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1112

**Economic Emergence:
An Evolutionary Economic Perspective**

by

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Economic Emergence: an Evolutionary Economic Perspective^{*}

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Abstract

The standard neoclassical approach to economic theorizing excludes, by definition, economic emergence and the related phenomenon of entrepreneurship. We explore how the most economic of human behaviours, entrepreneurship, came to be largely excluded from mainstream economic theory. In contrast, we report that evolutionary economists have acknowledged the importance of understanding emergence and we explore the advances that have been made in this regard. We go on to argue that evolutionary economics can make further progress by taking a more 'naturalistic' approach to economic evolution. This requires that economic analysis be fully embedded in complex economic system theory and that associated understandings as to how humans react to states of uncertainty be explicitly dealt with. We argue that 'knowledge', because of the existence of uncertainty is, to a large degree 'conjectural' and, thus, is closely linked to our emotional states. Our economic behaviour is also influenced by the reality that we, and the systems that we create, are dissipative structures. Thus, we introduce the notions of 'energy gradients' and 'knowledge gradients' as essential concepts in understanding economic emergence and resultant economic growth.

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1. Introduction

Conventional neoclassical economics has at its core the presumption that economic decision making is a matter of cold logic, namely, the application of a constrained optimisation rule. Over the past three decades, this rule has become set, increasingly, in the context of strategic interactions although much of macroeconomics continues to apply it in the context of a single ‘representative agent’. Despite the analytical precision that such a rule provides, it can only approximate actual behaviour in historical time when there is either certainty or quantifiable risk, i.e., in ‘simplistic’ contexts (Foster (2005)). It can only be used to calculate from calculable information. It cannot approximate economic decision-making when there is uncertainty, i.e., the absence of knowledge of the full set of events faced and the probabilities associated with them. Significant technological, organizational or institutional changes occur in states of uncertainty and, furthermore, these changes, in turn, can create new uncertainties in an economic system. This uncertainty does not prevent economic behaviour from occurring. On the contrary, we observe much creative and cooperative behaviour in states of uncertainty and the result is ‘economic emergence’ whereby new network structures form with characteristics that are irreducible to the elements of which they are composed.

If we choose to restrict economic analysis to logical applications of the constrained optimisation rule then we must always be dealing with a closed system. We cannot understand economic emergence which then has to be classified as ‘non-economic’ and/or ‘exogenous’. For example, although much has been written about the consequences of shifts in preferences and technological change, the origins of these changes tend to be omitted from economic analysis, despite the core roles that both play in the determination of economic growth. The origins of such changes have become the focus of disciplines outside of mainstream economics, namely, in marketing and business strategy. This separation has become less clear cut over the past two decades as behavioural economics and endogenous growth theory have risen in popularity but it remains the case that the constrained optimization rule is kept at the analytical core with particular assumptions relaxed in the light of evidence drawn from other disciplines or

economic experiments. So what we commonly see is the continued application of constrained optimization with some qualifications that help to align theory with reality, rather than a proper treatment of economic emergence (Witt (2010), Santos (2011)).

The school of thought in which economic emergence has been addressed most directly is evolutionary economics. This has been possible because evolutionary economists are concerned with how economic systems are transformed from within; evolutionary theory is inherently a theory of change that reflects not one, but a range of behavioural rules that are adopted and applied by economic decision-makers. For example, Nelson and Winter (1982) stressed the centrality of behavioural routines once it is accepted that decision-makers have to operate in the reality of historical time, with all its attendant uncertainties. In evolutionary economics, economic agents are viewed as reducing the uncertainty that they face and achieving economic goals by adhering to bundles of rules. Economic emergence occurs as radically new bundles of rules form into capital goods (technological rules), productive networks (organisational rules), contracting systems (institutional rules) and human skills (procedural rules). This is a process of ‘self-organization’ and it is honed by a process of ‘competitive selection’ whereby particular technologies, organisational structures, institutions and procedures come to dominate. In evolutionary economics, following Joseph Schumpeter, the agents of such change are those who are engaged in ‘entrepreneurship’ which involves experimentation with new combinations of rule-bundles to either produce new products or new processes to produce existing products more cheaply (Potts (2000), Dopfer et al. (2004)).

We argue in this article that, although evolutionary economists have been correct in identifying entrepreneurship as pivotal in economic emergence, too little attention has been paid to the more fundamental question as to why people often behave in a seemingly reckless manner in the face of uncertainty. It is the case that other kinds of heterodox economists, particularly post-Keynesians and neo-Austrians, have, for many decades, discussed why economic behaviour occurs in states of uncertainty. None were more eloquent on the subject than George Shackle (for example, Shackle (1961, 1973)). The essence of his analysis was that economic agents operate in environments that are

composed of interconnecting, ever-changing complex systems and that the attendant uncertainty brings with it both opportunities as well as threats. Taking advantage of states of uncertainty requires a combination of imagination, logic and some, necessarily incomplete, knowledge of the actual context in which a goal might be pursued (Loasby (2011)) Shackle's fundamental point was that no logic of calculation can be sufficient of itself to understand economic change and its emergent properties. Imagination has a fundamental role to play. Over the past two decades, evolutionary economists have, increasingly, begun to incorporate this kind of 'creative' and 'subjective' perspective on economic behaviour into their analysis through the employment of complex adaptive systems theory, suitably adapted for use in economic settings (see, for example, Allen (2005), Foster (2005), Witt (2008)).¹

Our goal in this article is to explore how we can deal with economic emergence from the standpoint of this modern evolutionary economic perspective. What we mean by 'modern' is in explicitly acknowledging that we are dealing with complex adaptive systems with particular kinds of self-organising features. Early versions of evolutionary economics made the process of competitive selection central, often applying replicator dynamic models that built on an implicit theory of Marshallian flux (Metcalf (2007)) and the conception of a competitive process, rather than competitive equilibrium (Alchian, (1950)). But treating competition as a process is only part of the evolutionary story. It helps us to understand the adaptation of an economy to the potential of any innovation, but it cannot explain either the origin of innovation or the ensuing trajectories of innovation sequences, in which solutions to problems serve only to open up yet further problems and opportunities. A full evolutionary account of economic emergence combines novelty generation, amplified through a process of self-organisation, with novelty resolution, through a process of competitive selection. In this way, the inherently open and uncertain evolution of economic systems, in which the economic order of today is the frame against which alternative economic futures are conjectured, can be

¹ Foster (1997/2011) attempted to capture this perspective in a theoretical construct labeled 'homo creativus' as an alternative to the more familiar 'homo economicus' construct.

accommodated. From the evolutionary economic perspective, order and emergence are inseparable. This has become known as the ‘continuity hypothesis’ (see Witt (2004) and Vromen (2008)) where economic evolution is not viewed as analogous to biological evolution but, instead, as a process of evolution in its own right which has biological underpinnings but is distinctly socioeconomic in character. This has led to the development of an associated ‘naturalistic’ approach (Witt (2008)) which views economic evolution as both emergent from our socio-biological history and also influenced by physical laws that all dissipative structures have to obey (Foster (2011)).

