

Introduction and overview

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This volume is dedicated to the goal of developing evolutionary economic analysis and associated sets of empirical tools to provide a coherent scientific approach that can deal with the real world of continual change in the economic system. Following on from Foster and Metcalfe (2001), we cast such endeavours in terms of complexity science, as applied in the context of complex adaptive systems in the economic domain. Two key themes can be discerned. First, a complex system is a network structure that contains elements and connections. These connections constitute knowledge and understanding. Thus, a theme throughout the volume is the fact that knowledge is core to economic systems and the source of economic value. Therefore, a clear appreciation of the nature of knowledge in a complex system setting is fundamental to analytical developments in evolutionary economic analysis. Second, selection mechanisms, captured in replicator dynamics, are viewed from a complex system perspective. This brings into clear relief the fact that replicator dynamics do not describe a tendency towards an equilibrium state or, from an empirical standpoint, regression to the mean. Looking at selection mechanisms in this way both emphasizes their relevance and, at the same time, highlights the fact that the variety they operate upon is of prior importance in economic systems because it arises from forms of knowledge that are much less prevalent in the biological domain.

As in Foster and Metcalfe (2001), this volume is expansive in its scope, embracing: quite abstract discussion of ontology, analysis and theory; discussions of how we can operationalize notions such as ‘capabilities’ from what we understand as ‘knowledge’; the use of simulation techniques; and empirical case studies. Such a mix is quite deliberate. We believe that any attempt to separate theory from empirical inquiry is both false and likely to lead to confusion and misunderstandings. Only through the constant interplay of theoretical speculation, the development of methodologies and related analytical techniques and the careful observation of complex reality can robust scientific inquiry emerge in the socioeconomic domain. As economics has become more specialized, so these aspects of scientific

inquiry have become separated and often incompatible with one another. Complex systems thinking leads easily to the conclusion that such a separation is untenable while, at the same time, because such systems display both order and organization, it is feasible to argue that reintegration is possible. In a sense, there is nothing new in this – it is what Adam Smith and many others did in the past with considerable intuitive skill. However, for decades, economists have sought to employ the increasing logical and calculative power at their disposal to replace intuition in the style of classical physics. Today, we are in the early stages of a quiet revolution in which economic complexity can be addressed directly with the powerful computational tools at our disposal instead of being cut into lifeless pieces. What is to follow in this volume is, we hope, a small contribution to this revolution in economic science.

Chapter 1 sets a challenging agenda both for the other contributors to the volume and to evolutionary economists generally. Kurt Dopfer and Jason Potts set down the foundations that they feel are necessary for the construction of evolutionary economic analysis. They ask the question ‘What is meant by claiming that an economy is a complex system?’, and set out the three principles – modularity, openness and hierarchic depth – that provide the answer. The fundamental point they make is that evolutionary thought cannot be ‘bolted on’ to mainstream thinking; it requires its own categories and concepts expressed in terms of these three principles. Their aim is to lay bare the relationship between complex system thinking and evolutionary thinking, as it turns out through the two quintessentially Marshallian notions, order and organization. Indeed, in the analysis of evolving knowledge-based systems, notions of order and organization, both of which are based on pattern formation, are primitive. They are also emergent and level dependent and neither entails any idea of general equilibrium.

Complex systems evolve because their components and subcomponents change at different velocities and because these velocities are mutually determining. To develop these ideas, Dopfer and Potts claim that it is essential to apply a more discriminating ontology, namely, one that is not ‘flat’, that is, permitting anything to exist at any level in a system. From the perspective of evolutionary science, this is related to the old and enduring question of being clear about the units of selection, the forces of selection, and the processes that result in ontological variation. This is an ambitious undertaking in that ideas of organization are far less well developed than ideas of order, and their argument cannot fairly be summarized without damage to the subtlety of its interconnections. Yet much of what they say is reflected in the ensuing chapters, albeit in a fragmented way and, although what Dopfer and Potts offers us is still very much ‘work in progress’, it is clear that they have made large strides towards their goal of

offering a coherent analytical framework for evolutionary economists to work with.

