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Towards a Conceptual System for Managing in the Anthropocene*

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Abstract

This note takes as its frame of reference the concept of 'deep thinking' developed by William Byers [Byers 2015]. According to Byers, deep thinking or creative thought can emerge when a problem is framed by two (or more) conceptual systems and it is found that there are areas of incoherency between the conceptual systems. A new conceptual system encompassing elements from the primary conceptual systems may arise from the effort to resolve the incoherencies. Managing in the Anthropocene is a problem domain that can be framed by two conceptual systems, one of which may be described as Newtonian, the other as evolutionary. This paper explores elements of a conceptual system for framing the problem of managing in the Anthropocene inspired by the incoherencies between Newtonian and evolutionary framings.

This note takes as its frame of reference the concept of 'deep thinking' developed by William Byers [Byers 2015]. According to Byers, deep thinking or creative thought can emerge when a problem is framed by two (or more) conceptual systems and it is found that there are areas of incoherency between the conceptual systems. A new conceptual system encompassing elements from the primary conceptual systems may arise from the effort to resolve the incoherencies. The critical element is the ability to see a problem domain through the lens of different conceptual systems. Byers illustrates the concept of deep thinking using examples from number theory involving the problem domains of counting and measuring. The counting domain gave rise to the conceptual system of positive integers; the measuring domain to the conceptual system of fractions. When these two conceptual systems were brought to bear on the problems of zero, infinity, and negative numbers, more encompassing conceptual systems emerged.

1. Problem Domain

The problem domain to be addressed by the 'new economic theory' could be summarily described as 'managing in the Anthropocene'. It has been brought to our attention that not only do human activities have an impact on naturally occurring Earth systems but, as well, the long term and systemic consequences of those activities will have a significant and

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negative impact on future generations of human beings. It is becoming clear that we are to some degree responsible for the future of life on Earth. The symptoms of our failure to take into consideration the long term and systemic consequences of our collective activities are clear: exponential growth of human populations, global climate change, loss of biodiversity, deforestation, pollution of water and air, loss of fertile soils, depletion of resources, human conflicts, famine, and the accumulation of wealth and power in an increasingly small number of hands. Much has been written on the subject of the global challenges facing humankind and it is not my intention to repeat or summarize it here. It is clear that the problem domain captured by the phrase managing in the Anthropocene encompasses both physical and social sciences.

"The increasing order or complexity is important and cannot be understood by reducing the system to foundational elements."

2. Conceptual Systems

There are two conceptual systems that can be brought to bear on the problem domain of 'managing in the Anthropocene'. The first is a conceptual system that has been labelled 'Newtonian'; the second is one that might be called 'Evolutionary'. Let us call these conceptual systems CS(N) and CS(E) respectively.

CS(N) might be described as reductionist, mechanistic, reversible, and deterministic. The system as a whole can be understood as the sum of its parts. The observer of the system is not a part of the system and has no impact on it. The system is governed by a small number of timeless and universal laws. Once these laws are understood and one point on the trajectory has been observed, the future and indeed the history of the system can be known. The forces at play in the system come into equilibrium.

CS(N) originated in the problem domain of physics in the 17th century. It is not by accident that CS(N) takes its name from Isaac Newton, the English physicist and mathematician who is widely recognised as one of the most influential scientists of all time and a key figure in the scientific revolution. Newton formulated the laws of motion and universal gravitation, which dominated scientists' view of the physical universe for the next three centuries.

In CS(E), the whole is greater than the sum of its parts. The properties of system as a whole emerge from the dynamic interactions among the constituent processes and those properties cannot be ascribed to the individual components. Time is fundamental and not reversible in the sense that cause always precedes effect. The laws or, more appropriately, the stabilities that are observed evolve from within the system. Higher levels of order can emerge when the processes that constitute the system are far from thermodynamic equilibrium. The structure of the system that emerges once a threshold or bifurcation point is reached is not predictable. The increasing order or complexity is important and cannot be understood by reducing the system to foundational elements. The observer is an integral part of the system as the act of observing the system may change the system.

CS(E) had its origins in the domain of living systems. It is associated with the Darwin's theory of evolution of the mid 19th century. It spawned general system theory [Bertalamffy 1968], cybernetics [Ashby 1956], and the new field of systems biology [Noble 2006].

Both physics and economics that dominate and frame the physical and social sciences respectively have proven to be resistant to CS(E) and the mainstream continues to seek resolution of anomalies or paradoxes within the confines of CS(N). Those who comprehend the incoherencies between CS(N) and CS(E) in their problem domains and seek to reframe have been marginalized by the mainstream. The resistance has been institutionalized in the organization of academia into disciplinary specialties and the adoption of rules and conventions that tend to legitimize scientific methods that involve analysis to the exclusion of methods of synthesis.

