a household or the global economy, if you are accounting for a conserved measure. You need a closed boundary to account for, a way to search within the boundary to measure the "total" and to know what's crossing the boundary. People making economic policy don't generally use conserved measures or have ways to define boundaries for the physical systems their policies are meant to effect, only agreements to do so. So there is no real way to measure cause and effect. Measures of economic variables often even change units from one measurement to the next, in a chain, as when measuring the size of things as %'s of change. The units of measure defined as a ratio of change over time effectively reset the physical unit of measure to 1 with each and every measurement. It's not a solid basis for budget accounting.

Details of how to define what energy uses to include in the budget for a business as a whole physical system are discussed in "System Energy Assessment" (Henshaw, et al. 2011). Details of how to examine irreversible processes of developmental change to assess time budgets for development processes are discussed in "Models Learning Change" (Henshaw 2010b). The discussion here has focused on how connecting inside and outside views of a system helps you learn about them, considering Figure 1 record of the economy's total energy use and wealth production as a stand-in for a global money/energy budget. Looking back and forth between inside and outside views made possible by the budget lets you study how the observed behaviors and views might be connected.

Because complex systems are continually changing how they work all the time, by one or another kind of accumulative processes, they really only exist as processes of accumulative change. So the budgets that connect inside and outside behaviors are development budgets, and raise questions about how the accumulative effects of small scale processes change large scale processes as the environments of the large scale processes create opportunity or constraints for the small scale. That idea is also embodied in the principle that "it takes a process to change a process". It can be observed in how any energy using process itself requires an energy using process to build it. For a simple example, it takes the energy use of picking up an apple (one process) to then begin the energy using process of eating an apple. That basic sequence is commony observable and identifies emerging complex systems of energy use to do the work, for which individual boundaries could be determined empirically, and examined for how they satisfy the explanatory principles of energy conservation and thermodynamics (Henshaw 2010c). How to defining such a budget for the energy using processes needed to build and operate a business as a whole system is discussed for the energy cost of producing wind energy in a recent special issue of Sustainability for EROI (Henshaw, et al. 2011).

The energy use narrative of development & learning curves helps simplify the task of understanding how small and large scale processes connect. It provides a simple outside view that includes numerous references to inside processes, to help connect them and have a larger picture view to return to after exploring small scale behaviors. As a small scale process works to build a larger one, like the building of a new factory needed to start a new business operation, small scale temporary energy uses are always needed to build larger scale and longer term ones. Connecting that chain of processes in importantly what successive accumulation during the growth of a system involves, the question raised when considering a development curve as a learning curve. It also means you can locate these developmental chains of succession in complex systems from their growth curves (Figure 4a).



4a - Develop - 4b - Decline

Figure 4

A system as an event in time for a cell of energy processes, following a natural succession. Life cycle phases match periods of beginning and ending. Inflection points (1, 2) in each "S" curve mark new direction of quantitative change and new kind of organizational change.

Another very useful property of this pattern successions is that observing any one period of regular proportional change typically implies the others have or will occur too, and so pointing general narrative of emerging processes change for energy using systems from any part. The individual phases of developmental change at each scale are so instrumental in the physical assembly operation and disassembly of complex system, they are like the “beads” on the chains of different scales of development processes seeming to be what hold complex systems together. Each scale of developmental change and each period of regular proportional change identifies accumulative organizational change, and implicitly an energy system building on its own foundations using smaller scale energy using processes to do so. In large part they are specifically identifiable with observation and have the role of building the continuities of the emerging systems observed.

Almost any kind of small process begins with some still smaller but still observable “seed process” that gets the larger process going. Either lightning or a spark needs an ionization cascade preceding it, or the current can’t flow, for example. That exposes how very frequently and smoothly nature somehow solves the “chicken and egg” problem. Not every larger process serves as either a seed for still larger ones or a producer of other seeds, of course. This is not a model of rules, but one of exploratory questions. Most systems eventually disassemble as well, with regular proportional change during periods of their decline, and come to a final end in a cascade of process not like but symmetric to the cascade from which the system began. Ending sequences are a chain of scales of organizational dysfunction that can be rewardingly studied too (Figure 4b).

