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## SYMPOSIUM ON INFORMATION AND KNOWLEDGE IN ECONOMICS

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### Making Connections

BRIAN J. LOASBY\*

LET ME BEGIN WITH TWO EPISODES TAKEN FROM A FASCINATING account of British scientific intelligence in the war of 1939-45, *Most Secret War* by R. V. Jones. In early April 1940 a British reconnaissance aircraft took photographs of Bremen harbor which showed it full of shipping. Unfortunately the information conveyed by these photographs was effectively zero, since it was the very first successful reconnaissance of the area since the outbreak of war, and so there was no knowledge about Bremen in wartime to interpret it. A few days later, the British acquired the knowledge that made these photographs very informative—but too late: the Germans invaded Norway, and the congregation of shipping in Bremen was not a normal phenomenon but a major part of the invasion fleet. Contrast this episode with a simple report in autumn 1943 that the 14<sup>th</sup> Company of the German Air Signals Regiment had posted detachments along the Baltic coast. Because the 14<sup>th</sup> and 15<sup>th</sup> Companies were known to be the two radar specialist units assigned to major project developments and the Germans were known to be developing some kind of long-range missile at Peenemunde, this report conveyed the information that the

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\* University of Stirling, Scotland.

I do not claim that the meanings I ascribe to 'knowledge' and 'information' are the only meanings they can usefully bear; they correspond to concepts that I find helpful in understanding human behavior as it is influenced by the operations of the human mind.

*Note.* Some paragraphs have been adapted from Loasby (2001).

Germans were about to start missile testing; consequently British intelligence had ‘a ringside seat at all the trials of the flying bomb’.

A specific report can provide information only if it can be connected to something else, and it is unlikely to provide much information unless this ‘something else’ is a pattern of relationships—how some things fit together. Such patterns constitute what I call knowledge. Knowledge is a set of connections; information is a single element which becomes information only if it can be linked into such a set. Information is not inherent in a message, but the product of an interpretation derived from supposedly relevant knowledge. A very important implication, which is ignored in most economic analyses of information (or of ‘knowledge’ treated as information), is that the information that is derived from a message may differ substantially according to the knowledge by which it is interpreted. That is a theme of Jones (1978); it applies to economists as to everyone else.

Knowledge should not be defined as that which is true: that has been a logically untenable position at least since the time of David Hume. All knowledge consists of patterns that are invented, and most of these patterns are eventually superseded; there is no procedure that ensures access to the truth, though some are better than others. (Ziman (1978, 2000) is an excellent guide to scientific procedures.) At any time some knowledge may seem unchallengeable, some highly reliable, some plausible within limits (which are rarely well-defined), some speculative, and some once accepted but now discarded.

The distinction between knowledge and information is very clear in the basic principal-agent model. The focus is on a single asymmetry of information: only the agent observes the state of the world. Knowledge is complete, and shared, including the knowledge of all possible states, what action the principal desires in each, and the knowledge that the agent has an inducement in some states of the world to misreport that state, unless supplied with appropriate incentives. In the Compendium provided James Friedman, Eric Rasmussen and Kenneth Binmore emphasize this distinction between information and knowledge; they also recognize how fundamentally the power of the analytical method depends on knowledge which is complete – and therefore inert. Suppose, for example, that principal and agent have different knowledge, and neither knows what knowledge the other has; suppose that their lists of possible states of the world are incomplete (there are ‘shocks’), or that someone thinks of a novel action. None of these are at all implausible; but they certainly complicate the analysis. The recourse to ‘rational expectations’ serves to eliminate awkward problems of differential knowledge in macroeconomics.

Of course, economic modelers can always confine their analyses to asymmetric information. However, they should then be cautious about the application of these analyses—far more cautious than many of them often are. One of the most obvious features of a modern economy is that, as Hayek pointed out, knowledge is dispersed and incomplete. This is not an unfortunate accident but a consequence of human activity, and a necessary condition of human progress. The growth of knowledge is promoted by the division of labor, because that produces differentiated knowledge. This is the foundational proposition of Adam Smith's *Wealth of Nations*; but Smith (1980 [1795]) had already applied it to the growth of science through the differentiation of sciences.