In the field of physics, paradoxes have been encountered at both the micro and macro scales, for example, the paradoxes of wave-particle duality and Schroedinger's cat, situations involving motions nearing the speed of light, and, in cosmology, the evolution of the universe from the moment of the big bang. The mainstream 'explained' these anomalies by appealing to theories involving randomness, the space-time continuum, and the multi-verse and continued to pursue the search for universal and timeless laws, a 'theory of everything' that would unite gravity with the electromagnetic, weak and strong forces. Recently, the philosopher Roberto Unger and physicist Lee Smolin have hypothesized a conceptual system that resolves incoherencies between CS(N) and CS(E) and effectively bridges the problem domains of physics and biology. In their conceptual system, time is real and fundamental and the universe is governed by laws that evolve from within the singular universe [Unger and Smolin 2015].

Mainstream or neoclassical economic theory was based on the concepts of the physics of the mid 19th century and was well within the frame of CS(N). It is essentially a system of deductive reasoning based on two foundational axioms concerning the behaviour of consumers and producers. It is a theory of value that legitimizes aggregation and in so doing makes macroeconomics possible. Should either or both of the axioms be falsified, the entire house of cards would collapse and an entire generation of economists schooled in neo-classical economics would have to admit that their careers were wasted. Many of the sub-disciplines of economics including behavioural economics [Kahneman 2011], institutional economics [Galbraith 1967], [Ostrom 1990], [Bromley 2006], and ecological economics [Brown 2015] have falsified the axioms, yet have failed to challenge the legitimacy of mainstream economics [Hoffman 2012]. The mainstream has accommodated these challenges by declaring that the neo-classical model is a model of a perfectly functioning economy and it is the purpose of policy to make the real world economy more closely approximate the neo-classical model. It has also added concepts such as rational expectations and a single economic agent to accommodate incoherencies. As early as 1898, Thorstein Veblen posed the question, 'Why is economics not an evolutionary science?' [Veblen 1898]. Since then a number of scholars have advocated that economics be framed as an evolutionary system [Boulding 1966, 1978, 1988], [Georgescu-Roegan 1971], [Beinhocker 2006], [Arthur 2009], [Dosi 2011], [Hidalgo 2015].

3. Elements of a Conceptual System for 'Managing in the Anthropocene'

This section explores an approach for exploring and understanding the problems of managing in the Anthropocene that is suggested when CS(N), the dominant conceptual system, is augmented by consideration of CS(E) as an alternative approach.

"Earth System, viewed as an evolutionary system, is subject to constant and irreversible change."

As already indicated, the problem domain for managing in the Anthropocene spans both physical and social sciences. What this suggests is a need for a meta-science, rather than a 'new economic theory'. Economic theory as framed by CS(N) seeks universal and timeless laws governing the behaviour of agents that are independent of context. But, the behaviour of economic actors or agents is conditioned by the bio-physical world and the extent to which the bio-physical world is understood by those agents. As knowledge of the ever changing bio-physical world increases, the behaviour of agents adapts and changes.

The system as a whole to be considered encompasses both the processes that transform material and energy and those that transform information that constitute the Earth system. The component processes can be understood from within CS(N) by analysis, but the behaviour of the system as a whole arises from the dynamic interactions among the constituent processes. This involves synthesis that puts the constituent processes into the context of the challenges to be met.

The Earth System, viewed as an evolutionary system, is subject to constant and irreversible change. It is open to the flow of low entropy radiant energy from the sun. The processes of the Earth System transform the low entropy radiant energy from the sun into high entropy energy or heat that is radiated into space and are far from thermodynamic equilibrium. Higher levels of order or novelty can arise in systems far from equilibrium. The accumulation and propagation of knowledge or know-how is the main driving force in evolutionary systems.

In the era of the Anthropocene, the future is influenced by what is yet to be learned. By Kenneth Boulding's nonexistence theorem that "we cannot predict what we are going to know or what know-how we are going to have in the future, or we would have it now", it follows that more emphasis must be placed on epistemology—how we learn—than on prediction and prescription. What we can know is limited by what we can observe. Learning arises from our need to link cause and effect, to explain or understand the processes that give rise to what we observe, and to anticipate the consequences of actions. We make and act upon hypotheses about our understanding of the underlying system until we observe phenomena that cannot be explained by our hypotheses. It follows as well that more emphasis be placed on abductive rather than deductive reasoning [Bromley 2006].

