



## Surveys

## A bibliometric account of the evolution of EE in the last two decades Is ecological economics (becoming) a post-normal science?

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## ABSTRACT

In ecological economics the debate on formalism and formalization has been addressed in the context of a lively discussion on ecological economics as a 'post-normal' (versus 'normal') science. Using ecological economics (EE) as a 'seed' journal and applying bibliometric techniques to all (2533) the articles published in EE from January 1989 to December 2009, we analyze the evolution of the field of ecological economics aiming to shed light on this debate. We observe the predominance (and increased relevance) of certain research topics: 'Methodological issues', 'Policies, governance and institutions' and 'Valuation'. Moreover, 'Collective action', 'Technical change and the environment' and 'Values' stand as emergent themes of research. Finally, we note that ecological economics experienced an 'empirical turn' reflected in a shift away from exclusively formalized papers towards exclusively empirical and, to a larger extent, 'formal and empirical' ones. The combination of the prominent and emergent topics and the 'empirical turn' mirrors the increasing awareness among researchers in the field of the need to address a key specificity of ecological economics – the interdependence of the economic, biophysical and social spheres. On this basis, we argue that at least through the lens of EE, ecological economics has evolved towards a post-normal science.

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## 1. Introduction

The field of ecological economics has emerged from the need to rethink the relationship between nature and humans and to know how to live in a sustainable way within the limits of the global ecosystem. It is methodologically pluralistic (Norgaard, 1989; Costanza et al., 1997a,b; Costanza and King, 1999), meaning that researchers do not subscribe to a single unified theory or methodology.

Ecological economics is primarily engaged in the search for solutions to some of the most urgent problems facing society today (Müller, 2003). The new environmental problems involve facts that are uncertain, there are values in dispute, the stakes are high and decisions are urgently needed (Funtowicz and Ravetz, 1994). In other words, ecological economics has to deal with issues of far-reaching consequences where uncertainty is high and where the normative questions of value cannot be avoided, going well beyond the scope of 'normal' disciplinary science in the sense of 'puzzle solving' (Kuhn,

1962).<sup>1</sup> In the same line, Costanza (1991: 335) emphasizes that ecological economics is a "new transdisciplinary field of study... [which] goes beyond the normal conceptions of scientific disciplines and tries to integrate and synthesize many different disciplinary perspectives." In short, ecological economics is said to be an example of post-normal science (Funtowicz and Ravetz, 1994).<sup>2</sup>

As a post-normal science, ecological economics should not claim, according to Funtowicz and Ravetz (1994), ethical neutrality, nor an indifference to the policy consequences of its arguments. The imperative for research within ecological economics of not being "... divorced from the policy and management process" was quite emphatically highlighted by Costanza (1991: 341) almost two decades ago. More recently, Gallopín et al. (2001) considered that it was vital for science in general, and ecological economics in particular, to focus

<sup>1</sup> Kuhn (1962) proposes that 'normal science' is the hallmark of science. Scientists should undertake 'puzzle-solving' activities because this contributes enormously to scientific development. Notwithstanding, Kuhn also acknowledges the limitations of normal science and points out that when scientists encounter anomalies that cannot be dealt with within the existing paradigm, a crisis may arise and research becomes extraordinary rather than normal (i.e., it may lead to changes in the paradigm).

<sup>2</sup> Funtowicz and Ravetz (1994) call ecological economics 'post-normal' so as to better contrast it with the 'puzzle-solving within a (dogmatic) paradigm' of 'normal science' as articulated by Kuhn (1962).

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on the linkages between the social, political, economic, biological, physical, chemical, and geological systems. However, Müller (2003) argues that in spite of its claimed status as a post-normal science, ecological economics is evolving in the direction of a 'normal' science. According to this author, ecological economics tends to neglect the social aspect, which does not conform to its claim to be the science of sustainability and policy issues tend to be neglected as well (Gale, 1998; Söderbaum, 1999). Shi (2004: 34) also underlines that "... ecological economics still has a long way to go to actually achieve the goal of better management of sustainability."

Beside this dispute on the status of ecological economics and the evolution of the relative importance of topics researched in this field, namely those related with policy, another closely related issue – 'rigor' and 'formalism' – has raised passionate debates among ecological economists.

According to some (e.g., Wätzold et al., 2006), the pronounced transdisciplinarity of post-normal sciences tends to undercut the development of formalism.<sup>3</sup> And the lack of formalism and generally accepted definitions and ideas tend, according to others (e.g., Müller, 2003), to weaken the field's position with respect to higher formalized sciences. Tacconi (1998), however, has another view point. Following the line of Lincoln and Guba (1985), this author argues that even outside 'normal' science, the 'rigor' of the research process may be maintained by setting criteria aimed at guiding a process of 'disciplined inquiry', which includes prolonged and/or intense inquiry, persistent observation, triangulation, analysis of difference, peer debriefing, member checks, reports with working hypotheses and thick description, impact on stakeholders capacity to know and act, and inquiry audit. Stressing the relevance of formal methods of research within ecological economics (more specifically, the virtues of computer simulation models as preminent tools to help understand the complex, non-linear, and often chaotic dynamics of integrated ecological economic systems), Costanza (1991) recalls nevertheless that even with elaborate modeling capabilities, researchers will always be confronted with large amounts of uncertainty about the response of the environment to human actions.

From what has been said, we can conclude that post-normal science is not at odds with 'formalism', quite the opposite. Instead, it is characterized by a multiplicity of methods, quantitative and qualitative (Swedeen, 2006), deductive and inductive, involving also phenomenological approaches (Ramos-Martin, 2003).

Aiming to contribute, at least to some extent, to clarifying the status of ecological economics, this paper presents a quantitative and comprehensive account of the evolution of the field by depicting the trends in topics and type of methods which underlie studies published in ecological economics, based on bibliometric techniques.

Bibliometric-based studies are increasingly being used as they provide key insights into the terms of influence, specializations and trends of a research field, involving a more objective assessment of the patterns of scientific research (van Raan, 2003; Silva and Teixeira, 2008, 2009). Although there are some recent bibliometric analyses in the environmental and ecological field of research (e.g., Fisher and Ward, 2000; Smith, 2000; Costanza et al., 2004; Krauss, 2007; Jappe, 2007; Rousseau, 2008; Luzadis et al., 2010), they do not deal with issues related to the evolution of the topics analyzed and type of methods employed in ecological economics.

Using all (2533) the articles published in the area's 'seed' journal, *Ecological Economics* (EE),<sup>4</sup> we classified the articles according to the main topic of research. To identify such topics, a review of key studies in the area was conducted. Additionally, we classified articles

according to their type (i.e., method of analysis) following an initial distinction, proposed by Nelson and Winter (1982), and later extended by Silva and Teixeira (2008, 2009) and Cruz and Teixeira (2010). The categorization of each article in terms of research topics and type was made on the basis of a thorough analysis and interpretation of the complete articles.

