Cambridge Journal of Economics 2003, **27**, 65–84

The microfoundations of macroeconomics: an evolutionary perspective

Jeroen C. J. M. van den Bergh and John M. Gowdy*

We consider the microfoundations controversy from the perspective of economic evolution. Although the analogy between biology and economics has been noted before, it has rarely focused on clarifying the micro–macro distinction in economic theory and modelling. The micro–macro debate is more developed in biology than in economics owing to a greater degree of specialisation and a greater degree of interaction between various sub-disciplines. The task for economists is to distinguish between insights directly relevant for economic theory and ones that hinge on unique features of biological systems. We argue that both micro and macro processes drive economic change and that macroeconomic change cannot be explained by micro-level optimising alone. We show that debates in biology about group selection and punctuated equilibria are relevant to understanding economic evolution. The opposition of reductionism and holism is of little use and, in its place, a hierarchical approach is proposed. This allows for both upward and downward causation and interaction between levels.

Key words: Evolutionary biology, Group selection, Hierarchical causation, Punctuated equilibrium, Sorting
JEL classifications: E11, O11, O3

1. Introduction

During the last quarter century, the microfoundations approach to macroeconomic theory has become dominant. As a result, the subject matter of macroeconomics has shifted steadily from questions of distribution and institutions to an almost exclusive concern with market efficiency in allocating goods and productive inputs. Pareto optimality has become the dominant goal of macroeconomic policy. On the other hand, a growing number of economists argue that the Walrasian microfoundation approach to macroeconomics is inadequate (Colander, 1996; Foster, 1987; Gintis and Romer, 1998; Gowdy, 1992; Hodgson, 1993B; Metcalfe, 1998). Even within the narrow framework of general

Manuscript received 24 March 2000; final version received 22 January 2001.
Address for correspondence: Jeroen C. J. M. van den Bergh, Department of Spatial Economics, Free University, De Boelelaan 1105, 1081 HV Amsterdam, The Netherlands; email: jbergh@feweb.vu.nl; and John M. Gowdy, Department of Economics, School of Humanities & Social Sciences, Rensselaer Polytechnic Institute, Troy, NY 12180-3590, USA; email: Lgowdy@aol.com

*Department of Spatial Economics, and Institute for Environmental Studies, Free University, and Rensselaer Polytechnic Institute, respectively. We should like to thank Peter Mulder, Carl McDaniel and two anonymous referees for helpful comments.

© Cambridge Political Economy Society 2003

equilibrium theory, some basic problems exist with the microfoundations position (Weintraub, 1977). For instance, applications of general equilibrium theory, as in computable general equilibrium (CGE) models, do not follow a consistent micro approach because not every individual agent or market is described. Instead, CGE models assume, through aggregation or the assumption of the representative agent, that groups or sectors act analogously to a single rational individual, that is, they maximise a single-valued profit or utility function subject to some resource constraint. As a result, contemporary macroeconomics lacks a theory of expectations formation above the level of the individual agent (Shackle, 1972). Theories of macrolevel financial institutions, for instance, are absent in current macroeconomics, in spite of these phenomena having been described decades ago (Keynes, 1936).

Many other fundamental objections to the microfoundations approach have been raised. Evidence indicates that most individuals do not act strictly 'rationally', either in a static sense or according to the rational expectations' hypothesis (Twomey, 1998). This is related to, among other things, the fact that decision-making costs are positive, and knowledge about the structure of the economy is imperfect (Becker, 1965; Heiner, 1982; Lancaster, 1991). In addition, models that include realistic properties of behaviour and realistic descriptions of markets have no unique equilibria (Clower, 1967; Hahn, 1965; Kirman, 1989; Leijonhufvud, 1968; Radner, 1968, 1970; Nicolaides, 1988; Dow, 1997). Moreover, theories of macroeconomic change based on a microfoundation of strictly rational behaviour have been challenged by theories in economic psychology and behavioural economics, as well as by findings in experimental economics (Simon, 1957; Caldwell, 1984; Hodgson, 1988; Kagel and Roth, 1995). Yet these findings have had little impact on either teaching (introductory texts) or applied (CGE) modelling.

The level of aggregation necessary in macroeconomic models requires unrealistic assumptions such as fungibility, homogeneity of inputs and outputs, and linearity (see Scarth, 1988, Appendix A6). Aggregate capital and production functions cannot be logically derived from firm-level production functions (see Harcourt, 1972, on the Cambridge capital theory controversy). Moreover, it must be assumed that aggregation is independent of policy in order to allow policy-relevant models as an outcome. Aggregation can be done along various schemes, and choosing one is always somewhat arbitrary. For instance, consider the microlevel relationships $y_1=f_1(x_1, x_2)$ and $y_2=f_2(x_1, x_2)$. Aggregation of the y_i into an aggregate variable Y, and of the x_i into an aggregate variable X, can occur via arbitrary functions G and H, respectively: $Y=G(y_1, y_2)$, and $X=H(x_1, x_2)$. Straightforward aggregation functions are sums or weighted sums (and integrals in models with continuous dimensions). Now suppose a unique macrolevel relationship exists between Y and X, say $Y=F(X)$. Then it follows that $Y=F(X)=F[H(x_1, x_2)]=K(x_1, x_2)$, with $K\equiv F^\circ H$. In addition, it is possible to derive the relationship between Y on the one hand, and x_1 and x_2 on the other hand, in another way, namely via $Y=G[f_1(x_1, x_2), f_2(x_1, x_2)]=\mathcal{J}(x_1, x_2)$, with $\mathcal{J}\equiv G^\circ(f_1, f_2)$. K and $\mathcal{J}$ are in general not identical, which contradicts the initial assumption of a unique macrorelationship between Y and X. This means that there is no one-to-one link between micro and macro relationships.

Different approaches have been followed to solve this problem (see Janssen, 1998). One is to set constraints on microlevel functions so that microlevel distribution plays no role in terms of macrolevel outcomes, and no information is lost in the aggregation. Alternatively, restrictions can be placed on the values taken by the microlevel variables, based on marginal rules motivated by rational behaviour. Whichever path is taken, it is impossible to allow simultaneously for aggregate variables to be equal to the sum of microlevel variables, and for macrorelationships (e.g., sectoral production functions) to be analogous to microlevel counterparts (firm production functions). This suggests that it is futile to search for a definite and unique microfoundation for macroeconomic relationships. Microeconomic and macroeconomic theories and models should be regarded as complementary.

It is not our purpose to criticise microeconomic models, which we think have provided, and still may generate, many useful insights. We argue that microeconomic and macroeconomic models can provide complementary descriptions of economies. We support this view by linking the micro–macro debate to similar debates in evolutionary biology. Consequently, our discussion takes place within a context of evolutionary economic change and the forces that drive it. One central implication of this is that the criteria of technical and individual 'efficiency' in a dynamic context, which are central to the microfoundations interpretation of economic change, are much too narrow to describe the complex reasons for change in the macroeconomy (see Bromley, 1990). This has been supported by various perspectives on inefficiency at an individual level, based, for example, on contracts (Foster, 1987), bounded rationality (Simon, 1957), or X-ineffiency (Leibenstein, 1966). Our motivation for considering the micro–macro debate in biology is that it has been discussed from many more angles than the similar debate in economics. This is partly the result of a more advanced specialisation, interaction and integration of subdisciplines, which are associated with particular levels and scales of study. Examples are molecular biology, genetics, cell biology, physiology, population theory, ecology and palaeontology.

We do not argue for a mechanical application of biological principles to economic phenomena. But we agree with Hodgson (1993A) that metaphors can inspire, i.e., generate new and novel ideas and results. Examples of revolutions in science that were influenced by transferring ideas from other disciplines include Darwin's theory of evolution, Maxwell's theory of gases, and Cournot's calculus of political economy (Hodgson, 1993A, pp. 20–1). Playing with metaphors implies approaching reality from different angles, and accepting that concepts are subjective and have both history and a context. Almost all uses of concepts, theory, and models have a metaphorical element to them. The task for economists is to distinguish between insights directly relevant for economic theory and ones that hinge on unique features of biological systems. Evolutionary thinking is as important to economics as it is to biology, for at least four reasons (van den Bergh and Gowdy, 2000). First, economic systems are subject to extremely fast developments characterised by qualitative, structural and irreversible change, and do not show any tendency towards either short-run or long-run steady states. Second, many elements of economic change can be cast in terms of changing compositions of populations of diverse agents, firms, technologies, etc. Third, economic systems have a great capacity for sustained learning and adaptation, at all (vertical) decision and spatial levels. Finally, evolution is a real phenomenon taking place at a horizontal organisational structure of the economy, involving science, technology, businesses, markets, the legal system, consumer preferences, and institutions and culture at a wider level (Nelson, 1995).