This perspective on economic emergence requires an understanding of both the genetic and culturally acquired drivers of human behaviour, honed in our anthropological history, and how these interface with the energetic requirements of living, dissipative systems. Correspondingly, the institutional rules that humans adopt in their various cultures, and how these change as circumstances change, have to be understood before we can analyse economic behaviour. This does not imply that conventional economic analysis should be rejected since humans clearly attempt to do the best they can within the circumstances that they face. Thus, the issue is not optimisation *per se* but rather the limits to calculative behaviour and the different ways in which individuals can respond to the information at their disposal. Thus, all evolutionary theories place the diversity of behaviours, rather than uniformity of behaviour, at their cores. So, whether or not behaviour is ‘optimal’, by some logical criterion, is very much a secondary question. .

It is not our goal here to further refine the definition of economic emergence. Because it involves qualitative change, defining emergence in any precise way has been somewhat elusive, even in complex systems science (see Hooker (2011)). We already have an excellent definition of economic emergence provided by Harper and Endres (2011) who classify it in terms of a four plus three array of characteristics. We are happy to accept this definition and move on: firstly, show that evolutionary economists have had much to say about economic emergence in the past; secondly, argue that economic emergence can be understood as a behavioural response to particular states of uncertainty; thirdly, show

that complex systems theory is the most appropriate analytical framework for understanding how and why emergence occurs in economic evolution.

The remainder of the article is organised as follows. In Section 2 we provide a historical overview of why economists have found it so difficult to capture emergence in economic analysis. For the heterodox economist, this overview is likely to cover material that is familiar but, for the benefit of younger mainstream readers, it seems worthwhile to provide some motivation for what follows. In Section 3, we discuss how evolutionary economists have dealt with economic emergence over the years. Again, this is in the style of an overview of the main points of differentiation with the mainstream rather than a comprehensive review. Section 4 focuses on the key catalyst of economic emergence, widely regarded as pivotal by evolutionary economists inspired by Joseph Schumpeter, namely, entrepreneurship. In Section 5 we seek to grasp why people are impelled to take large entrepreneurial risks in the face of radical uncertainty and to assess how this kind of behaviour can be captured using complex adaptive systems theory. Section 6 contains some concluding remarks.

2. Economic emergence and modern economics

In the twentieth century, economics became a discipline centred upon the notion that people who make economic decisions are ‘rational’ in the formal sense that they engage in constrained optimization. This theoretical perspective really got going following the publication of Marshall’s *Principles of Economics* but became strongly embedded in the discipline following the influential methodological writings of Lionel Robbins (1932) and the publication of Paul Samuelson’s *Foundations of Economic Analysis* (1947). There is little doubt that this simple bit of decision-theoretic mathematics can be useful, particularly in dealing with decision-making when the level of relevant knowledge concerning choices is very high and the time period is short. However, it has been known for some time that the fully informed, Olympian rationality assumed in modern applications of neo-classical economics can only be a useful approximation in special circumstances (Kaldor (1972)). By definition, this kind of economic analysis cannot deal with the emergence of economic structures that embrace new technologies to

produce new goods and services (Freeman and Louca (2002)). This was demonstrated most dramatically by Solow (1957) who was compelled to regard technological progress as something exogenous to the economic system with much discussion at the time on whether it is embodied or disembodied (Hahn and Matthews (1964)). There was limited interest in looking at economic growth as the outcome of an evolutionary process in which technological, organisational and institutional change are internal to the economic process and, as such, emergent. Indeed, in the post war era, most studies of economic emergence, through innovation and entrepreneurship, gradually became classified as outside of economics in the emerging fields of business strategy and technological history (Mokyr (1989, 2005)).

If economics is viewed as the science of constrained optimization, then it is correct to regard economic emergence in states of uncertainty as outside its compass. For example, if there are missing futures markets and prices in an economy, we cannot conceive of contracts to buy or sell for goods and services of unknown provenance, of unknown kind, of unknown uses, available at unknown, indeterminable dates in the future. Radical, or ontological, uncertainty means lack of knowledge; it means ignorance of the relevant economic data required for decision making (Shackle (1961) and Lane and Maxfield (2005)). That the price mechanism is fundamentally incomplete has been understood for a long time: Chicago economist, Frank Knight, had already acknowledged that uncertainty made neoclassical economics inapplicable (see Knight (1921)). And this poses a very big problem because many key decisions have to be made in the presence of significant radical uncertainty. Not only is there uncertainty concerning the nature and viability of new technologies ó physical, social and managerial ó there is also uncertainty concerning the attractiveness of new goods and services. More fundamentally still, an economy driven by innovation necessarily generates uncertainty from within. This was Joseph Schumpeter's central point. All innovations that challenge existing practices, make obsolescent prior knowing and require new thought frames in which the implications of such innovations can be understood. And it is these creative decisions that underpin all economic development and growth. Alfred Marshall, a founding father of evolutionary economics, understood this well (see Foster (1993), Metcalfe (2007))

but, despite the richness of his intuitive discussion of such decision-making in, for example, *The Economics of Industry* (Marshall and Marshall (1879)) he was never able to offer a body of economic analysis that could deal with choice under uncertainty.