Smith accepted Hume's argument that it was impossible to establish the truth of any general empirical proposition by logic or evidence, and Hume's advice to ask instead how people come to accept some propositions as true. The result was his psychological theory of the emergence and growth of science, the key features of which are the need to construct knowledge as a combination of classification systems and causal links, the role of imagination in doing so, and the internal motivations that drive the process. The stimulus to imagination is provided by the acute discomfort caused by the failure of existing patterns of knowledge to account for newly-observed phenomena, and the consequent urgency of inventing 'connecting principles' that will impose order on 'jarring and discordant appearances'. (This intrinsic motivation, beginning with unwelcome surprise and concluding with delight in creating a new pattern that works, appears to have had substantial survival value and is still effective both in the economy and the development of economic theory; but it is not prominent in current treatments of incentives.) Since new 'connecting principles' lead to new expectations, new activities and new observations, what began as an aid to ordinary living gradually incubated a new category of knowledge called 'scientific', and some people came to devote particular attention to it; as its growth accelerated it began to divide into distinctive branches, each with its own set of connections which gave rise to its own anomalies and consequent stimuli to imagination. (See Loasby 2002). This was the 'knowledge about knowledge' that Smith transferred to economics.

It is, of course, the division of knowledge, not asymmetric information, that Hayek is concerned about. It is also the division of knowledge that lies behind Allyn Young's (1928) principle of increasing returns: changes of organization, resulting from developments in knowledge (as in science) divide up activities in different ways, providing different foci

and different samples of experience and so offer novel opportunities for generating new knowledge. Increasing returns are *not* a property of a production function; they describe a process of discovery.

The conceptual basis for this view of knowledge is the notion of a system as a set of elements and an incomplete set of connections between them; thus not only different sets of elements but also different ways of connecting a given set of elements define different systems. Large systems typically include sub-systems within which connections are relatively dense, and between which connections are sparse; this is Herbert Simon's principle of quasi-decomposability, which he argued was generally applicable to any large system, such as an economy or human knowledge. (For an extended treatment, see Potts 2000; for a brief version see Potts 2001). Selective connections are characteristic of economies and of knowledge; and because economic performance depends on knowledge we may expect close connections between the two. As Marshall (1961, 138) perceived, 'organization aids knowledge' by providing structures within which it can develop; and as Smith perceived, knowledge is created by the organization of elements according to 'connecting principles'.

There is a great deal of evidence that human brains work in this way, as Hayek (1952) argued (see also Koppl 2004), developing neural pathways for handling sensory inputs by assigning them to categories which are already linked to other categories—most of the time without any conscious thought, because, as Herbert Simon insisted, cognition is a very scarce resource. It is also this cognitive scarcity, coupled to the ability of human brains to build up very different sets of connections, operating automatically, in different circumstances, that makes the division of labor so effective in expanding the knowledge base of a community. Economic systems are built on routines and asymmetric knowledge. Conventional economic theories are not, but the activities of economists certainly are.

We develop knowledge by varying our construction systems as we 'construe the replication of events' (Kelly 1963, p. 72). (Kelly based his theory of personality on the need to create imperfect representations of parts of a complex universe that was fortunately quasi-decomposable, but in which decomposability diminished with time.) Knowledge is structure, in the form of categories into which phenomena or concepts may be grouped, or in the form of relationships between such categories; and structure implies a non-integral space. It is an imperfectly connected system of imperfect connections, and any of these connections may change over time. The world system of knowledge is far from complete, and the knowledge possessed by, or even accessible to, any individual is a very small proportion

of that world system. Nobody knows how a Boeing 737 works; and nobody knows how the Boeing Company works.

