Philosophic Implications of Modeling the Complex Dynamics of Technoscience

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In this article we plan to discuss how some recent developments in complex systems dynamics may inform current philosophic debate concerning the nature and development of technoscience. The debates we have in mind have occurred between mainstream philosophers of technology and constructivists from science and technology studies. These debates have centred on issues of agency and determinism (or indeterminism) in technoscientific decision making. Recently some philosophers and social scientists have taken an inter-relational interpretation of such dynamics, for example Donna Haraway, Don Ihde and Bruno Latour. Simultaneously, over the past two decades economists have modeled various aspects of the economy—especially the market for technology—as the evolution of complex dynamical systems. Our intent in this article is to tease out fundamental resonances between these two bodies of scholarship. Whilst they have emerged in separate contexts, these two approaches complement each other. We will show how, taken together, these two areas of research constitute a complex dynamical approach to philosophy of technology.

One class of models of particular interest to those interested in the evolution of technoscience occur in Brian Arthur's work on the development of technology. In contrast to the negative feedback provided by the 'law of diminishing returns' operating in commodity markets, Arthur's models assume hi-tech markets are dominated by positive feedback, i.e. ever increasing returns on investment. Sources of positive feedback include: 1) the high cost of research and development relative to the cost of producing single instantiations of a finished product which necessitates huge initial investment in knowledge. For example, consider the cost of developing Windows xp® software compared to the cost of producing and distributing the software on CD. 2) The interrelated nature of 'software' and 'hardware' which holds consumers captive to a particular format. E.g. if one owns a considerable collection of music CD's one would hesitate to go out and buy a DAT player/recorder. 3) Special skills are often needed to operate hi-tech equipment, again making consumers hesitate to switch formats. For example, how many times does the average PC user switch word-processing platforms?

Arthur and colleagues developed a generalised Polya process model of such positive feedback hi-tech markets. The Polya process model is an iterative stochastic model whereby the chance that a particular event will happen in the future is a function of the number of times that the event has occurred in the past. Here the event in question is a consumer choosing a particular product over its competitor. In the model, after initial fluctuations, eventually market share becomes locked-in on a particular percentage, where it stays indefinitely. The market share on which the model settles is a function of contingent events in early iterations.

Arthur interprets this model as having several conclusions for the evolution of technology: There is no path-independent way of explaining what technology we will end up with. Instead the only way to understand why we adopt one technology over another is through investigation of the historical contingencies that led to its development and adoption. This conclusion seems to parallel those who take inter-relatonal approaches by taking into account human agency, the resistances and accommodations of materiality, and social constructions as all part of technoscience developmenet. Once a technology is adopted it can remain locked-in for long time, well beyond the time when superior technologies become available. Thus the lock-in of inefficient technologies precludes the market delivering the optimal technological solutions to our problems. Case studies of the locking-in phenomenon include the 12-hour, clockwise clock face, the VHS format for video cassette player-recorders, and the QWERTY keyboard.

Our article will show the implications of the complex dynamical approach as related to inter-relational analysis to technology for the following issues, which are themselves interrelated in complex ways:

Agency. What role does human agency play in technology development? Traditional answers range from which technology we adopt being a democratic decision to technology becoming autonomous leaving little role for human agency. Both inter-relational analysts and positive feedback models of technology show that this is not a simple dichotomy. Surely human decisions played a role in the development and adoption of the QWERTY keyboard. However, some of the events playing a crucial role did not involve individual decisions. Inter-relationalists, by noting some degrees of symmetry, bring into account the human agents, the materiality of the technologies and the social settings in which these occur. When the effects of seemingly small events become amplified by positive feedback, informed decision making becomes problematic. When a technology becomes locked-in dislodging it becomes a matter beyond mere individual decision. This work casts the autonomous technology thesis in a new light.

Evolution of technoscience. Several science studies researchers have proposed models for technoscientific development. For instance, in *Science in Action*, Latour sees the construction of a fact as a process of enlisting allies until opposing contenders are swamped. Galison, in *Image and Logic*, describes the scientific edifice as an intercalated brick wall whereby breaks in theory, experiment and instrumentation rarely line up. Similarly, in both *Technology and the Lifeworld* and *Expanding Hermeneutics: visualism in science,* Don Ihde shows how technological trajectories develop, which then are implicit guides for pathways. These images convey some sense of the dynamics of scientific evolution. However, complex systems dynamics can provide additional rich metaphors. For instance, the dynamics of technoscientific communities show signs of positive feedback. One source of such feedback is the relationship between success in publication and ability to secure funding for future research. The positive feedback structure of technoscience can contribute to the explanation of how results are established, as well as why established results tend to remain locked-in.

Technological determinism. There are a range of explanations of how we obtain the technologies we have. Candidate explanatory factors include individual genius, social interaction, the free market, etc. Such explanations are invariably reductionist. They seek to explain technological success in terms of factors in a particular dimension of the technoscientific enterprise. From the perspective of complex systems dynamics and inter-relational approaches, we are encouraged to approach the development of technology as emerging from the complex interaction of factors in multifarious dimensions. What emerges from such approaches is the recognition that technologies may serve multistable functions within multiple, but limited numbers of trajectories.

There may well be no general explanation of technological development. Instead we may need to look to the details of historical contingencies to explain the success or failure of particular technological undertakings.

Normativity. How do we judge success in the technological world? When we adopt a complex systems dynamics approach to technoscience both epistemic and ethical normativity become multidimensional and multistable issues that must take into account cognitive, social, economic and political factors.

Technoscientific decision-making. When we approach technoscience from a perspective that assumes that being rational involves optimising over a range of competing options standard rational choice theory can be applied. However, reasoning with respect to complex systems dynamics involves satisficing, not optimisation. The implications of adopting satisficing in the realm of technoscience need to be explored.

Values and Ethics. No one would deny the role that human values play in technoscientific development. However, standard accounts of the role of human values in design tend to make linear assumptions. What does an account of the role of human values in technoscience dominated by nonlinear interaction look like?

Our article will survey contributions to the complex dynamical understanding of technology from economics researchers who explicitly adopt a complex systems approach as well as those in the humanities whose inter-relational approaches implicitly address issues concerning the dynamic evolution of technology. We will show how each make complementary contributions to the complex dynamical understanding of technoscience.

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