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978-1-108-73800-2 — Evolutionary Economics
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1 Introduction

Historically, a number of approaches in economics, including varied works by Adam Smith, Karl Marx, Carl Menger, Alfred Marshall, Thorstein Veblen, Joseph Schumpeter, and Friedrich Hayek, have all been described as 'evolutionary'. This is understandable, because 'evolutionary' is a broad word, loosely denoting a concern with transformation, innovation, and development.

But today the term 'evolutionary economics' is more typically associated with a new wave of theorising signalled by the seminal work of Richard Nelson and Sidney Winter in their *An Evolutionary Theory of Economic Change* (1982). Although there is not yet any consensus on core principles, this wave of evolutionary thinking has given rise to a number of policy developments and has proved to be influential in several sub-disciplines, in business schools, and in institutions concerned with science and innovation policy.

Citation and other bibliometric studies show that modern evolutionary economics, despite its internal diversity, has created a global network of identifiable, interacting researchers. This Element turns to theoretical ideas and it outlines some of the shared basic assumptions of this broad approach. It also addresses the possibility of the creation of a shared theoretical framework based on generalised Darwinian principles. Further sections compare evolutionary economics with mainstream economics and with evolutionary game theory.

Another notable difference between evolutionary economics and mainstream and game-theoretic genres is that the former gives greater relative emphasis to appreciative (i.e., non-formalised and empirically oriented) theorising. Mathematical and statistical techniques are still widely used in this field, but there is less concentration on full analytic solutions and more on illustrative simulations including agent-based modelling, with attempts to explain real empirical phenomena. The concluding section to this Element considers the prospects for evolutionary economics in the future.

The term 'evolutionary economics' is applied to a diverse set of approaches that vary widely in terms of their basic assumptions, their distances from mainstream economics, their attitudes to Darwinian ideas from biology, and their range of policy conclusions. The historical sources and nature of some of these divergences will be explored later. This diversity results in part from the fact that 'evolution' is a vague word with a variety of meanings.

Despite this diversity, there are common themes among economists who describe themselves as evolutionary. There is a common emphasis on matters of economic change and transformation. Typically, evolutionary economists do not take institutions or technology as given: they treat them as costly to produce and focus on how they emerge and develop. They have a shared interest in

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novelty and innovation. Evolutionary economists also generally assume that complex phenomena do not often emerge by design. As in nature, complex phenomena frequently result from processes of self-organisation and competitive selection.

This Element examines the historical roots of evolutionary economics and then elaborates on its shared concerns and ideas. A further section establishes a simple taxonomy of differences within this stream of research. A subsequent selection considers recent work on shared evolutionary principles. Further sections elaborate on differences between evolutionary and mainstream economics and make comparisons between evolutionary economics and evolutionary game theory (Hodgson and Huang 2012). The final section considers the prospects for evolutionary economics in the twenty-first century.

2 The Emergence of Modern Evolutionary Economics

Etymologically, 'evolution', like the word 'development', stems from the Latin verb *volvere*. This means 'to roll' but it can refer more broadly to the general idea of motion. The companion verbs *evolvere* and *revolvere* are more explicit, respectively denoting forward and backward motion, as in the unrolling and rolling up of a scroll. The word 'evolution' therefore derives from a Latin word associated with a specifically directional and predestined activity; the scroll is unrolled to reveal that which is already written within.

In this spirit the word 'evolution' was first applied to natural phenomena by the German biologist Albrecht von Haller in 1744. He used the term to characterise embryological development as the augmentation and expansion of a preformed miniature adult organism, which was a common idea in the seventeenth and eighteenth centuries. In biology, the idea of preformation, where the embryo is deemed to contain in microcosm the form of its future development, lasted well into the nineteenth century, being embraced explicitly by Herbert Spencer and more subtly affecting Charles Darwin's thought (Richards 1992).

