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REGULAR ARTICLE

On the divergence of evolutionary research paths in the past 50 years: a comprehensive bibliometric account

Sandra Tavares Silva · Aurora A. C. Teixeira

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Abstract In the last two decades, there has been a noticeable increase in published research on evolutionary economics. The general perception is that formalization lags behind appreciative work. Notwithstanding, this general reading has yet to be supported by real data analysis. This work presents a survey on evolutionary economics, aimed at exploring the main research paths and contributions using bibliometric methods. The documentation is based on an extensive review of the abstracts from articles published in all economic journals over the past 50 years gathered from the *Econlit* database. Evolutionary contributions have apparently not converged to an integrated approach. Two rather extreme main research strands emerged: 'History of Economic Thought and Methodology' and 'Games'. Whereas formal approaches have a reasonable and increasing share of published papers, purely empirical-related works are relatively scarce, representing a meagre and stagnant percentage of published works. This highlights the need to redirect the evolutionary research agenda.

Keywords Evolutionary · Methodology · Bibliometry · Econlit

JEL Classification B52 · B41 · C89

S. T. Silva (✉) · A. A. C. Teixeira
Faculdade de Economia do Porto, CEMPRE,
Universidade do Porto, Porto, Portugal
e-mail: sandras@fep.up.pt

A. A. C. Teixeira
Faculdade de Economia, CEMPRE, INESC Porto,
Universidade do Porto, Porto, Portugal
e-mail: ateixeira@fep.up.pt

1 Introduction

Evolutionary economics appears as a hybrid framework of evolutionary theory, complex systems theory, self-organization theory and agent-based computational theory. At the same time, it is characterized by a methodological combination of Austrian, Behavioral, Institutional, Post-Keynesian and Schumpeterian economics (Dopfer and Potts 2004). This combination of theories and methods has the advantage of contributing to novelty in scientific knowledge. However, it generates a widespread and somewhat hazy scope, where it is extremely difficult to promote further in-depth theoretical developments and to coordinate individual empirical studies (Klaes 2004). While in neoclassical economics there is strong commitment around a common research core, evolutionary economics lacks a clear analytical framework. As Dopfer and Potts (2004) point out, evolutionary economics needs to conduct an in-depth analysis of the reality of the subject matter, that is, its ontological foundations.

There are different proposals concerning what should be an appropriate ontology for evolutionary economics. Some authors assume that certain ideas, insights and theoretical principles born in evolutionary biology can be organized to study evolutionary economic processes, whereas others openly deny this possibility. As Vromen (2004) states, not only do authors suggest different (personal favorite) ontological views, but they also disagree as to what ontology is all about (e.g., Hodgson 2002; Lawson 2003; Dopfer and Potts 2004; Knudsen 2004; Witt 2004, 2006).

In methodological terms, evolutionary economics does not show clear principles that can allow for the establishment of some unifying directions. In fact, the field is constituted of a great variety in tools and methods, many of which did not originate within economics or the social sciences. Examples are thermodynamics, biology, systems theory, complexity theory, cognitive science, computer science and neuroscience (Dopfer and Potts 2004).[1] This

[1]Typically, mainstream economics is associated with a well-defined neoclassical core, which necessarily involves equilibrium analysis. Despite the fact that mainstream researchers are increasingly more open to accepting more flexible assumptions, in comparison to those featuring the neoclassical hardcore in the 1950s and 1960s, most analyses are still conducted within the mathematical apparatus of equilibrium and maximization. Of course, the models are becoming more complex and the use of the computer and simulation experiments is frequent within neoclassical approaches. However, the work developed along some hybrid approaches, such as chaos theory (with Santa Fe at the top of the research in this field), can hardly be identified as neoclassical. At most, we can talk about a broader mainstream, which increasingly accepts these types of approaches. Nevertheless, core journals keep selecting work for publication that may be defined as mainstream economics because it is located within a well-defined neoclassical core (Harley and Lee 1997). Dow (2000) also highlights the existence of formal mechanisms such as peer review, which reinforce the institutional power of orthodox economics.

diffusion is not surprising since the subject domain is a high-dimensional, non-linear dynamic process of emergent complexity (e.g., Foster 2003; Lawson 2003).

An issue marked by methodological considerations is the use of mathematical models in economics. For the mainstream, almost all reasoning has been put forward in mathematical terms, with strong and clear advantages in establishing the logical coherence of theoretical arguments. However, outside the orthodox view, for example, in evolutionary theorizing, mathematical formalization is not a fundamental characteristic, even when models are used (Backhouse 1997).

Neoclassical economics depicts the economic world following a mechanistic perspective, inspired in physics, which implies determinism and predictability. In fact, this view considers that, given the initial conditions at the present time and the economic system's law of motion, any state in the future can be perfectly predicted (Castellacci 2007). On this line of thought, formalization is in general achieved with mathematical tools available to deal with deterministic, closed systems, where all relevant variables and the relationships between them are predictable, given to representation in a formal mathematical model (Dow 2000).

However, as Hodgson (1993) stresses, the economic world is characterized by uncertainty and unpredictability, which are introduced by purposeful behavior and the creativity of agents. This non-mechanistic, non-deterministic and unpredictable perspective is adopted by evolutionary theorizing, meaning a much higher level of complexity in economic analysis and greater difficulty in formalizing theoretical reasoning. Moreover, whereas for the economic mainstream, the process of economic growth converges to a final state of equilibrium, outside the mainstream, the economy is conceived as a never-ending and ever-changing process, and does not necessarily converge to a steady state of balanced growth (e.g., Metcalfe et al. 2002).

For some authors, for example Romer (1993), the wide dispersion that characterizes heterodox theoretical approaches is mainly determined by the absence of a mathematical, formal modelling framework similar to the one adopted by neoclassical economics, which is considered as fundamental for establishing logical coherence in theoretical reasoning. Moreover, Romer expects that, if the heterodox approaches continue to reject formalism, they will gradually disappear. However, as documented in Section 3, evolutionary economics has become increasingly more formal. Notwithstanding, this trend has been featured by the emergence of divergent ontological and methodological research paths. As mentioned above, evolutionary economics encompasses a wide range of research areas, such as technical change and economic growth, industrial organization, game theory, learning dynamics and bounded rationality structure, organization theory, financial markets and the interactions between economics, law and culture (Silverberg and Verspagen 2005). In spite of this large spectrum of approaches and of ongoing debates around ontological and methodological issues, there are important common elements in this approach. The economy is conceived as a complex and

evolving system, characterized by changing diversity and evolving processes of adaptive behavior, where novelty is endogenous and has a fundamental role (Andersen 1994). Agents are rationally bounded and heterogeneous, and the economy is, by definition, 'out-of-equilibrium' at any given time (e.g., NelsonWinter 1982; Dosi 1988a, b; Nelson 1995; Nelson and Winter 2002).[2] Theoretical evolutionary economic reasoning typically involves random and mechanical elements, where the former generate some variation among the variables in study, and the latter win systematically on existing variation. There are inertial forces that guarantee the survival of the winnowing (Silverberg and Verspagen 2005).

From the above debate, it seems apparent that evolutionary contributions have not converged to an integrated approach. This debate, however, lacks empirical evidence. Thus, the present paper illustrates the more important emergent paths in this field from the 1960s onwards. This effort in documentation is based on a review of the abstracts from articles published in all economic journals gathered from the *Econlit* database over the past 50 years.[3] In order to identify the paper as evolutionary, a search procedure was applied that covers not only the title and the abstract of the article but also its main text. Then, the abstract was analyzed so as to classify the article into main field and method of research (e.g., formal; appreciative; empirical).

The paper is structured as follows. The next section details the methodology underlying the study. After an overview of the history of evolutionary economics in Section 3, Section 4 argues that evolutionary researchers have been 'obsessed' with modelling issues, whereas evidence shows that there is in reality a significant gap arising from the scarcity of empirical-related studies. Section 5 further details the documentation exercise, offering evidence regarding the 'quality' of research within the evolutionary field. Finally, Section 6 concludes.

2 Bibliometric exercise on evolutionary research: methodological considerations

The use of the word 'evolutionary' in economics is so wide-ranging that Hodgson understands this as "a matter of fashion" (Hodgson 1999: 128). The

[2]Note that, in some cases (e.g., Nelson and Winter 1982), evolutionary models assume the possibility of equilibrium, mainly for tractability purposes.

[3]*EconLit* is the *American Economic Association*'s electronic bibliographic database of economic literature throughout the world. It is considered a fundamental research tool in economics, providing different types of information, from bibliographic citations, with selected abstracts, to international literature on economics since 1969. It covers a broad range of document types published worldwide, principally journal articles.

astonishing amplitude of the subject leads to significant difficulties in the analysis of its recent consolidation. Indeed, lively debate still persists as to the meaning of 'evolutionary economics', since the notion of evolution appears as a central concept in several analytical perspectives, even though with distinct interpretations and uses (e.g., Dosi and Winter 2002; Dosi et al. 2005).

Putting aside the issue of the broad use of the term evolutionary, we propose the following categorization for our bibliometric analysis: (1) Behavior (firms, consumers), organizations; (2) Technology, industry, trade; (3) Technological change, economic growth, business cycles; (4) Institutions, markets; (5) Development, environment, cultural change, human behavior, policy; (6) Games; (7) History of economic thought and methodology; (8) Regional economics, space analysis.

Our bibliometric analysis attempts to capture the recent paths that evolutionary economics has actively pursued and reinforced. More than 20 years after the seminal contribution of Nelson and Winter (1982), it is important to develop such an assessment. Given the specificity of 'Games',[4] the bibliometric exercise is undertaken considering two main sets: one with all eight research fields identified above, and another excluding 'Games'. The documentation is based on a review of the abstracts from articles published in all economic journals gathered from the *Econlit* database, which covers, among others, the core journals in the subject such as the *Journal of Evolutionary Economics*, *Research Policy* and *Industrial and Corporate Change*, over the past 50 years (1960s–2000s).

The database was obtained using the term 'evolutionary' as the search keyword. This search procedure is unrestricted and encompassing in the sense that the engine searches not only by subject/keyword but also by the title, abstract and main text of the articles. It is important to underline that bibliometric exercises always bare a limitation with regard to the chosen keyword(s)'s inability to embrace the entire reality under analysis—in the present case, evolutionary-related papers. Nevertheless, in practical terms, the key issue here is that the selected keyword ('evolutionary') is able to capture the core (or the vast majority) of works in the area of study. Alternatively, we could consider a 'battery' of keywords. Words (or a combination of words) such as 'routines', 'path dependency', 'learning', 'out of equilibrium', 'heterogeneity', 'uncertainty', 'satisficing', 'selection', 'cumulative', all part of the evolutionary jargon, might constitute a valid option. However, to be considered part of the evolutionary approach, they would need to be taken in context, that is, appear associated with other evolutionary-related keywords. In isolation, these terms (e.g., learning, out of equilibrium, uncer-

[4] Although evolutionary game theory has been a very dynamic research field, it should be "regarded as a field in its own right, with its own questions, and methods" (Nelson 1995: 51). In fact, its general analytical procedure is the specification of an evolutionary process, operative on a certain set of employed strategies, and the exploration of whether or not the existing strategies converge to a steady state and, if they do, the analysis of the characteristics of equilibrium.

tainty) would yield a vast number of papers that have nothing to do with the evolutionary approach. In the tables in the "Appendix", we summarize the output gathered from the *Econlit* database using these keywords. We observe that when considered in isolation as the search keyword, some of them (e.g., 'out-of-equilibrium'; 'uncertainty'; 'selection') produced a huge amount of articles (see diagonal of the matrix in Table 3 in "Appendix"), whereas when they are combined ('out-of-equilibrium' + 'learning' + 'one of the 16 words in Table 4 in "Appendix"' or 'uncertainty' + 'learning' + 'one of the 16 words in Table 5 in "Appendix"'), the output was drastically reduced (see last column in Tables 4 and 5 in "Appendix"). In this way, we argue that pragmatically 'evolutionary' comes forward as a parsimonious option.