This paper is structured as follows. The next section defines the main themes in ecological economics based on a qualitative review of the field of ecological and environmental economics. This exercise helped us to identify the most prominent research topics in the area. Section 3 details the methodological underpinnings of the study, and Section 4, based on the bibliometric exercise, highlights the main topics that have emerged and developed in the environmental and ecological field as well as the declining ones, giving particular emphasis to the issue of collective action. Finally, the Conclusions summarize the main contributions of this study.

## 2. Defining the Main Themes in Ecological Economics

The importance of ecological (and environmental) issues in the field of economics shows a clear upward trend (cf. Fig. 1).<sup>5</sup> Over the period from 1970 to 2009, there is an increasing number of articles and reviews in the field of the 'Social Sciences and Humanities' (SS&H) using 'ecology' or 'environment' as search keywords. Although displaying discontinuous temporal changes, both ecological economics and all articles in ecological and environmental economics have increased significantly over time.

The breadth of research topics is considered one of the strengths of ecological economics (van den Bergh, 2001; Røpke, 2005) and the distinct contributions accommodate some of the concerns of very different scientific domains, namely moral philosophy, politics, ethics, ecology, thermodynamics, economics, biology, natural history and natural sciences. Albeit recognizing the difficulty to categorize ecological economics in the same way one would a 'normal' academic discipline, we propose to group it into ten main topics.<sup>6</sup>

### 2.1. Theory Building

This topic outlines the sustained process of theory building which is a recurring cycle linking data, methods and theory itself in a coherent connection towards the generation, verification, and refinement of phenomena (Lynham, 2000). It includes conceptual and historical contributions and formative approaches.

### 2.2. Methodological Issues

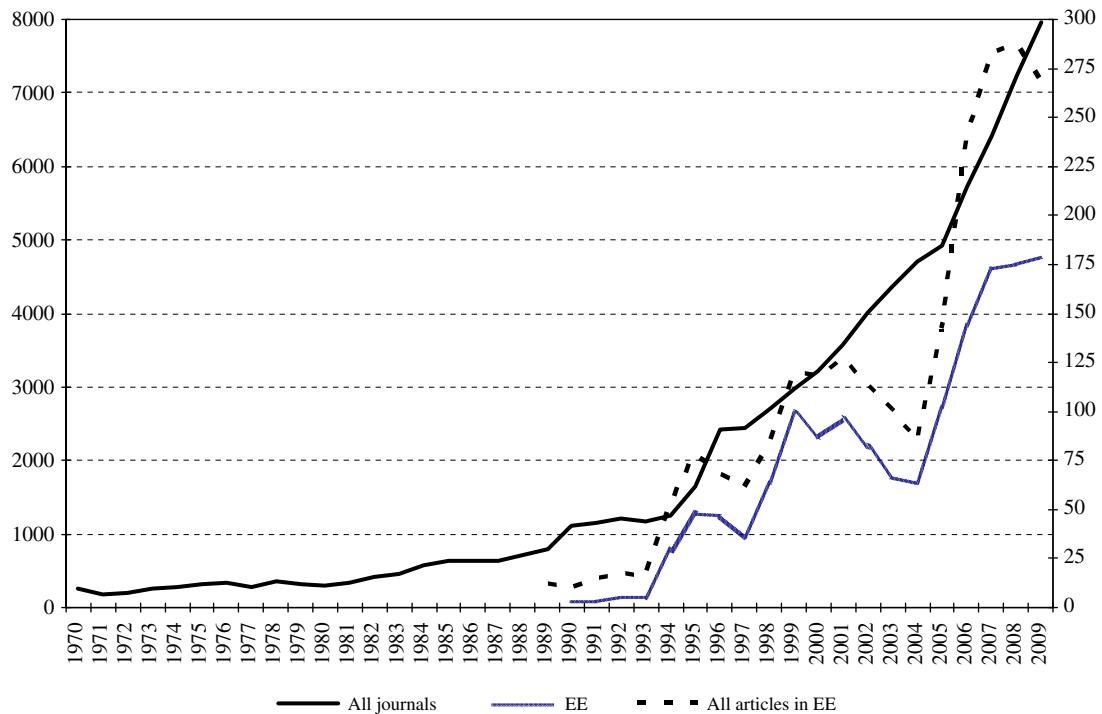
Since ecological economics is a multidisciplinary field of research (Norgaard, 1989; Costanza et al., 1997a,b; Costanza and King, 1999), there is a wide array of methods and models to analyze issues in

<sup>5</sup> It is important to recall here that 'ecological economics' and 'environmental and resource economics' are distinct groups of research. The latter, according to De Zeeuw (2008: 22), "... can be seen as a subfield in [mainstream] economics, [whereas] ecological economics originates from a strong disappointment with the economics profession, ... [being] more geared towards interdisciplinary research and action."

<sup>6</sup> To identify such topics, a review of key studies in the area was conducted, namely the 'Ecological Economics Elgar Reference Collections Critical Writings in Economics' (Costanza et al., 1997a,b), the 'International Yearbooks of Environmental and Resource Economics' (Tietenberg and Folmer, 2006), 'Handbook of Environmental and Resource Economics' (van den Bergh, 1999), and the 'Recent Development of Ecological Economics' (Martinez-Alier and Røpke, 2008). Existing surveys published in key journals (e.g., *Ecological Economics* and *Journal of Environmental Economics*) were also reviewed. Table A1, in Appendix, details how we arrived at the ten themes proposed here. In each column of Table A1 we placed the main topics mentioned in each handbook's/journal's aims; then through in-depth content analysis we organized the topics by their degree of similarity, leading to the classification of the ten topics presented in the column 'Our proposal'.

<sup>3</sup> 'Formalism' involves robust and widely accepted frameworks (e.g., mathematization and simulation) to sustain discussions – especially discussions with traditionally formalized sciences.

<sup>4</sup> From here forth, EE is used to refer to the journal and 'ecological economics' when referring to the field of research.



**Fig. 1.** Evolution of published articles on ecological and environmental research and in all journals in the area of the social sciences and humanities and in Ecological Economics (EE), 1970–2009. *Note:* Search performed in Scopus database restricting the search to articles and reviews in the field of ‘Social Sciences and Humanities’ considering ecology\* OR environment\* as search keywords. The total number of articles and reviews, between 1970 and 2009, containing ecology\* OR environment\* keywords in ‘Social Sciences and Humanities’ amounts to 78,465, whereas the corresponding total in Ecological Economics (EE) journals is 1505. EE started publication in 1989.

ecological economics and support theoretical research, derived from different approaches and from separate or integrated disciplines. This topic includes all issues whose main focus is the method, be they input/output approaches, cost/benefit analysis and its critiques, resource accounting methods, contingent valuing, multicriteria analyses, decision support systems, GIS (geographic information systems), material flow analysis, and welfare measures (indicators for sustainable economic welfare and others), as well as research on how to bring evolutionary game theory into the field of environmental economics (Gintis, 2000).