The dotted circle in Figure 4 is to represent the boundary of the as a “cell” of self-organization from a “process view” of the system as it would exist at any given time. It very much simplifies the concept to maintain separate “process views” and their boundaries with “development views” of its life cycle and connections to larger and smaller scale systems. Each then needs not be explicitly complicated to include the features of the other. From a process view it’s the internalized mechanisms found that do or do not successfully identify a discrete boundary for the system as a network “cell” and whole working unit of organization. The periods of regular proportional change imply the existence of some circular network of processes building on itself and an implicit boundary, but you’d need a way to define it to locate the system physically and budget its energy uses.

This is only one of many uses of narratives for organizing complex systems science research and practice. Narratives are a necessity for organizing observations and as "vague theory" treated as a story line, and prompt further learning. Narratives benefit from being objective in connecting "just the facts" as a precedent to studying how to creatively fit them together, and then remaining clear about the difference (Allen et al. 2001). What is presented here is a "just the facts" approach to identifying and studying individual complex energy systems. Tracing their energy flows is a little like "follow the money" to identify the chains of organization that animate and connect them, and for economies,… it turns out to be a lot like "follow the money". The key finding of using systems energy assessment (Henshaw et al. 2011) is that so much of the energy use for delivering products comes from paying people for their labor throughout the business chains that do it, energy use is directly proportional to spending.

11. Real budgets for the business of nature

Figure 5 is a simple process diagram, like an organism with a throughput channel along which gathered resources are passed and transformed. It diagrammatically shows the chain of essential interior feedbacks for it to build itself and operate as an energy using system. Equations 6 & 7 show a simple budget for the energy uses the developing system needs to take across its boundary from its environment. For simplicity all feedbacks with the environment and outputs to it are not shown. So the various accumulating products and by-products are included as part of the total taken from the environment. The seed energy (Eseed) starts the process of self-investment (Einv) by which the system uses energy from the environment to produce more energy for building itself. That growing surplus includes (Eret + Edevl) , for both combine with Einv to develop the system and to develop the products of the system, as well as (Eop + Eprod) for maintaining operations and production, plus (Eloss + Enet) for the wastes and maintaining net energy surpluses at every step. Over time the energy serving all 8 roles would develop and decay just as the system as whole does.

This chain of processes and energy uses are implied for all energy using systems, though we don't usually look for them and sometimes can't find them when we do.

Their budgets need to add up, for the parts to have the energy they need to operate, is the key. The gaps in your chain of information about where it comes from points to processes that can be studied to fill in the missing data by tracing connected energy uses. That allows one to discover how events begin, operate and end by an exploratory process, starting only information that you don't know how they do. These questions about energy use over time are things you can know before knowing how any part works. They are largely necessities implied for all energy systems needing to change organizational scales to develop and maintain energy conservation doing it (Henshaw, 2010b).

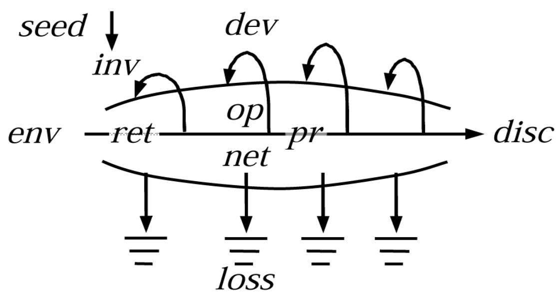


Figure 5

Simplified "body plan" diagram for the development process. The system scavenges its environment collecting, transforming and distributing the useful resources it finds.

