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Energy, aesthetics and knowledge in complex economic systems☆

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ABSTRACT

It is argued that the fact that economic systems are dissipative structures must be taken fully into account in economics if we are to understand the nature of the economic–ecological interface and how to deal with emergent environmental problems, such as global warming. Such problems are a product of economic growth, which is widely accepted to be the outcome of the acquisition and application of knowledge. Drawing upon disparate literatures within and outside economics, it is argued that economic growth should be more properly viewed as the outcome of a co-evolutionary process that involves the autocatalytic interaction of new knowledge and access of increasing amounts of free energy to do increasingly specialized forms of work. Specifically, the relevance of the 'energy hypothesis,' associated with Erwin Schrödinger and, more recently, revived by Eric Schneider and his collaborators, is assessed. This hypothesis states that all dissipative structures have, as their primary objective, the reduction of accessible free energy gradients. It is concluded that such a hypothesis cannot be rejected in the context of economic behaviour and that this opens up an important research agenda for economists.

1. Introduction

Over to past two centuries, we have witnessed unprecedented global growth in population and GDP per capita. This has been paralleled by rapid growth in the demand for energy and the emergence of worrying environmental problems. Despite these emerging problems, many people worldwide seem reluctant to sacrifice even a relatively small part of their material consumption to reduce the risk of further environmental degradation – the relentless pursuit of maximal economic growth

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remains a primary objective of many governments. When analysing the drivers of economic growth, economists generally see it as the outcome of a process that has, at its core, the growth and application of new knowledge. However, knowledge is something that is not easy to define or measure so there has been a tendency to view it as a commodity with unusual characteristics. This is the case in modern endogenous growth theory. Steedman (2004) has argued convincingly that it is not analytically legitimate or realistic to view knowledge in this way. If this is so, it is necessary to revisit what we mean by knowledge and its role in generating economic growth. Here it is argued that this misunderstanding can be traced back to the fact that economists have tended not to view the economic structures that they analyse as complex evolving systems.

Complex biological, social and economic systems differ in important ways with regard to the acquisition and use of knowledge but they all have something fundamental in common: their energetic character. So when we try to understand how economic evolution comes about, we have to examine how new knowledge interacts with the thermodynamic rules that all energy-using systems must obey. It is argued here that, in economic systems, the utilisation of new knowledge and increases in the work done through the application of energy are intimately related and feed upon each other. This has often been ignored by economists who commonly make extremely strong assumptions concerning the availability of knowledge and treat energy as just another factor of production, mostly ignored because of its strong complementary relationship with the use of capital goods.

Evolutionary economists have tended to make weaker assumptions concerning the extent of knowledge and its application, but they too have tended to understate the importance of the energetic dimensions of economic systems. Of course, there have been important exceptions, such as Nicholas Georgescu-Roegen and Kenneth Boulding but, in the main, it is in modern ecological economics (see, for example, Daly, 1996 and Lozada, 1999), not evolutionary economics, that we find most attention given to the energetic features of economic systems.[1] The lack of interest in the energetic characteristics of economic systems in evolutionary economics stems from its historical roots. In the first half of the twentieth century, when Joseph Schumpeter was trying to understand the growth and fluctuations of economic systems using what was then a novel, evolutionary approach, the role of energy was not really a pressing issue. Coal and oil were plentiful and political problems seemed to be a much more serious threat to capitalism than energy limitations and associated wastes and pollutants. The old warnings of Stanley Jevons in The Coal Question concerning the finite nature of energy stocks seemed to most economists, including Schumpeter himself in his History of Economic Analysis, to be misplaced.

So the notion that energy is just a tap that can always be turned on has been widely presumed in economics and, thus, energetic considerations have been largely omitted from the core of economic analysis. The result is that, today, when oil is peaking and fossil fuel emissions face carbon dioxide and other entropic waste boundaries, the economics that we have is not well-equipped to understand how the global economic system ended up in such a situation or to tell us what policies can be applied to render economic systems environmentally sustainable. The goal here is to begin to rectify this situation by considering, explicitly, the relationship between the adoption of new knowledge and the growth in energy use. In particular, the widespread presumption that the latter is uni-directionally driven by the former is questioned: first, because much of the knowledge relevant to evolutionary change involves subjective beliefs and these, in turn, are influenced by aesthetic judgements which have subtle connections with energetic processes; second, because, in the physio-chemical and biological domains, there is evidence to suggest that seeking to eliminate free energy gradients can be an end in itself, economic systems may also exhibit such behaviour.

2. The economic system is an energetic system

Economic systems are complex and adaptive and are 'dissipative structures' that maintain themselves far from thermodynamic equilibrium by the throughput of free energy available to do work (see Prigogine, 1978; Brooks and Wiley, 1986; Allen, 1998; Ayres, 1998). Thus, a free energy gradient is utilised to develop and mobilise structure and an entropy gradient is resisted, through maintenance and repair activities (see Tainter et al., 2003). In cases where free energy is imposed directly on physical matter, dissipation is the system response. In some cases that are close to thermodynamic equilibrium, patterned structure forms, as in the case of Bernard cells. In biological systems that maintain themselves away from thermodynamic equilibrium, physical structure exhibits a necessary degree of irreversibility so that when, for example, the sun sets or winter arrives, a tree can maintain itself without the need to immediately turn solar energy into chemical energy through photosynthesis. Higher level biological systems, such as mammals, do not use direct free energy gradients, instead, they consume organic structures that contain chemical energy and structure-building matter. They too have to maintain highly irreversible structures to do this.

Complex biological systems have evolved a capacity to use imported free energy to self-organise synergetic interactions within their structures. Competitive selection mechanisms tend to favour systems that can transform more free energy into work and, when it is restricted in supply, those that process energy into work most efficiently (see Kiala and Annila, 2008). In the popular mind, this is often thought of in terms of the physical strength and agility of an organism but competitive

[1] Important exceptions are Van den Bergh and Gowdy (2000) who discuss how evolutionary economics can develop an explicit ecological dimension and Metcalfe (2010) who discusses theories of technical change in which energy is dealt with in some detail and in a manner that is compatible with the approach taken here. Rosser (1992) offers an insightful historical review of the connections between economics and ecology in relation to evolutionary ideas both old and new.