The elements of an economy, set within an organizational structure, are agents. Rules provide the connective dimension of such structure and, as such, rule systems embody and articulate the knowledge contained in the system. Agents are the carriers of rules, they are the generators of rules, and they are the interactors, creating order and organization based upon the rules that they follow, so what evolves are rule systems or knowledges in particular (the plural is deliberate, as in Andersen – Chapter 6). Evolution is about making and reforming the connections between agents. This results in rule modification and entails variety and experimentation subject to the constraint that the manner of evolution must not compromise the viability of the rule-generating system. Since knowledge is always carried by individual agents and since economic action depends on cooperation, it follows that the knowledge of individual agents must be correlated, they must come to a common understanding to the requisite degree at the appropriate levels. Consequently, knowledge cannot be treated solely as a micro-agent property; rather it is a property of populations defined at meso levels for this is where correlation, the growth of common understanding, takes place. This is the meso level of analysis and it is the independent generator of all the micro and macro phenomena in the system.

Dopfer and Potts's analysis is sketched out at three interconnected levels to explore the idea of trajectories of evolving rules and, to this end, they replace 'methodological individualism' with 'methodological cyborgism', the necessarily statistical analysis of evolving rule systems. To make these ideas more concrete, they develop several analyses of how the transition between the micro and the macro is articulated via the concept of a meso trajectory, that is to say, an ordered pattern of change in rules and knowledge, which incorporates the familiar concepts of innovation, imitation and diffusion expressed as the emergence, spread and stabilization of new rules with modification. Among the many interesting points made, we note the significance of slack within such systems, the fact that disappearance of rules is just as significant as the creation of rules, and the fact that aggregates are ensembles that must be treated statistically and cannot be interpreted as uniform wholes. Taken together this is a powerful, albeit preliminary, statement of the nature of what Dopfer and Potts refer to as 'evolutionary realism'.

In Chapter 2, Paul Ormerod and Bridget Rosewell begin by observing that agent-based models of the kind to which the Dopfer/Potts reasoning, and other chapters in this volume, leads is bound to appear strange to most economists. The predictive power of the agent-based approach appears limited, results are often not transparent and the heterogeneity of agents

militates against straightforward, elemental description. However, this is not in practice a weakness but rather a necessary step to come to terms with a complex world. What is at stake in this chapter are the terms under which it is agreed that models can be validated. They suggest three criteria: the plausibility of the presumed rules of behaviour, a clear understanding of the range of facts to be explained, and the precision of predictions across the range of facts. They show how two very simple agent-based models of the business cycle and the process of competition in deregulated industries perform better than widely accepted mainstream models of these phenomena. These different models lead to different insights. In particular, that it is not necessary to base the business cycle on the propagation of exogenous shocks and that competition is not realizable as a static structure. The normative policy implications of this approach are, as they conclude, rather profound.

Within the body of evolutionary thinking in economics there is an increasing recognition of the role of the growth of knowledge as a co-evolutionary process. In some of the more managerially oriented literature this is reflected in a discussion of the capabilities theory of the firm. This is the theme taken up in Chapter 3 by Paolo Ramazzotti and in Chapter 4 by Peter Hall. Ramazzotti explores the connections between managerial strategy, learning processes and the division of labour starting from G.B. Richardson's widely accepted notion of capabilities as 'knowledge, experience and skills'. His central theme is that the structure of capabilities co-evolves with the structure of the division of labour, and that managerial decisions over the form of the latter necessarily impinge in a fundamental way on the development of the former. This follows because the division of labour, read the organization of the firm, is the context in which problems emerge and knowledge grows. A central feature of this exposition is the emphasis on potential conflict within the firm that may arise when management and workers, or any other internal coalitions for that matter, may have different cognitive, motivating frameworks. This may be reflected in conflicts over distribution of value added or more generally in power struggles that undermine the very operation of the firm. Thus, Ramazzotti points to the importance of leadership and loyalty as conflict-containing and -resolving elements in the internal coherence of the firm and, indeed, as elements of needed capability in themselves.

This leads the author into an interesting discussion of the two-way relation between capabilities and the boundary of the firm, the significance of the choice of the division of labour (external as well as internal) for the evolution of capabilities, the distribution of power and incentives to cooperate, and alternative strategies for enhancing competitive performance. One may conclude here that, in a fundamental sense, strategy has to reflect the

opportunities generally available for enhancing capabilities. When these are limited, and learning is more or less a redundant issue, it is perhaps more likely that management will seek competitive advantage through cost-cutting distribution-based policies, and organize the division of labour to minimize the ability of workers to deploy their knowledge through the imposition of tightly specified template routines. Conversely, where learning opportunities are rich, competition may depend more on product innovation and enhancement and require a more collegial approach to the organization of the division of labour.