The framework of evolutionary biology may enrich traditional economic analysis by showing how to account for a wider range of phenomena, namely, by going beyond methodological individualism.[1] As Hodgson (1995, p. xxi) argues: 'Recognition of the shared problems of complexity in both biology and economics may lead economists to place less faith in methodological individualism and to recognise the legitimacy of levels

[1] This is not to say that methodological individualism is not present in biology (see Ghiselin, 1974) or that all evolutionary approaches in economics reject reductionism (Friedman, 1953).

and units of analysis above the individual.' Consideration of recent controversies over micro and macro processes in evolutionary biology can shed light on similar controversies in economic theory for two reasons. First, biology provides a relevant description of evolutionary change using a delineation of hierarchies of selection and the movement up and down these hierarchies. This involves a range of theories, including Darwinian selection at the micro level as well as macrolevel theories of sorting. Second, evolutionary biology shows the explanatory power of explicit theories of group dynamics rather than regarding macro phenomena as simply the sum of the uncoordinated actions of individuals. Theories of group selection, and how the outcomes of group selection differ from individual selection, are well developed in biology. As in biology, both cooperation and competition play a fundamental role in economic evolution.

The main purpose of this paper, then, is to show that the debate on levels of analysis is not unique to economics, and in particular, that the microfoundations of macroeconomics, which are still take for granted by an overwhelming majority of (influential) economists, are not supported by an evolutionary perspective. A second purpose is to show that some lessons can be learned from evolutionary biology about how to study complex evolutionary systems. In this context, we propose a multilevel or hierarchical causation framework for future macroeconomic theories.

The structure of this paper is as follows. Section 2 discusses similarities between the micro–macro controversies in biology and economics. Section 3 considers the relevance of the much debated notion of group selection in biology for economics. Section 4 examines the relevance of the notion of punctuated equilibrium for economics. Section 5 presents an economic evolutionary framework for macroeconomics that is based on hierarchical causation and evolution. Section 6 concludes.

2. Parallel controversies in biology and economics

The field of evolutionary biology is today a major centre of activity in the philosophy of science, much as classical physics was the centre for most of the last century. And if some fields of science are further along in their understanding of reality, related fields should make sure that their explanations are consistent with the latest discoveries and insights (Wilson, 1998). Just as classical mechanics gave birth to the positivist philosophy of neoclassical economics, so too can evolutionary biology be an inspiration for new approaches to economic theory.

Evolutionary theories have been central to both economics and biology for well over one hundred years. For the most part, however, applications of evolutionary theory by economists have been limited to rather crude applications of Darwinian natural selection. As Hodgson (1992, 1993A) points out, it was Herbert Spencer's 'survival of the fittest' interpretation of Darwin that had the greatest impact on the formation of neoclassical economic thought. A long list of economists (Alchian, 1950; Enke, 1951; Friedman, 1953; Hirshleifer, 1977; Tullock, 1979) used the analogy of natural selection to reinforce the neoclassical model and to argue for the superiority of market outcomes. For the most part, the application of evolutionary ideas to economics is still limited to fairly crude survival-of-the-fittest metaphors.

Although valiant attempts were made in the past to apply more complex evolutionary metaphors to economics (Schumpeter, 1949; Veblen 1898), the effort was hampered by the dominance of theories of evolution in biology that almost exclusively emphasised gradual change and adaptation at the margin, and minimised the importance of sweeping, discontinuous change (Mesner and Gowdy, 1999; Hodgson, 1993A). The emphasis of economic models on gradualism and optimisation began to be seriously challenged in the, 1970s, when heterodox economists such as Boulding (1970) and Georgescu-Roegen (1971) introduced the concept of entropy to describe economic change as an irreversible, thermodynamic process. A breakthrough in legitimising non-equilibrium approaches to evolutionary economics was the publication in 1982 of Nelson and Winter's *An Evolutionary Theory of Economic Change*. This book paved the way for a variety of approaches to evolutionary economics, both near and remote from the mainstream. More recently, concepts from evolutionary biology such as path dependence (Arthur, 1989; David, 1985), adaptation (Holland and Miller, 1991), self-organisation (Foster, 1997; Witt, 1998) and co-evolution (Brander and Taylor, 1998; Norgaard, 1992) are beginning to have an impact on economic thinking. Evolutionary game theory, with a focus on equilibrium selection, also draws from evolutionary (mainly selection) theory (Weibull, 1995). Economists working with anthropologists and behavioural psychologists are developing realistic models of human behaviour in its social and biological context (Gintis, 2000; Tversky and Kahneman, 1974; 1981, Hodgson, 1997). Nevertheless, even among heterodox economists, the opinion is still pervasive that methodological individualism is the preferred approach to economic problems and that economic change is progressive and driven by efficiency improvements at the margin.

The points of conflict in contemporary economics and evolutionary biology are in many ways remarkably similar. As in the field of economics, many prominent biologists decry the empty formalism of mathematical modelling (Mayr, 1982). Others (Gould and Lewontin, 1979) challenge the 'Panglossian' view that all evolutionary change is for the better because it is the result of marginal improvements in 'fitness'. Others argue that microbiological principles can explain all evolutionary change—including morphology, the complexities of individual behaviour, ecological relationships (co-evolution) and social behaviour (sociobiology)—and that there is no need for concepts of macroevolution (Dawkins, 1976; Dennett, 1995). Likewise, the 'strong expansion' of neoclassical economics implies that there is only one true model of economic behaviour (Hirshleifer, 1985; Nicolaides, 1988, p. 314). Every aspect of social relationships or environmental interactions can be subsumed under a general equilibrium framework.

By contrast, interesting research showing an alternative perspective is emerging from the field of evolutionary economics building on multi-agent models of behaviour which incorporate concepts of complexity and hierarchy. For example, Potts (2000) has synthesised notions of sorting and selection (Vrba and Gould, 1986) at multiple levels in what he calls 'hyperstructure'. Kirman (1997) has developed economic models with agents that interact with each other on multiple levels and that learn from each other. Lawson (1997) argues for a 'transcendental realism' that permits multiple levels of action allowing separate theories as complementary.

In order to understand the notion of multiple levels of processes, two important higher-level theories of evolution are examined here, namely group selection and punctuated equilibrium. These have been proposed in addition to the traditional Darwinian selection of genes or individuals, and imply that there exist 'higher level' selection processes, that is, higher than natural selection acting solely on individuals.[1]

[1] A reviewer pointed out that even the crude versions of the 'survival of the fittest' argument indicate hierarchical structure and the emergence of order. Survival of the fittest need not imply independence of the sort found in the dogmas of neoclassical economics and its representative agent. It should also be recognised that even mainstream Darwinism has provided an important challenge to positivism by providing a concrete alternative to the static equilibrium of classical mechanics. Darwin made extensive use of metaphors and insights from other disciplines to develop a theory of causality including hierarchical processes and co-evolution.

3. Group selection

A hotly debated topic in evolutionary biology is group selection, a concept that fell out of favour in the 1960s and 1970s but has seen a resurgence in recent years (Wynne-Edwards 1962; Wilson, 1975; Ruse, 1979; Sober, 1981; Boyd and Richerson, 1985; Trivers, 1971, 1985; Alexander, 1987; Wynne-Edwards, 1991; Wilson, 1997; Sober and Wilson, 1998). The definition of group selection is that the fitness of every member of a group depends on a characteristic of that group that is not isolated in an individual. Proponents of group selection argue that groups characterised by genuine, i.e., non-kin and non-reciprocal, altruism may outcompete groups composed of selfish individuals. Group selection challenges the neo-Darwinian view that all evolutionary change is driven by individual characteristics alone (Wynne-Edwards, 1991). Its existence in human societies also challenges some of the basic behavioural assumptions underlying neoclassical utility theory and thus the microfoundations of welfare economics. Challenges to the neoclassical paradigm can be made all the stronger if it can be demonstrated that they are on a firm footing with the basic understandings of natural science.

