Economics and the Diffusion of Communication and Information Technologies: Joseph Schumpeter and the Self-organisation Approach

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ABSTRACT *Economic motivations and economic processes play a key role in the emergence and diffusion of communication and information technologies. The objective of this paper is to offer an economic approach which is better suited to understanding such motivations and processes within an interdisciplinary context than the conventional, equilibrium-oriented, perspective. It is argued that many modern 'neoclassical' economists, stressing competition, have little in common with the old 'classical' tradition in economics, which was based on synergies. The ideas of Joseph Schumpeter are highlighted as a distinct alternative to neoclassical economics and viewed from a self-organisational perspective. It is explained that self-organisation in the economic domain is a related, but different, process to that identified by Ilya Prigogine in physio-chemical contexts. In particular, knowledge and informational considerations become central. A modelling strategy that can track self-organisational growth processes and provide an assessment of their structural stability is discussed.*

Keywords: biological analogy, development, diffusion, dissipative structure, dynamics, evolution, information, irreversibility, knowledge, logistic growth, non-equilibrium process, Schumpeter, self-organisation, uncertainty.

Introduction

This paper deals with the interface of economics with interdisciplinary research concerning the emergence and diffusion of communications and information technologies. Given the inadequacy of equilibrium methods, widely applied in economics, in dealing with such developments, it is proposed that the best starting point for an alternative economic approach lies in the ideas of Joseph Schumpeter. However, Schumpeter offered no concrete way of actually modelling development processes, although he made it clear that the diffusion of innovations resulted in tractable nonlinear growth paths. It is argued that it is now possible to make this link through adoption of the self-organisation approach. It is explained that self-organisation in the economic domain is a different process to that identified by Ilya Prigogine in physio-chemical contexts. In particular, knowledge and informational considerations qualify considerably the energy/entropy approach adopted at the physio-chemical level of inquiry.

A modelling strategy, that can be used in the presence of evolutionary economic change, is discussed. Such a strategy can allow for the interdisciplinary character of such change, while, at the same time, it can capture the role of important economic considerations. It is argued that it is essential to recognise the key role that economic

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decision-making plays in the emergence and development of communications and information technologies. The inadequacy of conventional economic analysis is an insufficient ground for social scientists to ignore or downplay economic factors. The priority is to discover other economic approaches which can be applied fruitfully in such contexts.

Knowledge, Information and Equilibrium

When we look at the history of communications, what we observe is a sequence of emergent technologies. In each phase of development, information flows spread further and faster. Two way distance communication between individuals began with messengers, then conveyers of written letters, telegraph, telephones, faxes, e-mail and video links. One way communication formed into speeches, then hand written material, printed material, radio, film and television. Interconnections between them also developed, resulting in a complex, but organised, system of communications. In parallel with the increased range and speed of information flow, there was an increase in the decentralised storage of information in, for example, libraries, filing cabinets and computer disks. The decentralised storage of information provided the basis for the accumulation of knowledge in human minds. Gradually, the cognitive structures in human brains began to extend to embrace forms of knowledge based upon a wider range of interpretations of history and associated logical arguments based on selective use of the facts. Although the post-modern view is that this process was subject to subjective biases, the critical point is that the advance of information and communications technologies enabled individuals to consider an increasing range of positions and decide for themselves which one was considered most acceptable.

In addition to the spread of knowledge, information and communications technologies provided the foundation upon which capitalism could develop. The accumulation of information concerning judicial outcomes and the careful framing of statutes and constitutions led to increased fairness in legal matters. The existence of specific information concerning contractual arrangements greatly facilitated trade and economic development. Lawyers absorbed such information and were able to transmit it across complex systems of courts. Accountants could transmit information in accepted format, concerning the financial state of firms, to prospective lenders, suppliers and customers.

Thus, what occurred was a vast increase in organisation and complexity in the economic system contingent upon the spread of information and communications technologies. Different technologies expanded their share of communications activity while others declined, but few disappeared completely because of complementarities with emergent technologies. Emergence of such technologies have been based upon engineering technologies. However, the latter have, in turn, developed with the help of information technologies. Positive feedback is an essential feature of emergence and development. Stocks of information have facilitated the increase of knowledge but, in turn knowledge has facilitated development of new ways of storing information. It is clear that the entire economic system is built upon information stocks and flows, drawn on and contributed to by human knowledge which, as a cognitive structure, has a creative quality that generates novelty, inventions and innovations. Thus, the interplay of organisation, which is structured information flow, and knowledge are at the centre of economic development. In the words of Alfred Marshall:

> Capital consists in a great part of knowledge and organisation; and of this some part is private property and other part is not. Knowledge is our most powerful engine

> of production; it enables us to subdue Nature and force her to satisfy our wants. Organisation aids knowledge; it has many forms, that of various businesses in the same trade, that of various trades relatively to one another, and that of the State providing security for all and help for many.[1]

However, the neoclassical descendants of Alfred Marshall appear to have forgotten his words and attempted to 'commodify' all knowledge and communication as goods or services with market clearing prices. As Brian Loasby points out:

> Jevons' definition of "the economic problem" which has become the commonplace of microeconomic textbooks, ignores the growth of knowledge; indeed it ignores the location of knowledge. It is the definition of a planning problem, subsequent analysis of which, not surprisingly, leads to the isomorphism of perfect competition and perfect planning. It is remarkable how few of our cleverest economists have been able to see that this isomorphism demonstrates the irrelevance of both.[2]

Furthermore, even amongst those who would not consider themselves strictly 'neoclassical' in orientation, there has been a tendency to discuss information in terms of 'externalities' rather than as an intrinsic aspect of the economic system and all its components. New Keynesians also build much of their analysis upon asymmetric information and incompleteness of markets, i.e. 'thinness' in information flow. However, both relate to the malfunction of some 'perfect' or 'unbiased' information system, which has no meaning, except as a short-term approximation, when emergence and development is taking place. Babe[3] reflects the view of many in the field of communications and information technology who have come to reject economic approaches to understanding the emergence and development of such technologies. However, it is difficult to address such developments without dealing with the economic dimension in some way. This is well-understood by the most perceptive researchers in the field of information economics, such as Lamberton.[4] The problem is that the conventional economic paradigm is inappropriate. In this regard, critics, such as Babe, are misleading in confining this problem to 'neoclassical' economics.

As I[5] and, more recently, Khalil,[6] have pointed out, it is a much wider problem, involving the use of the 'equilibrium' method by a range of schools of economic thought. Whereas neoclassical economists focus upon price mechanisms in the presence of competitive forces to maintain equilbrium, Kaleckians and post Keynesians focus upon distributional mechanisms in the face of differences in power to maintain equilibrium. Both 'old' and 'new' Keynesians have continued to use the equilibrium method as the 'long run' foundation of their analysis. Thus, the equilibrium method is used widely in heterodox, as well as orthodox, economics.

The patently unsatisfactory nature of the linear, equilibrium paradigm has led, in the past decade, to the introduction of non-linear dynamics, to attempt to capture positive feedbacks in developmental processes. However, despite superficial appearances to the contrary, this does not result in abandonment of the 'equilibrium' method—the approach remains entirely deterministic with equilibrium being redefined as a menu of alternative states: a point, a curve, multiple points or a chaotic region. There are two outcomes. First, conventional econometrics becomes very limited in its applicability, so there is a tendency to rely on simulation. Second, the notion that economists can make point predictions is fundamentally challenged. Thus, equilibrium theorists who have gone down the non-linear dynamic path have paid a heavy price in order to retain their deterministic and, therefore, mathematically tractable, logic.

Furthermore, their equilibrium approach cannot address the process of emergence

and development that we observe in historical time. Kalil[7] points out that we have to make a firm distinction between dynamics and development and that this distinction has been confused by many prominent 'evolutionary' economists. He uses the example of the logistic equation which has been used widely to describe the growth trajectory of emergent products, industries and technologies. He points out that economists, such as Baumol and Benhabib[8] have reproduced the discrete logistic map equation, proposed originally in the chaos theory of Feigenbaum,[9] to show that raising the strength of positive feedback causes equilibrium to move from a point, to multiple points, then to a chaotic region. However, even though we frequently observe logistic growth paths when development is taking place, in no sense does the mathematics of discrete dynamic nonlinear equations capture the underlying process which is at work. Of course, *ex post*, it is always possible to find one nonlinear dynamic equation, from the infinite set available, which closely matches the growth process observed. Thus, equilibrium theorists have attempted to generalise equilibrium thinking to encompass growth processes, which are due to the presence of evolutionary development, simply by proposing that the world is discrete and non-linear. Inspection of their models, however, reveals that it is not nonlinearity which generates the dynamic paths which they consider but abstract temporal discreteness. If we consider, instead, the continuous logistic function, which is more appropriate in the case of most economic development processes, we cannot generate outcomes such as chaos.