Spencer was a hugely influential nineteenth-century evolutionary theorist, and he did much more than Darwin to popularize the term 'evolution'. Spencer also coined the phrase 'survival of the fittest', which Darwin adopted only sporadically. Spencer (1862, p. 216) defined evolution in terms of a single system and its 'change from an indefinite, incoherent homogeneity, to a definite, coherent heterogeneity through continuous differentiations'. Hence, instead of natural selection, Spencer appealed to a supposed, unexplained, universal law that led somehow to greater complexity.

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Spencer was inspired by Jean-Baptiste de Lamarck (1963), who in 1809 had similarly proposed increasing complexity as a law of evolution. Spencer also adopted Lamarck's proposal that acquired characters could be inherited. Darwin also thought that the inheritance of acquired characters is possible, but he saw this as a matter of empirical investigation rather than a universal law.

In the first edition of the *Origin of Species,* Darwin did not use the word 'evolution' and wrote 'evolved' only once. Subsequently he infrequently used the term 'evolution', but on the whole he preferred phrases like 'descent with modification'. Hence no Darwinian copyright can be imposed on the word 'evolution': it is not of Darwinian provenance.

The history of the word 'evolution' and of 'evolutionary' ideas in the natural and social sciences shows that these terms have been used in very different ways, and there is no historical basis to give them one particular meaning. Today 'evolution' is used in a number of senses, and there is little basis to claim that any one has greater legitimacy than the others. Attempts to give evolution some narrower and sharper meaning, whether Darwinian or otherwise, are unwarranted and unlikely to be successful.

Marx's economics has been described as evolutionary because it depicts history as going through a series of stages, namely from primitive society, through ancient civilisations, feudalism, and capitalism, and finally to communism. History thus unrolls in a Hegelian manner. Clearly this notion of evolution is redolent of the Latin *evolvere,* but it is a conception of change that differs greatly from Darwin's, as Thorstein Veblen (1906, 1907) astutely observed.

The first known use of the term 'evolutionary economics' in English was by Veblen (1898, p. 398). He gave this term a particular connotation that has not been widely adopted since. Veblen (1899, 1919) argued that economics should become 'post-Darwinian' and embody the insights of Darwinian evolutionary theory. He was one of the first to uphold that selection processes operated on institutions in society as well as organisms in nature: institutions as well as individuals were objects of selection (Camic and Hodgson 2011).

Although Veblen was one of the founders of the original institutional economics, his followers quickly abandoned his Darwinian legacy (Hodgson 2004a, Rutherford 2011). By the 1920s any appeal to ideas from biology had become extremely unpopular in all Anglophone social sciences. Even when Veblen's followers retained the word 'evolutionary', it was used to refer more broadly to development and change, and mostly without any Darwinian connotations. This was the case in the USA with the Association for Evolutionary Economics (AFEE), which was founded in 1966. Like Nelson and Winter

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(1982) and their 'neo-Schumpeterian' followers, AFEE invoked the term 'evolutionary' without any explicit appeal to Darwinian ideas.

Clarence Ayres was the leading intellectual influence over AFEE at its formation. Ayres (1932, p. 95) was rather dismissive of Darwinism. He had written that 'Darwin's "particular views" have gone down wind: variation, survival of the fittest, natural selection, sexual selection, and all the rest. Darwin is very nearly, if not quite, as outmoded today as Lamarck.' Ayres (1932, p. 234) promoted an interpretation in which 'evolution means the general theory of development without reference to particular mechanism of variation, selection or what not'. Generally, Ayres's views were very influential among original institutional economists in the post-1945 period. Consequently, Veblen's appeal for a 'post-Darwinian' economics was largely ignored, even among his followers.[1]

For a while, Schumpeter (1934, pp. 57–8) saw the term 'evolution' as 'discredited'. Later he adopted the term himself (Schumpeter 1939, 1942), but he never interpreted evolution in Darwinian terms (Hodgson 1993, Witt 2002). Yet he made analyses of technical change, entrepreneurship, and innovation the centrepieces of his work. He saw static analysis of circular flow as a limiting case and upheld the primary quest to understand the processes of restless dynamism and transformation. Work influenced by Schumpeter is also described as 'evolutionary economics' as evidenced by the title of *Journal of Evolutionary Economics*, published by the International Joseph Schumpeter Society.