Conceptually, the option for 'evolutionary' instead of 'evolution' is in line with Witt's (2003) argument. According to this author "... the notion of evolution is ... widely associated with a biological definition." If we want to "identify the generic features of evolution, we have to transcend all domain specific elements." In this context, Witt (2003: 12) assertively points that "… there is a crucial qualification for *evolutionary* dynamics." [our emphasis].

The total number of records analyzed was 2,510, although articles corresponding to comments, rejoinders, *corrigenda* were disqualified from the categorization. Also, some records do not include an abstract and were thus also excluded (but included in the temporal analysis). In the end, 1,952 records remained (2,377 with and without abstracts), 1,579 excluding 'Games'. The publication activity in evolutionary economics during the chosen period is analyzed in terms of the eight main themes, as identified previously.

Two important methodologies can be identified within evolutionary economics, as proposed by Nelson and Winter (1982): 'formal theorizing' and 'appreciative theorizing'. The first takes place when the economist develops a reasoning which puts forward, in a conscious manner, a theoretical argument. The second has to do with explanations about certain phenomena not identified as a 'theory'. In these accounts, complex causal arguments are frequently present, even if they appear in the form of stories. Therefore, the authors consider it a mistake to see the differences between this last level of abstraction and equilibrium theory developments as a distinction between description and theory. Instead, they correspond to two different kinds of theories, because the causal mechanisms and relationships are different (Nelson 1995).

In order to identify the main method of research, and following Nelson and Winter's (1982) original proposal, the articles were categorized into six classes: (1) formal; (2) appreciative; (3) formal and empirical; (4) appreciative and empirical; (5) empirical; and (6) surveys.

In the following section, an overview of the literature on evolutionary research is presented, providing a more quantitative analysis by applying this bibliometric methodology. This documentation effort is likely to constitute a

step towards a more rigorous account of the evolutionary research paths in the past 50 years.

3 Evolutionary perspective in economics: a theoretical and quantitative account

3.1 From 'old evolutionary economics' to the 1980s: biological metaphors in economics[5]

The relationship between biology and economics is remote and has worked in both directions (e.g., Hodgson 1999). The emergence of neoclassical economics in the 1870s was intrinsically associated with physics, not biology (Mirowski 1989; Ingrao and Israel 1990). Meanwhile, biology had a strong presence in the social sciences in the 1880s and 1890s.[6] Many authors recall Alfred Marshall's view that 'the Mecca of the economist lies in economic biology' (Marshall 1948: xiv). The heterodox author Thorstein Veblen clearly embraced biology, asking 'Why is economics not an evolutionary science?'.[7] Therefore, during the period 1890–1914, the biological metaphor entered economics, as is borne out in authors such as Marshall, Veblen, Spencer, Schumpeter, Menger, Hayek and others (Hodgson 1999). However, all these contributions did not lead to the appearance of an integrated approach. Andersen (1994) mentions how the marginalist revolution, the Keynesian revolution and the post-war formalist revolution contributed to the demise of those initial evolutionary perspectives. Nelson and Winter (2002) identified the increasing focus of neoclassical economic theory on equilibrium conditions in the early post-war period as the central factor in the disappearance of many evolutionary analogies.

This historical outcome did not arise only from external factors such as the dominance of the neoclassical paradigm (Andersen 1997). Indeed, there are also fundamental, intrinsic difficulties, such as the high level of unpredictability of the outcomes of evolutionary processes, which could block the falsification of evolutionary theorizing; the impression of eclecticism imposed

[5]Hodgson (1993) offers an excellent history of evolutionary theorizing in economics.

[6]By the end of the Victorian era, social scientists generally accepted the idea of a "biological root to human nature" (Hodgson 1999: 89). However, at the beginning of the twentieth century they started rejecting explanations based on biological concepts such as human attributes and behavior.

[7]In 1898, Veblen published his famous article 'Why is economics not an evolutionary science?' in the *Quarterly Journal of Economics*, proposing a reconstruction of economics based on Darwinian methods and metaphors instead the dominant mechanist ones. However, Veblen did not accept that human behavior was just the result of genetic inheritance, adopting an interactionist and anti-reductionist approach, with "both the agent and his environment being at any point the outcome of the last process" (Veblen 1898: 391).

by the "synthetic character of the evolutionary mechanism which forces evolutionary-economic theories to transgress the borders of different social-science disciplines" (Andersen 1997: 2). But, according to Andersen, the most important reason for the failure of the old evolutionary perspectives in economics corresponds to what he called a 'tool problem': those old visions could not be supported by adequate analytic tools.

Evolutionary ideas remained in the shadow until the publication of Armen Alchian's article in 1950 (Hodgson 1999). Alchian (1950) argued that the assumption of maximizing behavior by the firm was refutable. He proposed the existence of selection processes ensuring the survival of the more profitable firms, even if firms do not attempt to maximize profits. Friedman (1953) modified Alchian's ideas arguing that natural selection was a foundation for assuming that agents act "as if" they maximize, independently of their effective behavior. For Friedman, evolutionary processes lead to an evolutionary optimum. Penrose (1952) focused on some crucial issues in the relationship between economics and biology, which are still on the agenda today. She advised caution in what concerns the use of biological metaphors, criticizing Alchian and others of ignoring a fundamental characteristic of human activity in the economic world: deliberative and calculative behavior.

Two decades after Alchian, Nelson and Winter (1973, 1974, 1975) marked the resurgence of evolutionary thought in economics (see Table 1). These authors represent a crucial landmark in the revival of biological metaphors in economics and, more generally, in the social sciences. They adopted an interactionist perspective, conceiving different levels and units of selection and continuous interaction between the individuals, the institutions and their socio-economic environment (Hodgson 1999).

It is interesting to note that, from the few (11) articles indexed in *Econlit* relative to the 1970s, three are authored by Nelson and Winter. They constitute the fundaments of their 1982 book, *An Evolutionary Theory of Economic Change*.

3.2 The 1980s: Nelson and Winter's seminal contribution

Nelson and Winter (1982) conducted an in-depth discussion into the limitations of neoclassical economics that they identified at the theoretical, empirical and practical levels. They contended that the orthodox approach,[8] still relying on equilibrium analysis, leaves many phenomena associated with historical change completely ignored. In addition, they considered that the orthodox assumption of rational economic actors (meaning that they optimize) had not been significantly slackened in advanced neoclassical theoriz-

[8]They identified orthodoxy as "the modern formalization and interpretation of the broader tradition of Western economic thought whose line of intellectual descent can be traced from Smith and Ricardo through Mill, Marshall, and Walras" (Nelson and Winter 1982: 6).

Table 1 Evolutionary-related research articles published in the 1970s

Authors (year)	Title	Journal
Cornehls (1969)	On the use and misuse of Veblen's 'evolutionary economics'	Oxford Economic Papers
Oser (1970)	Some evolutionary developments in international trade and finance	Journal of Economic Issues
Barker (1971)	The evolutionary nature of the new rice technology	Food Research Institute Studies
Urban and Karash (1971)	Evolutionary model building	Journal of Marketing Research
Litschert (1971)	Formal long-range planning groups: their evolutionary nature	Journal of Economics and Business
Nelson and Winter (1973)	Toward an evolutionary theory of economic capabilities	American Economic Review
Hamilton (1973)	What has evolutionary economics to contribute to consumption theory?	Journal of Economic Issues
Nelson and Winter (1974)	Neoclassical vs. evolutionary theories of economic growth: critique and prospectus	Economic Journal
Isard (1975)	Notes on an evolutionary theoretic approach to world organization	Peace Science Society (International) Papers
Roberts (1975)	An evolutionary and institutional view of the behavior of public and private companies	American Economic Review
Nelson and Winter (1975)	Growth theory from an evolutionary perspective: the differential productivity puzzle	American Economic Review

Source: *Econlit* database

ing. Therefore, they proposed the development of an evolutionary theory of the capabilities and behavior of business firms operating in a certain market environment. In this sense, they strongly represented the return of biological metaphors to economics. In this theoretical frame, firms are motivated by profit and develop search actions in an effort to improve profits. However, those actions are not assumed to be profit-maximizing over given, well-defined and exogenous choice sets. There is a selection process operating in the firm's internal routines and the routines are understood as the appropriated and effective behaviours in a certain setting.[9] They are the outcome of profit-oriented, learning and selection processes (Nelson 1995).

Three essential analogies—routine, search, natural selection—were adopted by Nelson and Winter, in order to construct the link between their own concept of economic evolution and the struggle for life in biology. However, the authors strongly denied the existence of an exact correspondence. In their perspective, socio-economic evolution is characterized by the emphasis on the organism's adaptation to the environment rather than on the environmental selection of the organism. For this reason, there is a place for intentionality and novelty in human behaviour, and so Penrose's objection to the use of the biological analogy in 1952 seems to have been overcome (Hodgson 1999).

As for their main intellectual references, Nelson and Winter identified the influence of behavioral theorists such as Simon and Alchian. In particular, they acknowledged Schumpeter's 'pervasive' influence in their work (Nelson and Winter 1982: 39).[10]

Andersen (1997) perceived in these legacies a combination of distinct mechanisms: transmission, as in Simon's work on behavior; variety and creation, as in Schumpeter's developments in invention and innovation; and selection, as in Alchian's work on natural selection. Nelson and Winter (1982) used the computer to organize the necessary synthesis of these elements giving rise to a new modelling strategy that Andersen (1997: 7) summarized as follows: "(1) Define the minimum environmental characteristics, including input and output conditions as well as the spaces in which search for new rules are performed. (2) Define the state of the industry at time t as a list of firm states, which include physical and informational characteristics as well as behavioural

[9]"We use 'routine' in a highly flexible way, much as 'program' is used in discussion of computer programming. It may refer to a repetitive pattern of activity in an entire organization, to an individual skill, or as an adjective, to the smooth uneventful effectiveness of such an organizational or individual performance" (Nelson and Winter 1982: 97).