Khalil[10] also stresses, correctly, that development involves innovative processes which render notions of 'efficiency' meaningless as developmental growth occurs. What he does not stress, however, is that the continuous logistic equation can still capture this growth in a descriptive way, in the sense that we cannot deduce deterministic outcomes from it because we are dealing with a non-equilibrium process. Correspondingly, any stationary state achieved at the end of a logistic growth process will not be a stable equilibrium. Nonetheless, as Gunnar Myrdal stressed in his famous depiction of virtuous and vicious circles in the process of economic development, it remains the case that the combination of positive and negative feedback, which the logistic equation captures so well, does operate in non-equilibrium processes of growth. It is for this reason that it has been discovered so often in product cycles, innovation processes and the rise of technologies.

The prevalence of logistic growth processes, both in Nature and in the economy, challenged equilibrium theorists to provide discrete dynamic representations of such processes.[11] However, a development process which exhibits logistic growth is inherently non-equilibrium, and is not very prone to spin off into chaos—it is more likely to collapse, experience a discontinuous switch on to a new developmental path or become a structured process within a greater system. Non-equilibrium growth processes are stabilised by time irreversibilities and much of the system development which they summarise is explicitly designed to put in place informational mechanisms to ward off chaotic outcomes. What we observe in the real world is often the reverse of that predicted by equilibrium theorists: processes tend to be most stable when they are changing fast in a highly variable manner and least stable when they are static.

The Decline of the Classical Tradition in Economics

In considering the economics of the emergence and development of new technologies, the existence of logistic growth paths provides a 'stylised fact' upon which we can build an abstract representation of 'developmental growth'. However, it has been argued that economic approaches, which envisage growth paths as tendencies towards equilibrium positions, are unsuitable for this purpose simply because developmental growth is a

non-equilibrium process. At first glance, this appears to rule out much of what we think of as economics, but is this the case? To answer such a question requires us to reconsider what the fundamental character of economics actually is and why its character appears to have changed so much over the past century.

The evolution of the economic system has been thought of in two distinct ways: first as predominantly a development process involving synergies between individuals and between organisations of individuals, second, as predominantly a competitive process involving selection mechanisms which eliminate the unfit. The former has tended to be drawn from humanist ideas concerning social co-operation and individual creativity. The latter has tended to draw on materialist world views and relies upon biological analogies of a Darwinian type, in some cases tempered by Lamarkian qualifications. However, I have argued[12] that the use of biological analogies in economics constitutes a form of false scientism because the evolutionary biology drawn upon was already inspired by earlier economic, political and social thinking. In early classical political economy we can associate the developmental approach with Adam Smith and the competitive approach with Thomas Malthus. Let us look at each in turn.

Classical Political Economy as Socio-economic Synergetics

If we believe that synergies are central to economic development, then classical political economy, despite the recent tendency for its neoclassical descendants to stress competitive forces, has offered a powerful case for a synergetic approach. Adam Smith emphasised the inherent tendency for people to "truck and barter" and to enter into commercial contracts, provided that institutions were created to facilitate such economic co-operation. This was a revolutionary idea in its time and one which, through the introduction of laws to protect those who engaged in it, provided a fundamental force for the development and refinement of capitalism in the 19th and 20th centuries. Furthermore, Adam Smith's famous example of the pin factory and the division of labour provided a lasting and vivid description of how synergies occur in the economic system, yielding increased complexity, increased organisation and increased productivity. This was not a description of the 'market' working, neither was it simply 'economies of scale' at work. It involved the interaction of organisational and technological innovations catalysed by the existence of an entrepreneur. Thus, the organised complexity which arose in a productive enterprise was the outcome of a 'top down', rather than a 'bottom up' process, involving the application of knowledge in order to set up structures which embodied flows of information.

Fitzgibbons' study[13] of Adam Smith has demonstrated that he anticipated most of the points raised by modern critics, such as Babe,[14] concerning the problem of commodification of capitalist society. For Smith, capitalism could only survive if an overarching moral and ethical system was deliberately maintained. In the modern language of neoclassical economics, this was not a 'normative' position but rather a consideration of what a rational system of ethics might be. In other words, Smith not only considered synergies within the economic system but also synergies between the economy and society which would promote the well-being of individuals, beyond the utility derived from consumption.