### 2.3. Values

A potent force of social change is associated with values. It influences people’s actions and goals in life, intentions, motivations, and perceptions (Walter, 2002; de Vries and Petersen, 2009). Issues dealing with ethics, fairness, equity, ideology, citizenship, intergenerational justice, creative ideas applied to current social issues helping society in better dealing with the environment, perspectives concerning rights for nature, value-based judgments about diverse environmental problems and targets, are associated to the ‘Values’ topic.

### 2.4. Policies, Governance and Institutions

For ecological economists, international and intergenerational equity and sustainable development, including environmental sustainability, are goals that are at least as important as efficiency (Padilla, 2002; Woodward and Bishop, 1995). This conviction leads to distinctive approaches to policy analysis. This topic includes all the papers focusing on, among others: considerations of economy and efficiency towards the implementation of policies; instruments;

public–private environmental conflicts; property rights approach to managing the environment; policy responses to environmental risk and uncertainty; policy and performance issues; issues on the social dimension and distributional issues.

### 2.5. Technical Change and the Environment

Most regions of the developing world are attempting to improve their material standard of living by developing new technologies, particularly those that have a biological basis, and the widespread diffusion of both old and new technologies (Duchin et al., 1994). This topic includes papers focusing on models of innovation in pollution control, critical assessment of innovation models, the transition from hydrocarbons, technological pathways to a more sustainable energy system, innovation effects of environmental policies, and the best incentives to sharpen environmental technologies, sustainable techno-economic evolution and evolution of collective practices, as well as papers relating ecology and technology.

### 2.6. Trade and the Environment

According to Andersson (2006), a “full world” or “ecologically unequal exchange” are hardly comprehensible to many (mostly mainstream) economists, whereas an individual accustomed to calculating in terms of biophysical quantities, such as “ecological footprints”, can easily understand how trade, which is advantageous to all parties in monetary terms, may be questionable from the viewpoint of sustainability or distributive justice. This topic includes economic, legal and policy perspectives concerning world trade and its impact on the environment and what makes world trade environmentally sustainable.

## 2.7. Global Environmental Issues<sup>7</sup>

Studies on the global commons, trans-border environmental problems, applications to global and regional environmental issues, such as climate change, global warming, ozone layer, worldwide acidification of lakes and streams, acid rain, coastal areas, urban sprawl, eutrophication, water and energy systems, are included under this broad topic, as well as migration issues and their environmental implications. Poverty issues related with the environment, the interconnectivity of global biodiversity conservation with human poverty and macroeconomic processes, represent key areas of focus (Fisher and Christopher, 2007) and fall under this topic, as well as the income growth debate and sustainable development.

## 2.8. Production, Consumption and Sustainability

The relevance of adopting the “Agenda 21” action in order to stimulate sustainable consumption and production patterns is stressed by several authors (Røpke, 1999; Reisch, 2003; Tukker et al., 2010), since global responsibility has come to the centre of the debate (Fedrigo and Hontelez, 2010). This topic addresses issues that intend to respond to prevalent social discourses and to political and administrative concerns: industrial ecology and its impact on wealth, depreciation and waste (Ayres, 2001); the procedures of firms, sustainable production and consumption studies on business and the environment and the nexus of producer versus consumer responsibility (Lenzen et al., 2007); the limits to substitution and irreversibility in production and consumption (Stern, 1997); and how to bring about changes in consumption and production patterns (Tukker et al., 2010).

## 2.9. Biodiversity Conservation<sup>8</sup>

The rationale for focusing on biodiversity is anchored in its value, which encompasses intrinsic value, existence value (Folke, 1999; Røpke, 2005), and the value of the ecological services supported by the interaction between the organism’s population and communities of the natural environment, and the role of ecological services for humanity (Perring et al., 1992). Studies researching the inability of ecological systems to function under altered climatic conditions and their implications on biodiversity, the relation between the scale of economic activity and the nature of change in ecological systems and their impact on biodiversity loss, linkages between resilience biodiversity and sustainability and path dependency, as well as studies on the driving forces behind biodiversity levels, are included in this topic.

## 2.10. Valuation

This is another core topic within the field of ecological economics which is strongly rooted in theory (cf. Table A1). This topic addresses, for example, the valuation of ecosystem goods and services within multiple contexts, as well as papers whose core focuses on the application of different methodologies to evaluate environmental outcomes as the basis of further environmental choices.

## 3. Methodological Considerations

In order to appraise which are the emergent and declining themes and the main methods in the scientific area of ecological economics

<sup>7</sup> It is important to note here that the issues included in this topic often transversally connect to other economic-environmental issues, namely trade, technological cooperation, policies, and ethics. It may also involve the application of methods for estimating damage, suitability of optimal solutions and choice of instruments.

<sup>8</sup> This issue is a global environmental problem, however we opted for analyzing it separately given its importance on ecological economics research field.

over the past two decades, we examined all (2533) the articles published in the area’s ‘seed’ journal, *Ecological Economics* (EE), from January 1989 to December 2009, applying bibliometric techniques.<sup>9</sup>

The transdisciplinary *Ecological Economics* (EE) journal, published by the International Association of Ecological Economics, was chosen not only for its impact factor (2.422 in 2009), which reflects (at least partially) its quality and wide distribution among the ecological economics community, but also because it constitutes a key resource on ecological economics (Luzadis et al., 2010), as a source for the most influential research in the field (Costanza et al., 2004). EE is methodologically open and intends to extend and integrate the study and management of “nature’s household” (ecology) and “humankind’s household” (economics). Söderbaum (1994) considers such an integration necessary as the separation of these two realities has led to disavowing economic and environmental policies.

The EE articles were classified by type, following the initial categorization proposed by Nelson and Winter (1982) between appreciative and formal, and later extended by Silva and Teixeira (2008, 2009) and Cruz and Teixeira (2010) to include, beside appreciative and formal, empirical, empirical and appreciative, formal and empirical, and surveys. Thus, following Nelson and Winter (1982), Silva and Teixeira (2008, 2009) and Cruz and Teixeira (2010), in the present study, the articles classified as “*appreciative*” include theoretical arguments, appreciations, critical papers, and judgments. Papers characterized as “*formal*” encompass studies based on mathematization or an analytical or logical framework. Nevertheless, when these formal articles also include the testing of data in the models used, they were included as “*formal and empirical*”. The articles exclusively concerned with econometric or statistical testing of data were classified as “*empirical*”, whereas “*appreciative and empirical*” involved comments or appreciations on empirical data analysis. The articles involving a comprehensive review of published and unpublished work from secondary source data in the areas of specific interest to the researcher were classified as “*survey*”.