$$Ein = Eseed + Einv + (Eret + Edev) + (Eop + Eprod) + (Eloss + Enet) \quad (6)$$

$$Eseed > \alpha, \quad Eloss > \gamma, \quad Enet > \rho, \quad \alpha,\gamma,\rho > 0 \quad (7)$$

$$Eret / Einv > 1 * \varepsilon, \quad \varepsilon > 0 \quad \text{(EROI)} \quad (8)$$

How this can used to begin a complete energy budget for our economy as a whole is with understanding the energy cost for producing energy, EROI (Equation 7). The declining return on energy invested to produce energy reflects declining energy resources, complexity in obtaining them and competition for them. Following present trends it seems quite possible the energy available on earth will not continue to be cheap enough to run large parts of the developed complex economies that were designed for running on cheap energy. Studieson that question were begun by Charles Hall with his work on EROI, showing that the returns for using energy to produce fossil fuels increased from the 1920's to the 1980's and began a fairly sharp decline since (Gagnon & Hall 2009). One of Hall's other recent papers discusses the EROI threshold above breakeven ($1 * \varepsilon$, $\varepsilon > 0$) that would be needed to maintain a complex society built for using lots of cheap energy (Hall et al., 2009). Both paper are being updated in the special issue on EROI the System Energy Assessment paper is part of (Henshaw 2011).

There is good evidence, for example that this phenomenon contributed to the dramatic commodities price spiral starting in 2003 leading up to the 2008 financial collapse. What's important is the concept that EROI threshold, **ε,** is not a single value term, and that different sectors of a complex system may have different sustainability thresholds, with layer by layer of the economy vulnerable is EROI persistently declines. For the five years prior to the 2008 economic collapse there was an exceptionally high demand for oil and inadequate supplies that contributed to unprecedented systemically rising prices at ~25% per year. Other than natural causes for supply persistently lagging demand seem to not to have been found, the cost inflation clearly stretched many financial budgets to razor thin margins leading up to the unraveling of the financial system. The energy companies were not meeting demand as usual (Hamilton, 2009) and the normal market mechanism of price regulation did not operate. That scenario is what a growth economy accustomed to growing energy use at decreasing cost would be expected to do if real energy costs began to suddenly rise, as they have. It's the expected natural response of a growth economy, as a physical system, to the depletion of oil reserves and increasing costs of exploration discussed as "peak oil". Inflexible supply and persistently rising price have the rebound effect of driving the weaker parts of the economy out of business, making food resources unavailable to low income communities and low productivity jobs disappear in high income communities, until demand drops to relieve the strain instead of stimulating increasing supply. This is a very young science, but raises seemingly rather pointed and appropriate new questions.

12. Discussion

The evidence of coordinated worldwide effort to redouble efforts to increase economic productivity in the name of conserving resources appears to result in rapidly increasing resource use as it always did before, but in the name of slowing it down. It displays a quite remarkable level of popular and professional confusion. Perhaps it will add to the confusion to discuss it, absent some common language in which to discuss it.

People are extremely sensitive to having their errors exposed and being embarrassed by their faults. It's a realistic fear given how often finding fault is used to discredit people with the intent of taking advantage and harming their interests. It's possibly one of the reasons people don't ask questions that might embarrass them, and are fearful of questioning what everyone else seems to believe. Instead of embarrassing people or challenging their ideologies it would be very preferable to lead people with their curiosity instead.

The current scientific effort to learn how to respond to climate change seems to be being disrupted by being socially discredited. There was a prior case of the same thing, when the effort in the 1970's to discuss scientific studies of the limits to economic growth (Meadows et al. 1972) was socially discredited and removed from the public discussion, even as the constraints of environmental impacts became ever more severe. The mental blocks that society displays in that way are not the private domain of non-scientists is the interesting thing. History is full of examples of scientists themselves becoming attached to their ideologies and failing to adapt to new insights, or waging strenuous battles to reject seemingly inevitable new ideas. T.S. Kuhn observed that successions of scientific paradigms are both very natural, as new languages of description needed for new insights into a complex world, and also often occur by new generations replacing old, rather than by scientists learning from discoveries in their own fields, in saying:

"[it's]…what scientists never do when presented with even severe and prolonged anomalies". "They may begin to lose faith and then consider alternatives, but they do not renounce the paradigm that led them into crisis." p. 77 (Kuhn 1962)

So it appears natural for scientists, "knowledge workers" to respond to new insights with denial not unlike less sophisticated communities that are today dismissive of climate change. So we all have learning blocks it seems, and ideological divides that keep our languages from keeping up with change.