By the end of the 19th century, this stress on the synergies available through the promotion of economic liberty, in an appropriate ethical climate, remained strong in the classical tradition. Alfred Marshall, one of the acknowledged founders of neoclassical economics maintained Smith's view and consequently confined use of his 'mechanical analogy' to short periods when 'statical' assumptions could only hold approximately. By

Marshall's time, the institutions of capitalism had developed to such an extent, along with improvements in the storage and transmission of information, that the operation of markets had become much more important in eliminating gluts and shortages in systematic ways. Capitalism had developed markets in certain commodities which acted as homoeostatic mechanisms which provided valuable information to suppliers and demanders and it was necessary to provide an analytical framework within which these could be understood. However, Marshall steadfastly rejected the notion that the mechanical analogy could be used to understand economic development in the long period—he continued to see the development of capitalism, as Smith had, as an evolutionary process, centred upon synergies.[15] Furthermore, Marshall held firm to Smith's emphasis on the centrality of ethics to the proper functioning of an economic system.

Neoclassical economics as a Competitive Process

In the 20th century, economics came, increasingly, under the spell of Darwinism. Institutionalists, such as Veblen,[16] looked at what seemed to be the dog-eat-dog capitalism of frontier America and concluded that something akin to Darwinian natural selection was at work, but not necessarily to the betterment of society. Neoclassical economics was firmly rejected in preference for an emphasis on power relations. However, as the twentieth century unfolded, organised market activity continued to increase as the institutions created to encourage and protect it were strengthened. Gradually neoclassical economics came to prosper and the institutionalist and historicist approaches went into decline, particularly after the Bolshevik Revolution of 1917, when capitalism required an ideology, as well as a set of market institutions.

At that time, neoclassical economics was either Marshallian and concerned with the operation of the price mechanism in practical, short period settings or, following Leon Walras, preoccupied with the elegant, welfare maximising properties of an ideal theoretical system of general equilibrium. In both, competitive struggle of the Marxist or Veblenian type was downplayed. However, after Marshall's death, neoclassical economists began to equate general equilibrium theory, not with utopia, but with the actual state that market systems tended towards in the long period if they were competitive. The corollary was that such a tendency was only held back by the presence of 'imperfect competition'. Ideological considerations demanded that the myth of the perfect price system had to be linked, explicitly, with actual captialist economies in the 'Free World'. By the 1940s, neoclassical economists were coming under increasing pressure for presenting a general equilibrium model which, as Oskar Lange pointed out, looked more like a device to guide 'shadow price' central planning than a description of a competitive economy. Being entirely static, the model was unconvincing as a depiction of the capitalist system—it dealt with the theoretical outcomes of competition but said nothing about the process of competition.

After the second world war, neo-Darwinism swept through the biological sciences and, in the form of analogy, began to enter the social sciences and the humanities. Alchian[17] was one of the first to see how neo-Darwinism could help to justify the use of neoclassical general equilibrium economics. He argued that an optimal general equilibrium situation could prevail in the presence of a high level of competition because of the operation full-blooded Darwinian natural selection amongst firms. The latter did not optimise but natural selection ensured that only the most efficient survived.

It was at this juncture that neoclassical economics began to downplay its synergetic flavour and become a descendent of Malthus, the English parson, rather than Smith, the Scottish Stoic. In a world of now highly developed contractual law and sophisticated

markets, the synergies which Smith fought to promote were gradually taken for granted and the stress was increasingly on selective competition.[18] Although the mechanism appealed to was neo-Darwinian, Malthus' severe Christian vision of competition as the elimination of sin was central: lazy businessmen should be eliminated and unemployment was due to the slothfulness of the unemployed themselves. Previously, the connection between neoclassical economics and theology had been benign—the general equilibrium system had, lying behind it, an 'invisible auctioneer' which some had identified with the 'Hand of God'. However, the new Malthusian connection involved Old Testament retribution.

Such an approach had little impact in the 1950s, when social democracy was spreading and state welfare and stabilisation programmes were being set up. However, the creative, developmental dimension of the classical tradition was gradually de-emphasised. Economic expansion was not due to synergies, but rather exogenous factors, such as technical change which significantly, was likened to 'Manna from Heaven'. This approach was manifested in the neoclassical growth model which was devised in the 1950s and the 1960s. The connection with theology continued to be benign, but the old classical belief in facilitating the synergetic development of economic co-ordination and in promoting appropriate ethical and institutional arrangements, was downplayed significantly. In the microeconomics, which underlay the macroeconomics of neoclassical growth theory, there arose a 'supply side' concern to encourage competition at all costs. Ethical concerns were dismissed as 'normative' and firms, eliminated because of deregulation and microeconomic reform, 'deserved' their fate. Gradually, through the 1960s and the 1970s, the new synthesis of Christianity and a belief in Darwinian-inspired cut-throat competition gave rise to the New Right.