Publications in EE were also categorized in terms of the ten main topics detailed in the previous section: (1) Theory building; (2) Methodological issues; (3) Values; (4) Policies, governance and institutions; (5) Technical change and the environment; (6) Trade and the environment; (7) Global environmental issues; (8) Production, consumption and sustainability; (9) Biodiversity conservation; and (10) Valuation. Based on this classification, we assessed the relative weight of each topic of research and their temporal evolution over the period 1989–2009, considering five-year analysis frames.

The categorization by types, crossed with that by topics, enabled a full characterization of research in ecological economics, obtaining a broad view of the evolution of ecological economics from its roots to more recent times, as well as providing relevant insights into the relation between the relevance of ecological economics and the formalism of the research methods applied. The purpose was to identify patterns in research topics and types and to highlight a dynamic perspective of how the topics and types evolved in the period under analysis.

## 4. Evolution of the Scientific Field of Ecological Economics: Evidence from a Bibliometric Exercise

### 4.1. Main themes

Research within ecological economics grew sharply over the period in analysis, particularly from the first (1989–1994) to the second period (1995–1999), confirming Martinez-Alier and Røpke’s (2008) portrayal of the field.

<sup>9</sup> The data were collected from the ISI Web of Knowledge database (produced by Thomson Scientific). Items corresponding to books review, comments, corrigenda, and rejoinders were eliminated from the categorization.



The composition of the research area in terms of topics is not surprising (Fig. 2), with the dominance of 'Methodological issues' (22% of total published papers), 'Theory building' (17%), and 'Policies, governance and institutions' (15%). Given that the scientific roots of ecological economics date from 1989, the literature gave priority to defining the frontiers of the field, reassessing the theories, and developing some of its major streams, which explains the huge predominance of 'Theory building' in the initial period (1989–1994). As ecological economics gained maturity, 'Theory building' lost ground, confirming Swanson's (2000) contention that theory building tends to present increased relevance in the emergent phase of a field and less so in its mature phase. In contrast, 'Methodological issues' and 'Policies, governance and institutions' increased in importance over time. The first topic is prominent from 1995 onwards, which reflects the overwhelming evidence that ecological economics is inherently methodological aiming to develop new ways to effectively deal with the crucial aspects of ecological complexity, scale, and uncertainty (Proops, 1989; Costanza et al., 1997a). Consequently, the need arose for measurement, indicators and methodologies to assess the distinct aspects of sustainability, economic impact, risk, etc. (Maxwell and Randall, 1989; Tacconi, 1998; Herzi and Dovers, 2006; Venkatachalam, 2007; Baumgärtner et al., 2008). The EE journal's claim to fostering interdisciplinary research, in line with its quest for ecological economics to be open to various approaches (EE has a section dealing with methodological issues), may in part have contributed to the revival of interest in these issues, boosting the quantity of scientific research on methods.

'Policies, governance and institutions' stands as a rather dynamic field of study, gaining substantial relevance over time, most notably in the final period (2005–2009). This finding sustains the contention that most scientific research is politically motivated (Kallis and Norgaard, 2010) and is intended to support goals that are extrinsic to science itself: serving to build decisions, supplying meaningful information, assessing the probable results of specific policy actions (Sarewitz and Pielke, 2007), providing frameworks of governance (Shi, 2004), and shedding light on the performance and emergence of environmental institutions (Hodgson, 2010).

This trend is not detached from the increasing influence of ecological economics on the policy field given the goal of sustainability (van den Bergh, 2001) and the need to bolster its potential contribution to the decision-making process (Shi, 2004). As noted by Gowdy and Erickson (2005), ecological economics offers viable alternatives to the theoretical foundations and policy recommendations of standard/neoclassical welfare economics. Some argue (e.g., Martin, 2003; Holt, 2005) that given the difficulties facing policy-makers, as they always operate under partial knowledge (Kahn and O'Neill, 1999; Rosser, 2001, 2010), ecological economics appears as a more scientifically valid foundation for economic theory and policy, leading both to better policies directly concerning with human welfare and a better understanding of how humans interact with the natural world.

The remarkable evolution of the 'Policies, governance and institutions' topic reflects the increasing recognition of ecological economics as a 'policy-driven science' (Shi, 2004). It should be integrated in policy and management processes (Costanza et al., 1991; van Kerkhoff, 2005), sustaining the shift towards an holistic science and policy (Cortner, 2000; Lucas et al., 2008), incorporating social power relations (Gale, 1998; Juntti et al., 2009; Safarzyńska and van den Bergh, 2010), and contributing to the development of a better understanding of human behavior.

There is today a growing consensus within the ecological economics scientific community that it is crucial to provide for continuous exchange and co-evolution of scientific and policy knowledge, with a view to achieving sustainability (EU, 2009). This means that advances in scientific research lend support to a knowledge-based society and the

changes required to cope. Scientific research should further move forward and extend its role and foresight to support policy development and implementation (Quevauviller et al., 2005), and ensure engagement, interpretation and uptake of research results by stakeholders within business and civil society in a collaborative learning approach (Cortner, 2000).

This trend towards participatory processes, associated with the issue of 'collective action', reflects the increased importance of stakeholders in the political arena and the decision-making process (Gliken, 2000; McNie, 2007). Martin (2003) and van Kerkhoff (2005) agree that there is a shift towards a research agenda strongly influenced by users in need of scientific information. Walter (2002) nevertheless provides critical argument about ecological economics not having given sufficient emphasis to a community focus and orientation.

Even though the number of papers on 'collective action' is rather small, corroborating Walter's (2002) viewpoint, the evidence collected in the present paper shows that it has followed a clear upward trend within the broader topic of 'Policies, governance and institutions'. The emergence of new institutional arrangements with flexible and integrative forms of governance, in line with Ostrom's (1990, 1996) research, reflects the potential for social capital to embed participation practices and the involvement of citizens to play an active role in producing public goods and services relevant to them. The potential of these new arrangements has featured more prominently on the agenda of ecological economics which is reflected in its rapid growth since the middle of the 1995–1999 period. Thus, the subtopic of 'Collective action' (included in 'Policies, governance and institutions') can be considered an emergent theme in ecological economics. This trend reflects the growing importance of institutional arrangements anchored in participatory processes and their consequent attractiveness for science. The still limited (absolute) number of studies published in EE means additional research efforts are required, namely research on flexible institutions, adaptive organizations and alternative models of collective action, not only in less developed countries but also in highly and intermediate developed countries. The positive trend observed in the 'Policies, governance and institutions' (and 'Collective action') topic confirms Røpke's (2004) belief that social influences and specific political factors are (increasingly) important contributions to ecological economics.