Joseph Schumpeter (1911/1934, 1942) made a significant breakthrough in dealing with long term economic decision-making. He recognised that innovation was a key feature of economic development and that its tendency to result in clusters of incremental innovations implied that economic systems undergo a process of structural change that results in economic growth that is nonlinear. Unlike Alfred Marshall, who equated enterprise with the routine functioning of management, he identified entrepreneurship as the key source of innovation, and clearly acknowledged that this must involve motivations and actions not encompassed by neoclassical economics. Correspondingly, he argued that entrepreneurial activity cannot be viewed as a process of moving from one neoclassical equilibrium state to another in a way that affects neither the end point nor the origin and so is reversible. Rather, it is a force that keeps the economy out of equilibrium by continually imposing 'development from within', a phrase just as telling as his more famous 'process of creative destruction'. For Schumpeter, technological innovation and resultant economic development comes from entrepreneurial creativity whereby physical technologies, social technologies and human skills are intimately combined in novel ways to generate economic value. He viewed such behaviour as 'heroic' precisely because it does not involve conventional rationality because of the existence of very significant uncertainty. So he never attempted to formalize his entrepreneurial theory of economic development mathematically because he knew that this is an inappropriate way to deal with behaviour in uncertainty. Indeed, Schumpeter struggled to reconcile his theory of economic development with mathematically-formulated general equilibrium theory, developed by Leon Walras, that he admired so much (see Foster (2000)).

Friedrich Hayek also argued that the constrained optimization approach in neoclassical economics was inappropriate to deal with emergence and economic evolution (Hayek (1937)). Whereas Schumpeter tended to focus mainly upon emergent physical technologies, Hayek was more concerned with the emergence of social rules via a process

he labelled as ‘spontaneous order’. This did not deal with the generation and use of novelty to produce goods and services but, instead, with the tendency for economic decision makers to adopt common rules that are of mutual benefit. Like Schumpeter, he knew that processes of this kind could not be formalized mathematically and he ridiculed those who produced mathematical theories claiming to explain economic growth. Now, both Schumpeter and Hayek were pro-capitalist conservatives of very high standing in the 1940s yet, remarkably, their warnings about the fundamental inadequacy of neoclassical economics in dealing with the central process in capitalism - the emergence of physical and social technologies and the emergence of facilitating institutional rules - went largely unheeded. By 1950 Schumpeter had died and Hayek had departed the LSE, and the company of economists, to mix with philosophers of science and legal academics at the University of Chicago.

So economics in the 1950s moved inexorably towards a body of logic in which emergent phenomena could not be accommodated. From a scientific perspective, this was a quite remarkable trend because it meant that what are patently core drivers of economic evolution and growth, came to be ignored in favour of the mathematics of constrained optimisation, cast in a ‘force field’ representation of a fully connected network system imported from 19th Century physics (Mirowski (1989) and Potts (2000)). Back in the 1950s, it did not look like this kind of economic analysis would come to dominate. The ‘Keynesian revolution’ had raised fundamental questions concerning the validity of neoclassical economics as an adequate representation of economic behaviour. Although, microeconomics remained firmly in the neoclassical tradition, short, medium and long term macroeconomics took on a distinctly non-neoclassical flavour. For example, the medium term multiplier-accelerator representation of the business cycle became popular and Harrod’s theory (Harrod (1948)) became the baseline in the field of economic growth, with the related Harrod-Domar representation the preferred analytical basis of development planning.

Now, although these theoretical developments were non-neoclassical, they were also non-Schumpeterian and non-Hayekian because they were all designed to identify equilibrium

states of economic affairs. So they involved analytical constructs that ignored the role of imagination and history. They were constructs that regard every situation or event as the inevitable, sole and necessary consequence of antecedent situations or events (Shackle (1966), p.107). Indeed, they were also non-Keynesian because Keynes had firmly rejected the use of this kind of dynamical mathematics in his intense debates with Dennis Robertson concerning business cycle modelling. Deductive mathematical statements, by their very nature, are deterministic and, therefore, cannot accommodate fuzzy, qualitative processes such as technological emergence via entrepreneurship. Thus, the popular Harrod-Domar model just left technological change as an exogenous factor. And it remained so in the competing neoclassical and distributional growth theories of the two Cambridge that emerged in the 1950s.

Instead of trying to find ways of dealing with technological change in their growth models, neoclassical economists argued that what were required were better 'micro-foundations' for macroeconomics. This view had already gained a foothold after Keynes' death through the widespread acceptance of the 'neoclassical synthesis' interpretation of the Keynesian model, originally promulgated by John Hicks (Hicks (1937)). So, neoclassical economists found it relatively easy to advance into the fields of business cycle and growth theory in the following decades. The dynamical mathematical representations of the cycle and growth that had emerged were messy, complex, often did not have equilibrium solutions and were very difficult to verify empirically. Neoclassical economists sought to circumvent these difficulties with simple 'representative optimizing agent' analytical foundations that were easy to understand and apply if suitably strong 'simplifying' assumptions were made. In no sense could these advancing theories deal with economic emergence because the representative agent is a uniform agent, so there can be no possible connection to Schumpeter's entrepreneur or the 'Marshallian flux' and the differentiated firm (Metcalf (2007)).

By the 1960s, there were growing claims that neoclassical economics, despite its patent lack of connection with reality, could explain all economic behaviour. Gary Becker and his colleagues at the University of Chicago were prime examples of this imperialistic

tendency. The widespread adoption of a body of logic based on unrealistic assumptions and mathematical convenience, of course, meant that the messy, interdisciplinary process of emergence in complex economic systems could be avoided. And, gradually, ‘originality’ in economics came to be measured in terms of the capacity to discover clever theoretical combinations of abstract assumptions and functional forms that could match some data set, either through some econometric exercise or merely through judicious ‘storytelling’. There was little interest in economic emergence and, thus, little interest in the complex history that lay behind data sets. Correspondingly, as the neoclassical methodology became increasingly adopted in all branches of economics, economic history went into precipitous decline from the 1970s onwards. This was a fatal blow because, without an understanding of history, it is not possible to understand emergence and its causes and consequences (Freeman and Louca (2002)).

The economics discipline consolidated its constrained optimisation core in the second half of the 20th century partly because of an anxiety to be recognisably ‘scientific’. Samuelson, Arrow and Debreu replaced Veblen, Marshall and Schumpeter at the intellectual core and not only did this disconnect economics from economic emergence but it also made economists reluctant to accept the importance of behavioural traits beyond narrow neoclassical definitions of rationality. This was amply demonstrated recently in the blindness of the majority of economists to the impending global financial crisis in the first decade of the 21st Century (Akerlof and Shiller (2009)). Decades previously, John Maynard Keynes, very perceptively, had argued that business investment was driven by ‘animal spirits’ and that the resultant waves of optimism and pessimism caused fluctuations in economic growth. But the neoclassical synthesis had eliminated this attempt by Keynes to capture a particular kind of emergence. Instead, the Keynesian story became depicted as one of labour market failure in an otherwise well-functioning neoclassical (non-) world. Bereft of Keynes’ insight, 21st century neo-Keynesians could neither see a Minskyian boom in operation, due to contagious belief sharing between decision-makers faced with radical uncertainty, nor the obsolescence of institutional arrangements.