By the 1980s, Margaret Thatcher could echo her New Right economic advisers and say that there is "no such thing as society". Commodification of all aspects of society, promoted by the Chicago School, had become dominant and neoclassical economists abandoned all but a pale stereotype of their intellectual forefathers, Smith and Marshall, in favour of individualism, materialism and competition, unrestrained by sympathy. The loss of the synergy dimension of mainstream economics and a preference for static competitive interactions, conveniently formalised in mathematics and game theory, altered the discipline's character fundamentally. It could no longer be used, in a Smithian way, to understand the great technological and organisational transitions which were taking place.

Post-Veblenian Evolutionary Economics

A striking feature of economics over the past decade has been the rise in interest in what can be loosely called 'evolutionary' aspects of economic systems. If we set to one side those who call themselves evolutionary economists, but continue to apply equilibrium methods, there remains a group which can be labelled post-Veblenian which rejects static, general equilibrium depictions of the economy and adhere strongly to biological analogies.[19] Many have come to argue that the deficiency of neoclassical economics lies, not in the downplaying of synergies, but in not stressing the importance of competition enough and failing to explain the process involved.

Many Post-Veblenians do not choose the neo-Darwinian theory of natural selection as their biological analogy. Instead, they tend to favour a Lamarkian analogy. The latter analogy allows for the inheritance of behavioural characteristics acquired from experience in particular environments. Thus, 'routines' (Nelson and Winter)[20] or 'techniques' (Mokyr),[21] are viewed as counterparts to genes and can be modified through experience

in particular circumstances. Economic organisations, such as firms, do not need to rely entirely upon natural selection to adapt. The Lamarkian approach continues to use the selfish gene as a biological analogy. The gene has simply become 'cleverer' in adapting to experience. Reproduction can then give way to replication, which is more realistic in the case of economic systems.

However, it is really very helpful to base economic evolutionary arguments on selfish and clever techniques or routines? Would it not be much better, as Joseph Schumpeter argued, to forget about such reductionist biological analogies altogether and examine economic evolution in its own unique social, political and psychological context? Stephen Gould, the palaentologist, has warned, on several occasions, of the perils of using biological analogy in the social sciences and recounts many of the human tragedies which flowed from the application of social Darwinism and eugenics in the early part of the twentieth century. Dangers also loom large in the application of economic Darwinism in the post-Veblenian manner. In contrast to the New Right's quasi-religious faith in the 'discipline' of the highly competitive market, post-Veblenians depict the economy as dominated by power struggles from which change emerges. Since power struggle is primarily a political process, the door is opened for the intervention of interest groups in the process of economic evolution and for the imposition of preferred value systems. Eugenics involves artificial selection and, in the economic domain, focuses upon the deliberative elimination of 'weak' gene analogues, such as low productivity techniques or cultural practices which lead to the same result.

Post-Veblenians do not necessarily share his religious belief, but they do share the vision of Malthus, where competition is decisive and the exercise of power is all. Smith's synergetic vision of economic development, although not rejected, is devalued in a manner reminiscent of Karl Marx. However, perhaps the most disappointing feature of post-Veblenian evolutionary economics is that, in the end, the equilibrium method is not rejected. Competitive models generally have deterministic equilibrium solutions. This is true of, for example, the model of Nelson and Winter[22] and more recently, that of Metcalfe.[23] In searching for a way of formalising a competitive process, the result is a disequilibrium mechanism without a historical time dimension.

Post-Veblenianism is an outgrowth of institutional economics. However, it represents only one strand of that tradition: the other stemmed from John Commons, who did not rely upon biological analogy and stressed a synergetic, social science approach to economic evolution. What the Commonsian strand lacks is abstract representation—it is a descriptive, pragmatic approach to institutional change which, despite its dominance in the US in the interwar period, could not compete with neoclassical economics in the postwar era, when the ideological and scientific aspirations of economists changed. As we have observed, neoclassical economics became centrally concerned with competition and, therefore, it is not surprising that post-Veblenian evolutionary economics became the more prominent alternative.

Austrian Economics

In the late 19th and early 20th century, Austrian economics and neoclassical economics were regarded by many as the same. Some, such as Babe[24] still appear to hold this misleading position. The conflation is understandable because Karl Menger can be associated with the development of the 'marginalist revolution' and there was no more ardent supporter of the free market system than Friedrich von Hayek. However, in the postwar era, the difference became very marked—Austrians became strong critics of neoclassical economics in its modern guise. In essence, they held fast to the idea that the

economic process is characterised by evolutionary development, not dynamics. Correspondingly, they, eschewed mathematics and stressed the importance of endogenous institutional change. The fundamental idea of Smith, that economic development is primarily a process of synergy in conditions of uncertainty, is maintained. The focus is on individual interactions that give rise to 'spontaneous order'. Their opposition to regulation and government intervention stems from a view that, if these are driven by political interest groups, they can suppress evolutionary development. Their position is a modern version of that of Adam Smith.