Another strand of evolutionary thinking originates within the Austrian school of economists, particularly Carl Menger, Ludwig von Mises, and Friedrich Hayek. Menger's (1871) theory of the emergence of money is often cited as evolutionary because it is an attempt to understand the emergence of an institution. But evolutionary discourse in Austrian economists was much more developed in the case of Hayek (1967, 1973, 1979, 1988). He made use of notions of evolutionary selection and drew parallels between evolution in society and evolution in the natural world. But while Hayek acknowledged Darwin and used the Darwinian idea of selection, he saw Darwinism as one stage in a long, vaguely defined line of 'evolutionary' thinking rather than an intellectual revolution in its own right (Hodgson 1993).

Given the rather broad and vague set of concerns that have been described as 'evolutionary' and the wide usage of the term, we cannot object when other writers identify 'evolutionary' themes in various writers including Adam Smith,

[1] Jones (1995, p. 419) argued that 'Ayres simply failed to come to effective grips with Darwin's work'. Similar criticisms of Ayres's view of Darwinism are found in Hodgson (2004a).

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Karl Marx, Carl Menger, and Alfred Marshall. Evolution is a broad word, and it invokes lots of different ideas. There is nothing wrong with that. It would be a mistake to infer that 'evolution' implies a clear set of principles or inherently means Darwinian. The relevance, or otherwise, of Darwinian ideas for economics and other social sciences has to be established by evidence and argument, not simply by a semantic claim that evolution necessarily implies Darwinism or any other particular theoretical framework.

A number of works prepared the ground for the surge of evolutionary thinking in the 1980s. Hayek's prescient works in the 1970s have already been noted. Nicholas Georgescu-Roegen (1971) introduced the entropy law into economic theory and also made bridges between some types of evolutionary analysis and ecological economics. János Kornai (1971) developed a highly innovative and dynamic theoretical approach. Also, Kenneth Boulding (1981) produced a treatise entitled *Evolutionary Economics*.

But the strongest boost came with the publication of Richard Nelson's and Sidney Winter's (1982) *Evolutionary Theory of Economic Change*. Their line of research originated in the RAND organisation and was thereinspired by Armen Alchian (1950). Nelson and Winter were also influenced by Schumpeter's (1934, 1942) emphasis on innovation and dynamics, Hayek's (1948) stress on the role of knowledge, Herbert Simon's (1957) ideas on satisficing and bounded rationality, and the behavioural theory of the firm (Cyert and March 1963).

Since 1980 theoretical developments in evolutionary economics have been significant, and a huge amount of related material has been published, but as yet there has been no convergence on an integrated approach (Silva and Teixeira 2009). Despite the field's internal heterogeneity and lack of consensus on key issues, the networks, journals, and forums that developed after the 1980s created a scattered but linked community of scholars addressing common problems and overlapping research agendas. The scholars were also united by their common dislike of the static and equilibrium approaches that dominated mainstream economics.

By the 1990s it was possible to write of an international network or 'invisible college' of evolutionary economists who, despite their analytical differences, were focusing on the problem of analysing structural, technological, cultural, and institutional change in economic systems (Verspagen and Werker 2003, Witt 2008, Silva and Teixeira 2009). Reference within this informal college is typically made to a variety of alleged precursors such as Schumpeter, Hayek, Marshall, and Veblen, but the evolutionary college is too amorphous and eclectic to warrant a description in terms of a single mentor.