Rather than bounded rationality, which is usually interpreted as a particular limitation in processing knowledge, it is better to begin with bounded cognition. This has the advantage of corresponding with current ideas about the development of human cognitive abilities. In the early stages of evolution, standard behaviors were genetically programmed; later creatures were genetically endowed with some capacity to vary behavior by forming new linkages in their brains; performance received evolutionary priority over logical processing and neurological coding over explicit codification. Nevertheless what appeared to be appropriate could differ between individuals, because of differences in the sequence of their experiences. Despite our intellectual pretensions, this is still the basic method of knowledge formation in modern humans; that is why 'we know more than we can tell', and in particular why we can perform many actions that we are unable to specify in detail.

However, the emergence of consciousness introduced the important novel possibility of creating ideas about the future by making conjectures about new categories and relationships as yet unrecognized, leading to the possibility of taking novel actions with the intention of producing novel effects. The scope for variation between individuals was correspondingly increased, and with it the rate at which knowledge could grow. This new possibility, we should remember, is a modification of the old capabilities, which are not displaced, and it relies much more on linkages than logic. (All this is portrayed in Marshall's (1994) mental model of 'Ye Machine', a combination of psychological, biological and mechanical ideas prompted by acute discomfort about the nature of human knowledge.) Indeed, as psychologists have shown, our powers of logical reasoning are still primitive in relation to the ability to make novel connections; and if ignorance is to be gradually replaced by knowledge the latter is far more valuable.

Knight (1921, p. 206) observed that 'to live intelligently in our world . . . we must use the principle that things similar in some respects will behave similarly in certain other respects even when they are very different in still other respects'. One class of 'connecting principles' serves to indicate which things should be treated as similar, despite their differences (and also which things should be treated as different, despite their similarities); and a second class of principles suggests which categories, so ordered, should be assumed to be linked, and in what way. Thus the construction of knowledge is always potentially subject to interpretative ambiguity, and the boundaries of categories are likely to be differently

construed by people with somewhat different histories. Now changes in knowledge systems, as Potts argues, are mainly changes to adjacent states; and Marshall expected experimentation to occur at the margins of knowledge. But for a system of any complexity there are many adjacent states; moreover, what is adjacent tends to differ between people because of the heterogeneity of their experience, and which of these possibilities is perceived also tends to differ. So at any time there are many margins of knowledge, and therefore the potential for a great deal of variation.

However, although evolution is undoubtedly about the emergence of novelty through processes of variation and selection, it is also about stability—and necessarily so. If everything is changing, or even liable to change at any moment, then nothing can be relied on—for making decisions, interpreting information, or constructing new knowledge. Any process of variation and selection is meaningless unless both the variants and the selection environment persist for a time. In Marshall's mental model of a 'machine' the lower level maintains a collection of routines which have worked satisfactorily: this frees the higher level for imaginative exploration and presents clearly defined problems when an established routine fails to cope with a new situation. Penrose's (1959) firm similarly requires both evolving resources and an administrative structure; firms are sense-making systems which (if successful) combine the cognitive distance which supports specialization with cognitive similarity in the dimensions which maintain focus on the objectives of the business.

Because it consists of patterns formed by connections, any particular 'piece of knowledge' is not easy to define. It is not only economists for whom this causes difficulty. James Fleck, nominally writing about 'artefacts, knowledge and organization' complains that 'A focus purely on knowledge makes the evolutionary problem very tough. It is very difficult to put boundaries around an idea' (Fleck, 255); and to simplify his analysis he discards knowledge in favor of 'the artefact-activity couple'. However, Alfred Marshall realized that 'the difficulty of putting boundaries around an idea' was essential to economic evolution.

Every locality has incidents of its own which affect in various ways the methods of arrangement of every class of business that is carried on in it: and even in the same place and the same trade no two persons pursuing the same aims will adopt exactly the same routes. The tendency to variation is a chief cause of progress; and the abler are the

undertakers in any trade the greater will this tendency be  
(Marshall 1961, 355).