[10]Hodgson (1999) considered the epithet 'neo-Schumpeterian' used by Nelson and Winter and others as misleading. He recalled the allergic feelings Schumpeter had to analogies with biology. In his opinion, the use of the term 'evolution' by Schumpeter meant a general idea about economic development, without recognizing selection processes and inheritance of information or structure through learning or imitation.

rules and meta-rules. (3) Calculate by means of (1) and (2) the activities of the industry in period t as well as the resultant state variables (including possible changes of rules) which characterise the system at the start of period $t + 1$. (4) Make similar calculations for a series of periods and study the evolution of the application of different rules as well as other characteristics of the

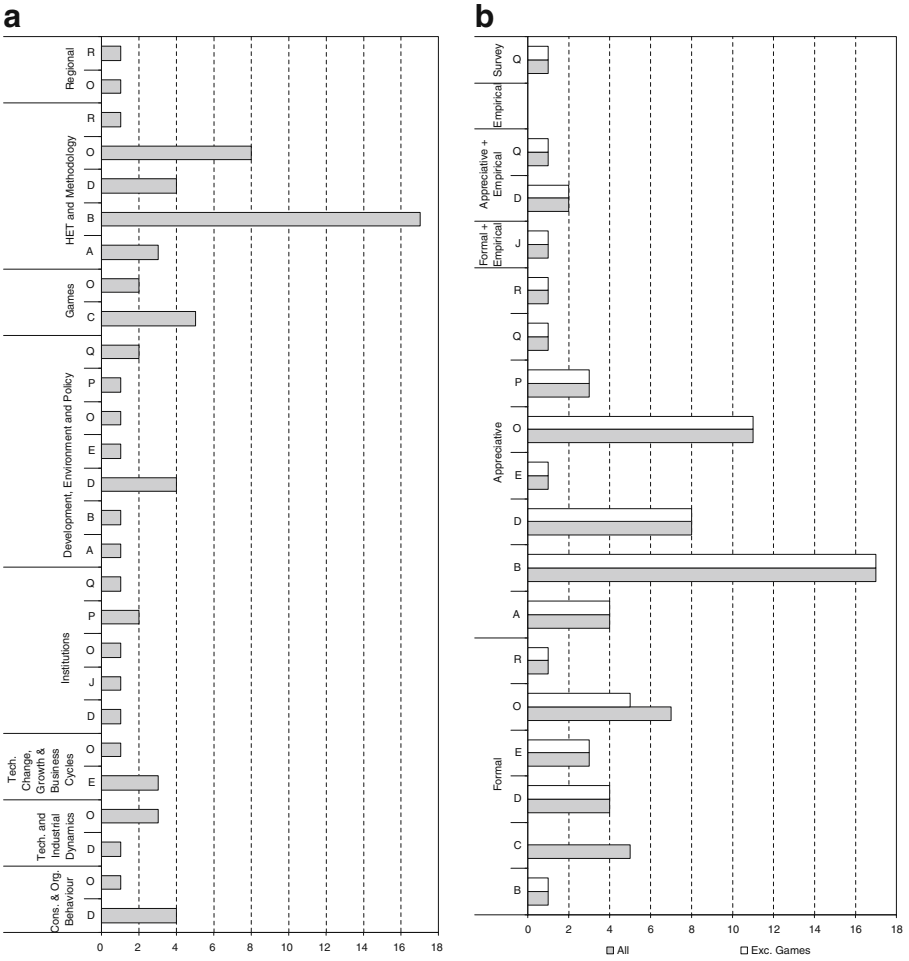


Fig. 1 Published papers on evolutionary economics from 1982–1991, by theme (JEL) and method, with and without 'Games'. *A* General economics and teaching, *B* Schools of economic thought and methodology, *C* Mathematical and quantitative methods, *D* Microeconomics, *E* Macroeconomics and monetary economics, *F* International economics, *G* Financial economics, *H* Public economics, *I* Health, education, and welfare, *J* Labor and demographic economics, *K* Law and economics, *L* Industrial organization, *M* Business administration and business economics; Marketing; Accounting, *N* Economic history, *O* Economic development, technological change, and growth, *P* Economic systems, *Q* Agricultural and natural resource economics; Environmental and ecological economics, *R* Urban, rural, and regional economics, *Z* Other special topics

industry (economy)". In Nelson and Winter (1982), this modelling scheme was used in the treatment of several problems within growth theory and industrial economics.

In the 10-year period following the publication of Nelson and Winter's book, published research in evolutionary economics continued to be focused essentially on appreciative theorizing around economic thought and methodological considerations. In fact, 46% of the published articles concerned 'HET and Methodology' (Fig. 1a), with 68% of the total articles following an appreciative approach (Fig. 1b). Although a reasonable proportion (29.2%) of papers fell under formal methods, the scarcity of empirical studies was apparent—only 5.6% of the total papers involved some type of empirical research, and purely empirical papers did not exist at all. If we exclude 'Games', the corresponding figures are: 51% for 'HET and Methodology'; 71% for appreciative methods; 22% formal methods; and 0% and 6% for purely empirical and some empirical research, respectively. Therefore, the exclusion of 'Games' reinforces the weight of 'HET and Methodology' and of appreciative methods.

3.3 The 1990s onwards: the rise in evolutionary research

After the seminal influence of Nelson and Winter (1982), evolutionary economics continues to grow and the number of economists focusing on this domain seems to be on the rise (Lawson 2003; Klaes 2004).

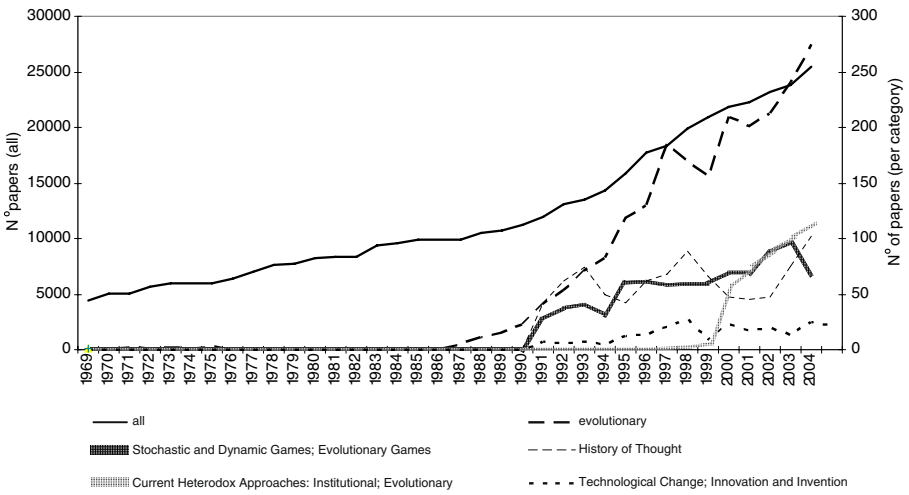


Fig. 2 Evolution of published papers on evolutionary-related research and all economic areas in *Econlit*, 1969–2004. Note: The total number of articles in Evolutionary-related research is 2,369 whereas the total number of papers published in *Econlit* from 1969–2005 is 453,457; this number includes both papers with and without abstracts

As Fig. 2 illustrates, before 1990, the importance of published evolutionary-related research was almost negligible. More than 90% of the total papers were published after that date. On a yearly basis, between 2000 and 2004, it represents around 9–10% of the total papers. Despite the revival of Evolutionary Economics in the mid-1980s, namely following the publication of Nelson and Winter's (1982) seminal book, its impact only came to be fully perceived after the 1990s. This trend can, at in least in part, be explained by the emergence of journals whose core targeted more specifically evolutionary research (e.g., the *Journal of Evolutionary Economics*, founded in 1991, and *Games and Economic Behaviour*, in 1989).

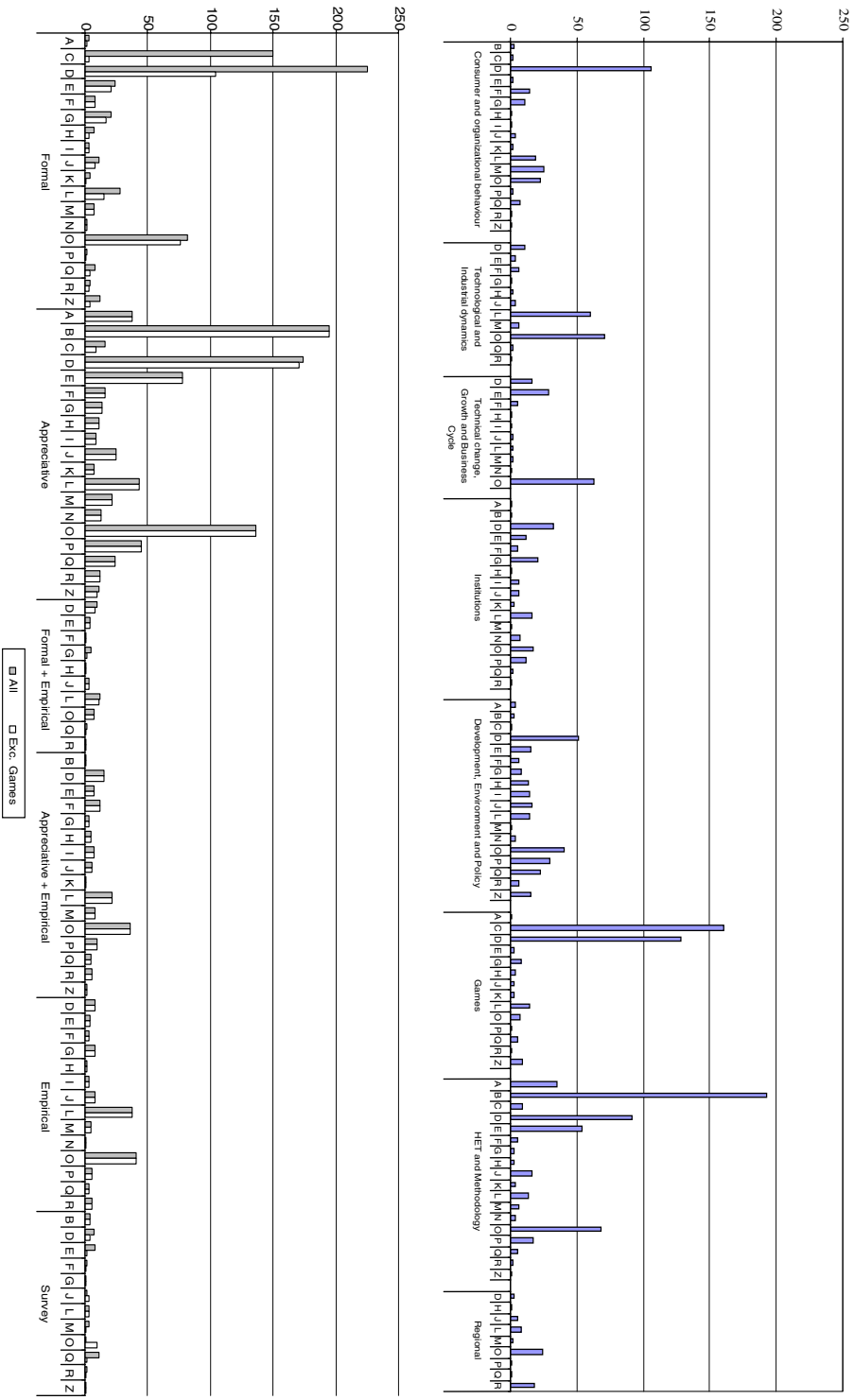
It is interesting to note that, within evolutionary-related research, the most dynamic sub-fields (using *Econlit* categorization) were, in the period under analysis, 'Stochastic and Dynamic Games, Evolutionary Games' and 'Current Heterodox Approaches: Institutional; Evolutionary' (the latter particularly after 1999). The evolution of the sub-field 'Technological Change; Innovation and Invention' was, in comparative terms, relatively sluggish.