There are also potential links with research programmes that originated outside economics. Among these is the 'organisational ecology' approach

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(Hannan and Freeman 1989), work on organisational adaption (Levinthal 1992), and other work of an evolutionary nature in organisation studies (Aldrich and Ruef 2006).

Post-1980 evolutionary economics has also been prominent in various policy debates, particularly concerning policies for technological development, innovation, and business strategy (Dosi *et al.* 1988, Lundvall 1992, Nelson 1993, McKelvey 1996, Murman 2003). Its influence is generally stronger in business schools and other applied research institutions than in university departments of economics. Nevertheless, policy work emanating from evolutionary economics ranges from advocacy of major state interventions in the economy to vigilant support of free-market policies.

3 Evolutionary and Mainstream Economics Compared

Although differences exist within evolutionary economics on many theoretical and practical questions, we can conceive of a paradigm shift fuelled by insights from both evolutionary and institutional thinking. Figure 1 maps the landscape of theoretical depictions of individual interactions in economics. Both axes concern theories about the world, rather than the world itself. The horizontal dimension refers to the minimum number of actors in the theory concerned. The vertical dimension refers to the assumed extent of knowledge and deliberative (rational) consideration of the (rational) deliberation and knowledge of other individual actors in the theory.

Starting with the bottom-left corner of the figure, simple monopoly refers to elementary monopoly theory – without price discrimination – where the monopolist merely faces an aggregate demand curve, and individual consumers do

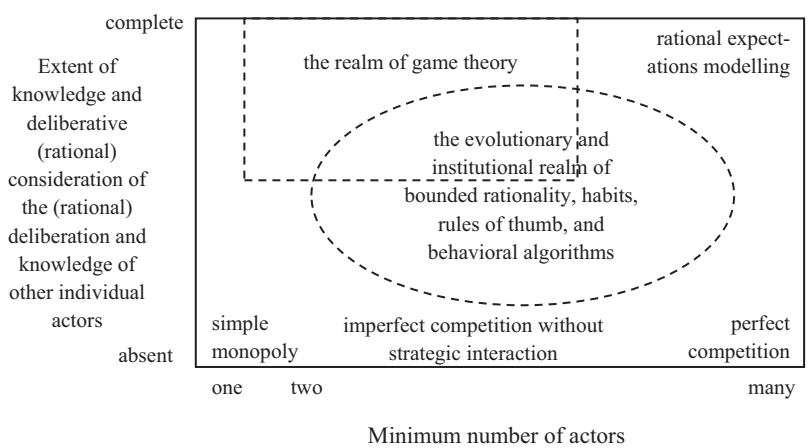

Figure 1 A landscape of economic theory

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not otherwise come into the picture. In the bottom-right corner, perfect competition beholds the price-taking competitive firm of the textbooks. For most of the twentieth century, economic theory explored the linear region at the bottom of this diagram, between simple monopoly and perfect competition, including early theories of imperfect competition without strategic interaction.

Rational expectations modelling appears in the top-right corner of the figure. These models assume that agents through experience quickly become aware of the 'true' underlying model of the economy. Assuming a sufficient number of other competing agents who are all similarly informed, the well-known result is that government macroeconomic policy is ineffective. The rationality assumptions, however, are universal and extreme. It is widely known that this result does not hold up with even partial relaxations of these assumptions, such as the introduction of heterogeneous agents who vary in their information-processing capabilities (Haltiwanger and Waldman, 1985).

The widespread adoption of game theory in the 1980s (although it had much earlier precedents in the works of Augustin Cournot and Joseph Bertrand) led economists into new territory. Strategic interactions were considered with a limited number of actors, often with the 'common knowledge of rationality' assumption that not only are individuals rational but also everyone believes that all others will act rationally. Long reasoning chains like 'if I think that she thinks that I think . . . ' emerge, often creating intractable logical problems of self-reference and infinite regress (Hargreaves Heap and Varoufakis, 1995).