Differences within a population are essential to evolutionary reasoning; the homogeneity of firms in a perfectly competitive industry is incompatible with the growth of knowledge that is essential to economic development. Economists who have thoroughly internalized their knowledge of the two fundamental theorems of welfare economics are very likely to find Marshall's approach either misguided or a serious obstacle to economic theorizing. Samuelson pointed to the necessity of 'getting Marshall out of the way'; but in emphasizing that increasing returns are 'the enemy of the optimality conditions that perfect competition can ensure' he failed to recognize that perfect competition is the enemy of progress through the growth of knowledge that constitutes increasing returns (Samuelson 1972 [1967], 24, 39).

The attempt to evade a proper analysis of the role of knowledge in economic development by focusing on the 'public good' characteristics of knowledge treats knowledge as if it were information. A great deal of knowledge that is in the public domain is very difficult for most people to access. Why, for example, do we need elaborate arrangements to teach students what is already published knowledge? As Cohen and Levinthal (1989) pointed out, even specialists in science and technology cannot handle knowledge developed elsewhere unless they already have, or put substantial effort into developing, the relevant 'absorptive capacity'. New knowledge has to be connected to knowledge that is already possessed, and the linkages that are formed depend on what this is. The content of knowledge may be modified in the process; indeed, the 'new combination' may suggest opportunities that were not perceived by the originator of this new knowledge, who was making a different set of connections. This is not unusual in the emergence of new theories and of technological innovations.

The denial of Knightian uncertainty is crucial for the standard treatment of information and knowledge. It is then natural to misinterpret Simon by treating bounded rationality as equivalent to a cost of information and satisficing as an optimal response, and to avoid asking how boundedly rational agents can know enough to be certain that their simplifications do not involve error. The answer to that unasked question may be found in what I propose to call Hayek's Impossibility Theorem: 'any apparatus of classification must possess a structure of a higher degree of complexity than is possessed by the objects that it classifies; and . . . therefore, the capacity

of any explaining agent must be limited to objects with a structure possessing a degree of complexity lower than its own' (Hayek 1952, p. 185).

The question may also be applied to those who analyze complexity in this way: how do they know that their models of complex systems are adequate representations of the systems to which they are applied? To this question also, Hayek's Impossibility Theorem supplies the answer: they cannot know. Just as our analysis of systems should not take as its reference point a fully-connected system, which directs us to questions about specific failures and their remedies, but start from the problem of creating and maintaining connections that are appropriate for particular purposes, so the problem of complexity is not one of simplifying a supposedly complete model, which is a fantasy, but of constructing some representation by selecting and linking elements. Both are exercises in Knightian uncertainty, for which there are no correct procedures, but the possibility of rewards for skill. Information needs to be interpreted, and the interpretation depends upon the classification systems and the connections between categories by which people attempt to make sense of phenomena—for sense has to be made by constructing knowledge.

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### ABOUT THE AUTHOR



**Brian Loasby**, a Cambridge graduate, held appointments at the Universities of Aberdeen, Birmingham and Bristol before joining in 1967 the new University of Stirling, where he is now emeritus professor. He was elected Fellow of the British Academy in 1994 and was vice-president of the International Schumpeter Society 2000-2004. The prime focus of his work is the growth and organization of knowledge within economics and economic systems, ranging from the history of thought and economic methodology to business management, entrepreneurship and innovation, with increasing emphasis on cognitive and evolutionary aspects. His publications include *Choice, Complexity and Ignorance* (Cambridge University Press 1976), *The Mind and Method of the Economist* (Edward Elgar 1989), *Equilibrium and Evolution* (Manchester University Press 1991), *Knowledge, Institutions and Evolution in Economics* (Routledge 1999), joint winner of the Schumpeter Prize in 2000, and many articles in economic journals (for biography see [www.economics.stir.ac.uk/staff](http://www.economics.stir.ac.uk/staff)).

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