There are important evolutionary research centers, especially in Europe, for example, SPRU, Science and Technology Policy Research, in England; MERIT, Maastricht Economic Research Institute on Innovation and Technology, in the Netherlands; St. Anna School of Advanced Study, in Italy; CRIC, Centre for Research on Innovation and Competition, in England; MPI, Max Planck Institute, in Germany; BETA, Bureau d'Economie Théorique et Appliquée, in France (Verspagen and Werker 2003). Moreover, journals such as the *Journal of Evolutionary Economics*, the *Research Policy*, and *Industrial and Corporate Change*, acknowledge evolutionary thinking (Verspagen and Werker 2003; Egashira 2006).

It is possible to identify many distinct types of research fields in evolutionary economics, even within the strictest area of evolutionary technological change and economic growth. Inspired by the work of Nelson and Winter (1982), several research families have developed since then Silva (2008), for example, the Innovation Systems literature (e.g., Freeman 1988); the analysis of Sectoral Patterns of Technical Change (e.g., Pavitt 1984; Dosi and Orsenigo 1988); the Technological Gap literature (e.g., Fagerberg 1988); Path-dependency and Lock-in Models (e.g., David 1985; Arthur 1989); Evolutionary Growth Models (e.g., Silverberg 1984).

However, the area of 'Technical Change and Economic Growth' corresponds to only 7% of the total published papers between 1992 and 2005 (see Fig. 3). The most important areas are 'HET and Methodology' (29%) and 'Games' (19%).

The theory of the firm also appears as an important research subject within evolutionary economics—'Consumer and Organizational Behavior' accounts for 12.0% of published papers. After the contribution of Nelson and Winter (1982), with important insights on the concept and nature of the firm, many contributions followed their lead (e.g., Kay 1984; Dosi and Egidi 1991; Winter 1995).


0
50
100
150
200
250
Consumer and organizational behaviour
Technological and Industrial dynamics
Technical change, Growth and Business Cycle
Institutions
Development, Environment and Policy
Games
HET and Methodology
Regional
Formal
Appreciative
Formal + Empirical
Appreciative + Empirical
Empirical
Survey
All
Exc. Games

◀ **Fig. 3** Published papers by categories and methods, 1992–2005. *A* General economics and teaching, *B* Schools of economic thought and methodology, *C* Mathematical and quantitative methods, *D* Microeconomics, *E* Macroeconomics and monetary economics, *F* International economics, *G* Financial economics, *H* Public economics, *I* Health, education, and welfare, *J* Labor and demographic economics, *K* Law and economics, *L* Industrial organization, *M* Business administration and business economics; Marketing; Accounting, *N* Economic history, *O* Economic development, Technological change, and growth, *P* Economic systems, *Q* Agricultural and natural resource economics; Environmental and ecological economics, *R* Urban, rural, and regional economics, *Z* Other special topics

When we exclude 'Games', the share of 'HET and Methodology' gets a boost (35%), whereas the other themes maintain similar weights (15% for 'Consumer and Organizational Behavior'; 11% for 'Technological and Industrial Dynamics'; and 8% for 'Technical Change and Economic Growth').

With regard to distribution by method, the exclusion of 'Games' has an important impact on the weight of Formal-related research—its share falls from 32% to 19%. This decrease is compensated by a rise in the Appreciative method (from 48% up to 58%). The remaining categories, particularly Formal+Empirical and Empirical, maintain approximately the same share (Fig. 3).

Imperative to the development and spread of evolutionary economics seems to be the digital computer, although the influence of the computer within economics is very recent. Mirowski (2002) highlights the rise of the 'cyborg' sciences, which occurred mainly in the USA during World War II, and its profound effects on the content and organization of the natural and social sciences. He stresses the pressure exerted by the current scientific *diaspora*—caused by the impact that the end of the Cold War and the associated changes in the funding of scientific research had on physics, with "the … contraction of physics and the continuing expansion of molecular biology" (Mirowski 2002: 10)—, on the beginning of the transformation of economic concepts. As a result of such interdisciplinary research, a different method of economics emerged, based on a combination between computational languages and institutional themes. According to Mirowski (2002: 11), the reluctance of economists to abandon the classical mechanics paradigm in favour of a new paradigm based on computer science and cognitive sciences in general results in "numerous tensions in fin-de-siècle orthodox economics".

The boost in evolutionary economics seems unquestionably associated with the development of computational methods, which has increasingly enabled processing the complexity associated with its open-system approach.

In the next section, some considerations are made on what appears to be an excessive emphasis on modelling and formalization issues on the part of evolutionary researchers. As documented below, empirical-related research has been relatively neglected.

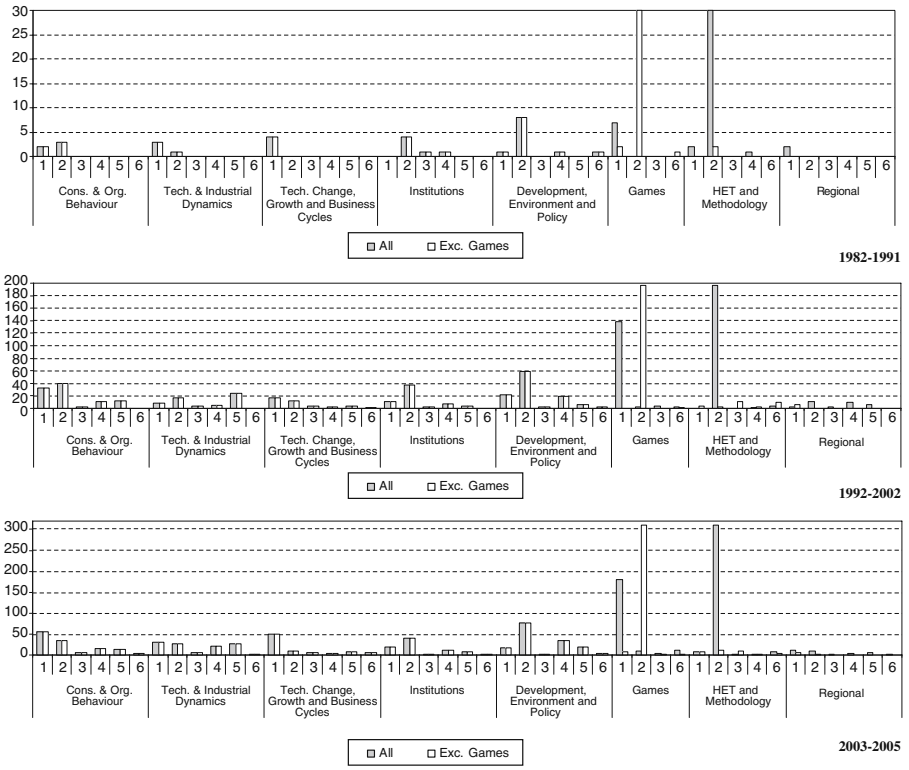


Fig. 4 Published papers (*number*) by theme and method, 1982–2005. 1 Formal, 2 appreciative, 3 formal+empirical, 4 appreciative+empirical, 5 empirical, 6 surveys

4 The need to redirect the evolutionary research agenda: from modelling 'obsession' towards empirical work

Within mainstream economics, it is usually suggested that an argument is only properly justified when it is formally articulated. Although many still argue against the problems of formalism, the importance of formalization is clear in the emergence and consolidation of some economic research streams.[11] Within evolutionary economics, as Nelson (1995) argued, since the publication of the book *An Evolutionary Theory of Economic Change*, the use of evolutionary concepts has been increasingly associated to formal theorizing. Figure 4 offers evidence supporting such a statement, that is, the rise in formal contributions, namely associated with 'Games', within this research area.

The developments in nonlinear dynamic systems have been an important stimulus to theorizing in evolutionary economics (Klaes 2004). Such develop-

[11] For example, the formalization of already existing ideas by the new neoclassical growth models was crucial to the renewed interest in economic growth observed since the mid-1980s.

ments are used for example in evolutionary game theory, which represented, respectively 9.7%, 17.2% and 21.9% of the total papers published in 1982–1991, 1992–2002, and 2003–2005. However, as already mentioned, this is a particular evolutionary research field with assumptions (e.g., convergence and equilibrium) that are not consistent with the core reasoning of evolutionary economics.

Behind the increasing importance of formalization in evolutionary research stands the development of a considerable amount of work on complex dynamic systems through computed simulation. The evolution of computers and programming languages and techniques is a crucial factor driving the development of formal evolutionary models in economics (Nelson 1995). Andersen (1997) stresses the impetus given by programming languages and computer models to evolutionary economic studies. The author identified the possibility of a comparable development in the study of economic evolution in close relation to Artificial Life, "Artificial Economic Evolution" (Andersen 1997: 4), giving as an example the work of Lane (1993a, b). In this line of research, genetic algorithms and classifier systems are used as mechanisms for formalizing the learning procedures of artificial agents.[12]

Learning procedures can be modelled as a change in the probability distribution of possible actions that the firm might take at any time, emerging as the outcome of feedback from what has been developed and its consequences (Nelson 1995). The learning equations are very similar to the ones used to describe population evolution as in the population ecology theories (e.g., Hannan and Freeman 1977, 1984; Holland et al. 1986).

Andersen (1997) argued that the viability of evolutionary economics lies in the consideration of four characteristics: (i) a population perspective; (ii) a combination of an algorithm and a complete formal approach; (iii) an empirical orientation, and (iv) an interaction with older, verbal studies of economic evolution. The use of a population perspective suggests a 'box of tools' for evolutionary economics (Andersen 1997: 2). Although Alchian (1950) was the first author explicitly to propose the population perspective, Nelson and Winter (1982) were pioneers in exploring the toolbox idea suggested in that approach. As the mechanism underlying economic evolution is rather complex, evolutionary economic studies tend to synthesize. As this synthesis should be the outcome of distinct sub-mechanisms, the basic task remains in showing how an evolutionary process can be synthesized from a range of individual ones (Andersen 1997).

The major difficulty here arises from the fact that the mechanisms are usually associated with different sciences. For example, the preservation and

[12] Although many social scientists argue against these procedures, considering that they appeal to a "discrete genetic mechanism of inheritance à la biological DNA", their supporters consider that they can be used "agnostically simply as algorithm tools to allow learning to happen, if not as models of how learning actually happens" (Silverberg and Verspagen 2005: 513).

transmission of rules and norms are frequently seen as a sociological object, but are also analyzed in institutional economics; the phenomena of variety and creation is studied in psychology, but also as innovation analysis in economics; selection is especially analyzed in standard economics; mechanisms of segregation and closing are studied not only in industrial economics, but also in sociology. Efforts to integrate all these mechanisms in the study of evolutionary processes are necessarily ambitious and risky. However, "it is the synthesis between different theories rather than the contributions to the detailed understanding of the individual mechanisms which is the core factor of evolutionary economics" (Andersen 1997: 3).

Therefore, Andersen proposes that evolutionary theorizing in economics explains a fact of economic life taking as a reference previous facts and a causal link. This demonstrably includes a mechanism of preservation and transmission, a mechanism of variety and creation, a mechanism of selection, and a mechanism of segregation among distinct populations. "The emergence of an evolutionary process presupposes that none of the individual mechanisms becomes too dominant. If preservation dominates, the result is a stasis of economic knowledge, while a dominance of a variety-creation leads to non-deterministic chaos" (Andersen 1997: 3). The computer revolution creates the conditions to give a full account of the evolution of a population of firms and technologies.