Game theory occupies an upper region in the diagram. Note that the realm of game theory extends downwards to some extent into an area where agents are assumed to take partial but incomplete account of the strategic deliberations of others. This lower area within the game theory box includes behavioural game theory (Camerer 2003).

In the central region of the diagram, between game theory and the monopoly-competition axis at the bottom, lies the realm of modern evolutionary and institutional economics. Like game theory it assumes a structured world of limited interconnectedness, dominated by rules. Unlike much game theory, it adopts a more limited view of individual deliberative and calculative capacities. Decision-making takes place in the context of complexity and radical uncertainty, limiting the chains of logical reasoning concerning the likely reactions of others to different behaviours. The concept of equilibrium becomes less central. The ontological fundamentals of this central region involve institutional structures and algorithmic learning processes entailing program-like habits and rules (Hodgson 1997, 2007a, 2007c, Potts 2000, Vanberg 2004). As Kurt Dopfer *et al.* (2004, p. 263) put it: 'the central insight

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is that an economic system is a population of rules, a structure of rules, and a process of rules'. This conception makes explicit links between evolutionary economics and the study of institutions (Hodgson 2004, Hodgson and Stoelhorst 2014, Stoelhorst 2014).

Note how evolutionary and institutional economics occupy the centre of the diagram. The oddity is that mainstream economics has journeyed around the periphery rather than the centre of this domain. Evolutionary and institutional economics may thus have the potential to be a new mainstream (Hodgson 2007c).

This evolutionary-economics-as-mainstream outcome is resisted by the preference for complete analytical formalism in mainstream economics (Klamer and Colander 1990, Krueger 1991, Blaug 1997, 1999). But rather than designing models to reach complete analytical solutions, evolutionary economics often employs algorithmic approaches and techniques such as agent-based modelling. Besides employing 'formal' (principally mathematical) theory, evolutionary economists emphasise the additional importance and role of (more empirically driven and discursive) 'appreciative' theorising (Nelson and Winter 1982, p. 46).

Such a possible shift in the nature of mainstream economics was predicted by Frank Hahn (1991, pp. 48–50) when he wrote of putting aside 'the pleasures of theorems and proof' in favour of 'the uncertain embrace of history and sociology and biology'. Hahn also believed that 'the subject will return to its Marshallian affinities to biology'. Echoing such sentiments, Kenneth Arrow (1995, p. 1618) argued that 'the very notion of what constitutes an economic theory will have to change' and suggested that 'the biological is a more appropriate paradigm for economics than equilibrium models analogous to mechanics'.

But these statements by Arrow and Hahn are now decades old, and movement by mainstream economics in the direction they predicted has been relatively slow. Although there is increased discussion of the challenges of complex phenomena by mainstream economists and mechanisms of evolutionary selection are used in evolutionary game theory, the notions of equilibrium and optimization are still as prominent as they were in the 1980s and 1990s (Hodgson 2019, ch. 3).

4 Evolutionary Economics and Evolutionary Game Theory

This section compares evolutionary game theory with evolutionary economics. The review of evolutionary game theory here is brief and does not do justice to the enormous literature in this and related fields. Within game theory there are also other strains – such as behavioural game theory and cognitive game

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theory – that have interacted with evolutionary game theory. As well as embodying evolutionary concepts, much game theory now emphasises learning, which also may seem to resonate with evolutionary economics. But as shown below, evolutionary economics and game theory research are quite different in other respects.

Evolutionary game theory was first formally developed by Richard Lewontin (1961) in evolutionary biology. Subsequently Maynard Smith (1972, 1982, Maynard Smith and Price 1973) defined and developed the concept of an *evolutionarily stable strategy* (ESS). Robert Axelrod's (1984) use of game theory (involving selection among competing strategies) inspired many social scientists, and Robert Sugden (1986) imported the ESS concept into economics. Since the early 1990s there has been an explosion of interest in evolutionary games from economists and other social scientists.