This evidence of vigorous widespread resistance to new thinking seems particularly ironic, in addition to being unfortunate. We live in a world driven to create ever more revolutionary new ways of using the earth and living our lives. The curves in Figure 1 illustrate how that is built into our whole growth paradigm, using every step to build a bigger step. In a gradually progressing way it naturally demands ever greater adaptation from individuals and society as old ways are displaced buy new ones of ever larger scale and increasingly complexity. The question is whether that itself could sometimes be a cause of resistance to new thinking, blinding society just at the time it needs to learn how to see better? At the least it seems inconsiderate of our long standing natural handicap of becoming stuck on old ways of thinking.

My hypothesis, for where that resistance comes from, is that once people think they have an explanation for things they often lose their curiosity about the subject then explained, and lose contact with the questions they had beforehand. Becoming unaware of the remaining open questions, or changing realities, would keep you from learning more when it's needed. If one thinks of things as explained, the greatest loss is of the kind of playful thinking one automatically calls upon when simply observing something new, just learning how to recognize them. If what you see in the world reminds you of your own answers, and poses no questions to you, playfully thinking about them can't happen.

What seems to partly work to help people recover that ability for original learning is just to "suspend theory" for minute, or for an hour, with the confidence that any "appalling doubts" raised in the period can be completely discarded. It's just a device for looking at things with fresh eyes, but one that seems to work. Another is to choose to look for "patterns that are out of place", to be curious about, to open the world of natural processes that operate by themselves and not by our theory. Noticing cognitive dissonances is another creative way to find things that are organized differently from how you yourself would explain them. With only a small trickle of new questions as a result of noticing the world beyond your explanations it really fosters new learning.

One “pattern out of place” worth suspending theory for an hour or two is how this complex life-like creative organization of natural systems is not yet a subject of the other sciences. Physics as well as economics describes all of nature as following equations, and have lots of equations for growth and growth systems. They describe growth as following fixed rules, though, rather than as a process of change. Equations don’t change. They are themselves not eventful in their behavior, but completely predefined and quite unlike the highly eventful processes commonly observed in the eruptions of organizational development that natural growth systems display. It’s not that equations have not proved amazingly useful for the unchanging properties of the world and the systems around us. It’s that the sciences still generally relies on them for things they are not so useful for too.

Equations have excellent applications for many complex phenomena, such as for chemical processes or the weather. Their behaviors that concern us are apparently not greatly misrepresented by being treating them as deterministic and following constant rules. What equations seem most ineffective in representing are circumstances in which opportunistic processes have a significant role, such as where growth systems dominate, directions of development follow locally evolving processes of invention and societies of learning organisms actively explore their environment. The rule learning systems follow is that they’ll change their rules, as they invent new ways to respond to their changing opportunities. That’s a rule that poses valid questions, that are not valid for any equation. That’s at least what people do, and ecologies seem to as well, and various other forms of spontaneously developing organization in the relationships between living things. Those are the parts of nature best not reduced to explanation, but watched for what they’ll do. If science used equations for observing economies with fixed equations, though, where they don’t apply, as exhibited by the worldwide use of economic stimulus for resource use constraint, while striving for limitless growth using rules of thumb for money unconnected the physical processes it requires. It appears to be another case of old explanations suppressing curiosity about our ever changing world.