It is, of course, not difficult to point out the severe limitations of neoclassical economic analysis in dealing with economic growth and, over the years, many perceptive economists, not cited here, have done so only to be dismissed as being over-concerned with methodology or even unscientific. The desire to have neoclassical micro-foundations for all economic analysis became unstoppable yet it was clear very early on just how limited the explanatory power of such analysis is. This became immediately apparent in the 1950s when Solow (1957) discovered that a growth model based upon straightforward neoclassical principles could only explain about 20% of long term economic growth in the United States, undoubtedly the most dynamic economy of the 20th century. The other 80%, the unexplained residual, was deemed to be due to technological progress that took place outside the rational, cost minimising behaviour presumed in the neoclassical model. The fact that this seemed to imply that the neoclassical representation of constrained optimization was of secondary importance was resolutely ignored by most neoclassical economists. Instead, the following three decades saw a typical mix of: handpicking of abstract assumptions, the selection of mathematically convenient functional forms to obtain equilibrium solutions and *ad hoc* devices to (invalidly) relate timeless theory to historical or cross country data (see Durlauf et al. (2008) and Hoover and. Perez (2004)).

By the early 1990s, endogenous growth theorists would claim that Solow's unexplained residual could be explained by introducing knowledge as an additional factor of production with unusual characteristics that yield economies of scale or spill-over externalities. In this neoclassically-based theory, a stock of knowledge is generated by R&D, involving researchers incentivised to discover inventions that can be innovated into new capital equipment to sell to consumer goods producers. As usual, some clever assumptions and functional forms are required to make the theory work and what did it tell us? Only general things we already knew: investment in education and training matters, it is important to promote and facilitate innovation, patents are socially beneficial but must not be over-protective. By definition, equilibrium endogenous growth theory lacks any explanation of the process of economic emergence, yet it aspires to be explanatory. Most notably, the key agent of economic progress, entrepreneurship is virtually ignored. For example, in the influential book of Aghion and Howitt (1998),

“entrepreneur” does not even appear in the index, which is remarkable given that the authors claim that their theory is “Schumpeterian”. What they offer is distinctly un-Schumpeterian: an equilibrium structure that cannot accommodate a disequilibrium process, nor the abnormal returns that are the signal of enterprise and evolutionary potential (see Alcouffe and Kuhn (2004)).

The discussion here has tended towards macroeconomics because that is where traditional neoclassical micro-foundations have been adopted so universally over the past three decades. A micro-economist might well protest that such foundations are untypical in modern microeconomics where game theory has become the favoured analytical device and experimental economics is providing the basis for a new “behavioural economics”. But game theory is really constrained optimization when another decision maker constitutes part of the constraint. As Elsner (2010) points out, a prior process of emergence, such as spontaneous order, is necessary to establish the “rules of the game”. Grüne-Yanoff and Schweinzer (2008) also point out that all game theoretic models require narratives in their construction and in solution determination. Thus, game theory offers useful analytical tools for particular circumstances but not a general theory. This shortcoming has become increasingly apparent over the past decade with the development and consolidation of behavioural economics and experimental economics (see, for example, Gintis (2009) and Smith (2008)). So neoclassical critiques are no longer just the province of heterodox economists:

“Emergent arrangements and behaviours, even if initially constructivist, must have fitness properties that incorporate opportunity costs and social environmental challenges invisible to constructivist modelling, but these are an integral part of experience and selection processes. This leads to an alternative, ecological concept of rationality; an emergent order based on trial-and-error cultural and biological coevolutionary change.” Smith (2008, p. 322)

This position is very close to that held for decades by many evolutionary economists, namely, that building the axiomatic structure of economic theory up from one narrowly defined “rationality” rule is not defensible in the light of the evidence.

3. Emergence and economic evolution

Neither Smith (2008) nor Gintis (2009) really offer a compelling new way of dealing with economic emergence, beyond saying that it requires input from all of the social sciences. This limitation is, in part, due to the fact that they only review a small part of the evolutionary economic literature. Since Veblen's (1898) powerful critique of nascent neoclassical economics, there has been wide acceptance by evolutionary economists that any comprehensive treatment of economic behaviour must recognise, explicitly, the role of economic emergence (see Dopfer (2005)). However, the neoclassical revolution pushed evolutionary economics out of the mainstream and it was not until the pioneering work of Nelson and Winter (1982), that an identifiable group of neo-Schumpeterian evolutionary economists began to have an impact. Technological, organisational and institutional changes are viewed by them as the core drivers of economic growth, inducing a non-equilibrium process of structural change that involves innovation diffusion and competitive selection. Such a process is fed by heterogeneity of behaviours and of knowledge and catalysed by acts of entrepreneurship. What is offered is a more realistic depiction of the process of economic emergence but it is one that cannot be captured by formal theorising simply because it is embedded in history.²

Many of the new evolutionary economists did not come from an institutionalist background and, thus, they have followed the modern tradition of trying to employ mathematics in evolutionary economic analysis. So, for example, competitive selection is often represented in frequency-dependent mathematics, such as replicator dynamics; innovation diffusion is often presumed to result in a growth trajectory that follows a logistic or other sigmoid shaped function. But, useful and relevant as this modelling is, it tends to downplay the process of economic emergence. This is because analytical mathematics is deterministic and, necessarily, excludes the qualitative process that characterises emergence. For example, the replicator dynamic model (see Metcalfe

² Nelson and Winter (1982) argue that this does not mean that evolutionary analysis is atheoretical but, rather, that it involves a balance of 'appreciative' theorizing and 'formal' theorizing.

(1998)) begins with the presumption that there is a given population of differentiated firms in an industry and works through the adaptive consequences of this distribution of behaviours. It yields a dominant technology, although this need not be the technology that produces at the lowest cost or the technology associated with the highest quality good or service. Only in the simplest, one dimensional replicator process does competition lead to the dominance of the least cost producer. Innovation fits naturally into this evolutionary framework since it creates the variety upon which selection works. But, again, representing the process of innovation as a sigmoid growth trajectory in value added or cumulative asset value is incomplete because it also involves qualitative change.