There are important differences between classical games and evolutionary games. In many classical games, players have common knowledge about the rules and structure of the game, although this assumption is modified in behavioural game theory (Camerer 2003). But in all evolutionary games, players lack such common knowledge, have bounded rationality, and inherit rather than choose their strategies. Because players are selected from sizeable populations and matched randomly, they do not attempt to influence other players' future actions. This feature distinguishes evolutionary games from repeated games involving calculated strategic threats. At least in developments so far, players are relatively myopic and naïve in evolutionary games.

Evolutionary game theory claims significant success in modelling how social phenomena can arise from the interactions of utility-maximizing individuals. Examples include the emergence of altruism (Gintis 2003, Gintis *et al.* 2003, Nowak and Sigmund 2005, Sanchez and Cuesta 2005, Fletcher and Zwick 2007, Bowles and Gintis 2011), social learning (Kameda and Nakanishi 2003, Wakano *et al.* 2004, Wakano and Aoki 2006, Nakahashi 2007), social norms (Axelrod 1986, Binmore and Samuelson 1994, Ostrom 2000, Bicchieri 2006), moral behaviour (Skyrms 1996, 2004, Alexander 2007), and signalling and the emergence of language (Hurd 1995, Nowak *et al.* 1999, Zollman 2005, Pawlowitsch, 2007, 2008, Jäger 2008). Although some of the basic assumptions of these models are challengeable, the analytical significance of these contributions is widely acknowledged. It can be argued that many are useful heuristic models to help our understanding of reality on grounds similar to those proposed by Robert Sugden (2000). It has even been suggested that aspects of evolutionary game theory are redolent of the work of Veblen (Villena and Villena 2004).

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Overall, evolutionary game theory has spawned a large and internally diverse set of approaches. But while evolutionary game theory now claims some empirical applications, the research field is not yet empirically driven to any great degree. It is propelled instead by formalistic explorations of the space of possible assumptions and by attempts to deal with problematic or incongruous formal outcomes or specifications. It reflects the norm in the prestigious core of mainstream economics itself and pays foremost attention to 'formal' rather than 'appreciative' theorising.

For Nelson and Winter (1982, pp. 45 ff.) a theory is 'a tool of inquiry'. The broad process of analysis and understanding – with a 'focus on the endeavour in which the theoretical tools are applied', including engagement with empirical data – amounts to *appreciative* theory. By contrast, with *formal* theory, 'the focus is on improving or extending or corroborating the tool itself'. For Nelson and Winter, these two different 'styles' or 'kinds' of theorising 'are necessary for economic understanding to progress satisfactorily, and there are strong if subtle connections between them'.

From a casual inspection of the two literatures of evolutionary economics and evolutionary game theory it is obvious that the former makes relatively more use of appreciative theorising, although both modes of argument can be found in either camp. While many evolutionary economists make use of formal models, the most well-known work in this field is more empirically orientated and empirically driven, as we show later.

A problem when comparing evolutionary game theory with evolutionary economics is that there is relatively little dialogue and overlap between the two genres. On the one hand, the 'formal' evolutionary game theorists rarely if ever refer to works by Dosi, Nelson, Winter, or Witt. They do not seem to regard their own game-theoretic work as a useful but optional tool to be used in the context of a broader process of theoretical enquiry into the nature of the world; rather it is often paraded and applauded as if it were sufficient theory itself. On the other hand, evolutionary economists make relatively little use of evolutionary or any other form of game theory, although some game-theoretic work has been published in *Journal of Evolutionary Economics*. Furthermore, when they turn to models, specifications of replicator dynamics are not placed in a game-theoretic context, and there are preferences for statistical approaches or agent-based modelling.

Agent-based models typically are applied to problems where the discovery of analytic solutions is difficult or impossible. But in such models, slight parametric or design changes often lead to very different simulation outcomes. As a result, many mainstream economists dismiss agent-based modelling, and it has limited exposure in the more prestigious journals of economics.

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