That the outcome of evolutionary processes cannot be predicted is not to say that all futures are possible. Ervin Laszlo puts it this way: "The evolutionary paradigm challenges concepts of equilibrium and determinacy in scientific theories; and it modifies the classical deterministic conception of scientific laws. The laws conceptualized in the evolutionary context are not deterministic and prescriptive: they do not uniquely determine the course of evolution. Rather, they state ensembles of possibilities within which evolutionary processes can unfold." [Laszlo 1987] Emphasis should be placed on determining the limits or constraints on future trajectories. These constraints define a 'cone' of possible trajectories, starting at the present, from which choices can be made.

Values are the criteria for making choices. As framed by CS(N), values are thought to be universal and timeless. As framed by CS(E), values emerge from within the system and are context dependent.

The problem domain is complex; it is compositionally rich insofar as the number of processes is apt to be large and the flows of material and energy among them have a multitude of physical properties that must be differentiated; the dynamics of the processes range from geological time measured in millennia to reaction times measured in nanoseconds; many of the relationships among and within processes are nonlinear with the consequence that the system response to a disturbance is specific to its location in space and time.

The human mind by itself is incapable of understanding in a meaningful way how complex systems work. The best, if not the only, way to understand complex systems is to 'experience' them using exploratory simulation [Casti 1997], [Holland 2012] just as the climate system is a complex system consisting of a large number of processes with dynamic feedback structures that can be best understood using large scale integrated assessment models.

4. Implications for Approach to Modeling and Model Structure

Most models in science and economics are framed by CS(N). They are representations of systems closed to learning and adaptation. The model developer/model user is outside the system. They are seldom intended for the communication of understanding needed to foster an informed public. Thus framed, these models are largely inappropriate for the problem domain of managing in the Anthropocene. Models intended for the problem of managing in the Anthropocene need to have some of the following characteristics, which are presented here in no particular order:

1. The objective of the model should be to explore alternative trajectories and communicate understanding. The emphasis should be on learning rather than prediction or prescription. To this end, the model needs to be transparent, accessible to a wide range of users, modular, and flexible if it is to be continuously updated and maintained.
2. The model must synthesize both the domain of economics with its focus on the behaviour of agents and exchange among agents and the domain of the biophysical world with its focus on processes, both naturally occurring purposeful, and the flows of materials and energy among them. These two domains are linked: agents 'own' elements of the biophysical world, establish and manage the processes that transform materials and energy to meet human needs, and exchange materials, energy and information.

3. The model must be global in scale to accommodate the concepts of biophysical limits and planetary boundaries, but must be spatially disaggregated to accommodate differences and exchange among regions. A minimum of three regions would be required but probably not more than ten.
4. The model should reflect the planet Earth as a complex evolutionary system, open to energy from the sun, materially closed, subject to constant, irreversible and unpredictable change, whose future is in part determined by what humanity will do and by what has yet to be learned. Higher levels of order emerge from Earth system processes that are far from thermodynamic equilibrium.
5. In order to handle ecological limits and sustainability, the model must incorporate structure for representing the stocks and flows of materials and energy and the processes that transform resources and energy sources into the goods and services required for human uses. This accounting must be done using energy and mass units and with sufficient compositional detail to recognize that materials and energy carriers differ in their physical and dynamical properties. Accounting for stocks and flows of fresh water should be included. Resources include land, energy in coal, oil and gas, hydro electric potential, forests, minerals, and materials.
6. If the model is to be relevant for climate change, it is important that the model represent both renewable and non-renewable energy sources, the processes that transform energy sources into energy carriers, (hydro-carbon fuels, hydrogen, and electricity), and the stocks of artifacts (vehicles, buildings, infrastructure, etc.) that use fuels to provide the services (nutrition, shelter, mobility, recreation) needed to support human populations and to drive industrial processes. It is also important to recognize that all energy is not created equal: energy from different sources and in different carriers are not perfect substitutes. As well as the greenhouse gas emissions from the use of fossil fuels, the model should keep track of emissions from other human activities including deforestation, cropping, and livestock production.
7. Emissions from human sources are then input for a climate systems model that would serve to calculate concentrations of greenhouse gases and global temperatures, including dynamic feedback from the response of earth systems to warming.
8. If the model is to be relevant for the issue of food security, it must include accounting for land use by region (agriculture land suitable for cropping, range land, forest land and other land), the production of crops including water use, the use of fertilizers and pesticides, production of meat and animal products, fish harvesting and fish stocks.
9. If the model is to be relevant for examining the role of finance and the relationship between finance and the real economy, and the distribution of income and wealth, it must include exchange among agents denominated in money units and the concept of indebtedness. This can be accomplished by distinguishing different classes of agents in each region: at least households by three or four income levels—government; central banks; commercial banks; corporations.