Their insistence that such intractable processes of evolutionary development involve fundamental uncertainty means that they must be non-equilibrium in character. In such circumstances, markets are defended as hard won emergent institutions which confer large information advantages on their participants. Inflation is disliked because it interferes with the workings of these institutions and leads to a regression to more primitive forms of exchange, such as barter. Prices are viewed as very useful signals in an uncertain world and it is felt that we would be much worse off without them. In the Austrian world, prices are ever-changing in competitive conditions, but become fixed if monopoly power, in the public or private sectors, determines them for the purposes of extracting rents.

In Austrian economics we have profit seekers rather than profit maximisers, utility seekers rather than utility maximisers. The latter allows for novelty and the former for entrepreneurship. Equally, the presence of fundamental uncertainty leads people to subscribe to collective rules and norms which can reduce uncertainty and convert it, not into certainty, which is impossible, but something akin to quantifiable risk. Uncertainty leads to the emergence of institutions, but new institutions mean that different uncertainties emerge. 'Bedrock' institutions become constitutionalised, peripheral ones come and go. The former are difficult, but not impossible, to reverse by politicians. Few irreversibilities are absolute in the economic system but they remain so in the temporal sense that there cannot be a return to pre-existing arrangements, only new arrangements.

Austrian economists do acknowledge that competition is important to ensure that individuals and groups are not allowed to engage in strategies to extract economic rents. However, their definition of competition extends far beyond relative prices and there is a recognition that regulations and institutions will change continually as the needs of individuals change. As such, there is considerable overlap between Austrian economics and legal studies. A related problem with Austrian economics is that it has little or no economic modelling dimension. It can be very prescriptive, often dogmatic, but non-empirical. Furthermore, in practice, the Austrian slogan that the 'future is unknowable' is often refuted by observation. At any point in time, there are core structures which do not change quickly and there are peripheral structures which do change but are often tractable in their development over time.

Joseph Schumpeter

The economics of a world where the irreversibility we observe in history interacts with Austrian novelty is that of Joseph Schumpeter. His focus, in his work on business cycles and economic development, is concerned with the diffusion of innovations as a process containing irreversibilities. The outcome of such processes are increasingly complex, more organised and durable structures. Schumpeter's individuals adhere to routines but seek novelty, in the Austrian way. Profit seekers are the true 'heroes' for Schumpeter, as they were for Adam Smith, because they act in an 'economic' way and attempt to turn knowledge into productive structures. To do so they set up channels of communication

through which information can flow. To a significant extent, entrepreneurs facilitate organisational, more than technical, innovation. Schumpeter stresses the importance of cost cutting and this arises, to a significant extent from organisational innovation (such as Smith's pin factory).

Prices are important because they determine how much profit will be made. Once entrepreneurs have committed themselves to productive organisations, they will, in the short period Marshallian sense, attempt to minimise cost and maximise revenue. However, these decisions, largely undertaken by management accountants, are not fundamental, they do not affect the limit to which growth tends, but rather the growth rate at which the limit is approached. The fundamental and difficult decisions which influence the limit are those associated with how much profit to retain for investment and for the payment of interest on loans for investment.

Consequently, relative prices and costs must enter the picture in understanding diffusion processes. However, relative prices are less pervasive in determining the limits to which diffusion will tend. By definition, the entrepreneur has only the vaguest idea of the price structures which will prevail. His or her skill will be in determining whether a new good or service can be offered which will be viewed as novel enough to buy. Clearly relative prices and costs embedded in the founding structure of production will determine the initial viability of production. Thus, costs and prices prevailing at the founding of productive structures are crucial in determining the scale and scope of production which, in turn, will influence the limit to which development can tend. However, after founding, bygones are largely bygones. Only marginal, Marshallian 'economising' responses to a limited set of prices can then occur.

