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Introduction

Knowledge and complexity

The inspiration for this special edition came from a series of presentations, and some lively debate, at a workshop held in Budapest at the Central European University[1]. The theme of that workshop was focused on the topic of 'Limits to Knowledge—the Implications of Complexity'. The papers in this special edition explore complexity, and the limits to knowledge, from a variety of standpoints—economics, history, philosophy, management, industry, and simulation. The debate is organized, roughly, around three core themes. Firstly, there is the recognition and definition of the limits to knowledge that our new understanding of Complexity gives us. Secondly, there are the implications of this for academia, science and the ethics of business and governance, as these limits to knowledge affect the degree and even the possibility of real 'transparency' in human affairs. This leads in turn to interactions and co-operation that can either be based on a contractual basis, legally bound, or may operate through the evolution of trust and ethical behaviour. Thirdly, the discussion concerns possible steps concerning our possible response to this situation, and what measures we should use in making decisions and policies. Clearly, in the post-modern, irreversible universe of emergent organisation and behaviour that we now see we inhabit, our previous academic goals of seeking 'objective knowledge and absolute truth' have to be relinquished. However, what it is that we should seek in its place is not clear, nor is the nature of the new relationship between Science and Society that we should expect. When we examine PhDs we are asked to check whether a thesis provides a contribution to 'knowledge'. But if the topic is dealing with human systems it is not clear who's knowledge this might be, nor indeed what knowledge is precisely.

Work in the 'hard' and 'soft' sciences has been pursuing these ideas for some time. In the hard science, once the study of Open Systems was engaged, then this automatically threw into question the usual vision we have of knowledge. For isolated and closed systems classical thermodynamics gave us the knowledge to predict the transformations and final equilibrium states of a system. Obviously, for frictionless systems such as those involved in planetary motion, Newton's Laws allowed the prediction of orbits and

[1] The Workshop was a great success and was splendidly hosted by Yehuda Elkana, the Head of the Central European University, and indirectly by the philanthropist George Soros. We are most grateful to both of them and to the staff who were so helpful in organising and running the meeting.

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eclipses, both forwards and backwards in time. Knowledge was complete and related directly to prediction. But, open systems were much more problematic. Firstly, for an open system, it is not necessarily obvious where the boundary should be. If there are factors on the 'outside' affecting the 'inside', then they might be included in a larger model, thereby attempting to move back to the old, closed view. But then these factors would in turn be affected by others still further 'out', and so on, simply displacing the difficulty of choosing the boundary. In addition, for open systems, factors on the 'inside' affected by the 'outside' may also affect the 'outside' and what we are really looking at is a co-evolutionary process where changes on the inside lead to changes in the outside, and vice-versa. What, then, is the meaning of our boundary since knowledge of the system within the boundary is clearly no longer sufficient to determine what must happen? The simplest definition of a complex system is one that can respond in more than one way to its environment. This 'choice' in response arises from the fact that non-linear processes within the system can potentially amplify microscopic heterogeneity hidden within it. Because of this, its response to the 'outside' can be creative, and it can expand the descriptors of the system as new properties emerge, and new attributes and dimensions are turned on.

So, 'knowledge' about the future trajectory of the system can be both quantitatively and qualitatively wrong. In the former case, a reconfiguration of what is inside the boundary can simply produce a change in its performance, while in the latter case, new attributes and dimensions can emerge that change what was inside the boundary to something it was not. Innovation can occur, and it may have untold implications for the future evolution of both the 'inside' and the 'outside' the system. Similarly, the same 'intervention' may produce two different results on what were believed to be similar systems, since a single complex system can respond to an intervention in different possible ways. The outcomes could differ qualitatively and this surely must therefore introduce some doubt into the ethical basis for the intervention.

Even if we could decide where to put the boundary, and hence what our system definition was, the non-linear processes present and the unknown degree of internal heterogeneity would mean that we would be very unclear about what the system might or might not do. These new ideas force us to accept a significant reduction in our powers of prediction, and even in our ability to frame a useful question. And yet, we would almost certainly prefer to fly in an aeroplane designed by engineers rather than post-modernists and may like a professional violinist to attempt Beethoven's violin concerto. So knowledge and skills do exist, and some opinions are worth more than others. However, the aeroplane and the violin are artefacts and the situations encountered are normally within an 'expected range'. Training and practice have prepared the pilot and the violinist to handle events more successfully than a novice. But, in an evolving socio-economic system, where history is changing the expectations, opportunities and threats from within and without, it not at all clear that practice and training can have the same effect. Our societies are characterised by demographic, economic, social, political, and technological change that affect the basis of all our strategies and calculations, rapidly devaluing any particular piece of knowledge, and making it imperative that we constantly re-generate our knowledge. Strategies based on prediction, planning and control therefore seem ill attuned to such a reality, and this raises the question of possible alternatives. In his paper, Bob

Artigiani tells the story of how Nelson changed the face of naval warfare. Instead of fighting according to the accepted rituals and rigid rules of previous admirals that led to stylish battles with relatively few casualties, he broke the rules of accepted form, sailing in piercing formations and creating havoc and dismay. The second part of his strategy was to develop a fleet whose captains knew and understood each other deeply, who could anticipate and respond to each other's movements, so that they could then deal successfully with whatever local havoc and dismay was encountered. This points to an interesting lesson in which success comes as a result of adaptability and flexible response rather than prediction, planning and control.