In placing knowledge at the centre of the analysis of firm performance, any writer faces formidable obstacles and these are the focus of Peter Hall's detailed investigation into some of the theory and empirics that struggle to make sense of the notion and significance of tacit knowledge. If it is accepted that only human minds can know, in the ways relevant for social and economic action, then one immediately faces a different problem, namely, the idea that a firm can be said to know at all. Clearly, if any team is to function, the knowledge of its members must be sufficiently correlated to permit complementary, purposeful action. How this correlation is established is a fundamental issue in the organization of the firm and, as Hall points out, it is made vastly more complicated by the existence of substantial tacit elements in what can be correlated. All this matters because of the link between the differential performance of firms and the claim that these enduring differences are related to differential knowledge in general and differential tacit knowledge in particular.

More problematic still, any evolutionary theory of firm performance is intrinsically dynamic and accepts that changes in the external environment are part and parcel of the competitive process. If a firm is to survive it must adapt and if it is to adapt it must possess the necessary dynamic capabilities that enable its members to know more and to organize the correlation of that new knowledge. Thus, the central question becomes the empirical status of the mapping between dynamic capabilities and changes in firm performance. In Hall's account this requires two issues at least to be addressed, the identification of knowledge that yields strategic advantage, and the translation of knowledge into capabilities that can be articulated. This leads to some interesting conundrums, for example, the attributes of tacitness that protect knowledge from external, competitive scrutiny also make it difficult to communicate that knowledge within the firm to the degree required for effective correlation and the growth of understanding. To the extent that knowledge is easy to correlate within, then why does it remain difficult to correlate without?

Whether one is concerned with knowledge growth in-house or the external acquisition of knowledge in networks or other collaborative

arrangements, the empirical difficulties are formidable, and are so by the very nature of tacit knowledge as an object of enquiry. Perhaps in part this is because what a firm knows is as much to do with its constituent 'knowers' as it is the nature of what it is they are claimed to know. Hall is quite correct in saying that optimizing models of the firm may give strategic insights into the formation of dynamic capabilities independently of issues centred on the nature of knowledge. Yet here one must be careful; evolutionary theory is quite compatible with the optimizing firm, as it is with any theory of the purposeful firm, rather what matters is not the optimality of behaviours but the variation of behaviours within the competing population, so bringing us back to his initial concern, namely, 'why do firms differ?'. A careful reading of Hall's chapter should help those who seek to undertake further empirical investigation of these issues.

In the following two chapters, we turn to more formal approaches to understanding an evolving economy.¹ They have at their core the essential role of diversity, but the way diversity is levered differs substantially across the two contributions. In Chapter 5, Peter Allen uses computer engineering techniques to explore the economic significance of complexity, interpreted in terms of the qualitative as well as the quantitative adaptation of a model system. As with all evolutionary systems the drive comes from diversity, as Dopfer and Potts stress 'flat' systems are dead systems. In turn, diversity is related to the ongoing division of labour and the consequent distribution of knowledge. In a complex economy, human expertise is localized and the wisdom of the system only applies collectively, at most. By virtue of our specialisms we are largely ignorant of the wider world, and as Friedrich von Hayek and others have argued it is precisely this attribute of human society that makes the case for the market economy as a discovery process, a process that capitalizes on local knowledge and general ignorance.

The force of Allen's chapter lies in the identification of the unexpected properties of knowledge-based and market-incentive-based discovery processes. His key insight is the realization that the expansion of a system into new conceptual spaces and dimensions, the *sine qua non* of development, is the dual to the growth of knowledge. The economic system is restless precisely because its existing configurations are always being challenged in a dialogue with new possibilities, the latent potential of which is always unknown and, necessarily, conjectured. Those innovations that 'take off' change the future system irreversibly and necessarily modify the conditions under which subsequent innovations will be tried and tested.