The first major clash over group selection occurred in the 1960s with the publication of Wynne-Edwards' (1962) book *Animal Dispersion in Relation to Social Behaviour*, which drew a critical reaction from Hamilton[1] (1964A, 1964B), Williams (1966), and to a lesser extent E. O. Wilson. Early versions of sociobiology were strongly opposed to group selection, and argued that social behaviour is the result of genetic or individual selection (Wilson, 1975). An extreme position is Dawkins' (1976) selfish-gene interpretation. A good assessment of the sociobiology debate is Ruse (1979).

Two key sociobiological explanations of altruism are kin selection and reciprocal altruism, both of which attacked Wynne-Edward's formulation of group selection. Proponents of kin selection argued that apparently altruistic behaviour is genetically based because altruists are actually protecting their own genes by helping close relatives survive (Hamilton, 1963; Maynard Smith, 1964). The reciprocal altruism position is that apparent altruism is based on the expectation that favours will be returned (Trivers, 1971).

Opponents of group selection argued that a basis for group inheritance is missing. Dawkins and Williams argued that there is no clear mechanism to ensure that an advantageous pattern of change for the group is replicated by the actions of the individuals in the group. In other words, if a characteristic valuable to the group is not also of value for the individual or better the 'gene' (directly or indirectly), then it will not be passed on.

The last two decades have seen a resurgence of interest in group selection and cooperative behaviour in biology as well as social science (Boehm, 1999; Boyd and Richerson, 1985; Dugatkin, 1999; Sober and Wilson, 1998; De Waal, 1996; White, 1998; Wilson, 1998). According to Boehm (1997), kin and reciprocal selection cannot explain generous acts towards non-kin that remain unreciprocated. Boehm, Sober and Wilson, and other advocates of group selection argue that Darwinian selection may act at the level of the group as well as the individual. Group selection can occur when the group-level effects outweigh the individual-level effects (Dugatkin, 1999, pp. 22–7). Others counter that non-reciprocal and non-kin altruism is rare in animals and humans, and therefore group selection effects are weak, if they exist at all. Countering this claim are many examples of non-kin-based cooperation (Wilkinson, 1990; Scheel and Packer, 1991; Bernasconi and

[1] Sober and Wilson (1998, pp. 40–3) argue that Hamilton's 'unbeatable strategy' was actually a theory of group selection, even though he did not himself stress the importance of competition between groups for his model.

Strassmann, 1999). The existence of social cognition among humans suggests that group selection in human populations and thus in economic systems may be more significant, owing to the fact that possible individual behaviour is elicited or suppressed by cultural norms (Boyd and Richerson, 1992).

An important element in the discussion about group selection and altruism is free rider behaviour. Free riders will profit from the benefits of being part of the group without having the traits that assure these benefits. When the relative proportion of free riders in the group increases, the benefits of altruism and thus group selection will slowly disappear. In other words, group selection may work as long as the free riders do not dominate the group. Suppression of free rider behaviour can be effective when resource scarcity and competition are low (it is relatively easy to be altruistic), but it will be less effective when resources are scarce and competition is tough (altruism implies a serious sacrifice). Typically, selective pressure is higher in the second case, so that individual selection will leave more of an impact than group selection. In human groups, however, selfish behaviour may be suppressed by a variety of social mechanisms and institutions. If cooperating groups of humans are more likely to survive than non-cooperating ones, then it is not necessarily beneficial to the survival of genes or individuals to be strictly selfish.

All this has a direct bearing on the microfoundations debate. If the selection of economic agents or behaviour patterns depends on group characteristics, further doubt is cast on the methodological individualism of neoclassical theory. A significant amount of experimental evidence now exists that non-selfish behaviour is prevalent even in strictly economic contexts. Recent work using data from biology, anthropology and psychology has shown that the distinction between altruistic and non-altruistic cooperation is so blurred as to be of little use. Behavioural research using game theoretic models show that cooperative behaviour is the outcome when realistic options are allowed such as continuous communication among players and retaliation toward free riders. As summarised by Gintis (2000), games such as the Ultimatum Game (Güth *et al.*, 1982), the Public Goods Game (Isaac *et al.*, 1994), and the Public Goods Game with Retaliation (Dawes *et al.*, 1986) consistently show that cooperative, group-beneficial behaviour is pervasive in human groups. The results of the Ultimatum Game have held up even when played with substantial amounts of real money (Fehr and Tougareva, 1995). Even in the Dictator Game, sharing is the norm, with the average amount shared being 50% with two-way identification of the parties involved and 26% in an anonymous game (Bohnet and Frey, 1999). Contrary to the received wisdom of standard economics, in a variety of settings under a variety of assumptions, non-selfish motives are better predictors of behaviour than the strictly selfish motives of 'homo economicus'.

Boyd and Richerson (1992) argue persuasively that, when retaliation (punishment for anti-social behaviour) is allowed, cooperation or almost any other conceivable behaviour may evolve in large groups. The importance of punishment in the evolution of economic behaviour has been confirmed by Fehr and Gächter (1996). They conducted an experiment in which cooperators could retaliate directly against free riders at some cost to themselves. Even though punishment is costly to individuals, a significant number did retaliate with the result that free riding was almost entirely repressed. Bowles and Gintis (1999A, 1999B) examine the economics of egalitarianism focusing on the evolution of group selection and strong reciprocity. Using data from a variety of human societies, they argue that 'homo reciprocans' is as distinctively human as 'homo economicus'. As D. S. Wilson (1999) points out, evolutionary models predict that a single population will contain a variety of behavioural patterns. Commenting on Bowles and Gintis' (1999A) paper, he writes:

> Economic models also frequently predict mixed outcomes, but the image of human populations as a community of interacting behavioural strategies has not emerged as strongly from economic theory as from evolutionary theory. It is therefore gratifying that Bowles and Gintis emphasise the possibility of more than one human nature; human populations may consist of a spectrum from extreme altruists to extreme sociopaths. In addition to this theoretical plausibility, there is growing empirical evidence that a propensity to cooperate or exploit forms an important axis of human behavioural variation. Seeing human groups as both communities of interacting strategies and (partially) adaptive units deserves to become a major theme in the future.

Empirical research on group selection from historical anthropology as well as game-theoretic models showing the advantages of cooperation has lent support to the group selection argument. When applied to human populations with complex socio-economic systems of rewards and punishment, group selection can add to the explanatory power of macroevolutionary theories and models. Boehm (1997) argues further that human institutions have had a great impact on our physical evolution. During most of our existence as a species, we have lived in small bands of hunter-gatherers (Lee and Daly, 1999). Among these groups a highly stable 'egalitarian syndrome' arose as a survival mechanism. Competition among males was reduced (see the articles in Gowdy, 1998; Lee, 1993) as well as the intensity of selection within the group, thereby reducing variation among phenotypes (Boehm, 1997, p. S100).

Not only do experimental results and game theoretic models allow a variety of human actions including cooperation, altruism and other group-level behaviours, recent work in artificial intelligence also casts doubt on the universality of single microlevel explanations of human behaviour. Economists have been involved in creating artificial societies since the 1970s, when Thomas Schelling created an artificial 'checkerboard' world which demonstrated that even slight changes in preferences had profound effects (Schelling, 1978). This simple insight has been confirmed in a number of evolutionary economic models that include endogenous norms and institutions, among others, Sugarscape (Epstein and Axtell, 1996) and Echo (Holland, 1988). Hemelrijk (1997, 1999) has constructed sophisticated virtual societies which under plausible assumptions evolve unambiguously altruistic behaviour. Hemelrijk's work lends support to the evolutionary advantage of coalitions both within and between groups.

Related to these virtual experiments is the work of Watts (1999) and others showing how complex and cooperative systems may evolve from relatively simple initial conditions. The link between network theory and game theory is intriguing and provides support for and is reinforced by group selection arguments. Watts, for example, argues that trust and reciprocity may evolve on different substrates. A major finding of work on 'small world' dynamics is that cooperative behaviour emerges in large organisations under a wide variety of conditions, even assuming a homogeneous population. The efficiency of the outcome is strongly dependent on the connective structure of the substrate. These order-out-of-chaos models also show that reductionist models of evolutionary stable strategies are conditional on how the geometry of the substrate is defined and on which scale. The connectivity of the system matters to the kind of behaviour (competitive, cooperative or altruistic) exhibited.