With a dynamic similar to the latter topic, '(E) Valuation' has experienced a steady and marked increase over time, particularly in the 2000s. Since sustainability is a core issue in ecological economics, a growing interest in valuation is expected, focused on incorporating ecosystem goods and services into economic accounting and policy decision-making. Costanza et al. (1991) forecast that this area promised to be a major focus of research in ecological economics. Our evidence corroborates these authors' contention to the extent that 'Valuation' emerges as a prominent issue in ecological economics research. Indeed, it is a central issue in environmental economics (Perkins, 2003). Given the existence of several different approaches to assign values to non-marketed goods and services, some of them with conflicting formulations (O'Connor, 1993), ecological economics has attempted to assess alternative methods concerned with the effects of human actions on other species and nature, ecological complexity, social diversity, and ethical considerations, both in the short and long term. Thus, the evolution of the 'Valuation' topic has captured growing interest in developing better frameworks and methods to tackle valuation with new approaches, attempting to link the economic value of ecosystems with three key items: 1) the physical, chemical, and biological role of ecosystems in the long-term; 2) the appropriateness of the scale of measure (e.g., money, utility or energy embodied value) (Klauer, 2003); and 3) the appropriate discount rate to apply to ecosystem services in order to better quantify the ecological economic interdependencies (Costanza, 1991).

**Table A1**  
Main themes on Ecological Economics.

Costanza et al. (1997a)	Costanza et al. (1997b)	Costanza and King (1999)	van den Bergh (2001)	Page and Proops (2003)	Martinez-Alier and Röpke (2008)	Ecological Economics journal aims and scope	Our proposal	Other references
Current human dilemma	Basic organizing principles of ecological economic	Econ/env. interaction	Growth debate	Disciplinary approaches (philosophy, politics, sociology, economics and law)	Roots	Critical assessments of the basic assumptions underlying current economic and ecological paradigms and the implications of alternative assumptions	Theory building (conceptual and historical contributions and formative approaches)	Silva and Teixeira (2008); Silva and Teixeira (2009); Cruz and Teixeira (2010)
Sustainable scale		Ecological limits and sustainable scale						
Ecosystems biodiversity and ecological services		Material and energy flows in ecological and economic systems	Energy/thermodynamic					
Substitutability vs. complementarity of natural, human and manufactured capital	Historical roots and motivations	Sustainable development	Sustainable development	Sustainable development	Resilience and evolution in socio-ecological systems	Implications of thermodynamics for economics and ecology		
The historical development of economics and ecology		New paradigm	Dynamic processes	The precautionary principle Environmental security Ecological modernization				
Population and carrying capacity		Eco-modeling				Valuation of natural resources; alternative principles for valuing natural wealth Integrating natural resources and environmental services into national income and wealth accounts Case studies of economic-ecologic	Methodological issues (and Integrated economic modeling) and green accounting methodologies	Silva and Teixeira (2008); Silva and Teixeira (2009); Cruz and Teixeira (2010)
Measuring welfare and well-being		Cost benefit analysis			The metabolism of society			

	Integrated economic modeling and assessment Accounting for natural capital	Indicators		Issues in valuation	conflict or harmony		
		Contingent valuation		Environmental sustainability and social welfare	Integrated ecologic-economic modeling at scales from local to regional to global		
Valuation, choice and uncertainty	Valuation of ecological services	Valuation		Economic valuation of ecosystem services		Valuation (including valuation of ecological services and assessment, applied green accounting) Values (environmental ethics fairness, feminism, equity and distribution)	<a href="#">Paula and Cavalcanti (2000)</a> ; <a href="#">Cairns (2001b)</a> ; <a href="#">Jamieson (2008)</a> <a href="#">Luzadis et al. (2010)</a> ; <a href="#">Cairns(2001a)</a> <a href="#">Luzadis et al. (2010)</a>
Fair distribution and efficient allocation		Ethics Intergenerational equity					
Policies, institutions and instruments		Environmental policy and management; Ecotaxes Corporate behavior Common property	Behavior and environmental policy	Human behavior, institutions and governance	Methods of implementing efficient environmental policies	Policies, governance and institutions	
Trade and community		Trade and environment	International trade and environment	Technological change Trade and globalization		Technical change and the Environment Trade and the environment	Special issue EE vol54, Issue2, 3, 2005 <a href="#">Ekins (2003)</a> , EE, 1994,vol9 (1)
		Global warming		Global climate change	Income growth and environmental impacts	Global environmental issues (migration, climate change)	<a href="#">Carraro (2003)</a>
		Sustainable forestry		Population Consumption	Sustainable production and consumption	Production, consumption and sustainability	
		Sustainable fisheries Sustainability of natural capital; sustainable agriculture		Biodiversity	Renewable resource management and conservation	Biodiversity conservation	<a href="#">Barbier et al. (1995)</a> ; <a href="#">Klauer (2003)</a> ; EEVol53, Issue4, Vol 67, Issue2