However, the mathematical representation of processes such as competition and innovation does not wholly eliminate their emergent character. In the contemporary lexicon of emergence, they capture *weak* emergence not the *strong* emergence that we associate with, for example, Schumpeterian radical innovation and associated entrepreneurship (see Comins (2002)). All emergent processes and the economic growth trajectories that they shadow, must have a deterministic component because of the fact that economic systems are dissipative structures and, as such, have to remain structurally coherent and, to some degree, be irreversible over historical time (Foster and Wild (1999a)). This structural persistence has a mathematical structure that can be estimated parametrically using econometrics. But such quantitative modelling of a growth trajectory remains, necessarily, an incomplete representation of an evolutionary process that involves structural change. By implication, the statistical residuals in a logistic diffusion model that has been estimated econometrically must contain all the non-deterministic components of an emergence process, in addition to normal Gaussian stochasticity (see Foster and Wild, 1999b).

What we often observe in historical time series data is that the past is a more powerful explanation of the present than any hypothesis derived from formal logic. But we also generally observe that this association with the past is not stable and, indeed, catastrophic discontinuities can occur. History matters because economic systems must, necessarily, be time irreversible in order to function coherently as complex network structures. When

we observe logistic growth, the evolutionary economic interpretation is that it reflects a process of self-organisation whereby, as organised complexity increases, unanticipated connections become available that either increase efficiency or raise the quality of what is being produced.³ This is followed by a competitive selection process that consolidates efficiency gains, lower cost and/or higher quality but can also result in a lack of a strong emergent capability. Whether or not strong (re-) emergence is possible is difficult to discern using historical time series data, although systematic shifts in residual variance patterns can sometimes provide a clue that discontinuous structural shifts are about to occur (Foster and Wild (1999b)).

Thus, there is little doubt that evolutionary economists have been successful in dealing with weak emergence in both their theorising and in empirical applications. They have also understood the importance of strong emergence and recognised that it is the source of economic evolution and growth. Since the seminal contributions of Joseph Schumpeter, it has been accepted that the generation of novelty via entrepreneurship is the pivotal catalyst in economic emergence. But this has been very difficult for evolutionary economists to deal with analytically (Witt (2009b)). Clearly, this is a field in evolutionary economics that requires further development before a full treatment of economic emergence can be delivered.

³ It is worth pointing out that the process of self-organization operates somewhat differently in socio-economic complex systems compared to the physio-chemical ones studied by Prigogine (see Prigogine 2005). In the presence of energy, convection cells and termite hills do not involve the emergence of novelty. In biology novelty comes from random mutations that are subject to selective pressure. In the economic case, where we have the active pursuit of knowledge, when we observe is the self-organization of economic structures which become nodes of novelty which are then subject to selection. Once we leave to strict world where novelty is a random event into one where novelty is actively pursued, then we do not have a strict delineation. Self organization can be a vehicle for generating novelty in the form of emergent bundles of rules. We can think of self organization as a novelty focusing device. Structures that are so created can develop their own adaptive capability and, thus, need not necessarily be subject to the rigors of selection.

4. Entrepreneurship: the most economic of all economic behaviours?

Emergence involves, among other things (Harper and Endres (2011), wholes being more than the sum of their parts. This is, of course an old idea (Lewes (1875)) and is recognised in mainstream economics in the context of economies of scale and scope and learning, or experience, curves. However, as noted, these are generally kept outside the constrained optimization body of theory. In contrast, both in evolutionary economics and in business strategy, analysis of these processes is central and tends to centre on the operation of entrepreneurship. Entrepreneurial individuals or groups in organizations take on the difficult task of: setting up networks of connections between elements, such as machines (embodying physical technologies) and people (embodying skills); using sets of organizational rules (social technologies); and accessing appropriate and affordable energy sources. There have been a number of contributions in this field by evolutionary economists generally adopting either a case study methodology, agent-based simulation or some combination of both (see, for example, Malerba et al (2001) and Foster and Potts (2009)). This recognition by evolutionary economists that entrepreneurship is important as a catalyst for emergence is, of course, a significant advance beyond the neoclassical approach in which entrepreneurship is only implicit or just the operation of rational choice in unusual conditions (see, for example, Hopenhayn and Vereshchagina (2009)).

So, evolutionary economists think of economic emergence as essentially a product of the combinatorial actions of entrepreneurial individuals (Schumpeter Mark I) or groups (Schumpeter Mark II) who bring together physical and organisational technologies, capital goods and human capital in novel ways. The result is a whole that cannot be reduced to the sum of its parts and this is reflected in entrepreneurial profit. Strong emergence involves radical innovation which sets down a core connective structure.⁴ Weak emergence involves incremental innovation that is a process of self-organisation that finds profit in network structure improvements (learning by doing) and in

⁴ Hooker (2011) identifies strong emergence with a bifurcation in a complex system. Although economic systems necessarily share features with physical systems, this system dynamic definition cannot be seen as general because of the adaptive and knowledge creating nature of economic systems.

peripheral increases in connectivity. Economic emergence of this kind does not take place in an institutional vacuum. What we observe is the formation and adoption of facilitating rules as emergence occurs. The “spontaneous order” that Hayek discusses occurs when there is an explicit need for it. Some think that this process is separate from emergence because it does not involve the generation of novelty but, in reality, a rule structure has to co-evolve if economic emergence is to be successful.⁵ For example, Adam Smith gave us one of the first examples of economic emergence whereby the expansion of trade and contracting because of presumed self-interest led to an economy with characteristics not reducible to the sum of its parts. But, as Smith well understood, this was only possible if facilitating rules existed or came into being to permit this emergence to occur.

An entrepreneurial individual or group is creative in combining physical technologies, embodied in machines, social technologies, embodied in organisations and a careful selection of people with different kinds of skills. But here we have a paradox. Entrepreneurship is economic behaviour *par excellence* but the entrepreneur cannot behave in the manner of *homo economicus*, engaging in well-defined constrained optimization. This is because, like an artist or an inventor, to some degree, s/he faces radical uncertainty which means that the totality of possible outcomes is unknown and the probabilities associated with those that are known are unknown. Now, it may well be that *subjectively* the entrepreneur does engage in a conjectural optimization exercise in planning a project. But given the complexity of the problem to be solved and the uncertainty that is pervasive, it must be an exercise based upon assumptions that are often no more than beliefs, opinions or hunches. No matter how carefully such optimization is done, a project will stand or fall on subjective conjectures made and, of course, because of this, the majority of entrepreneurial projects fail, as Joseph Schumpeter stressed.