Most of the literature on altruism–cooperation–selfishness in economics focuses on the consumer. Perhaps this is because the profit motive that drives production seems transparently individualistic. Many aspects of economic production, however, lend themselves to the application of concepts from group selection and cooperation. Theories of joint production, for example, are beginning to be used to enrich our understanding of complex interactions between firms and between social, natural and social systems (Baumgärtner *et al.*, 2000; Faber *et al.*, 1998). Fehr and Falk (1999) use experimental evidence to argue that with incomplete labour contracts, wage rigidity may be explained by cooperative behaviour on the part of workers and employers. In any case, the existence of strong reciprocity in human behaviour casts doubt on the standard model of economic man in utility theory and thus microeconomic-based concepts of social welfare.

To close this section, it is useful to mention that, recently, evolutionary psychology has emerged as an approach that combines some of the sociobiological and group selection theses with an evolutionary perspective on human psychology (Crawford and Krebs, 1998; Pinker, 1997). This approach is based on the idea that our present behavioural rules (automaticity and heuristics) derive mostly from adaptations to our natural environment and social circumstances during the Pleistocene era. In particular, it is argued that the human brain has evolved adaptations to group interactions, notably language, complex social strategies, and a capacity to recognise motives behind the observed (especially cheating) behaviour of others. According to Ben-Ner and Putterman (1998, 2000) evolutionary psychology suggests an important new research area in economics, namely the influence of the environment on individual preferences. Environment should here be interpreted very broadly, including physical, geographical and biological entities, artefacts, technology and social structures. Jackson (2000), Siebenhüner (2000) and Sethi and Somanathan (1996) examine in particular the role of natural environment and resources, and wonder if human behaviour can be made consistent with requirement for a sustainable long run development of the global economy. Some preliminary insights are:

(i) current artefacts and natural environments are very different from those during the period when the human species evolved;
(ii) consumption beyond the level of (basic) needs is dominated by the striving for 'positional goods', ultimately (unconsciously) aimed at enlarging fitness, or more simply, increasing the probability of finding an attractive partner;
(iii) cultural pressure to strive for 'positional goods' stimulates a belief that both individual and aggregated income growth are necessary conditions for realising individual human happiness.

4. Punctuated equilibrium

A second higher, macrolevel theory in evolutionary biology is 'punctuated equilibrium', first formulated by Eldredge and Gould (1972) and, like group selection, subject to intense debate.[1] When first proposed, this was not really a new theory but rather a new interpretation of palaeontological data. Eldredge and Gould merely claimed that the fossil records of 'morphospecies' typically show long periods of stasis interrupted by bursts of rapid change. As Gould and Eldredge (1993) point out, this finding is consistent with traditional explanations of evolution. Mayr (1959) and Wright (1931), for example, formulated gene-based theories of species evolution that could produce relatively rapid

[1] Note the comment by Samuelson (1993): 'Orthodox biologists are like orthodox economists. When confronted by tensions between their paradigms and reality, they work to explain away the aberrations. Hence, there is a cottage industry in the writing of articles demonstrating that those long tails are useful; or that they are surrogates and markers for special fitness . . . '.

changes in phenotypes. The idea that the pace of evolutionary change might be rapid need only supplement, not overturn, neo-Darwinian adaptationism. It was only later that Eldredge and Gould realised that the radical implication of punctuated equilibrium is that it challenges the idea that natural selection is the only important mechanism of evolutionary change. Gould and Eldredge (1993) see evolution as a hierarchical process with natural selection operating at the individual level but with other biological, climatic and biogeochemical changes also responsible for the array of species and ecosystems present at any given historical moment. According to Gould and Eldredge, it is the notion of hierarchical selection that really embodies the radical content of punctuated equilibrium because it challenges the notion that what now exists must be present because it has won the struggle for survival at the micro level.

The acknowledgement of the existence of macroevolution is one of the most important contributions to come out of the punctuated equilibrium debate. That macroevolutionary outcomes cannot be explained solely by micro phenomena is accepted by biologists, even those generally unsympathetic with the punctuated equilibrium position (Ayala, 1998, p.128). This line of thought has important implications for economics, and one need not accept the validity of punctuated equilibria in biology to see its importance for economic theory. Regardless of the ultimate outcome of the punctuated equilibrium debate in biology, the issues raised are important for the social sciences and for economics in particular. The arguments in the debate between what Eldredge (1996) calls the 'ultra-Darwinist' and the 'hierarchical' approach to evolutionary biology have implications that reach far beyond biology. Eldredge (1996, p. 101) writes: 'Everyone approaching complex systems—whether in physics, chemistry, biology or the social sciences—needs beware the simplicities and distortions of reductive analytic description and the insistence that all structure devolves from a single simple process.'

To capture the difference between micro- and macroevolution, Gould and Vrba (1982) distinguish between 'sorting' and 'selection'. Sorting is a broad term that simply means differential survival rates. Some species survive while others do not for a number of reasons including 'selection', that is, Darwinian selection due to competitive pressure. Selection is a cause, while sorting is a broader term merely indicating an outcome. Sorting can occur at all levels not just among individuals (or genes) in biology and not just among firms (or production techniques) in economics. Moreover, causes of differential survival rates can flow up or down the hierarchy. Gould and Vrba argue further that the term 'adaptation' is too broad to describe the reality of natural selection. They propose to use the word adaptation to describe 'any feature that promotes fitness and was built by selection for its current role' (Gould and Vrba, 1982, p. 6). They use the term 'exaptation' to refer to features that 'evolved for other uses (or for no function at all) and later "coopted" for their current role' (Gould and Vrba, 1982, p. 6). Exaptations are fit for their current role but were not designed for it. Their presence is due to a combination of micro- and macroeconomic events and processes. Current utility should not be confused with reasons for origin. More than semantic nit-picking is involved here. Gould and Lewontin (1979) argue that the emphasis on adaptation to the exclusion of other concerns has led researchers to overlook vital aspects of evolutionary change including a higher sorting process.

The distinction between adaptation and exaptation is critical in describing the economic world (Gowdy, 1992). There are numerous examples of technologies and products that were designed for one thing and proved to be useful for another. A well-known case is Thomas Edison's invention of the phonograph while working on a machine that would record telegraphic impulses on paper discs (Mokyr, 1990, p. 286). A more current case is the drug Viagara, which was originally tested to treat angina and hypertension, until its well-known side effects were reported by patients. Labour skills may also 'evolve' for one function and prove to be useful for another function later. When the Ford motor company was founded in 1903, its first workers were drawn from the bicycle and carriage shops (Braverman, 1974, p. 146). The assembly line was perfected in the automobile industry but was quickly adopted by a variety of other industries. Notions of exaptation and historical circumstance are being widely used in the field of management. Rühli and Sachs (1999), for example, examined the merger of Ciba and Sandoz and found little support for traditional strategic management theory based on rational choice. They write: 'The merger decision and the outcomes with respect to strategy, organisational solutions and corporate culture are largely determined by patterns, by driving and buffering forces and by processes from the past.'

An interesting example of sorting at different levels in economics is given by Mokyr (1990, p. 13), who distinguishes between microinventions and macroinventions. Microinventions are those that involve small, incremental improvements in existing techniques already in use, while macroinventions are radical new changes without clear precedents in their new uses. For Moykr (1990, p. 13): 'The essential feature of technological progress is that the macroinventions and microinventions are not substitutes but complements.' A richer way of seeing this relationship is in terms of nested hierarchies (Simon, 1962; Wollin, 1999). Marginal and revolutionary processes work together in a complex network of bottom-up and top-down influence.