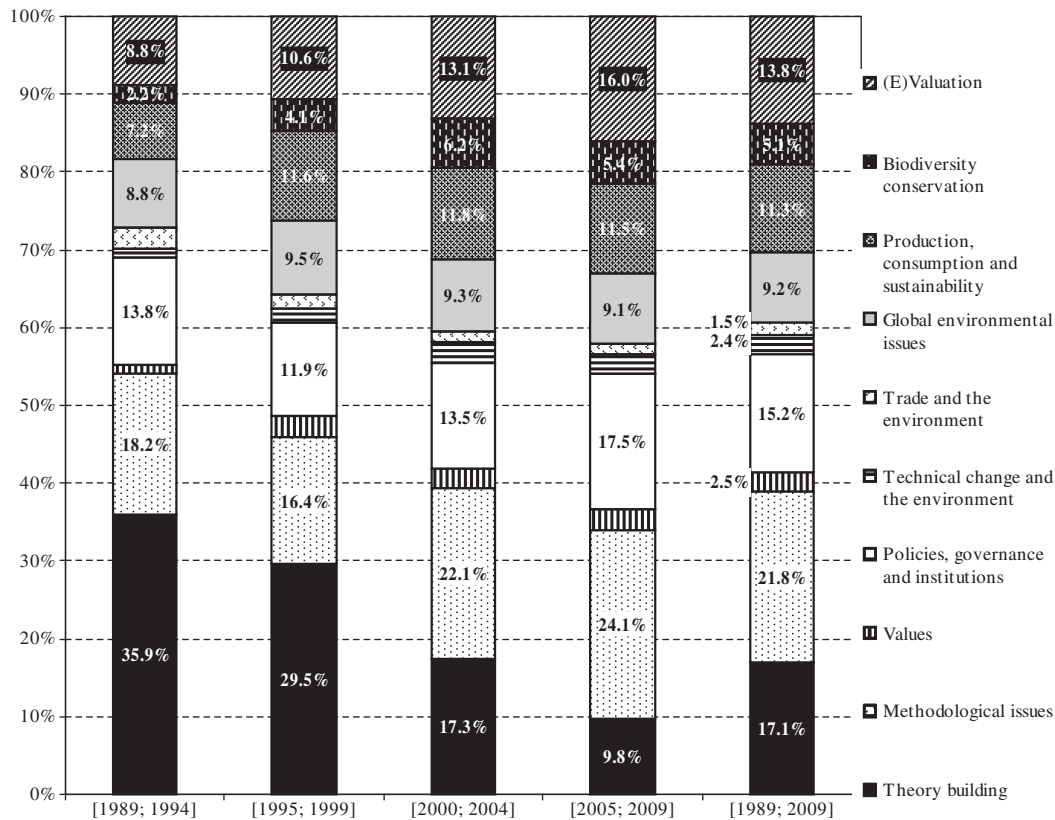


Fig. 2. Papers published by topic in Ecological Economics (EE), 1989–2009. Note: The classification of the topic of each article was based on the analysis of the full article available from Science Direct.

Source: Authors' computations based on the all the articles published in EE gathered from Scopus in February 2010.

The 'Global environmental issues'<sup>10</sup> topic has been fairly stable over the time span considered, accounting for approximately 10% of the total papers. This suggests that contributions to this topic have maintained both moderate and systematic appeal among EE researchers.

Although 'Biodiversity conservation' is considered a core subfield in ecological economics (Gowdy and Ferrer-i-Carbonell, 1999) and EE dedicated special attention to this theme in the last period of analysis (2005–2009), it lost importance (decreasing from 6.2% to 5.4%). The interest in 'Production, consumption and sustainability', albeit having grown rapidly from the first (1989–1994) to the second period (1995–1999), has since then remained quite steady.<sup>11</sup>

Significantly, and somewhat surprisingly, 'Technical change and the environment', 'Values', and 'Trade and the environment' are three rather unexplored researched themes within EE, representing less than 3% of the total papers. In contrast to the first two topics ('Technical change and the environment' and 'Values'), which experienced a noticeable rise over time, 'Trade and the environment' decreased in importance. The trend of this latter topic is contradictory to the interest EE seems to have in it, reflected in the existence of a special issue on the matter (Ekins et al., 1994), to Jayadevappa and Chhatre's (2000) expectations as to a growing interest in the

<sup>10</sup> There are some papers related with the themes included in 'Global environmental issues' that could also be matched to other topics (mainly to 'Methodological issues', 'Biodiversity conservation', 'Valuation' and 'Production, consumption and sustainability'). Nevertheless, we opted to classify them in the topic 'Global environmental issues' as their 'core' concern gave them a 'global' dimension.

<sup>11</sup> It is important to note that a reasonable number of papers classified in the 'Policies, governance and institutions' topic also dealt with the issue of 'Production, consumption and sustainability' but as a secondary focus.

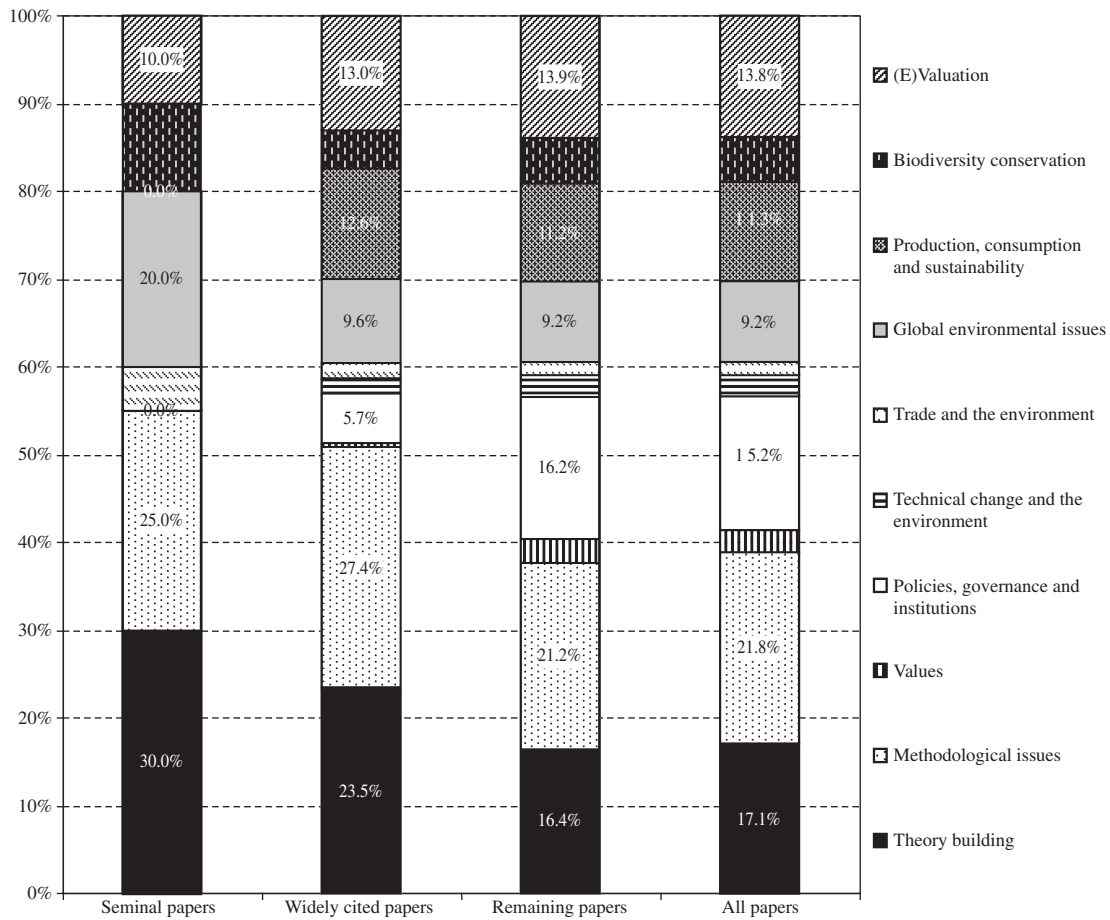
interactions between trade and the environment in the 'foreseeable future', and Ehrlich's (2008) contention that 'trade' is one of the areas to which ecological economics is paying 'proper attention'. The relative lack of interest reflected in this trend may call into question at least partially the EE's so-called multidisciplinary and holistic approach, as this topic encompasses economic, legal and policy perspectives. In particular, the important debate on the contradictory role of trade from the standpoint of sustainability or distributive justice (Rugman et al., 1998; Ekins, 2003; Andersson, 2006) is neglected.