⁵ Harper and Endres (2011) identify this as “synchronic” emergence in contrast to “diachronic” emergence which involves the generation of novelty. This can be a useful distinction but it can sometimes be difficult to maintain it because of the co-evolutionary nature of innovation diffusion and rule formation.

Thus, economic emergence, which is at the very foundation of economic evolution and consequent growth, does not depend on the application of logic based upon objective knowledge and a flow of objective information. Rather it depends upon the exercise of imagination aided by logical calculation and it is imagination which makes the difference. What an entrepreneur does is to conjecture that the existing economic order can be arranged differently. S/he perceives that the past is not a guide to the future and has the energy and desire to put this conjecture to an economic test. Although the motivation of entrepreneurs may be to seek profits, what they cannot do is maximize them in the traditional neoclassical manner. A common mistake is to think that this is irrational behaviour (Ariely (2008)). If a decision-maker is trying to operate in a set of interconnected complex systems and is subject to radical uncertainty concerning the potential of the novel project that is being pursued, it would quite irrational to try to engage in neoclassical optimization. It is also the case that, in ever-changing complex systems, to simply do nothing because computing optimal solutions is impossible would be a great error.

If we look at the entrepreneurial projects undertaken by large firms, we can see that they are motivated by an understanding that, if adaptation is not made from a currently successful position, the firm will eventually fail or be taken over (Christensen (1997)). In other words, it is rational from an evolutionary perspective for a large firm to invest in speculative R&D; to place bets even if most of them turn out to be worthless. In the real world of complex economic systems, entrepreneurial actions are rational actions even though it is understood that they may lead to failure. Of course, it is also true that when a decision-maker does not feel very threatened by actual or upcoming obsolescence, systemic breakdown, or competitive attack, s/he will tend to behave in a manner closer to the neoclassical ideal. So we observe that firms which survive the early stages of development, and come to understand their processes and products well, tend to engage in efficiency enhancing investment. For example, they may substitute capital for labour to achieve more optimal efficiency, subject to funding constraints. A long time ago, Alfred Marshall (1890) tried to capture this intermediate phase of the firm's life cycle in his imagery of the 'trees in the forest', in which a firm and its managers pass through a

sequence of developmental stages from inception to maturity. But Marshall also cautioned that such firms would also be heavily constrained by their history ó in other words, the flexibility presumed by neoclassical theory is not generally present.

Historical lock in, because of the complexity of physical, cultural, conceptual and organisational structure that has been built up successfully, is always present and this limits the firm's room for manoeuvre. Here there is an evolutionary dilemma - increased efficiency tends to be achieved by creating tighter specialised connections in networks, but specialised organizations are generally less flexible than loose groups of unspecialized individuals, making adaptation in maturity more difficult to achieve. There is always far more adaptive potential in an industry than there is in any individual firm and far more adaptive potential in the economy as a whole. So, again, being overly rational in the neoclassical sense can be a handicap. A common case cited in the field of business strategy is that of IBM which achieved high levels of organisational efficiency but became incapable of adaptation (Foster and Kaplan (2001)). So an entirely separate branch had to be created to innovate and create the personal computer. In complexity theory, it has been long recognised that the optimisation of a whole system generally involves suboptimal behaviour in its individual components.

Now, although it is rational to be entrepreneurial when lock-in (Arthur (1994) and David (2005)) precludes full flexibility and the absence of a decision is clearly damaging, enterprise remains a subjective and speculative act in highly complex and uncertain circumstances. So it generally requires a great deal of optimism to proceed and there is plenty of evidence that supports the contention that over-optimism is pervasive amongst entrepreneurs (see, for example, Shane et al. (2003)). In other words, a certain emotional state is required before an entrepreneurial project is embarked upon. And there are many people, even when faced with situations of decline, boredom or unpromising possibilities, will not be entrepreneurial and prefer to try to make only marginal adjustments in a bad situation. As Joseph Schumpeter vividly pointed out, entrepreneurship is not a universal behavioural attribute. Typically, people who are highly connected to a social structure of some kind find it difficult, emotionally, to break ranks. This is firmly embedded in our

cultural history - when humans were still hunter-gatherers, connection to the band was very strong, so individual entrepreneurial behaviour or inventions that favoured an individual were little in evidence and could even be a ground for exile and death. So, economic entrepreneurship, in contrast to social and political entrepreneurship, began to assume a dominant role only relatively recently in human history.

So the evidence suggests that there is an inherent human desire to act creatively and cooperatively in states of uncertainty in the hope of success. Economic growth depends on this and countries that suppress entrepreneurship are doomed to fail. But where does this drive come from? Modern neoclassical economics is, first and foremost, a formal body of decision-making logic concerning the application of constrained optimization. Apart from acceptance that there is a general desire to seek pleasure and avoid pain, with utility deemed to diminish at the margin as the consumption of a good is increasing, there is little concern with motivational questions. When the problem posed is only one of scarcity, this can be a useful focus, but any substantive evolutionary theory of economic behaviour that seeks to explain how wealth is created and accumulated requires an explicit treatment of motivations. And the key motivations, from an evolutionary economic perspective, are those that drive entrepreneurship. So, to understand economic evolution, it is necessary identify what the psychological foundations of entrepreneurial behaviour are and why we observe such wide-ranging levels of economic entrepreneurship at different times in history and in different locations.

5. Emotions, energy and emergence

In evolutionary economics, it is generally acknowledged that economic decision-makers face significant cognitive limitations and this has resulted in general acceptance of Herbert Simon's conception of 'bounded rationality'. A few evolutionary economists have gone further to consider the economic implications of cognitive limitations more deeply (see, for example, Loasby (2007), Witt (2008) and Nooteboom (2009)). These contributions reflect recent findings in psychology, echoed much earlier by Scitovsky (1978), which indicate strongly that, before we can engage in logical exercises in our

cognition, there has to be a facilitating emotional state (Damasio, (1995) Elster (1998) and Arierly (2008)). And, of course, we all know how illogical people can be when they are very angry, even to the extent of acting against their longer term self-interest. We also know that a strong emotional connection to a religious faith can impel a person to become a suicide bomber. These are, of course, extreme examples but it is generally true that emotional dispositions matter in determining the aspirational goals that people seek using their logical capabilities. It is also true that our emotions, unlike many of our recently acquired logical capabilities, e.g., mathematics, were set down deep in our hunter-gather past and remain virtually unchanged. What have changed, of course, are the contexts in which our emotions are stimulated.