These ideas are worked out in the context of two different simulation models of an economy and of a manufacturing system based on core principles of selection and experimentation. In both models, fitness surfaces evolve over time and, as with all algorithmic processes that are good at

'hill climbing', they risk entrapment in suboptimal regions of the economic space. To escape requires experimentation, innovation, but at a price: the future is not predictable, nor can the present be uniquely explained in terms of the past. Observed life is one of many possible histories; it is mere contingency that we are where we are and, if the tape could ever be run again, the world would be quite different. Consequently, it is futile to talk of the optimality of arrangements at any stage in history; all we can note is that history makes itself. The question 'do we live in the best of all possible worlds?' can only invoke the response 'who knows?'

The real force of this conclusion is that continued progress depends on wasteful experimentation; it is not our careful calculations that have produced the modern world but our imagination, and this means that mistakes will be made and these are, with the benefit of hindsight, the broken signposts of progress. To this degree, optimality, the search for accountability, is the enemy of ongoing development. Agent-based modelling suggests another powerful conclusion. Our world occupies an increasingly rich and dimensional space of possibilities but it never occupies more than a small proportion of the possible alternatives. There is always unfulfilled evolutionary potential. Thus, the emergent structural attractors of the system are always incomplete representations of what might have been. Those who link economic development with economic freedom and the capability to change, such as Amartya Sen, are clearly on the right track. However, in making this connection, they cannot say what development will mean in terms of future structures and relationships. That is the Faustian bargain that the complexity perspective presents.

Chapter 6 by Esben Andersen is a thorough evaluation of the challenges faced in developing a more general evolutionary account of the economy as distinct from the partial evolutionary representations of processes that are the stock in trade of the first generation of work since the pathbreaking study of Nelson and Winter (1982). As with Allen's chapter, there is a strong emphasis on the evolution of knowledge as the fundamental driver of economic evolution, with practical knowledge in focus precisely because it is this kind of knowledge that generates connecting principles between economic phenomena and noumena. Similarly, there is a dominant concern to incorporate the principles of the division of labour in the analysis, reflecting the theme so powerfully sketched by Allyn Young, that increasing returns, associated with the growth of knowledge, applies between as well as within specialized activities.

As Andersen makes clear, evolutionary theory is growth theory or rather theory of the differential growth of particular interconnected entities. The central principle here is that economic variety drives economic change, a principle first enunciated with precision by R.A. Fisher but amplified with

telling effect by the evolutionary biologist G.R. Price. Andersen shows how Price's formula can always be deployed to decompose the growth of some focal variable into a 'selection effect' and an 'innovation effect' with the respective moments, variances and covariances of the joint population distributions being the measures of the evolutionary forces at work. This is a theorem of great power and generality that applies both within and between industries at as many levels of aggregation as one cares to specify. As with all evolutionary theory based on selectionist principles, how the economic world changes depends on how its various attributes are correlated. Thus, the search for an evolutionary theory of economic growth is a search for the relevant theories of the causes of economic correlation. We know that this necessarily involves dealing with markets and innovation analytically, but clearly there is more at stake.

This is a formidable intellectual challenge, made particularly difficult, as it is in Peter Allen's chapter, by the qualitative variation associated with the addition of new economic activities and the deletion of existing ones. Andersen sketches how these challenges can be confronted: by including endogenous research activity, by decomposing activities into subactivities and by introducing specialized intermediate goods into the analysis. He also demonstrates, along with Allen, how simulation techniques can be used to stretch our understanding of analytical results, reinforcing the significance of computer engineering in the evolutionist's tool kit. This is a rich agenda made particularly promising because the Price formula provides an opportunity to bridge directly between advanced work in evolutionary biology and evolutionary economics. Further work of this nature is likely to be crucial in determining the empirical agenda for the evolutionary economic research programme.

The final three chapters are more empirical in tone, while picking up on the evolutionary themes of their predecessors. In Chapter 7, Francisco Louçã explores the theme of statistical error in the historical development of economics, a theme of particular importance in the context of the competing claims of chance and necessity in the evolution of economies. He demonstrates how the idea of 'error' has passed through at least three incarnations: beginning with the notion of a mistake in measurement, developing into the idea as the deviation from average, predicted behaviour which is a property of a model not the real world, and finally, transmuting into the notion of an additive non-interacting disturbance to some system that is in equilibrium. He explores the conflicts between the early econometricians on this matter, pointing to the very wide range of (incompatible) meanings attached to the error term in modern economics. His conclusion is one that fits closely with the other chapters in this volume, namely that a biological notion of error as mutation opens up the scope for path-dependence and the impossibility of

arbitrarily separating a model structure from the forces of error. We note in passing that the Fisher/Price methodology explored by Andersen is precisely a framework of this nature, as indeed is Allen's discussion of complexity.