The evolution of "Technical change and the environment" is grounded on the growing importance the literature has given to the relation between technical change, innovation and sustainable development, mainly related with climate and energy policy (Vollebergh and Kemfert, 2005). The increased interest in 'Values' is in line with the general concern for ethics in economics, and above all with the relevance of the endogeneity of ethics, conceptions and beliefs in all decision-making systems. It calls for the development of new approaches to integrate these features and break with the ethical exogeneity of neoclassical environmental economics (Choudhury, 1995).

Fig. 3 shows the breakdown of the articles by topic and by citation group ('seminal papers', 'widely-cited papers', and 'other' papers).<sup>12</sup> 'Seminal' papers (which represent about 0.8% of total papers) have greater weight in 'Theory building', 'Trade and the environment', 'Global issues', and 'Biodiversity'. In the case of 'widely-cited papers',

<sup>12</sup> 'Seminal' papers are those that have 100 or more citations, whereas 'Widely-cited papers' are those that have 30 or more citations (including obviously 'Seminal' papers).





**Fig. 3.** Papers published by topic and by citation group in Ecological Economics (EE), 1989–2009. *Note:* The classification of the topic of each article was based on the analysis of the full article available from Science Direct. ‘Seminal’ papers are those that have 100 or more citations; ‘Widely-cited papers’ are those that have 30 or more citations (it includes ‘Seminal’ papers).

Source: Authors’ computations based on the all the articles published in EE gathered from Scopus in February 2010.

focus is higher under ‘Theory building’, and (to a larger extent) ‘Methodological issues’.

Considering that policy-related matters are paramount within EE, it is quite surprising that the ‘Policies, governance and institutions’ topic does not appear in the seminal papers and is underrepresented among the widely-cited papers. This might, in part, be explained by the fact that this topic only emerged as more significant in the final period (2005–2009), and it is therefore likely that ‘seminal’ and ‘widely-cited’ papers on this topic could emerge in a near future.

#### 4.2. Main Type/Methods

A noticeable tendency in the data (cf. Fig. 4) is the increasing dominance of formalism, allied to the need for testing (‘empirical’), and the marked decline of ‘appreciative’ papers, which in the initial period represented almost 40%, dropping to 15% in the later period (2005–2009). Indeed, papers published in EE increasingly resort to ‘formal and empirical’ methods, which become dominant after 2000 and represent, for the whole period (1989–2009), around 42% of the total papers published.

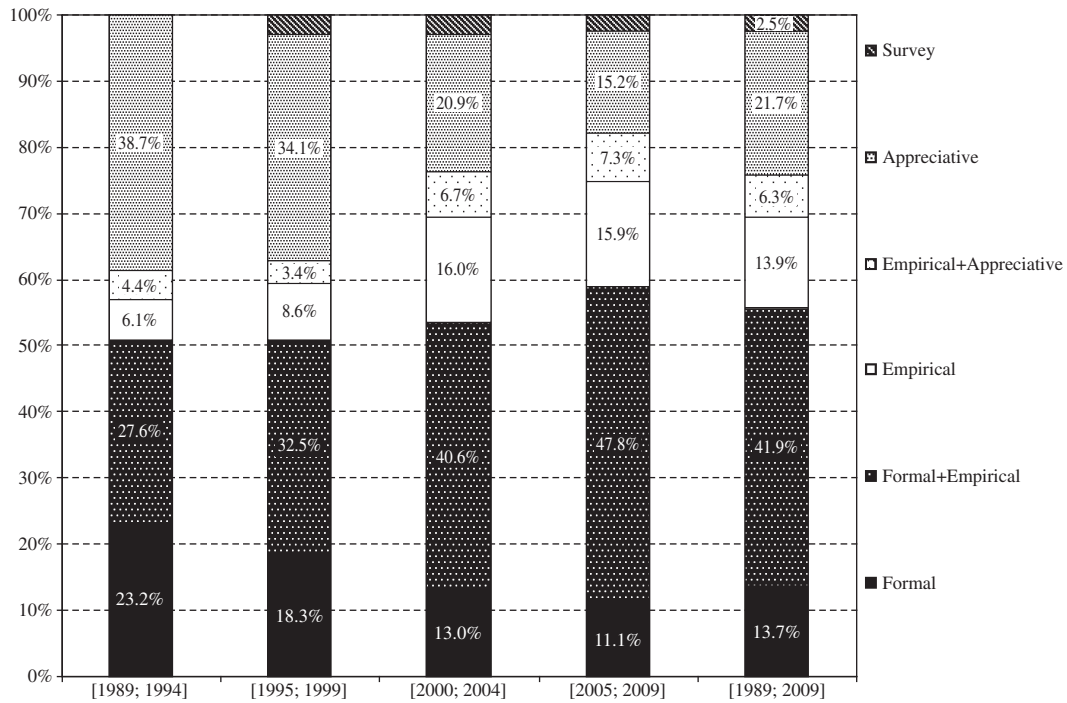
This is likely to reflect the global trend within economics for increasing ‘rigor’, often associated to formal modeling and mathematical apparatus (Mayer, 1993; Mirowski, 2002), characteristic of methods and measurement tools, which observed continuous growth in importance throughout the period, as mentioned earlier (cf. Fig. 2). But at the same time, the increase in empirical-related papers (‘empirical and appreciative’, ‘empirical’, and ‘empirical and formal’)

reveals a growing concern on the part of authors to produce new knowledge in ecological economics focusing on real-world problems and issues (Harris, 2003).