Curiosity and exploration were clearly important in our past ó when hunting grounds became exhausted or inadequate, only those bands that contained individuals who had explored other terrains widely could have an adaptation plan that might work and this must have been an important selective force in human evolution. The entrepreneur today is, in essence, doing the same thing and, although Schumpeter portrayed the entrepreneur as an individualistic character, in reality, entrepreneurship is about successful team building. S/he may be the leader, but partners, employees, financiers, etc, are also potential beneficiaries. No entrepreneur succeeds in isolation. Of course, it is no great revelation to state that an emotional disposition is necessary before logical choices are made. Marketers of products have known this for a long time. Both emergent structures of preferences and emergent technological structures require the presence of an emotional driver. But how does this actually work in an economic setting?

Humans have vivid imaginations. This is manifest in their enormous appetite for fictional stories. They also have a great capacity to share imaginings to such an extent that shared myths can drive selfless behaviour. When myths are espoused they affect behaviour and determine goals and aspirations. So, for example, a religious myth can lead to behaviour designed to achieve an aspiration of getting to a heaven of some kind. In the secular world, the myth that great material wealth leads to happiness makes people tolerate working long hours doing boring and unpleasant tasks and stress that can be life

threatening. Entrepreneurial behaviour involves an imagined novel product or service that can be delivered by an imagined productive structure that yields imagined wealth and/or power. Once such an aspiration is emotionally locked in, then knowledge, information and logic are applied to try to creatively achieve the aspiration. It is this creativity that results in emergent physical and social technologies. Now, it is often said that ‘necessity is the mother of invention’ but entrepreneurship is more than this. Entrepreneurship creates new technological niches and associated products without necessity (although necessity is certainly an excellent incentive!). Complex systems of all kinds become more complex and ordered and, thus, grow in the presence of increasing supplies of human or non-human energy that can be used to do work.

Entrepreneurial individuals and groups, through their almost unique human capacity to convert imaginings into applicable knowledge, behave in a way that is consistent with the self-organisational tendencies of all dissipative systems. This is because their behaviour results in the reduction of energy gradients (Foster (2011)). They are driven by the same emotional apparatus as their hunter-gather ancestors who were genetically programmed to struggle to survive in environments where energy was in very limited supply. So economic emergence is not only a product of the desire to satisfy wants for goods and services, it also seems to intensify in the presence of cheap and plentiful energy supplies.

If this is so, it has deep implications for how we do economics. In particular, uncertainty, generally regarded in conventional economic theory as a state to be avoided, is often regarded by humans as a state offering opportunities to gain power and wealth. So emotionally-driven decision-makers may seek to achieve ambitious aspirational goals in relatively unknown territory, rather than engage in logical exercises in well-known structural settings. This, of course, turns economics on its head: emergence and economic evolution take centre stage. The roots of this kind of behaviour are deeper than biological, they are physio-chemical, depending upon the fact that we, and the economic structures that we create, are dissipative structures. If there is an energy gradient available, a dissipative structure will exploit it to become more complex and ordered

(Schneider and Sagan (2005)).⁶ If cheap and easy to access energy is available there will be economic emergence, facilitated by entrepreneurship, and the result will be economic evolution (and growth). The human capacity to acquire and use new knowledge accelerates this process in three ways: it can enable energy to be used more efficiently, it can find new uses for any consequent energy surpluses and it can find ways of extracting more useful energy from the environment. The history of economic emergence is replete with innovations that have enabled the substitution of inanimate energy for human physical and mental effort, and the marked rise in the capital/labour ratio is indicative of this process (see Metcalfe (2010a)).

What this co-evolutionary story implies is that, in addition to understanding how knowledge translates into technological innovations we need to also understand the role of energy supply and its translation into work. In dissipative structure theory, energy gradients are reduced but, in the economic case we have an extra dimension. Human, creativity produces knowledge gradients that can be exploited by entrepreneurs. Available knowledge is mined for profit-making combinations with only a minority making strikes. The knowledge gradient is decisively determined by: socio-cultural rules concerning the acceptability of entrepreneurial and innovative activities; the extent and content of education and training; the prevalence of institutional rules that facilitate innovation and entrepreneurship; the existence or otherwise of safety nets for entrepreneurial failures; the availability of resources to support enterprises. Of course, all of these are familiar in the context of innovation policy but no such policy is going to be successful without an understanding of social, cultural and economic history. It is necessary to identify the relevant meso rules (Dopfer et al. (2004)) that exist and how they are bundled together before any such policy can be properly framed. For example, if a society is very hierarchical with strong institutional constraints and lacking in meso

⁶ Georgescu-Roegen (1971) pioneered the idea that economists should be aware of the thermodynamic nature of economic systems. However, he was not excited by the idea of a dissipative structure as described by Prigogine. His major concern was the destructive impacts of entropic wastes which had badly affected his home country of Romania due to coal burning. Boulding (1981) was one of the first to provide a coherent explanation of the necessity of economic systems to throughput energy and the consequences thereof.

rules that permit the existence of reliable markets and contractual arrangements, then its economic evolution is likely to be limited (Landes (1998)). It will access few new energy gradients and will generate little new knowledge.

Of course, the question arises as to how could such a low growth outcome occur if the theory of dissipative structures is correct? The answer is that this theory only applies in the presence of an energy gradient. It says nothing about knowledge gradients. So the prevalence of energy dissipation is conditional upon the extent to which knowledge can be acquired and institutions (meso rules) agreed upon to both access energy and devise ways of using it. In human history none of this happened very quickly. It is only about 10,000 years ago since the current warm inter-glacial period began and humans started to artificially increase energy gradients by domesticating animals for food and practising agriculture at a significant scale, using fire, wind and water. The novel technologies that have allowed us to access new energy gradients and new ways to use energy could not have been devised and enacted without the formation of appropriate shared knowledge structures in individual minds.