10. If the model is to be relevant for exploring the phenomenon of financial bubbles, it must include the concept of debt. What is needed are the variables contained in balance sheets that indicate the assets, both financial and real, against which debt is issued. A fully articulated set of income and balance sheet accounts subject to the usual accounting identities are financial constraints that limit the behaviour of economic agents. Of particular importance is to keep track of income from employment as this source of income is an important determinant of income distribution.

11. The model should not include feedbacks that represent the behavioural responses to tensions between the availability of resources, the capacity to transform them and the needs of the population. Rather the model user should examine alternative ways of resolving those tensions. In this way the model user is an integral part of the system and learns how the system responds to alternative settings of control variables.

12. The model should include enough structure for the calculation of an array of performance indicators including GDP, economic well-being, ecological footprint, resource efficiency. A more nuanced concept of prosperity requires stock as well as flow variables. Adequate stocks of public social infrastructure from which services can be provided, such as schools, roads, hospitals, are as important a component of prosperity as private stocks such as houses, cars, appliances, and home computers.

5. Can such models be built?

The global modelling initiatives taken by the Club of Rome in the 1970s show that global scale systems models can be built that can generate new and important insights. These initiatives ignited the debate on global futures, which were instrumental in the establishment of IIASA as a center for systems modelling, and led to 'sustainable development' as a global imperative.

The first initiative involved the World Dynamics model, developed by a team led by Jay Forrester at MIT. The findings from this model were reported in *The Limits to Growth*, published in 1972. The most important finding was that biophysical limits to growth might be reached in the 21st century should the pattern of human activity dominant in the 20th century persist. This initiative was followed quickly by the development of the Regionalized Multilevel World Model by an international team led by Mihajlo Mesarovic and Eduard Pestel. The results from this effort were published in *Mankind at the Turning Point*. It saw the World as a system of interacting regions whose future would be dependent upon socio-political choices constrained by conditions in each region in each time period. This represented an important departure from the (Newtonian) world view of Limits to Growth that the world is a homogeneous system whose evolution in time is pre-determined once initial conditions are specified.

There is a rich experience in modelling biophysical processes, both in the naturally-occurring and human domains. The concept of activity analysis may be traced to Tjalling Koopmans [Koopmans 1951]. Its relationship to energy and the entropy law was developed by Georgescu-Roegen [Georgescu-Roegen 1971]. The input-output modelling of Leontief is essentially a quantification of activity analysis at a national scale using currency denominated units as a proxy for physical units [Leontief 1985]. Robert Ayres' work in materials and energy process-product modelling [Ayres 1972,1978] introduced the use of mass and energy units and mass and energy balance principles in the design of process models. Dynamic bio-physical process models were realized using the stock/flow accounting framework proposed in what was called 'the design approach to socio-economic resource modeling' [Gault et al, 1987]. The Australian Stocks and Flows Framework, a large scale dynamic bio-physical stocks and flows model developed at CSIRO by a team led by Barney Foran, is an application of the principles of the 'design approach' [Turner et al 2011].

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It cannot be said that there is such a rich experience in modelling exchange and indebtedness among actors/institutions using an integrated set of income statements and balance sheets. But there is some recent and promising work in this domain that has been called stock/flow consistent modelling [Kinsella 2011], [Ciani et al 2015].

The Global Systems Simulator, developed by Robert Hoffman and Bert McInnis in association with the Canadian Association for the Club of Rome in 1993, serves to illustrate the use of open simulation models as learning devices. The computer-based model does not by itself resolve tensions between human needs and the bio-physical resource base from which those needs are met. Rather, the user sets variables that control the processes represented in the model; the simulation is run and tensions reported; then the user of the model explores how the control variables might be manipulated to resolve the tensions. The tension free scenarios that result from this process are the product of the interaction between the computer-based simulator that represents interactions among the bio-physical processes that constitute the system and the user who is a source of novelty/creativity. This outcome is not pre-determined in the logic of the simulator, nor does the simulator select the optimal or best trajectory from among the set of possible or coherent scenarios [Hoffman and McInnis 2015], [Hoffman and McInnis 1997].

Surely the challenge before us is to communicate understanding of complex global systems. Without such understanding there is little hope for coherent and co-ordinated actions to address the global challenges that threaten humankind. There is no better way to do so than providing widespread access to transparent and flexible global systems simulators so that the long term and systemic consequences of societal choices can be experienced before they are taken.

The development of a next generation of global models rooted in the theory of complex evolutionary systems and incorporating lessons learned from the first generation of global models, is a first step in meeting this challenge.

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