An example illustrating the complex and hierarchical interactions between institutions, technology and economic evolution is Australia's wine industry (Wollin, 1999). In a remarkably short period of time, this industry grew from a mostly domestic enterprise producing an annual output valued at $20 million (AU$) in 1985/86, to an international industry producing an output valued at $234 million (AU$) in 1991/92. Wollin (1999) examines this success in the light of concepts from evolutionary biology. He cites a variety of factors that pre-adapted the Australian wine industry to take advantage of changing international tastes, technological advances and institutional rigidities that made the European wine industries less able to adapt to new situations. New Australian wine drinkers were not bound by European traditions in wine drinking and were predisposed to experiment in new varieties and tastes. Australian winemakers were also free to experiment with new techniques of making wine and new grape varieties. Wollin (1999, p. 13) writes of the sudden surge in Australian international wine sales:

> The old-world wine producers initially failed to respond to this new challenge. The new and smaller Australian industry group was able to innovate and take a significant share of markets at old-world producers' doorstep, whereas the European industry groups were bound by their traditions, regulations and institutional systems and unable to block the Australian initiative.

Pushing the analogy a little further, institutions may also be seen as exaptations. Nelson and Pack (1999) argue that the success of Asian economies between 1960 and 1996 was due in large part to the fact that those countries had institutions which could assimilate modern technology. In Taiwan, for example, almost no electronic goods were produced in 1960, but by 1990 they amounted to 21% of manufacturing exports (Nelson and Pack, 1999, p. 418). This kind of rapid adoption of new techniques and processes requires entrepreneurs and workers with pre-existing skills that can be transferred to other activities.

The punctuated equilibrium debate is relevant as a general lesson for the social sciences because it demonstrates the need for theory of evolutionary change incorporating hierarchies of causality (see Somit and Peterson, 1989). In economic systems, inheritance can occur in different ways at different levels in the hierarchy of economic processes and structures. This makes macroevolution in economics even more relevant than in biology. Nevertheless, for the same reasons, the opposition between individual or genetic selection versus 'punctuationism' and sorting is less concrete and clear in an economic than in a biological context.

5. Macroevolution as hierarchical causation

Holism can be defined as the notion that the whole is greater than the sum of its parts, a view denied by extreme reductionism and the neoclassical starting point of methodological individualism. Holism means that the characteristics of the whole cannot be derived from a complete knowledge of the parts. The implication is that reductionism will never provide all the answers to questions about the whole system's features. Features of the whole system are said to 'emerge' in a deterministic sense. The degree of conflict between holism and reductionism depends on the definition of reductionism. If it includes understanding both the parts and the interactions between the parts—which requires a decomposition of the whole into its parts—then reduction need not be antagonistic to understanding the whole. In many cases, the reductionism–holism debate is not fundamental, and the issue is instead how much complexity regarding interaction among parts is allowed in the description, and whether macro factors or processes may be approximately derived from summing micro processes. A hierarchical approach can resolve the 'which-degree-of-reductionism' debate by understanding or explaining systems on multiple levels rather than reducing all phenomena to a single level, whether micro, macro or meso. In a hierarchical system, entities and processes at one level can be made dependent on those at higher or lower levels. This leads to a system with upward and downward causation.[1]

In the natural sciences, researchers employ a variety of methods and techniques to examine different phenomena at different hierarchical levels. Molecular biologists, geneticists and ecologists employ theories and empirical techniques appropriate for their sub-specialities. In economics, however, attempts to establish independent explanations at the macro level are immediately subject to unrelenting efforts to reduce them to micro-type models. The best-known example is the reduction of Keynes' rich description of the macroeconomy to a sterile, mechanical system by Hicks (1939), Patinkin (1948), Samuelson (1947) and others.

Regardless of the ultimate outcome of the group selection and punctuated equilibrium debates in biology, it appears that higher-level theories make at least as much sense in economics as in biology. The reason is that economies lack a single selection level owing to the fact that they do not have a unique physical inheritance unit comparable to the role of the gene in biological systems. As a result, change is less restricted by historical paths than in biology, and selection or better sorting may occur at various levels, including individual economic agents, stakeholder groups, sectors, products, institutions, cities, regions, countries and so on. This implies that macrolevel economic theories can be formulated without reference to lower level descriptions and that they may complement

[1] Note Samuelson's (1993) statement: 'The bottom line is that we face a hierarchy of levels of competition (and cooperation), and there is no a priori presumption that what conduces to victory at one level also conduces at another.'

theories at both higher and lower levels. In this context, the opposition of reductionism and holism is of little use. Instead, a hierarchical approach makes more sense, as it would allow for both upward and downward causation. The main implication of macrolevel evolutionary theories is that they challenge the micro foundations argument that striving toward efficiency at the firm (or species or gene) level is the sole mechanism driving evolutionary change. This idea and the reaction to it is a central theme that can link contemporary evolutionary theory and economic theory.

Evolutionary biology offers a reference point for developing a hierarchical perspective on macroeconomics. At the same time, the rich history of evolutionary and institutional economics can be built upon. This includes the work of Marx, Veblen, Schumpeter, and Nelson and Winter. In addition, it covers theories of the evolution of hierarchical management organisations (North 1990; Simon, 1962; Sah and Stiglitz, 1986). Today, however, most of the interesting work on economic hierarchies is being done in the field of management, not economics (Astley, 1985; Betton and Dess, 1985; Stewart, 1997; Romanelli and Tushman, 1994; Wollin, 1999).

Although uncertain, one can broadly describe future theories of macroeconomics based on such a hierarchical causation framework.[1] They require a micro approach in the sense that relevant micro diversity needs to be described in a really dynamic way. This in fact means that some theories will be more micro—in the sense of distinguishing more micro units—than present micro-based macroeconomic theories, since the latter still employ representative agents for sectors, consumers, savers or labourers. Next, downward and upward causation imply feedback between different levels of description in the hierarchy. For instance, in describing individual utility or welfare, one can include the influence of income or expenditure comparisons with other individuals (i.e., relative welfare). This means that individuals (micro units) are essential but no longer 'isolated'. In mathematical terms, it implies additional complexity and non-linearity such that an economic equilibrium is no longer evident and certainly cannot be easily calculated. Finally, hierarchies of description are likely to lead to emergent properties, i.e., features or indicators that cannot be simply derived, understood or predicted on the basis of knowledge about the micro units. An example is social institutions (including norms, public agencies, public policies, etc.) that emerge from the complex and dynamic interactions of individuals and their prototype institutions, through 'group behaviour' (cooperation) and individual as well as group selection (see, e.g., Dopfer, 1994). Other examples are expectations of individuals that interact in complex ways, directly (individually, via imitation) and indirectly via real

[1] Just as we were preparing a final revision of this paper a relevant new book was published (Potts, 2000). Potts regards economic systems in terms of nested sets ('hyperstructures') of connections among components, and economic changes in terms of micro- and macrodynamics of connections. He argues that microeconomics requires the use of discrete, combinatorial mathematics, for example, graph theory, to describe and analyse economic systems and changes. As opposed to this, traditional equilibrium theory assumes a continuous reality, allowing the application of techniques like integral and differential calculus as well as concepts like equilibrium, representative agent, production function and utility frontier. Potts' graph or network approach can deal with complexity, which is defined as a dynamic interpretation of balance between order and chaos—sort of a counterpart of equilibrium in a static setting. Here order relates to the presence of few connections among system components, and chaos to the presence of numerous connections. Complexity is then associated with a certain range of the number of connections in between. 'Underconnection' can be caused by, for instance, path dependence and means an inflexible, non-adaptive system; overconnection, as in some unregulated financial markets, means continous and unpredictable change (chaos); complexity, in between, means a system with a relatively stable structure that has the capacity, within boundaries, to adapt to external changes as well as changes from within (i.e., at lower levels in the hierarchy of system connections).

macro indicators that are partly subject to group (public) control (GDP, inflation rate, interest rate). In mathematical terms, these give rise to multilevel feedback and nonlinearities, which also cast doubt on the existence of economic equilibria.