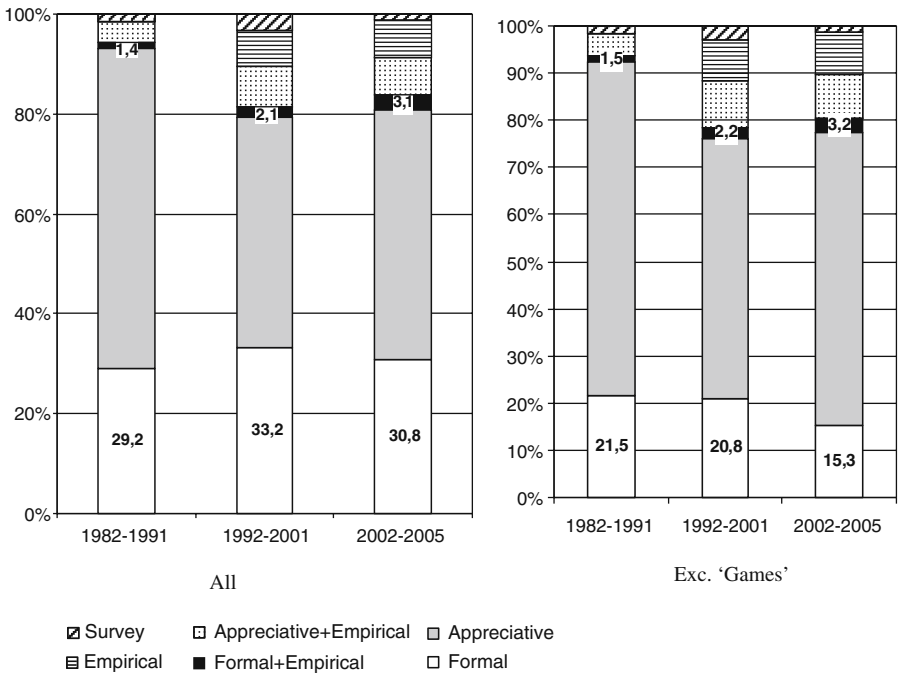


Fig. 5 Distribution of published papers (%) by method, 1982–2005

Although recognizing from experience that progress into more formalization may tend to reduce the segments to alternative thinking, Andersen (1997: 21) considers that the "transformation to a paradigm-based new evolutionary economics may be eased by tools which mediate between, on the one hand, the informal and empirical approaches and, on the other hand, the fully mathematized analysis of evolutionary processes".

Considering this kind of mediation rather than complete formal approaches, and reflecting on the mathematical modelling of biological evolution in the 1930s, Andersen suggests that recent evolutionary modelling in economics will be developed into part of an overall synthesis between descriptive contribu-

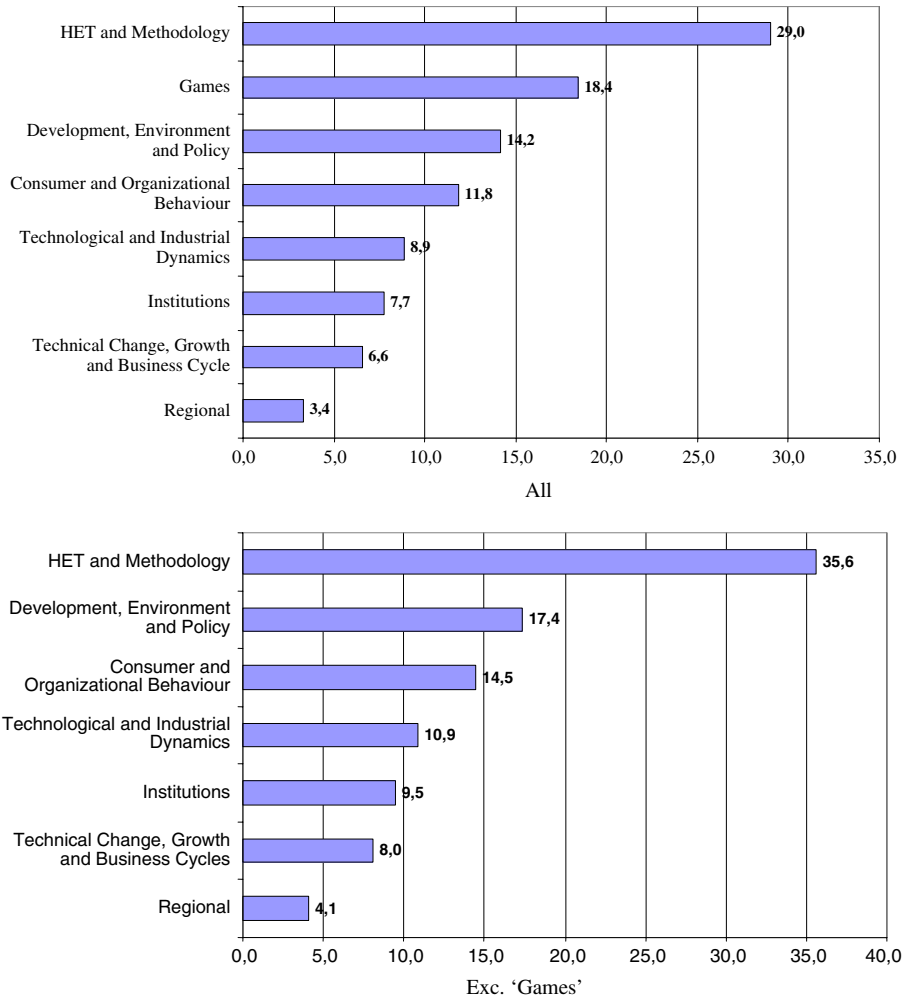


Fig. 6 Journal articles in evolutionary economics by main theme (% total). Source: Authors' own computations based on journal articles collected from the *Econlit* database, 1969–2005

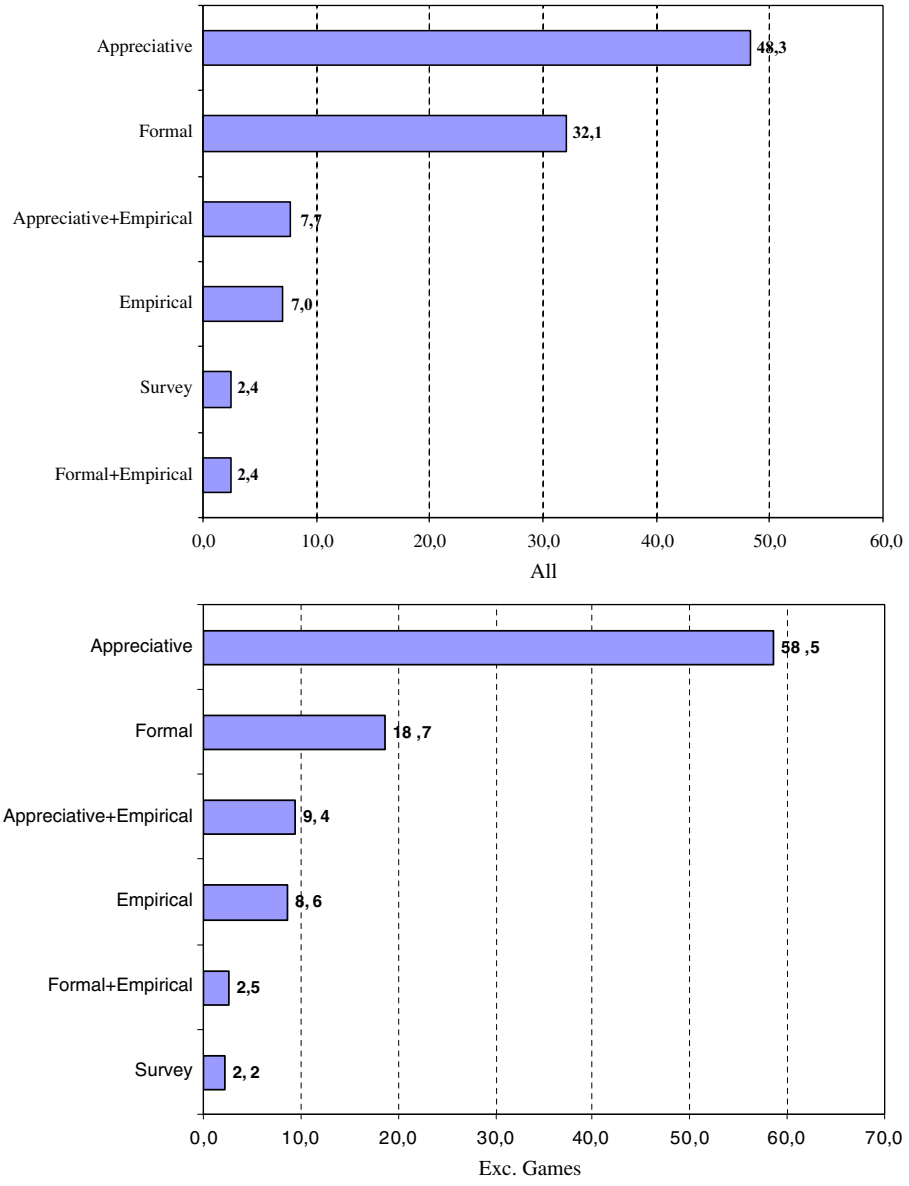


Fig. 7 Journal articles in evolutionary economics by main method (% total). Source: Authors' own computations based on journal articles collected from the *Econlit* database, 1969–2005

tions and theoretical studies of economic life, and its adaptability and diversity. The feasibility of evolutionary economics is strongly connected to its empirical nature as a science. The modelling efforts must be made in interaction with well-defined areas of empirical analysis (Andersen 1997).

Table 2 Distribution (%) of main themes and methodology ($n = 1{,}936$; n exc. Games = 1,579)

Themes/method	Formal	Appreciative	Formal + empirical	Appreciative + empirical	Empirical	Survey	Total
Consumers and organizations behaviour	38.9	33.6	3.5	11.4	11.4	1.3	11.8
Technological and industrial dynamics	23.8	25.6	5.2	15.1	29.1	1.2	8.9
Technical change, growth and business cycles	55.1	17.3	7.9	4.7	9.4	5.5	6.6
Institutions	20.0	54.0	3.3	13.3	8.0	1.3	7.7
Development, environment and policy	15.0	52.6	1.5	19.7	9.1	2.2	14.2
Games	91.3	3.1	2.0	0.0	0.0	3.6	18.4
HET and methodology	1.8	95.4	0.2	0.5	0.0	2.1	29.0
Regional	23.1	30.8	4.6	21.5	16.9	3.1	3.4
Total	32.1	48.3	2.4	7.7	7.0	2.4	100.0

Source: Authors' own computations based on journal articles collected from the *Econlit* database, 1969–2005

Fig. 8 Distribution of HET and Methodology, Games, and Technical Change, Growth and Business Cycles, by categories and methods. *A* General economics and teaching, *B* Schools of economic thought and methodology, *C* Mathematical and quantitative methods, *D* Microeconomics, *E* Macroeconomics and monetary economics, *F* International economics, *G* Financial economics, *H* Public economics, *I* Health, education, and welfare, *J* Labor and demographic economics, *K* Law and economics, *L* Industrial organization, *M* Business administration and business economics; Marketing; Accounting, *N* Economic history, *O* Economic development, Technological change, and Growth, *P* Economic systems, *Q* Agricultural and natural resource economics; Environmental and ecological economics, *R* Urban, rural, and regional economics, *Z* Other special topics

However, our results show that, in this domain, there are very few works combining formal and empirical analysis (cf. Fig. 5). In the analysis encompassing all research fields, the percentage for this type of study ranges from 1.4% (1982–1991) to 3.1% (2002–2005). Excluding 'Games', those percentages remain quite similar.