The oddest evidence of that seems to be in the etymology of the word "physics" itself. The words "physics" and "physical" come from the Greek word for growth (Webster 1913), and from "natural production" by growth as the basis for the Greek word for "knowledge of nature". Growth, considered as a consequence of fixed universal laws is one of the subjects of both conventional and non-linear thermodynamics. Considering growth as a process of change, though, is not a current subject of physics. It would appear that physics no longer studies the original subject of physics because it's one subject that equations can't effectively represent, and the search to find equations for everything eliminated people's curiosity about it.

The knowledge of nature needed to solve our growth crisis seems to be one of those things rather hidden in sight, and not studied for lack of curiosity about it. The most curious thing about growth systems, that some become sustainable systems, is how they mysteriously use "ESP" (an equal stress principle) to end their own growth, without prompting. It's frequently unclear how, but those kinds of systems do evidently change from investing in expanding scale to improving the quality of their design and relationships, in mid-stream, as in figure 4a. One attractive way to phrase the difference, stating a key idea form a proposal by Fritjof Capra and Hazel Henderson (2009), is to call it "the natural succession from quantitative to qualitative growth". It appears that growth systems that are actually self-interested stop using their development resources for growth before it becomes unprofitable. For how that natural succession works the real teacher is nature and the growth systems we can observe doing it. For us it might be a matter of switching from being efficiently productive to putting our time money and effort into being efficiently observant and communicative.

The ancient problem for economies gas been with a long succession of complex human societies thriving and then dying just as quickly (Tainter 1988), like short lived organisms in having both quick begging and ends. What humans would want from their economies would be more on the order of emulating the long lived ecologies. For an ecology ending quantitative growth does not end its creative development in the least. Its variety of genetic diversity continues to evolve as new forms appear and proliferate, continually. As a relatively steady state it only means that each new form gets a reasonably long ride, as it were. So stabilizing our development resources, at a sustainable level where they can remain profitable, to support continual exploration of new economic forms, seems to be what the shift to qualitative development would be for us.

13. Conclusion

As much sense as some of this seems to make, it's still hard to avoid wondering about the appearance that it's the profitability of using efficiency to increase economic production that clouds the reasoning of the very groups of people who expressly care the most about reducing our impacts on the earth. There are lots of reasons for it but no good explanation if those who seem to be the most ethical on earth are subject to being distracted by money. So I don't think it's quite clear why the people promoting environmental restraint ignore the rather clear growing impacts coming directly from everyone using efficiencies to enhance their productivity to increase their consumption. That our employers are constantly prodding us to be more efficient, and promptly pay more so we can consume more for helping them expand their businesses, has to be fairly visible to literally everyone. It's not clear how something that obvious goes unnoticed, undiscussed and unstudied by people promoting policies for the world working the opposite way. It certainly doesn't seem to be insincerity or lack of intelligence. I have to just fall back on the common element, our cultural habit of believing old explanations to the point of losing the ability to check. What seems clear, though, is that as much as we pride ourselves on being free thinking, we're clearly not thinking freely.

The original question of science "I wonder how that works?" was quite open ended. It didn't always produce results, but it sometimes did. People asking it were often puzzled about the complex things nature does with remarkable simplicity, like growth, seeing patterns and expecting them to continue unless something changed. In this discussion we started with evidence of a remarkably simple behavior of the entire world economy. It happens to contradict a set of cultural expectations and global economic policies, in a way that lots of people have noticed but have been unable to communicate. We looked at how different communities of scientists using different languages understood that efficiency is a primary force of economic productivity and growth. One group seemingly didn't see the need to mention the large policy implications, and the other mentioned it but went unnoticed. We looked at how to think of growth as a process of organizational learning, and to understand why natural complex systems look different from inside and outside. We looked at how those and other differences in viewpoint for complex organization may require separate languages of description and result in people having different explanatory languages for the same things and remain unaware of the conflicts. We looked at how to consider energy as a kind of common language to use in tracing the connections between the different views of energy systems, and how they can be considered as the physical implications of management decisions using money.