Similarly, over recent decades, the flexibility and decentralised nature of markets has led them to be adopted as primary economic mechanisms, stimulating innovation and market growth, and rolling back state control and central planning. Governments have fallen back on trying to attract inward investment according to regional needs, and on 'picking winners' in terms of sectors and companies. But severe problems are also emerging for the behaviour of economic markets, since profit-driven behaviour does not necessarily lead naturally to any guaranteed minimum level of service, environmental protection or consumer safety. In some sectors such as utilities, health, education, food, pharmaceuticals, telecoms to name but a few, we appear to be moving into a new era beyond simple markets. In these, the market is seriously affected by an emergent regulatory process, sometimes set up by government with entirely unclear aims, or increasingly framed by active stakeholders. This emerging power sits above markets and decides what can and cannot be offered for sale. This is a response to the sentiment that price signals alone are not considered adequate 'knowledge' to successfully direct the market to respond to consumer needs without causing other disadvantageous effects. Naturally, these debates affect issues concerning the institutional and regulatory structures that should affect international finance and also international development. However, despite these interesting developments, it still must be said that if we do not understand the possible outcomes and stability of evolving markets neither do we understand the implications of the interventions or regulatory frameworks that we impose in addition. But this lack of clarity feeds the emotional and ideological motives that underlie most debates on these issues. Instead of exploring, experimenting and evaluating possible paths, with open discussion and declared assumptions, the real issues are often coupled to personal rivalries, exaggerated claims and emotive oratory and large quantities of blame awaiting the unfortunate and the unwary.

Complex systems challenge us because they do not offer any simple, easy recipes. They are about the on-going capacity of systems to transform themselves, and for success to turn to failure and failure to success. Learning does not end because any knowledge we have is rapidly spread around, used by others and devalued. Systems respond creatively to any new behaviour that we deduce from new knowledge, and so we must continue doubting, testing, exploring and learning. Everything that can be made into a 'method' will fail because of the learning responses of others. Any measure of success will cease to be so once it is known that it is measured. This is just part of the self-transformation of complex systems, in which our interpretive frameworks (models) of ourselves and our situation have to be tested and up-dated all the time. Our understanding must also change, and this requires a modest view that whatever we think we know, whatever our current model is,

then, it could be wrong and may need to be changed. This 'research-based' vision is somewhat different from the religious fundamentalist, ideologically based or even Confucian views that have tended to dominate in earlier times.

Science has come of age and has demonstrated its own limits. The traditional view is fine for very simple cases where a situation can be isolated and taken into the laboratory for prolonged testing and multiple trials. But a social or economic system cannot be treated in this way, as each individual is transformed and changed by experience, and the internal heterogeneity leads to learning and irreversible changes that defy traditional methods of repeatable experiments. Irreversibility itself arrests 'normal' science, since it is impossible to 'stop the clock' and run a few experiments, and ignorance of internal heterogeneity puts an inevitable question mark over the comparability of any two cases. Without repetition, or a statistical ensemble traditional science is condemned to approach closer to common sense. Instead of decisions being determined by a 'scientific management', based on optimised outcome and net present value, we are forced back towards judgement and informed opinion. The wisdom of keeping options open, of using experience and tacit knowledge and of facing the reality of 'risk' are all-important. A society that does not accept the reality of risk but only the satisfaction of blame will bring early fossilisation on itself. Exploring, innovating and experimenting will always present some risks, but without them there will be no learning, and no contextual adaptation of learned procedures. Science has traditionally been about accumulating an edifice of generic knowledge based on a systematic approach of hypothesis and experiment. But without repeatable experiments, and without the certainty of comparable situations, definitions of 'science' based only on 'testing testable conjectures' are too restrictive. We must move to a new, open approach that sees present interpretive frameworks (models) as useful while they work, but always open to reformulation and change as the situation evolves. This does not mean that any opinion is as good as any other and that 'anything goes', since the experiences, uses and assumptions of a given interpretive framework would support its temporary authority. However, it would represent the present understanding of the modeller and could be used as a communication device in conversations concerning the domain in question.

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