6. Conclusions

Since its inception as a discipline with the publication of *The Wealth of Nations* over 200 years ago, there has been a steady narrowing of the subject matter of economics (Hodgson, 1993A). The broad view of classical economics has been steadily reduced to a theory of the allocation of scarce resources among alternative ends. The almost exclusive emphasis on efficiency has led to a conception of economic evolution analogous to the ultra-Darwinian position in evolutionary biology. Like the debate between the advocates of punctuated equilibria and their opponents, the microfoundations controversy centres on how to explain change. Why does the configuration of economic entities differ between two points in time? The neoclassical answer is 'efficiency'; those firms or techniques that are 'fit', measured by the criteria of economic profit, survive and those that are not fit perish.[1] Furthermore, the existing array of firms and techniques in a competitive economy must be the 'best' in terms of efficiency, since these firms and production techniques have survived the natural selection game. A hierarchical explanation provides a more general framework in that it recognises the importance of efficiency at the microlevel, but also recognises that other factors drive economic change on other levels. We argue that macroeconomics should draw on advances in evolutionary biology to develop more general theories to explain the rich and varied world of real economic change. Group selection and punctuated equilibria point to multiple levels of selection and imply a macroevolution that is not just microevolution scaled up.

In this paper we have argued that:

(1) The microfoundations of macroeconomics, which the majority of (influential) economists still take for granted, are not supported by an evolutionary perspective. Some readers of this journal will not be surprised by this, but it should be noted that evolutionary economics so far has had little to comment on macroeconomics and the microfoundations. Moreover, this finding can perhaps convince some believers of the microfoundations that do not find the traditional criticism (some of it mentioned in Section 1) convincing.

(2) A similar debate on micro versus macro has taken (and is still taking) place in evolutionary biology. Here, ultra-Darwinism represents the pure microfoundations (more micro in fact than neoclassical economics with its representative agent), while theories of group selection and punctuated equilibrium present higher level theories.

(3) The latter two theories can provide relevant insights for economic theorising. A first observation is that, since a counterpart of the gene is lacking in economic systems, higher-level processes seem even more likely than in biology. Moreover, group selection is important for economics, as it surely is a more effective mechanism in human than in lower animal populations. It means that norms and culture cannot always be assumed as given or constant, but that they form an integral part of the system modelled and analysed.

[1] The superior survival rate of profit maximising firms is contradicted by numerous studies (see Dutta and Radner, 1999).

(4) A framework of hierarchical causation, i.e., upward and downward impacts, or microlevels influencing macrolevels and vice versa, provides a more acceptable approach to the study of macroeconomics. This is consistent with developments in other fields of science studying complex (adaptive) systems. The advantage of such a multilayered feedback system is that it can incorporate theories that so far have presented opposite, partial and incomplete perspectives on the functioning of macroeconomic systems. A dynamic evolutionary perspective is needed to make sure that the essential role of diversity at various levels in the hierarchy is recognised, rather than neglected through aggregation and representative agent assumptions.

Today, the general equilibrium approach of standard theory is being challenged as never before. It is more clear than ever that it provides at best a very partial and at worst (and most likely) a very biased perspective on reality. Various alternatives to neoclassical theory including ecological economics, institutional economics, evolutionary economics, Marxian economics and post-Keynesian economics all criticise the microlevel models of consumer and firm behaviour underlying general equilibrium theory. Alternative approaches are getting support from behavioural research, game theory and other fields in social and natural science. Reconciling the growing body of relevant knowledge in fields related to economics, guided by theoretical advances in evolutionary biology can lead to a unification of alternative schools of thought and at last offer a well-structured alternative to neoclassical theory.

Subsequent work can develop formal representations of the hierarchical causation framework that integrate convincing elements of current micro- and macroeconomic theories, so as to generate empirically testable hypotheses. In addition, it might try linking up with advances in complex systems research and related fields. This may go along with the use of new types of mathematics as well as numerical techniques for evolutionary modelling of complex systems.

Bibliography

Alchian, A. A. 1950. Uncertainty, evolution and economic theory, *Journal of Political Economy*, vol. 58, 211–22

Alexander 1987. *The Biology of Moral Systems*, Hawthorne, NY, Aldine de Gruyter

Arthur, B. 1989. Competing technologies, increasing returns, and lock-in by historical events, *Economic Journal*, vol. 99, 116–31

Astley, W. 1985. The two ecologies: population and community perspectives on organizational evolution. *Administrative Science Quarterly*, vol. 30, 224–41

Ayala, F. 1998. Beyond Darwinism? The challenge of macroevolution to the synthetic theory of evolution, pp. 118–35 in Ruse, M. (ed.), *Philosophy of Biology*, Amherst, NY, Prometheus Books

Baumgärtner, S., Dyckhoff, H., Faber, M., Proops, J. and Schiller, J. 2000. 'The Concept of Joint Production and Ecological Economics', mimeo

Becker, G. 1965. A theory of the allocation of time, *Economic Journal*, vol. 75, 493–517

Ben-Ner, A. and Putterman, L. (eds) 1998. *Economics, Values and Organization*, Cambridge, Cambridge University Press

Ben-Ner, A. and Putterman, L. 2000. On some implications of evolutionary psychology for the study of preferences and institutions, *Journal of Economic Behavior and Organization*, vol. 43, 91–99

Bergh, J. C. J. M. van den and Gowdy, J. M. 2000. Evolutionary theories in environmental and resource economics: approaches and applications, *Environmental and Resource Economics*, vol. 17, 37–57

Bernasconi, G. and Strassmann, J. 1999. Cooperation among unrelated individuals: the ant foundress case, *TREE*, vol. 14, no. 12, 477–82

Betton, J. and Dess, G. 1985. *The Application of Population Ecology Models to the Study of Organizations*, New York, Oxford University Press
Boehm, C. 1997. Impact of the human egalitarian syndrome on Darwinian selection mechanisms, *The American Naturalist*, vol. 150 (Supplement), S100–21
Boehm, C. 1999. *Hierarchy in the Forest: The Evolution of Egalitarian Behavior*, Cambridge, MA, Harvard University Press
Bohnet, I. and Frey, B. 1999. Social distance and other-regarding behavior in dictator games: comment, *American Economic Review*, vol. 89, no. 1, 335–9
Boulding, K. 1970. *Economics as a Science*, New York, McGraw-Hill
Bowles, S. and Gintis, H. 1999A. Is equality passé? *Boston Review*, vol. 23
Bowles, S. and Gintis, H. 1999B. 'The Evolution of Strong Reciprocity', mimeo, University of Massachusetts, Amherst, MA
Boyd, R. and Richerson, P. J. 1985. *Culture and Evolutionary Process*, Chicago, University of Chicago Press
Boyd, R. and Richerson, P. J. 1992. Punishment allow the evolution of cooperation (or anything else) in sizable groups, *Ethology and Sociobiology*, vol. 113, 171–95
Brander, J. and Taylor, S. 1998. The simple economics of Easter Island: a Ricardo–Malthus model of renewable resource use, *American Economic Review*, vol. 88, no. 1, 119–38
Braverman, H. 1974. *Labor and Monopoly Capital*, New York, Monthly Review Press
Bromley, D. W. 1990. The ideology of efficiency: searching for a theory of policy analysis, *Journal of Environmental Economics and Management*, vol. 19, 86–107
Caldwell, B. 1984. *Appraisal and Criticism in Economics: A Book of Readings*, Boston, Allen & Unwin
Clower, R. 1967. A reconsideration of the microfoundations of monetary theory, *Western Economic Journal*, vol. 6, 1–8
Colander, D. 1996. Overview, in Colander, D. (ed), *Beyond Microfoundations*, New York, Cambridge University Press
Crafts, N. 1995. Exogenous or endogenous growth? The industrial revolution reconsidered, *Journal of Economic History*, vol. 55, 745–69
Crawford, C. and D. Krebs (eds) 1998. *Handbook of Evolutionary Psychology*, New Jersey, Lawrence Erlbaum
David, P. 1985. Clio and the economics of QWERTY, *American Economic Review Proceedings*, vol. 75, 332–7
Dawes, R. M., Orbell, J. M. and van de Kragt, J. C. 1986. Organizing groups for collective action, *American Political Science Review*, vol. 80, 1171–85
Dawkins, R. 1976. *The Selfish Gene*, New York, Oxford University Press
De Waal, F. 1996. *Good Natured: The Origins of Right and Wrong in Humans and Other Animals*, Harvard University Press, Cambridge, MA
Dennett, D. 1995. *Darwin's Dangerous Idea: Evolution and the Meanings of Life*, New York, Simon & Schuster
Dopfer, K. 1994. How economic institutions emerge: institutional entrepreneurs and behavioral seeds, pp. 299–330 in Shionoya, Y. and Perlman, M. (eds), *Innovation in Technology, Industries, and Institutions*, Ann Arbor, University of Michigan Press
Dow, S. 1997. Mainstream economic methodology, *Cambridge Journal of Economics*, vol. 21, 73–93
Dugatkin, L. 1999. *Cheating Monkeys and Citizen Bees*, Cambridge, MA, Harvard University Press
Dutta, P. and Radner, R. 1999. Profit maximization and the market selection hypothesis, *Review of Economic Studies*, vol. 66, 769–98
Eldredge, N. 1996. Ultra-Darwinian explanation and the biology of social systems, pp. 89–103 in Khalil, E. and Boulding K. (eds), *Evolution, Order and Complexity*, London, Routledge
Eldredge, N. and Gould, S. J. 1972. Punctuated equilibria: an alternative to phyletic gradualism, pp. 82–115 in Schopf, T. J. M. (ed.), *Models in Paleobiology*, San Francisco, Freeman Cooper
Enke, S. 1951. On maximizing profits: a distinction between Chamberlin and Robinson, *American Economic Review*, vol. 41, 566–78
Epstein, C. and Axtell, R. 1996. *Growing Artificial Societies: Social Science from the Bottom Up*, California, Santa Fe Institute
Faber, M., Proops, J. and Baumgärtner, S. 1998. All Production is joint production—a thermodynamic analysis, pp. 131–58 in Faucheux, S., Gowdy, J. and Nicolaï, I. (eds), *Sustainability and Firms: Technological Change and the Changing Regulatory Environment*, Cheltenham, Edward Elgar