Dopfer[25] stresses that the Schumpeterian entrepreneur does not survive and prosper through economising and learning:

> What characterises the Schumpeterian entrepreneur is thus a behavioural attribute that represents something like *unlearning by doing*. Old cognitive and behavioural dispositions must be 'erased'—in a process of *mental traversing*—in order to serve as a base for innovative cognition and behaviour.[26]

The entrepreneur initiates a process that:

> . . . incessantly revolutionises the economic structure *from within*, incessantly destroying the old one, incessantly creating a new one. This process of Creative Destruction is the essential fact about capitalism.[27]

Thus, Schumpeter consigns equilibrium tendencies to a secondary transitory role and specifies an *endogenous* process where the entrepreneur, not competition, precipitates change. Without the energy and restless spirit of entrepreneurs, competition would yield monopoly dominance to the lowest cost producer and change would cease in equilibrium. Entrepreneurs ensure that such equilibria, even if attained, can never be stable. Thus, he did not believe that the biological analogy of natural selection was informative but, instead, saw economic evolution as an endogenously driven development process, punctuated by discontinuities:

> [d]evelopment . . . is a distinct phenomenon, entirely foreign to what may be observed in the circular flow or in the tendency towards equilibrium. It is spontaneous and discontinuous change in the channels of the flow, disturbance of equilibrium, which forever alters and displaces the equilibrium previously existing.[28]

There is a view that Schumpeter argues that inventions are the basis of economic development. This is incorrect:

> . . . inventions . . . do not give rise to economic development, but are rather their result. Inventions occur if the entrepreneur requires them . . . It is not inventions which have made capitalism, but capitalism which has brought forth its necessary inventions.[29]

Furthermore, Schumpeter did not argue that the accumulation of technical knowledge results in economic development:

> The view exists that there is an autonomous element in the technological and organisational progress that carries in itself a law of development and that rests essentially on the advances in the accumulation of our knowledge . . . This view is incorrect. No automatic progress exists, and where it does exist, it does so only to a very limited extent.[30]

Thus, Schumpeter rejected all views of development and growth as driven by exogenous forces. People inherently accumulate knowledge and create novelty from that knowledge, but economic development comes from entrepreneurial action to draw in particular novelties and convert them into workable inventions. There is never a shortage of these novelties in relation to the level of economic development attained, only a shortage of entrepreneurial vitality. Thus, we have a subtle synergy argument which has been misunderstood by many: technological change and organisational innovation mutually reinforce each other in the presence of a catalyst, namely the entrepreneur, the embodiment of the human capacity to go beyond the familiar into uncertainty, to precipitate economic development. Ultimately, economic development is due to a specific aspect of human behaviour which is beyond mere curiosity and non-deterministic: I have labelled such behaviour as that of *homo creativus*.[31]

Economic Self-Organisation

In developing an approach to economics suitable for dealing with the emergence and diffusion of technologies, it is clear that Joseph Schumpeter offers the most promising starting point. However, there are two drawbacks. First, his attempts to integrate his vision of economic development with Walrasian depictions of general equilibrium of the 'circular flow' presents difficulties. Second, he did not offer any technical recommendations concerning modelling development processes. Today, we have the new field of self-organisation upon which to develop models of development processes exhibiting synergy. However, we encounter, again, attempts to express self-organisation in terms of discrete dynamic equations with equilibrium properties. This is particularly true of synergetics in the natural sciences but this is because such equations are superimposed upon rich experimental data in order to discover a mathematical representation of a transition from one equilibrium steady state to another. Phillip Wild and I have argued[32] that such methods are inappropriate in economic contexts because structural change is an ongoing non-equilibrium process and because economists rarely have experimental data. Furthermore, although self-organisation occurs in all types of system, it differs depending upon the level of complexity we are considering.

Self-organising systems (or dissipative structures), at the physio-chemical level of inquiry, absorb available energy and export entropy, to become more complex and more ordered.[33] Processes of this type contain irreversibilities and run up against energetic and entropic capacity limits that, when approached, lead to nonlinear discontinuities in structure of various types. However, the physio-chemical self-organisation approach is of

limited value in understanding evolutionary behaviour at higher levels of natural complexity. Brooks and Wiley (1986) argue that such an approach involves the imposition of energy by the environment but, at the biological level, the more advanced life forms actively seek energy in their environment. In order to acquire energy, biological systems must build up knowledge of their environment, both directly, and indirectly through their inherited genetic structure. Redundant knowledge, embodied in obsolete structures, must be ejected, usually through the operation of selection mechanisms. So entropic waste, itself, acquires a qualitatively different character in biological systems. Limits to structure-building remain, but they are due to specialisation in choice of energy source and an irreversible commitment to specialised knowledge embedded in structural complexity.