Louçã demonstrates that in dealing with complex systems in economics, how we deal with something as seemingly innocuous as statistical error turns out to have fundamental implications for how we conduct statistical modelling exercises in economics. These implications are vast in that they challenge the validity of a very large proportion of empirical findings in academic journals of good standing and call for new ways of modelling that take explicit account of the evolutionary character of economic processes. Although we can be inspired in this quest by modelling strategies adopted by biologists, the higher order of complexity that we observe in socioeconomic systems will require more sophisticated modelling methodologies that grow out of the way we conceive of knowledge and associated understandings in such systems. It is in this regard that the insights offered by Dopfer and Potts (Chapter 1) can be of great assistance.

A central aspect of any evolutionary model is that the relative position of different competing entities changes over time, that is to say we expect to find mobility in relative positions with regard to variables of evolutionary significance. This is a difficult empirical domain in which to work, since its elucidation depends on having available data at a sufficiently disaggregated level over a sufficient period of time; the latter to wash out the less systematic forces, the former to ensure that evolution's signature is not erased by aggregation effects. In Chapter 8, Uwe Cantner and Jens Krüger explore this problem in an assessment of the amount of interfirm mobility in relation to productivity performance and relative market position across 11 German manufacturing industries over the 1981–93 period. In contrast to other approaches, they make imaginative use of two measures, the so-called Salter curves and Markov chain mobility indices, to unpack their data. They demonstrate that there are significant differences in mobility across industries and reach the general finding that mobility with regard to rates of productivity growth is always greater than mobility in terms of market shares; a finding they summarize in the notion that the technological sphere is more turbulent than the economic sphere. These results are also relevant to the issues raised by Paolo Ramazzotti and Peter Hall in that they imply a link between dynamic capabilities and their translation into competitive performance. As the authors point out, the elucidation of theoretical models that connect the different dimensions of turbulence provides a promising avenue for further evolutionary research, picking up issues in earlier chapters.

In Chapter 9 by Andreas Pyka, Bernd Ebersberger and Horst Hanusch, many of the threads contained in the previous chapters are drawn together

into a discussion of ways in which a market, the energy market in their case, can be explored and modelled using evolutionary concepts and methodologies. The problem they pose is how development can be understood in terms of economies transforming themselves over time, quantitatively and qualitatively, through structural changes, broadly conceived. The answer they provide is that agent-based modelling is the preferred evolutionary method, as suggested by Paul Ormerod and Bridget Rosewell, Peter Allen and Esben Andersen. Such a framework enables variety to be represented formally and its dynamic consequences to be modelled in rigorous fashion. Crucially, it opens up the possibility of vicarious economic experiments; this is exactly the claim that is made for these techniques in computer engineering. From a policy point of view this is of crucial importance, since it allows for the experimental design of any degree of complexity and is capable of uncovering stable relationships that are beyond analytic representation. The authors go on to catalogue the requirements for an agent-based model of the energy market that is capable of addressing key policy questions, such as the balance between renewables and non-renewables or the implications for CO₂ emissions, as well as the nature of past major energy transitions.

Taken together the chapters, originally presented at the second Brisbane Club conference in Manchester, 5–7 July 2002, provided a sharpening of our focus on the relationship between economic evolution and economic complexity. Needless to add, the meeting raised more questions than it answered, particularly in relation to the notion of complexity and the growth of knowledge. We anticipate that this will be one of the themes of the next Brisbane Club meeting.

Finally, it remains to thank the many contributions of our colleagues who helped to organize the workshop. In particular, we thank Sharon Hammond and colleagues in the ESRC Centre for Research on Innovation and Competition for their assistance together with the ESRC for its financial support. We also thank Sharon Dalton for the very considerable contribution she made editing the chapters and turning the manuscript into a finished product. We thank them all and hope we can call on their services again.

NOTE

1. A companion paper by J.S. Metcalfe, J. Foster and R. Ramlogan, 'Adaptive Economic Growth', analysed modern capitalism as a self-transforming process, tracing the relationship between micro diversity and emergent macro structure in the presence of enterprise and the coordinating role of markets. This paper is to appear in the *Cambridge Journal of Economics*.

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