Fehr, E. and Falk, A. 1999. Wage rigidity in a competitive incomplete contract market, *Journal of Political Economy*, vol. 107, no. 1, 106–34
Fehr, E. and Gächter, S. 1996. 'Cooperation and Punishment', Working Paper, Institute for Empirical Economic Research, University of Zürich
Fehr, E. and Tougareva, E. 1995. 'Do Competitive Markets with High Stakes Remove Reciprocal Fairness? Experimental Evidence from Russia', Working Paper, Institute for Empirical Economic Research, University of Zürich
Foster, J. 1987. *Evolutionary Macroeconomics*, London, Allen & Unwin
Foster, J. 1997. The analytical foundations of evolutionary economics: from biological analogy to economic self-organization, *Structural Change and Economic Dynamics*, vol. 8, no. 4, 427–52
Friedman, M. 1953. On the methodology of positive economics, in *Essays in Positive Economics*, Chicago, University of Chicago Press
Georgescu-Roegen, N. 1971. *The Entropy Law and the Economic Process*, Cambridge, MA, Harvard University Press
Georgescu-Roegen, N. 1989. 'Quo vadis homo sapiens sapiens?' mimeo. Duke University, Georgescu-Roegen collection
Ghiselin, M. 1974. *The Economy of Nature and the Evolution of Sex*, Berkeley, University of California Press
Gintis, H. 2000. *Game Theory Evolving*, Princeton, NJ, Princeton University Press
Gintis, H. and Romer, P. 1998. 'The Human Side of Economic Analysis: Economic Environments and the Evolution of Norms and Preferences', mimeo, Department of Economics, University of Massachusetts
Gould, S. J. and Eldredge, N. 1993. Punctuated equilibrium comes of age, *Nature*, vol. 366, 223–7
Gould, S. J. and Lewontin, R. 1979. The spandrels of San Marco and the Panglossian paradigm, *Proceedings of the Royal Society of London B*, vol. 205, 581–98
Gould, S. J. and Vrba, E. 1982. Exaptation—a missing term in the science of form, *Paleobiology*, vol. 8, 4–15
Gowdy, J. 1992. Higher selection processes in evolutionary economic change, *Evolutionary Economics*, vol. 2, 1–16
Gowdy, J. (ed.) 1998. *Limited Wants, Unlimited Means: A Hunter-Gatherer Reader on Economics and the Environment*, Washington, DC, Island Press
Güth, W., Schmittberger, R. and Schwarz, B. 1982. An experimental analysis of ultimate bargaining, *Journal of Economic Behavior and Organization*, vol. 3, 367–88
Hahn, F. 1965. On some problems of proving the existence of an equilibrium in a monetary economy, in Hahn, F. H. and Brechling, F. (eds), *The Theory of Interest Rates*, London, Macmillan
Hamilton, W. D. 1963. The evolution of altruistic behavior, *American Naturalist*, vol. 97, 354–6
Hamilton, W. D. 1964A. The genetical evolution of social behavior I, *Journal of Theoretical Biology*, vol. 7,1–16
Hamilton, W. D. 1964B. The genetical evolution of social behavior II, *Journal of Theoretical Biology*, vol. 7, 17–52
Harcourt, G. 1972. *Some Cambridge Controversies in the Theory of Capital*, London, Cambridge University Press
Heiner, R. 1982. The origin of predictable behavior. *American Economic Review*, vol. 73, 560–95
Hemelrijk, C 1997. Cooperation without genes, games, or cognition, in Husbands, P. and Harvey, I. (eds), *Fourth European Conference on Artificial Life*, MIT Press, Cambridge, MA
Hemelrijk, C. 1999. Effects of cohesiveness on inter-sexual dominance relationships and spatial structure among group-living virtual entities, in Floreano, D., Nicoud, J. and Mondada, F. (eds), *Advances in Artificial Life*, Berlin, Springer
Hicks, J. R. 1939. *Value and Capital*, Oxford, Oxford University Press
Hirshleifer, J. 1977. Economics from a biological viewpoint, *Journal of Law and Economics*, vol. 20, no. 1, 1–52
Hirshleifer, J. 1985. The expanding domain of economics, *The American Economic Review*, vol. 75, no. 6
Hodgson, G. M. 1988. *Economics and Institutions*, Cambridge, Polity Press
Hodgson, G. M. 1992. Thorstein Veblen and post-Darwinian economics, *Cambridge Journal of Economics*, vol. 16, 285–301
Hodgson, G. M. 1993A. *Economics and Evolution: Bringing Life Back Into Economics*, Ann Arbor, University of Michigan Press