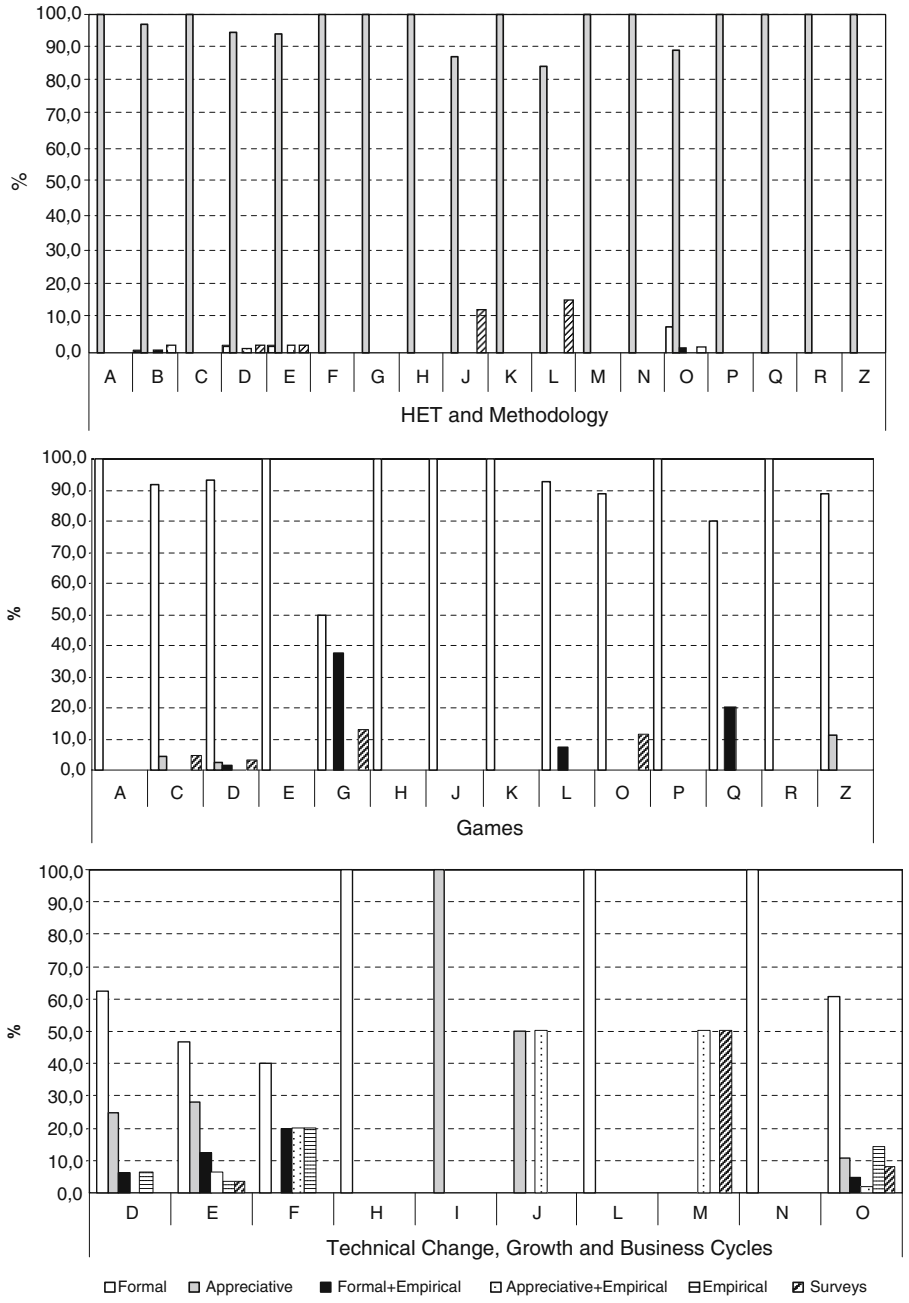
In the next section, we put forward a systematic overview of evolutionary research paths for the entire period from 1969 to 2005. After that, we present some evidence regarding the "quality" of research within the evolutionary field.

5 Further account of evolutionary research

5.1 Results for the period 1969–2005

The overall results reveal two rather extreme main research themes (Fig. 6): "History of Economic Thought (HET) and Methodology" and "Games." Regarding the first stream of research, contributions tend to focus on "Schools of Economic Thought and Methodology" (37.4%) and "Microeconomics" (16.9%). As for the "Games" theme, the bulk (82.9%) of the published papers address "Mathematical and Quantitative Methods" (46.5%) and "Microeconomics" (36.4%). Within this latter category, "Search, Learning, Information and Knowledge" represents half of the corresponding total. Note that when we exclude "Games", there is a clear boost in "HET and Methodology" (35.8%) with all the remaining categories showing similar shares.

The distribution of papers by method reflects to a large extent the corresponding main themes (cf. Fig. 7). In fact, the most important method is the appreciative one accounting for approximately half the articles, which is the main method in "HET and Methodology". Similarly, formal approaches represent 32.1% of the papers, a substantial part of which are "Games".


100,0
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A B C D E F G H J K L M N O P Q R Z
HET and Methodology
A C D E G H J K L O P Q R Z
Games
D E F H I J L M N O
Technical Change, Growth and Business Cycles
Formal
Appreciative
Formal+Empirical
Appreciative+Empirical
Empirical
Surveys

In fact, when we exclude "Games" the share of formal papers decreases to 18.7%, whereas the appreciative-related research rises in relative weight (from 48.3% to 58.5%). Generally speaking, as noted previously, empirical works are relatively scarce within evolutionary-related research. Indeed, for all the themes only 17.1% (20.5% excluding "Games") of the papers analyzed involve some kind of empirical examination, with exclusively empirical papers reaching the meagre figure of 7%.[13] This is also in line with the findings of Egashira (2006), focused on *all* papers published in *JEE* over the period 1996–2005, which shows that the percentage of empirical research is around 6%.[14]

Focusing on the subjects which cover a larger number of papers ("HET and Methodology", and "Games"), their positioning in terms of method is almost the reverse—95.4% of the "HET and Methodology" articles employ appreciative methods, whereas 91.3% of the "Games" papers are formal. Empirical methods are more frequently used by works centered on "Technological and Industrial Dynamics" (49.4% of the total papers in this category) and "Regional" (43%). In the "Technical change, Growth and Business Cycle" category, the most common method is formal (63%) and not, as expected, empirical. This latter method is only applied in 22% of this theme's papers. In the remaining categories, the appreciative method appears as the most widely used (Table 2).

The following figures show quite clearly that, regardless of the subcategories in the "HET and Methodology" and "Games" categories, there is a noticeable pattern towards one single method—appreciative in the first case and formal in the second. In contrast, in the "Technical change, Growth and Business Cycle" theme, the pattern is more diffuse. In fact, for the most important categories—"Macroeconomics and Monetary Economics" (25%) and "Economic Development, Technological Change" and "Growth" (51%)—all

[13]Note that this result is not dependent on the methodology pursued, namely the exclusive use of 'evolutionary' as the search keyword. Using other (combinations of) keywords does not change the results obtained with regard to the proportion of empirical-related research—using 'evolution*' as the search keyword leads to a similar percentage as that of empirical-related research, 8%.

[14]We additionally examined three other non-orthodox journals, two of them focused especially on innovation and technological issues—*Industrial and Corporate Change* (ICC) and *Research Policy* (RP)—and the other with a broader scope—*Journal of Economic Issues* (JEI). Considering the last five years (2002–2007), we read all the corresponding abstracts (193 from ICC; 460 from RP, and 150 from *JEI*), then identified those that pursued an evolutionary approach, and finally classified these latter according to their main research method (appreciative, empirical, formal, appreciative+empirical, formal+empirical). From this exercise, we concluded that 21.8% (8.7%) [38.7%] of *ICC* (*RP*) [*JEI*]'s papers follow an evolutionary strand. Moreover, out of these papers 38.1% (*ICC*), 55.0% (*RP*), and 11.5% (*JEI*) involved some kind of empirical examination. Exclusively empirical papers reach smaller figures—31.0% (*ICC*), 40.0% (*RP*), and 0.0% (*JEI*). As we demonstrate in the text, our main bibliometric exercise, encompassing a huge number and diversified type of journals, conveys intermediate figures, respectively 17.1% (some empirical examination) and 7.0% (exclusively empirical papers).

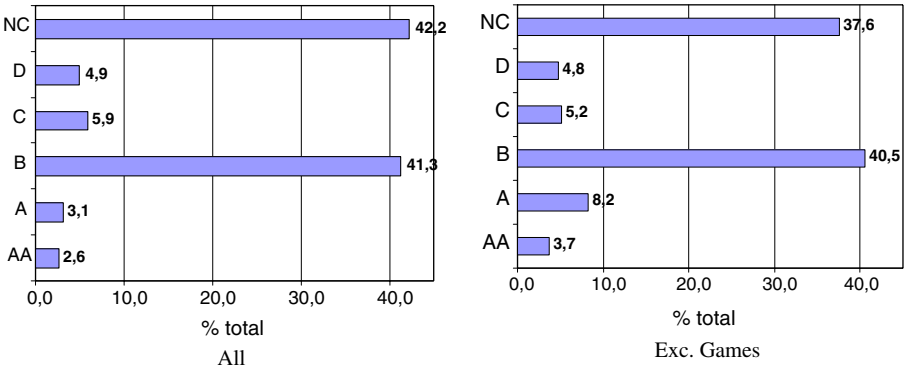

Fig. 9 Evolutionary papers by journal ranking categories

types of methods are used with "Formal" in the lead as the most frequent approach (Fig. 8).

5.2 On the 'quality' of evolutionary research

Scientific papers are fundamental vehicles for knowledge diffusion world-wide. However, these papers have different "qualities,", and quite naturally only papers with high "quality" sustain future works (Laband and Piette 1994).[15]

Based on the March 2006 RePEc's journal list by impact factor[16] and (partially) applying the classification system of the Tinbergen Institute,[17] we computed a ranking of the academic journals indexed in *Econlit*. The Tinbergen Institute has drawn up a classification of journals in the field of economics. In this ranking, journals have been classified as: AA: generally accepted top-level journals; A: very good journals covering economics in general and the top journals in each field; B: good journals for all research fields. Such a classification is roughly based on the following cut-offs (according to the impact factor), AA: >3; A: >1.5; B >0.3. We have added three other categories, C: >0.1, D: impact factor lower than 0.1, and NC: journals that are not ranked (in RePEc, the Tinbergen Institute ranking, or Kalaitzidakis et al. 2003).

The distribution of papers by journal ranking categories shows that approximately half are published in top-quality (AA–B) journals (Fig. 9).