The provision of new knowledge is widely accepted as a driver of growth but, just as important, is what we don't know. In complex economic systems characterised by uncertainty, ignorance is pervasive. But it is this lack of knowledge that allows imagination to do its work (Witt (2009b) and Loasby (2011)). What matters is that meso-rules exist that permit a knowledge gradient to exist and be exploited. New knowledge formation is a virtual construction project based upon beliefs, hunches and intuitions rather than objective information. And it is the lack of a connection between aspiration formation and objective knowledge that allows emotions to play such an important role.

The innovation diffusion process, whereby successful entrepreneurs mutate into well-informed managers in settled organizational structures, is well understood in evolutionary economics. The bundle of routines that was loosely put together initially is transformed into a smoothly running complex economic system that delivers products efficiently. But making systems work harmoniously in this way also involves behaviour that is

emotionally driven. Because of this, success can sometimes be accompanied by misplaced confidence. This is another form of ignorance and it can lead to lack of adaptiveness and the ultimate demise of an economic organisation. Thus, the 'creative destruction' that is much discussed in evolutionary economics is a matter of emotional dispositions in states of uncertainty, first, in generating strong emergence through entrepreneurship and, second, in creating conditions that result in the decline and demise of a previously successful organization.

Emergence is necessary for survival and growth in all dissipative systems. In biological systems, genetic emergence occurs because certain random mutations suit changing conditions best. In economic systems, emergence occurs because of deliberate and purposeful attempts to gain wealth and power, in the form of control over the energy processing capabilities of people, land and artefacts. Because vast energy resources have been tapped, economical emergence has not stopped because basic needs have been met. Entrepreneurship seems to know no bounds. Millionaires will often risk all to become billionaires. But, strikingly, this was not so in hunter-gatherer societies where material accumulation was avoided because it hindered mobility and any surplus windfalls were rapidly consumed or even wasted. The presumption was that these were temporary so it was important to make few behavioural adjustments because of them. In hunter gatherer bands, where there is a strong collective identification, there is little individual drive to accumulate material wealth (Sahlins (1998)). Power is a shared experience and the seeking of individual power is frowned upon beyond leadership in the service of the band. Only when reliable new hunting and gathering lands are discovered by the curious traveller does population and consumption per capita grow. The current inter-glacial warm period has enabled humans to gradually access increasing amounts of vegetative, animal, climatic and fossil energy, enabling population and energy consumption per capita to rise while the emotionally determined drivers of human behaviour have remained the same.

In economics, when we try to include emergence in economic analysis, as Hayek stressed, we cannot say anything about specific acts of economic creativity but we can

identify the rule set that is necessary for such creativity to emerge. Just as conventional economists presume that more is always preferred to less, i.e., a utility map exists, we can presume that our emotional dispositions are such that we are impelled to form aspirational goals of some kind and to seek to achieve them in states of uncertainty. What these aspirational goals are in particular cases can be understood by careful cultural, social and political research of a historical character. We must understand what the *meso* rules are before we can assess the extent to which technological emergence can occur because of entrepreneurship. When we understand what the key rules are, agent-based simulation and calibration can be applied in a process of *theoretical discovery* which, in turn, can be used to derive hypotheses that can be assessed in relation to observed statistical associations (see Foster and Potts (2009)).

So, adopting a complex adaptive systems perspective on economic behaviour requires economists to understand relevant aspects of history, psychology, sociology, biology and physics. Long ago, before economics became a specialised discipline, it was understood that this had to be the case. For example, Adam Smith, who gave the discipline of economics its scientific structure, knew this although, in his time, he could only raise more questions than answers. But when he wrote about importance of the *division of labour* for economic growth, he was explaining economic emergence: that of a more complex productive organisation using more complex capital equipment, more complex organizational rules and the more effective utilization of energy. And he stressed the importance of *meso* rules to the functioning and development of capitalism. Like Joseph Schumpeter, Smith offered no mathematical representation of this process of emergence but he knew that it was the key to economic growth (Metcalf (2010b)). The challenge that evolutionary economists now face is to embed their analysis in modern complex adaptive systems science in a way that offers a clear alternative to economics based upon the constrained optimization rule.

6. Concluding remarks

Emergence is fundamental to economic growth and development and cannot be regarded as exogenous and, thus, external to economic analysis. It occurs because of entrepreneurship which is the most economic of human actions and is endogenous in complex economic systems. It is endogenous because it is an intrinsic part of the process whereby energy and knowledge are brought together to create economic structures that produce goods and services. Because economic systems are dissipative structures, entrepreneurship results in actions that reduce energy gradients. The difference between economic structures and biological ones lies in the human capacity to create knowledge gradients using imagination, logic and information processing capacities. This enables economic systems to create larger energy gradients and to reduce them more effectively. As they become more complex and organised, they are able to throughput more energy. In the economic domain, doing this involves radical uncertainty and requires an emotional disposition that permits toleration of significant risk. What humans are able to do, unlike any other species, is to discover new knowledge that increases access to energy, enables energy to be used more efficiently and creates artificial structures that can use energy surpluses.

Self-organisation theory has, for half a century, recognised that structure will emerge in appropriate energetic conditions. It has been recognised for much longer that the dissipative structures that emerge are subject to competitive selection in the biological domain. In the human domain, self-organisation involves both a radical phase of strong emergence when novel combinations of knowledge and energy flow are set down and followed by a phase of weak emergence when there are learning and innovation diffusion processes at work. This is how economic systems emerge and this process should be placed at the core of economic analysis. Without an economics properly grounded in complex adaptive system theory, it will be very difficult for economists to understand and mitigate major problems, such as global financial crises and global warming.

The rise in interest in behavioural economics and experimental economics, because they both connect directly with psychology, is encouraging in this regard but there is a tendency to test hypotheses derived from constrained optimization theory rather than to shift attention towards a fundamentally new ontology that recognises, explicitly, the dissipative nature of economic systems (Witt (2010)). Knowledge in such systems is not just a commodity-like input into constrained optimization exercises but a virtual network in which the rules that connect observed elements is intimately connected to the set of behavioural routines that we adopt. Emergence involves expansion of the knowledge network and its application in the establishment of a set of interconnected routines that constitute an economic structure. In evolutionary economics it has long been understood structures that emerge from this process of economic self-organization are subject to a process of competitive selection. This leads to the dominance of the most appropriate structure in a given set of environmental conditions and, by inference, the best bundle of rules is selected. Thus, evolutionary economics provides an analytical framework that embraces economic emergence without difficulty and is, thus, a sounder basis for economic science in the future than one rule-constrained optimization theory.

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