I have argued[34] that, at the economic level of inquriy, biological self-organisation is, again, inadequate to explain structure building because knowledge, this time, is not just imposed, by experience and genetic inheritance, but actively acquired. The deliberate acquisition of knowledge, in combination with acquired skills in accessing special energy sources, leads to the design and creation of 'artificial' complex structure. Thus, the limits to economic structure-building can transcend both physio-chemical and biological constraints—they are determined by the choice of specialist knowledge and the specialist nature of the structural complexity that it gives rise to. Economic organisations, like their biological counterparts, export entropy in the form of structure that embodies obsolete knowledge, but not necessarily through selection mechanisms. Entropy exportation can also be the object of new knowledge acquisition and planning. Self-organisation is not an analogy, it operates in all types of dissipative structures. At all levels, the parallel development of complexity and organisation embodies irreversibilities in structure, causing the growth of the system in question to tend towards zero. Such a slowdown renders systems vulnerable to structural discontinuity and associated uncertainty as to their future. However, in economic cases, it is possible for organisations to adapt their structure through, for example, the substitution of new products, human capital and physical capital for old.

In two papers, by myself and Phillip Wild,[35] an empirical methodology has been devised to deal with economic self-organisation. A combination of methods are applied: the econometric estimation of nonlinear logistic growth models and the application of statistical methods—moving window spectral methods—to examine the unexplained residuals to identify the non-deterministic dimension of developmental growth. These methods can identify the existence of time irreversibility, structural change and uncertainty—all features of economic self-organisation—in a growth process. Although such modelling cannot be predictive in the conventional sense, transitional probabilities can be provided which can give advance warning that a process of self-organisational development is likely to be subject to nonlinear discontinuity of some type, ranging from system death through to a transition to a new phase of development. Which of these outcomes, in turn, are most likely involves qualitative investigations of the component structure of the system and its interface with its environment.

Of course, there are many instances when we simply do not have enough data to implement the above approach to evolutionary modelling. However, the first stage, the estimation of nonlinear models, can be undertaken on comparatively small samples of data. In such situations, qualitative analysis becomes central and it is necessary to be guided by a more appropriate methodology, such as that proposed by Tony Lawson.[36] Of course, there is nothing really revolutionary in this—firms have investigated their product cycles using a simpler mix of the suggested quantitative and qualitative approaches for decades.[37]

Conclusions

I have attempted to argue that it is essential that we incorporate economic behaviour into studies of the emergence and development of communications and information technologies. By using an economic self-organisation approach, we can operationalise the intuitions of Joseph Schumpeter in a non-equilibrium modelling strategy. The economic self-organisation approach recognises that information stocks and flows are inherent in the economic system and that knowledge, as a cognitive structure, provides the source of novelty which, in turn, is the source of economic development.

The great mistake made by mainstream economists is to treat knowledge and information as analogous to stocks and flows of commodities. This has confused the objects of economic behaviour with their inherent composition. The notion of a cost dimension excludes the essential character of knowledge—in a world of uncertainty, knowledge cannot be quantified. We are tempted to consider the search for knowledge in terms of cost and benefits but we know that novelty cannot be discovered in such a manner—it is acquired in an unintended and tacit way. What the economic self-organisation approach tries to do is to accept this and trace its consequences on the time paths of the economic variables which we can observe.

Knowledge is applied, as Kurt Dopfer stresses, to create organisation which consists of a structure of information flows. As economic self-organisation proceeds, knowledge is used to draw in energy and materials in order to create more complex systems with increased flows of information. The limits of knowledge limit self-organisational development and improvements in information flow become exhausted. Survival depends on new knowledge. Creativity involves the setting up of novel organisations with new information flows and the abandonment of old structures. It is in this sense that I take issue with the simple idea that knowledge is simply about positive sum games. Take Babe's Boulding-inspired example[38] of the teacher who does not lose knowledge when it is imparted to students. From an economic self-organisational perspective, the teacher does lose knowledge in teaching because s/he incurs an opportunity cost in not having the time to research new knowledge. Furthermore, this is very much an economic problem—the teacher who does not maintain knowledge through active acquisition may well lose her or his job.

Without explicit consideration of time, we cannot understand knowledge. Knowledge becomes obsolete, because it is a cognitive structure, which, like all other dissipative structures, is formed as a process of self-organisation, provided time and money are available. Acceptance of the fact that knowledge becomes obsolete is the flip-side of the notion that knowledge involves the discovery of 'novelty'. The economics of Alfred Marshall and Joseph Schumpeter cannot be understood unless both sides of the coin are recognised. I have argued that the true classical tradition, stemming from Adam Smith, resides in their economics, not the neoclassical economics which came to dominate in the twentieth century. To understand the emergence and development of communications and information technologies, we must apply their economics and learn to replace obsolete mechanical equilibrium thinking with the self-organisation approach, both in our theorising and in the empirical methodologies which we adopt.

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