[15]For an excellent approach to the issue of the impact of top-ranking journals, see Vieira (2004).
[16]This list provides a simple impact factor, computing a ratio of citations by the number of articles in the journals. These computations are experimental and based on the citation analysis provided by the CitEc project, which uses data from items listed in RePEc. Citation counts are adjusted to exclude citations from the same journals (http://ideas.repec.org/top/top.journals.simple.html).
[17]http://www.tinbergen.nl/research/ranking2.html, accessed in March 2006.

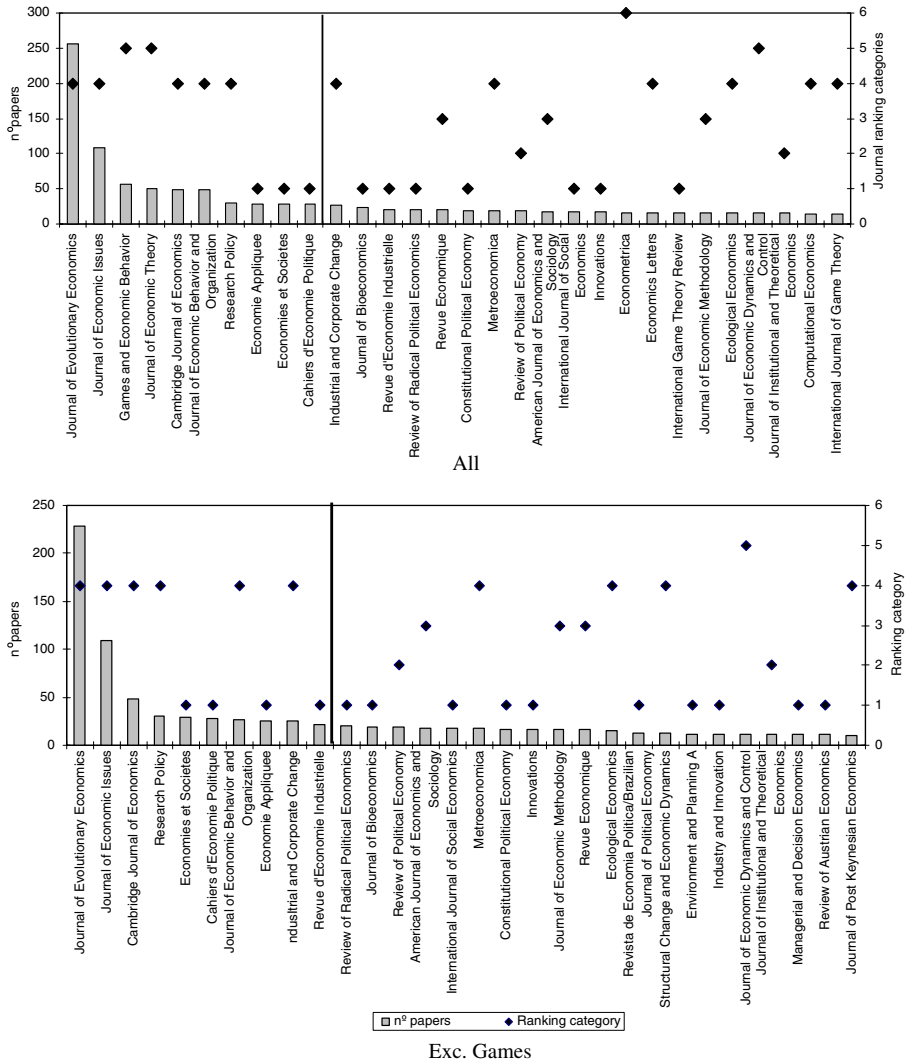

Fig. 10 Evolutionary papers by Top-30 Journals. Source: Authors' own computations based on journal articles collected from the *Econlit* database, 1969–2005 ($n = 1{,}936$; n exc. 'Games' $= 1{,}579$). 1 NC, 2 D, 3 C, 4 B, 5 A, 6 AA; note: Top-30 Journals cover approximately 55% of total papers

The percentage of papers that are published in non-ranked journals is also quite significant (38–42%). Note that the relative "quality" of research in the evolutionary domain decreases slightly when we exclude "Games," particularly the weight of A-Journals (the percentage decreases from 8% to 3%).

	AA	A	B	C	D	NC	Group Total
Consumers and Organizations B	5.2	5.2	48.9	1.3	3.9	35.4	100
Technological and Industrial Dy	0.6	1.7	55.2	4.7	1.7	36.0	100
Technical Change, Growth and	4.7	2.4	58.3	6.3	2.4	26.0	100
Institutions	2.7	8.0	37.3	4.7	4.0	43.3	100
Development, Environment and	2.6	3.6	31.0	6.2	6.2	50.4	100
Games	8.4	30.8	37.3	2.0	4.2	17.4	100
HET and Methodology	1.8	1.2	37.0	8.5	7.1	44.3	100
Regional	1.5	3.1	33.8	3.1		58.5	100
Total	3.7	8.2	40.5	5.2	4.8	37.6	100

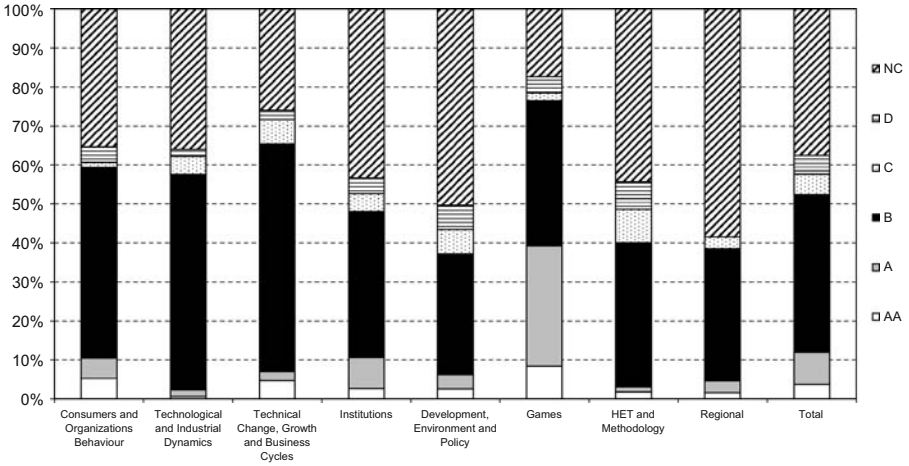

Fig. 11 Evolutionary papers by main theme: distribution (%) by journal ranking. Source: Authors' own computations based on journal articles collected from the *Econlit* database, 1969–2005 ($n = 1{,}936$)

Figure 10 represents the number of papers published by academic journals, identified by ranking. As can be easily seen, only a small portion of evolutionary papers were published in top-ranked journals. The picture highlights the importance of the class B journal—*Journal of Evolutionary Economics*—in terms of publication of evolutionary research. Over the entire period, from 1969 to 2005, only an insignificant fraction of the published papers was associated to an AA class journal (*Econometrica*).

When we exclude "Games," AA journals disappear from the Top-30, and only one A journal remains (*Journal of Economic Dynamics and Control*).

The previous results are corroborated by the evidence presented in Fig. 11. Considering the published articles by main category, only the category "Games" has a considerable fraction in top-ranking journals (*AA* and *A*). Figure 12 also confirms this fact.

The Fig. 12 underpins the evidence of the previous figure, where A and AA journals publish fundamentally Games-related research, whereas C and D journals publish a considerable fraction of HET & Methodology-related research. B journals are relatively eclectic.

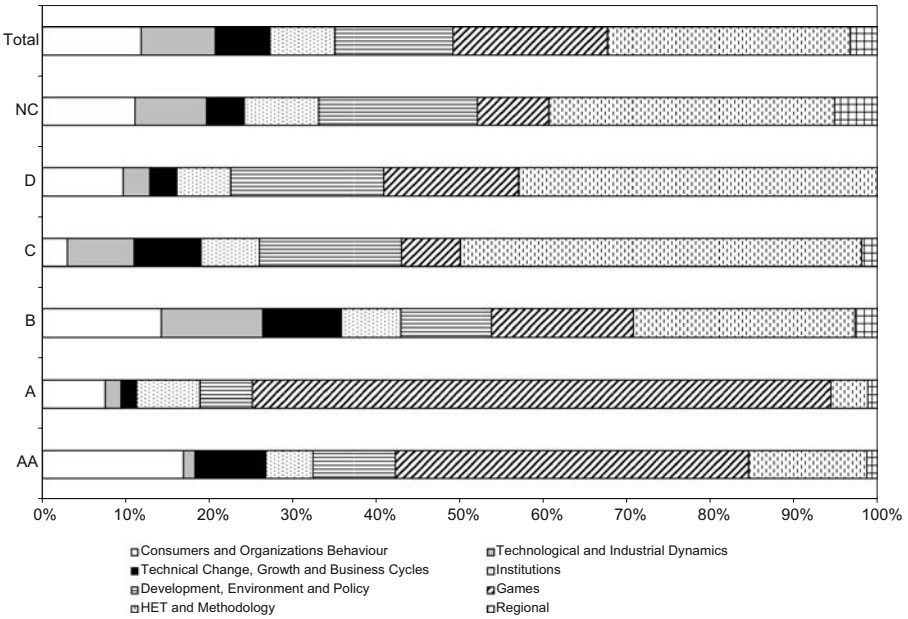

Fig. 12 Evolutionary papers by journal ranking: distribution (%) by main theme. Source: Authors' own computations based on journal articles collected from the*Econlit* database, 1969–2005

In terms of the methodology adopted in the articles, the importance of formal approaches in papers published in the top journals is obvious. Once more, this is associated with the framework implemented in papers centered on the theme "Games." Figures 13 and 14 confirm this.

From the evidence below, it is possible to conclude that the articles published in top academic journals, in a considerable proportion, are based on a formal frame. In fact, around 70% of the total papers published in *AA* journals are formal. In *A* journals, this percentage rises to almost 90%.

By intersecting the method and journal ranking category (Fig. 14), we observe that the highest-ranked journals publish essentially Formal-related research. Papers combining Formal and Empirical are nonexistent in AA journals and the fraction in A and B journals is quite small. The appreciative method tends to be the most representative category in the lowest-ranked journals.