Science isn't about being confident of your explanations. It's about having explanations you can be confident in. After "I wonder how that works?" comes "What can I know for sure when I realize I just don't know much?", perhaps the gold standard question of science. Finding answerable questions is a slower process than finding answers, but can accumulate. It also benefits from reasking old questions others thought had been answered. The most creative work of real science seems to be in looking for those truly answerable questions, not looking for the best available answers for unexamined questions.

True exploration is not something that runs on a schedule, but needs different kinds of focus and reflection and so can't really be hurried. It also seems clear that the time for making bad choices about the earth has evidently run out. It's probably safe to say we should make some of the obvious ones, like not trusting explanations that are obviously unsupported by simple observation. To somehow snatch some kind of victory from defeat in our losing war with nature seems to require pausing to think. We need a true path through the numerous upwelling environmental social and economic crises that surround us. It's embarrassing, but also in a way a nice surprise that it looks like it's not so much our values that have been misleading us, but our languages. If they are so out of touch with the physical world we live in, then we need to reconnect them.

It's surely upsetting to recognize that our "best laid plans and purposes" can drift so far out of alignment, but still also good to notice. Being quietly curious about small things that others have kept skipping over is another part of how this group of problems was discovered. If you're just open to questioning, for example, it can seem unlikely the rules people have for things are what the universe follows, particularly if it's apparent most people think it's different ones and generally don't understand each other's. But still, it also makes something we don't yet know about nature the more trustworthy for it. There's no way to tell what we'd discover, looking for true purposes like that. We'd just have to look at where we are, and see what there is to find. It could really be worth the trouble. If the world is actually made of something you might call a physical reality, with all these changing complexly organized forms working by themselves in a way that our explanations are no match for, and we overlooked it somehow, exploring it seems likely to expose new worlds of opportunity. In learning to better understand the nature of things, perhaps we'll also find some of the bridges to better understanding each other we have long been wanting to find.

14. Acknowledgments &

Developing new languages for our experience of the natural world is shared journey, taking lots of contributions from many kinds of people and places, people shocking you into recognizing new things and occasionally rewarding you for doing so. I've been surrounded by challenging thinkers for a long time,

15. Bio

Philip F. Henshaw's innovative systems science work goes back to 1970's, studying the eruptions of organizational development in heat transfer system in building micro-climates and their many emergent changes of state. A method of observing their phases of change evolved into a general method for using physics principles as diagnostic tools, to investigating any kind or scale of complex natural system that develops by growth. Such systems can be associated with the development of a cell of internal organization for a net-energy system, identified as an individual from the natural boundary of its working parts (Henshaw 2011). That allows those natural systems to be defined as common subjects for sciences with differing languages and purposes, such as physics and economics. It might not lead to equations, but helps identify natural features and energy budgets for study by different sciences for consideration from their independent points of view. The author lives in New York City. He has a B.S in physics from St. Lawrence University, an MFA in environmental design from the Univ. of Pennsylvania, and a substantial accumulated body of original research and publication. He does consulting, research and writing as *HDS systems design science.*

16. References (44)

Abramovitz, M., David, P. A. (1973). Reinterpreting Economic Growth: Parables and Realities, The American Economic Review, ISSN 00028282, 63(2), pp 428-439. http://www.jstor.org/stable/1817106

Alcott B. (2005). Jevons' paradox, Ecological Economics, ISSN 0921-8009. 54(1), pp 9-21.

Allen, T.F.H., Tainter, J.A., Pires, C., Hoekstra, T.W. (2001) Dragtnet Ecology – "Just the facts, Ma'am": The Privilege of Science in a Postmodern World, Bio Science, ISSN 1023-8654, Jun 2006, 61(6).

Annila, A., Salthe, S.N. (2009). Economies evolve by energy dispersal. Entropy, ISSN 1099-4300, 11: 606-633.