Hodgson, G. M. 1993B. Why the problem of reductionism in biology has implications for economics, *World Futures*, vol. 37, 69–90
Hodgson, G. M. (ed.) 1995. *Economics and Biology*, Aldershot, Edward Elgar
Hodgson, G. M. 1997. The ubiquity of habits and rules, *Cambridge Journal of Economics*, vol. 21, 663–84
Holland, J. 1988. The global economy as an adaptive process, pp. 117–24 in Anderson, P. W. *et al.* (eds), *The Economy as an Evolving Complex System*, California, Santa Fe Institute
Holland J. and Miller, J. 1991. Artificial adaptive agents in economic theory, *American Economic Review Papers and Proceedings*, vol. 81, 365–70
Isaac, R. M., Walker, J. M. and Williams, A. W.1994. Groups size and voluntary provision of public goods: experimental evidence utilizing large groups, *Journal of Public Economics*, vol. 54, 1–36
Jackson, T. 2000. Why is ecological economics not an evolutionary science? Paper presented at the 3rd conference of the European Society for Ecological Economics (ESEE), Vienna, May
Janssen, M. C. W. 1998. Aggregation, in Davis, J. B., Hands, D. W. and Mäki, U. (eds), *The Handbook of Economic Methodology*, Cheltenham, Edward Elgar
Kagel, J. H. and Roth, A. E. 1995. *The Handbook of Experimental Economics*, Princeton, NJ, Princeton University Press
Keynes, J. M. 1936. *The General Theory of Employment, Interest and Money*, London, Macmillan
Kirman, A. 1989. The intrinsic limits of modern economic theory: the emperor has no clothes, *The Economic Journal*, vol. 99, 126–39
Kirman, A. 1997. The economy as an interactive system, pp. 491–532 in Arthur, B., Durlauf, S. and Lane, D. (eds), *The Economy as an Evolving Complex System II*, Reading, MA, Perseus Books
Lancaster, K. 1991. *Modern Consumer Theory*, Vermont, Edward Elgar
Lawson, T. 1997. *Economics and Reality*, Routledge, London and New York
Lee, R. 1993. *The Dobe Ju/'hoansi*, Fort Worth, Harcourt Brace
Lee, R. and Daly, R. 1999. *The Cambridge Encyclopedia of Hunter-Gatherers*, Cambridge, Cambridge University Press
Leibenstein, H. 1966. Allocative efficiency vs 'X-efficiency', *American Economic Review*, vol. 56, 392–415
Leijonhufvud, A. 1968. *On Keynesian Economics and the Economics of Keynes*, New York, Oxford University Press
Maynard Smith, J. 1964. Group selection and kin selection, *Nature*, vol. 201, 1145–6
Mayr, E. 1959. Isolation as an evolutionary factor, *Proceedings of the American Philosophical Society*, vol.103, 221–30
Mayr, E. 1982. *The Growth of Biological Thought*, Cambridge, MA, Harvard University Press
Mesner, S. and Gowdy, J. 1999. Georgescu-Roegen's evolutionary economics, in Mayumi, K. and Gowdy, J. (eds), *Bioeconomics and Sustainability: Essays in Honor of Nicholas Georgescu-Roegen*, Cheltenham, Edward Elgar
Metcalfe, J. S. 1998. *Evolutionary Economics and Creative Destruction* (Graz Schumpeter Lectures, 1), Routledge, London
Mokyr, J. 1990. *The Lever of Riches*, New York, Oxford University Press
Nelson, R. 1995. Recent evolutionary theorizing about economic change, *Journal of Economic Literature*, vol. 33, 48–90
Nelson, R. and Pack, H. 1999. The asian miracle and modern growth theory, *Economic Journal*, vol. 109, 416–36
Nelson, R. and Winter, S. 1982. *An Evolutionary Theory of Economic Change*, Cambridge, MA, Harvard University Press
Nicolaides, P. 1988. Limits to the expansion of neoclassical economics, *Cambridge Journal of Economics*, vol. 12, 313–28
Norgaard, R. 1992. Coevolution of economy, society and environment, in Ekins, P. and Max-Neef, M. (eds), *Real Life Economics*, London, Routledge
North, D. C. 1990. *Institutions, Institutional Change and Economic Performance*, Cambridge, Cambridge University Press
Patinkin, D 1948. Price flexibility and full employment, *American Economic Review*, vol. 38, 543–64
Pinker, S. 1997. *How the Mind Works*, Harmondsworth, Penguin
Potts, J. 2000. *The New Evolutionary Microeconomics: Complexity, Competence, and Adaptive Behavior*, Cheltenham, Edward Elgar

Radner, R. 1968. Competitive equilibrium under uncertainty, *Econometrica*, vol. 36, 31–58
Radner, R. 1970. Problems in the theory of markets under uncertainty, *American Economic Review* vol. 60, 454–60
Romanelli, E. and Tushman, M. 1994. Organizational transformations as punctuated equilibrium: an empirical test, *Academy of Management Journal*, vol. 37, no. 5, 1141–66
Rühli, E. and Sachs, S. 1999. The NOVARTIS megamerger: an intra-organizational evolutionary perspective, *Strategic Change*, vol. 8, 217–26
Ruse, M. 1979. *Sociobiology: Sense or Nonsense*, Dordrecht, Reidel
Sah, R. K. and Stiglitz, J. E. 1986. The architecture of economic systems: hierarchies and polyarchies, *American Economic Review* 76, no. 4, 716–27
Samuelson, P. A. 1947. *Foundations of Economic Analysis*, Cambridge, MA, Harvard University Press
Samuelson, P. A. 1993. Altruism as a problem involving group versus individual selection in economics and biology, *The American Economic Review*, May, 143–48
Scarth, W. M. 1988. *Macroeconomics: An Introduction to Advanced Methods*, Toronto, Harcourt Brace Jovanovich
Scheel, D. and Packer, C. 1991. Group hunting behavior of lions: a search for cooperation, *Animal Behavior*, vol. 41, 697–710
Schelling, T.. 1978. *Micromotives and Macro Behavior*, New York, Norton
Schumpeter, J. 1949. *The Theory of Economic Development*, Cambridge, MA, Harvard University Press
Sethi, R. and Somanathan, E. 1996. The evolution of social norms in common property resource use, *American Economic Review*, vol. 86, no. 4, 766–88
Shackle, G. L. S. 1972. *Epistemics and Economics*, Cambridge, Cambridge University Press
Siebenhüner, B. 2000. 'Evolutionary Psychology in Economic and Environmental Research', mimeo
Simon, H. A. 1957. *Models of Man. Social and Rational*, New York, Wiley
Simon, H. 1962. The architecture of complexity, *Proceedings of the American Philosophical Society*, vol. 106, 467–82
Sober, E. 1981. Holism, individualism, and the units of selection, pp. 93–121 in Asquith, P. D. and Giere, R. N. (eds), *Philosophy of Science Association* 1980, vol. 2, East Lansing, MI, Philosophy of Science Association
Sober, E. and Wilson, D. S. 1998. *Unto Others: The Evolution and Psychology of Unselfish Behavior*, Cambridge, MA, Harvard University Press
Somit, A. and Peterson, S. 1989. *The Dynamics of Evolution: The Punctuated Equilibrium Debate in the Natural and Social Sciences*, Ithaca, NY, Cornell University Press
Sonnenschein, H. 1988. Oligopoly and game theory, in *The New Palgrave Dictionary of Economics*, London, Macmillan
Stewart, J. 1997. Evolutionary progress. *Journal of Social and Evolutionary Systems*, vol. 20, no. 4, 335–62
Trivers, R. L. 1971. The evolution of reciprocal altruism, *Quarterly Review of Biology*, vol. 46, 35–57
Trivers, R. L. 1985. *Social Evolution*, Menlo Park, CA, Benjamin-Cummings
Tullock, G. 1979. Sociobiology and economics, *Atlantic Economic Journal*, vol. 220S, 1–10
Tversky, A. and Kahneman, D. 1974. Judgment under uncertainty: heuristics and biases, *Science*, vol. 185, 1124–31
Tversky, A. and Kahneman, D. 1981. The framing of decisions and the psychology of choices, *Science*, vol. 211, 453–58
Twomey, P. 1998. Reviving Veblenian economic psychology, *Cambridge Journal of Economics*, vol. 22, 433–48
Veblen, T. 1898. Why is economics not an evolutionary science? *Quarterly Journal of Economics*, vol. 4, 373–97
Vrba, E. S. and Gould, S. 1986. The hierarchical expansion of sorting and selection: sorting and selection cannot be equated, *Paleobiology*, vol. 12, 217–28
Watts, D. 1999. *Small Worlds*, Princeton, NJ, Princeton University Press
Weibull, J. W. 1995. *Evolutionary Game Theory*, Cambridge, MA, MIT Press
Weintraub, E. R. 1977. The microfoundations of macroeconomics: a critical survey, *Journal of Economic Literature*, vol. 15, no. 1, 1–23

White, R. 1998. Toward the 'new synthesis': evolution, human nature, and the social sciences, *Choice Magazine*, September, 1–20
Wilkinson, G. S. 1990. Food sharing in vampire bats, *Scientific American*, vol. 262, 76–82
Williams, G. C. 1966. *Adaptation and Natural Selection*, Princeton, NJ, Princeton University Press
Wilson, D. S. 1997. Introduction: multilevel selection theory comes of age, *The American Naturalist*, vol. 150, July (Supplement), S1–4
Wilson, D. S. 1999. Evolutionary support, *Boston Review*, vol. 23
Wilson, E. O. 1975. *Sociobiology: The New Synthesis*, Cambridge, MA, Harvard University Press
Wilson, E. O. 1998. *Consilience*, New York, Alfred Knopf
Witt, U. 1998. Self-organization and economics—what is new? *Structural Change and Economic Dynamics*, vol. 8, no. 4, 489–501
Wollin, A. 1999. 'New Wine into Old Markets: A Multilevel, Punctuated-equilibrium View of International Macro-entrepreneurship', mimeo, Graduate School of Management, University of Queensland, Australia
Wright, S. 1931. Evolution in Mendalian populations, *Genetics*, vol. 16, 97–159
Wynne-Edwards, V. 1962. *Animal Dispersion in Relation to Social Behavior*, Edinburgh, Oliver & Boyd
Wynne-Edwards, V. 1991. Ecology denies neo-Darwinism, *The Ecologist*, vol. 21, May/June