The relative amount of published empirical papers is very low, regardless of the journal ranking considered and for both analyses, with and without

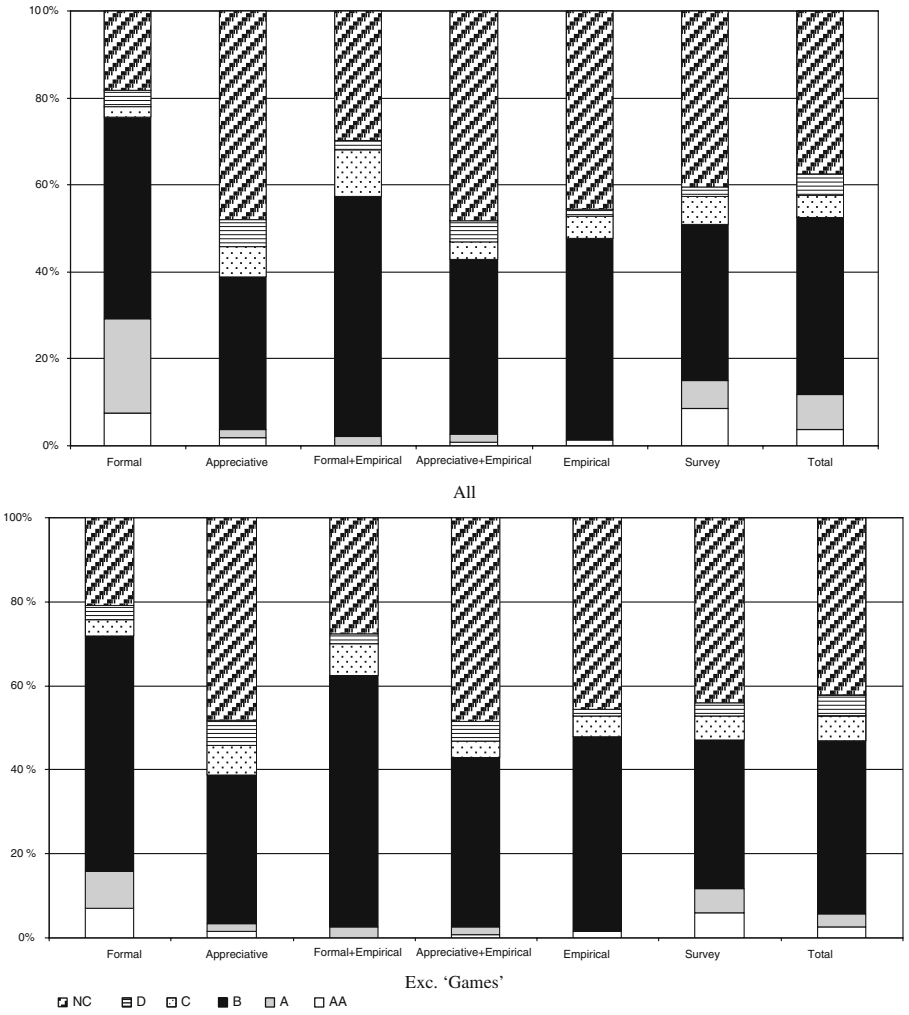

Fig. 13 Evolutionary papers by method: distribution (%) by journal ranking. Source: Authors' own computations based on journal articles collected from the *Econlit* database, 1969–2005

"Games." Once more, this reveals an important gap in evolutionary economics: empirical research is incipient.

6 Conclusion

In the context of an overview on evolutionary economics, the purpose of this paper was to explore the main research paths and contributions of this theorizing framework using bibliometric methods.

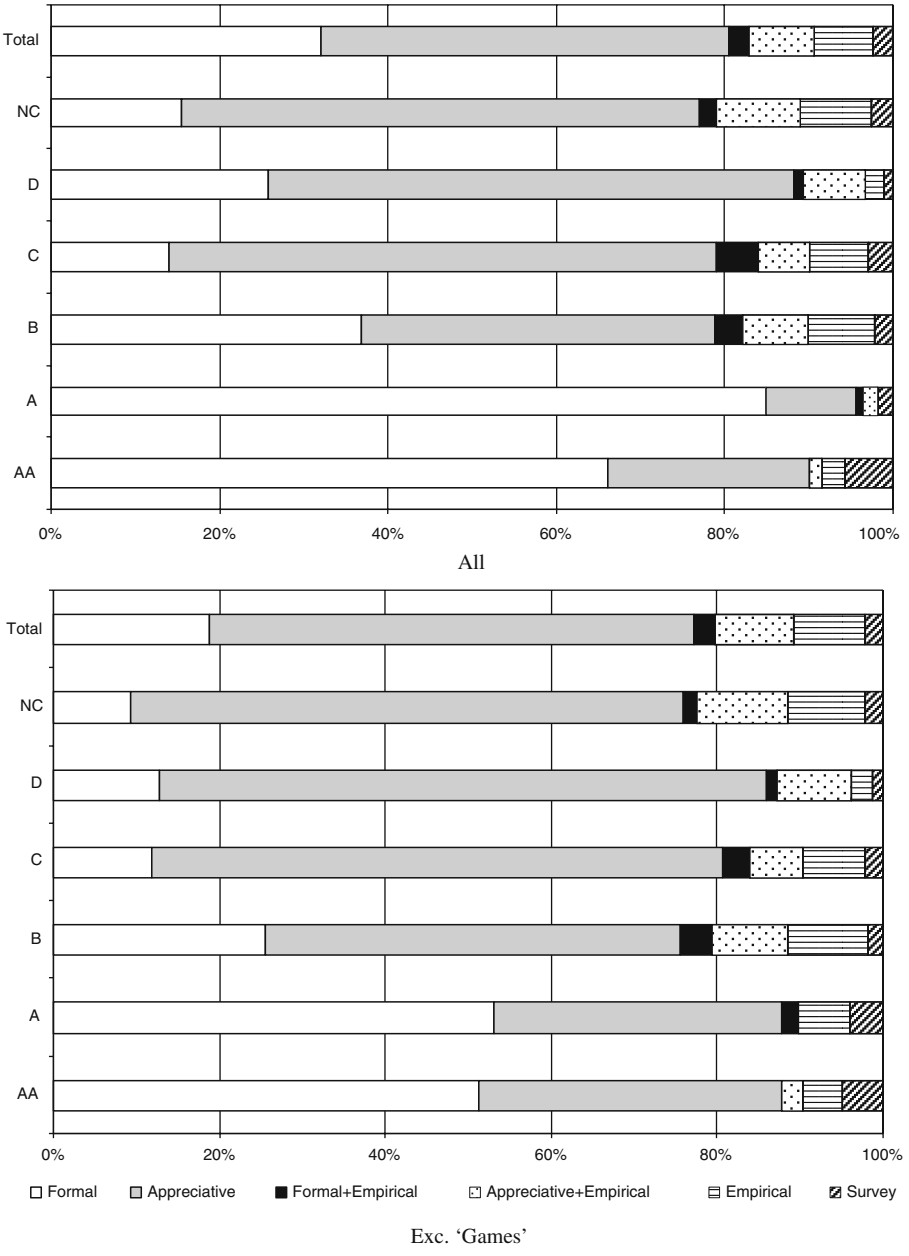

Fig. 14 Evolutionary papers by journal ranking: distribution (%) by method. Source: Authors' own computations based on journal articles collected from the *Econlit* database, 1969–2005

From all the evidence we collected for the period 1969–2005, a crucial concern emerged: the scarcity of empirical research within evolutionary economics. This evidence is particularly striking since the ontological foundations of evolutionary thought represent a commitment with real-world economy. Therefore, we think that this quantified evidence may help to redirect the debate concerning the evolutionary research agenda.

The problem within evolutionary research does not just reside in the formalization of concepts. Our study shows that more than 30% of the total published papers adopt a formal approach. Of course, most studies included in that fraction correspond to "Games," which is a particular field in evolutionary economics. In fact, 91.3% of the total published papers in the "Games" category in the period 1969–2005 is formal. However, in other main themes, formal approaches are also significantly present, for example 55.1% in "Technological Change, Growth and Business Cycles" and almost 40% in "Consumer and Organizational Behavior," for the entire period. Nevertheless, with the exception of "Games," there is significant dispersion in terms of the adopted formal frames within evolutionary research. This has to do with the intrinsic, broad dispersion associated with the ontological foundations of the discipline, which has not allowed for a common, formal framework such as the axiomatic, equilibrium, closed-system approach adopted in neoclassical research.

In spite of the importance of the debate on the formalization of evolutionary concepts, our documentation effort showed the need to re-focus the debate, by questioning the scarcity of empirical evolutionary research. An economic research field that requires proximity with real-world agents cannot be sufficiently validated unless it goes into empirical work. Moreover, the relevance of evolutionary research in terms of political economy demands such an effort.

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Appendix

Table 3 Alternative search method using a 'battery' of keywords related with the evolutionary jargon (combination of two keywords)

	Evolutionary	Routines	Path dependency	Learning	Out of equilibrium	Heterogeneity	Uncertainty	Satisficing	Selection
Evolutionary	2,510	32	15	393	632	23	129	9	260
Routines		146	0	39	3	0	11	1	18
Path dependency			103	10	6	0	6	0	7
Learning				5,625	783	85	434	8	215
Out of equilibrium					20,248	251	1,072	14	747
Heterogeneity						2,424	99	0	129
Uncertainty							11,496	7	439
Satisficing								54	5
Selection									8,559
Cumulative									
Schumpeterian									
systems of innovation									
Darwin*									
Non-optimal									
Irreversible									
Diversity									
Complexity									
Bounded rationality									

Table 3 (continued)

	Cumulative	Schumpeterian	Systems of innovation	Darwin*	Non-optimal	Irreversible	Diversity	Complexity	Bounded rationality
Evolutionary	27	64	9	67	1	7	50	62	30
Routines	2	8	2	3	0	0	2	4	2
Path dependency	4	1	2	0	0	0	4	2	0
Learning	39	20	17	7	1	19	57	82	63
Out of equilibrium	38	37	1	13	5	42	77	87	46
Heterogeneity	10	0	1	1	0	5	52	20	2
Uncertainty	54	14	1	4	3	137	47	117	62
Satisficing	0	2	0	0	0	0	0	0	7
Selection	18	12	4	35	0	7	44	52	8
Cumulative	916	3	0	2	1	1	3	6	0
Schumpeterian		339	0	1	0	0	1	6	0
systems of innovation			102	0	1	0	4	6	0
Darwin*				206	0	1	1	3	1
Non-optimal					55	1	0	0	0
Irreversible						378	5	2	0
Diversity							1,645	45	2
Complexity								1,690	20
Bounded rationality									263

Table 4 Alternative search method using a 'battery' of keywords related with the evolutionary jargon (combination of three keywords using 'learning' and 'out of equilibrium' as the basis)

	Routines	Path dependency	Learning	Out of equilibrium	Heterogeneity	Uncertainty	Satisficing	Selection	Cumulative
Learning	x			x					
Learning		x		x					
Learning				x	x				
Learning				x		x			
Learning				x			x		
Learning				x				x	
Learning				x					x
Learning				x					
Learning				x					
Learning				x					
Learning				x					
Learning				x					
Learning				x					
Learning				x					

	Schumpeterian	Systems of innovation	Darwin*	Non-optimal	Irreversible	Diversity	Complexity	Bounded rationality	No. papers
Learning									2
Learning									0
Learning									20
Learning									60
Learning									0
Learning									57
Learning									2
Learning	x								5
Learning		x							1
Learning			x						0
Learning				x					0
Learning					x				2
Learning						x			3
Learning							x		6
Learning								x	19

Table 5 Alternative search method using a 'battery' of keywords related with the evolutionary jargon (combination of three keywords using 'learning' and 'uncertainty' as the basis)

	Routines	Path dependency	Learning	Out of equilibrium	Heterogeneity	Uncertainty	Satisficing	Selection	Cumulative
Learning	x					x			
Learning		x				x			
Learning					x	x			
Learning						x	x		
Learning						x		x	
Learning						x			x
Learning						x			
Learning						x			
Learning						x			
Learning						x			
Learning						x			
Learning						x			
Learning						x			

	Schumpeterian	Systems of innovation	Darwin*	Non-optimal	Irreversible	Diversity	Complexity	Bounded rationality	No.papers
Learning									6
Learning									2
Learning									7
Learning									1
Learning									23
Learning									1
Learning	x								1
Learning		x							1
Learning			x						1
Learning				x					0
Learning					x				12
Learning						x			4
Learning							x		11
Learning								x	12

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