Brookes, L. (1979). A Low Energy Strategy for the UK by G. Leach et al: a Review and Reply, Atom, No. 269, March pp 3-8.

Capra, F., Henderson, H. (2009). Qualitative Growth - A conceptual framework for finding solutions to our current crisis that are economically sound, ecologically sustainable, and socially just, *Inst. of Chartered Accountants*, England & Wales. http://www.fritjofcapra.net/articles100709.html

Fountain H. (2008). Drip irrigation may not save water, analysis finds, NY Times, ISSN 0362–4331, 11/17/08. http://www.nytimes.com/2008/11/18/science/18obwater.html?ref=science

Georgescu-Roegen, N. (1999). The Entropy Law and the Economic Process, ISBN 1 58348 6003, Harvard University Press: Cambridge, MA, USA.

Google (2011) "efficiency savings", Ngram. http://ngrams.googlelabs.com/graph?content=efficiency+savings&year_start=1800&year_end=2000&corpus=0&smoothing=3

Greenhalgh G. (1990). Energy conservation policies, Energy Policy, ISSN 0301-4215, 18(3), 293-299.

Grubb, M. (1990). Energy Efficiency and Economic Fallacies - A Reply, Energy Policy, ISSN 0301-4215,18(8), pp783-785.

Gupta, A. (2009). Empirical Look at Global Efficiencies - Straightforward empirical analysis of 131 countries. BioPhysical Economics, SUNY ESF, Syracuse NY. http://web.mac.com/biophysicalecon/iWeb/Site/BPE%20Conference_files/Download%20Gupta.pdf

Hall C.A.S. (2004). The myth of sustainable development: Personal reflections on energy, its relation to neoclassical economics, and Stanley Jevons, Journal of Energy Resources Technology, ISSN: 0195-0738, 126(2).

Hall C.A.S, Ko J.Y. (2007). The myth of efficiency through market economics. In: Leclerc, G. and Hall C.A.S eds, Making World Development Work: Scientific Alternatives To Neoclassical Economic Theory, ISBN 0-826-33733-3, Univ. New Mexico Press.

Hall, C. A. S., Balogh, S. and Murphy, D. J. R. (2009). What is the Minimum EROI that a Sustainable Society Must Have?, Energies, ISSN 1996-1073, 2(1), pp25-47.

Gagnon, N., Hall C., Brinker,L. (2009). A Preliminary Investigation of Energy Return on Energy Investment for Global Oil and Gas Production, Energies. ISSN 1996-1073, 2009(2), pp 490-503

Hamilton, J.D. (2009). Causes and Consequences of the Oil Shock of 2007-08. Brookings Papers, ISSN 007-1303, Spring 2009. http://www.brookings.edu/economics/bpea/~/media/Files/Programs/ES/BPEA/2009_spring_bpea_papers/2009_spring_bpea_hamilton.pdf

Henshaw, P.F. (2009). Why Efficiency multiplies consumption. BioPhysical Economics Oct16-17, 2009, SUNY ESF, Syracuse NY. www.synapse9.com/pub/EffMultiplies.htm

Henshaw, P. F. (2010a). Complex Systems, Encyclopedia of the Earth, ISSN: 0950-4125. http://www.eoearth.org/article/Complex_systems

Henshaw, P.F. (2010b). Models Learning Change. Cosmos and History, ISSN 1832-9101, 6(1).

Henshaw, P.F. (2010c) The Energy Physics of Continuity in Change. Current revision of theorem and notes, http://www.synapse9.com/pub/drtheo2010.pdf

Henshaw, P.F., King, C., Zarnikau, J. (2011). System energy assessment (SEA): Defining a standard measure of EROI for energy businesses as whole systems, in special issue on EROI, Charles Hall ed., Sustainability, MDPI, ISSN 2071-1050, arXiv:1104.3570v1 [physics.soc-ph]. http://arxiv.org/abs/1104.3570v1

Herring, H. (1999). Does energy efficiency save energy? The debate and its consequences, Applied Energy, ISSN: 0306-2619, 63(3),209-226.

Herring, H. (2006). Energy efficiency—a critical view. Energy, ISSN: 0360-5442. 31(1), p10-20.

Herring, H., Cleveland, C.J. (2008). Rebound effect. Encyclopedia of the Earth, ISSN: 0950-4125. http://www.eoearth.org/article/Rebound_effect

Jevons, S.W. (1885). The Coal Question: An inquiry Concerning the Progress of the Nations, Flux, A.W.(Ed.), ISBN 0521829534, 1965, A.M. Kelly NY.

Khazzoom, J. D. (1980). Economic Implications of Mandated Efficiency Standards for Household Appliances, Energy Journal, ISSN 1750-6220, 1(4), pp 21-39.

Khazzoom, J. D. (1987). Energy Savings Resulting from the Adoption of More Efficient Appliances, Energy Journal, ISSN 1750-6220, 8(4), pp 85-89.

Kuhn, T. S. (1970). The structure of scientific revolutions, Second Edition, Univ. of Chicago Press. ISBN 0226458083.

Lovins, A. (1988). Energy Savings Resulting from the Adoption of More Efficient Appliances: Another View, Energy Journal, ISSN 1750-6220, 9(2), pp155-162.

Madlenera, R., Alcot, B. (2009). Energy rebound and economic growth: A review of the main issues and research needs, Energy, ISSN: 0360-5442, 34(3), pp 370-376.

Meadows, D. H., Meadows. D. L., Randers J., Behrens III. W. W. (1972). The Limits to Growth, commissioned by the Club of Rome, ISBN 0451057678.

Meadows, D. H., Randers J., Meadows. D. L. (2004). The Limits to Growth: The 30-Year Update, ISBN 193149858X.

Midgley, G., Foote, J., Ahuriri-Driscoll, A., Wood, W. (2007). Towards a new framework for evaluating systemic and participative methods, Plenary lecture, ISSS Proceedings, ISSN: 1999-6918.

Owen, D. (2010) The Efficiency Dilemma The New Yorker Issn: 0028-792X, Dec. 20, p 78

Polimeni J.M., Mayumi K., Giampietro M., B Alcott B. (2008). The Jevons paradox and the myth of resource efficiency improvements, ISBN 1844074625, Earthscan UK.

Saunders, H. D. (1992). The Khazzoom-Brookes postulate and neoclassical growth, The Energy Journal, 13(4), ISSN 1750-6220, pp131-148.

Saunders, H. D. (1984). The Macrodynamics of Energy Shocks, Short Run and Long Run, Energy Economics, ISSN: 0140-9883, 6(1), pp 21-34.

Soros, G. (2011) The Emerging Economic and Political Order: What Lies Ahead?, Institute for New Economic Thinking - Bretton Woods Conference, recorded talk, Apr 8. 2011. http://ineteconomics.org/net/video/playlist/conference/bretton-woods/B

Tainter, J.A. (2008). Forward to ibid. (Polimeni,2008) .

Tainter, J.A. (1988). *The collapse of complex societies,* Cambridge Univ. Press, ISBN-13 9780521386739.

Tesfatsion, L., Judd, K., (2006). *Handbook of Computational Economics Agent-Based Computational Economic*s, NORTH-HOLLAND ISBN 10: 0-444-51253-5.

Turner, G. (2008). A comparison of The Limits to Growth with 30 years of reality, Global Environmental Change, ISSN: 0959-3780,18(3) 397-411.

Webster (1913). Webster's Revised Unabridged, 1913 Edition, online index by ARTFL at the Univ. of Chicago. http://machaut.uchicago.edu/

York, R. (2006). Ecological paradoxes: William Stanley Jevons and the paperless office. Human Ecology Review, ISSN 1074-4827, 13(2).