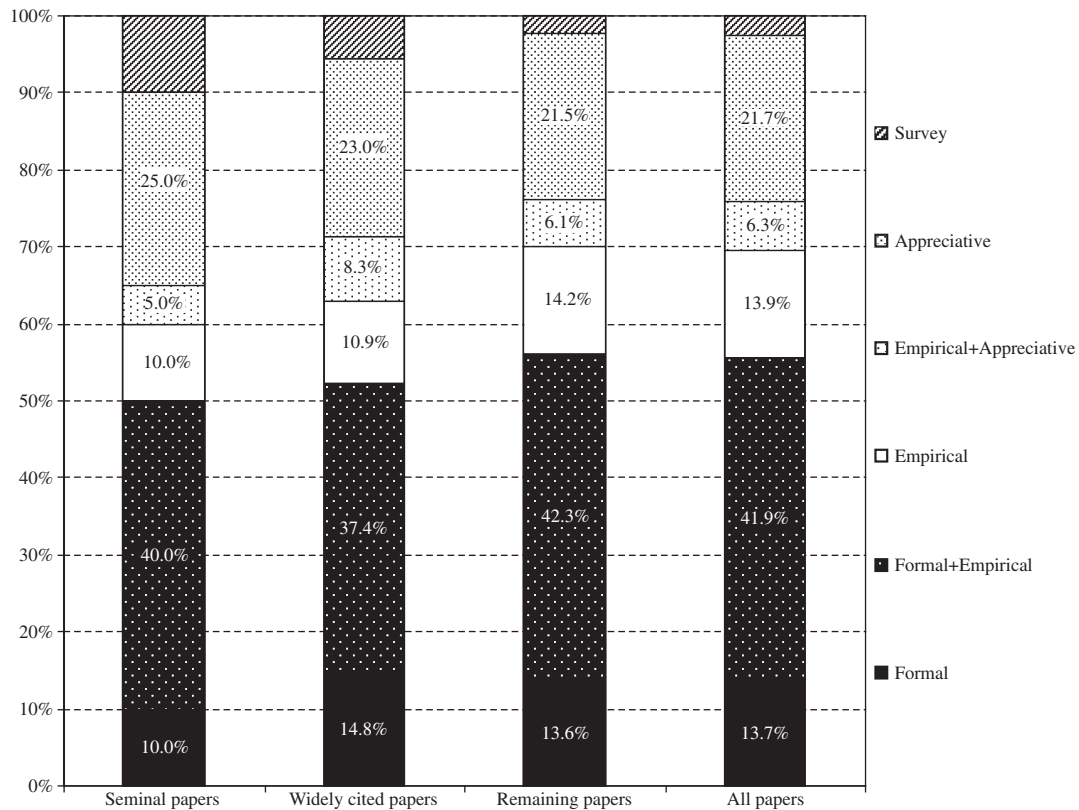
Such a trend is in accordance with Ramos-Martin’s (2003) claims that the scientific field of ecological economics is evolutionary and deals with the relation of humankind with nature and policy generation, demanding, in this vein, data about both human and natural systems. Accordingly, ecological economics is naturally an ‘empirical science’, being based on direct observations to describe, understand and forecast, due to the complexity and uncertainty of these systems (considered, in the words of Ramos-Martin (2003), ‘representative of the phenomenological approach’). In this sense, empiricism seems to have a natural niche in the framework of ecological economics and this perception may, at least in part, explain the positive evolution of the empirical-related studies (involving ‘empirical’, ‘formal and empirical’, and ‘empirical and appreciative’).

Based on the evidence on the type of methods underlying the papers analyzed, we could argue that they seem to reflect not so much the ‘formalization turn’, which had in the meantime occurred in the top-ranking journals in economics (Cruz and Teixeira, 2010), but rather an ‘empirical turn’ where testing and validating theory with empirical analysis stand as central to the scientific field.

Crossing types of papers with their influence (measured by citations), we observe somewhat awkwardly (Fig. 5) that ‘seminal’ papers have a marked incidence of ‘appreciative’ and above all ‘survey’ types – ‘seminal’ papers present a share of surveys at around 10%, whereas the corresponding share for ‘All’ papers is 2.5%. In the



**Fig. 4.** Papers published by type in Ecological Economics (EE), 1989–2009. *Note:* The classification of the type of each article was based on the analysis of the full article available from Science Direct. Source: Authors' computations based on the all the articles published in EE gathered from Scopus in February 2010.



**Fig. 5.** Papers published by type in Ecological Economics (EE), 1989–2009. *Note:* The classification of the topic of each article was based on the analysis of the full article available from Science Direct. 'Seminal' papers are those that have 100 or more citations; 'Widely-cited papers' are those that have 30 or more citations (it includes 'Seminal' papers). Source: Authors' computations based on the all the articles published in EE gathered from Scopus in February 2010.

case of 'appreciative' papers the shares are, respectively, 25.0% and 21.7%. In the case of the 'widely-cited' papers, the situation is analogous but the differences are less marked. This, as we will detail ahead, is closely related with the fact that 'Theory building' papers present an above-average share of 'appreciative' papers.

4.3. Crossing Themes and Types

Crossing topic and type of papers (Fig. 6) we can see that 'Theory building', 'Values' and 'Trade and Environment' present above-average ('All') shares of 'appreciative' (respectively, 50.9%, 48.4% and 30.8% vs. 21.5%), markedly above-average/'All' (21.5%). Moreover, 'formal' papers are especially over-represented in the topics 'Theory building' (25% vs. 13.7%), 'Technical change and the environment' (19.7% vs. 13.7%) and, to a lesser extent, 'Methodological issues' (16.8% vs. 13.7%).

The incidence of 'formal and empirical' papers is especially noticeable in '(E)Valuation' (69.1% vs. 41.9%) and 'Methodological issues' (51.3% vs. 41.9%). Papers on 'Policies, governance and institutions', 'Trade and the environment', and 'Production, consumption and sustainability' present a larger (than the average/All) share of the 'Empirical' type (respectively, 20.7%, 23.1% and 23.1% vs. 13.9%).

Additional insight can be brought by crossing type and topic (Fig. 7). 'Formal' type papers fall essentially within the 'Theory building' topic (31% vs. 17.2% average), whereas 'Formal and empirical' are predominant in 'Valuation' (22.8% vs. 13.8%) and 'Methodological' themes (26.7% vs. 21.8%), whereas 'Production, consumption and sustainability' is slightly above the average (12.6 vs. 11.3%). Topics that are mainly empirical fall under 'Policies, governance and institutions' (22.7% vs. 15.2%) and 'Production, consumption and sustainability' (18.8% vs. 11.3%), while the 'Theory building' theme stands first in the 'Appreciative' type (40.1% vs. 17.1%). 'Surveys' have greater incidence under

'Theory building' (26.6% vs. 17.1%), 'Values' (6.3% vs. 2.5%), and 'Technical change and the environment' (6.3% vs. 2.4%).

5. Conclusions

In the present paper, a descriptive and exploratory bibliometric exercise was performed based on the analysis and interpretation of all (2533) the articles published in Ecological Economics from 1989 to 2009. Some of our key findings are worth highlighting as they contribute to the characterization of the field and provide some pointers as to whether ecological economics, viewed through the lens of EE, has evolved towards a post-normal science.

One first core result is the predominance of certain research topics, namely, 'Methodological issues' (21.8%), 'Policies, governance and institutions' (15.2%) and 'Valuation' (13.8%), which observed furthermore an increase in relevance over time. It is important to underline that the evolution of these three topics is to some extent interconnected. This outcome is perfectly in line with the view that ecologic economics is a policy-driven science (Shi, 2004) and that, consequently, it is intrinsically an applied science which intends to play a role in promoting the quality and the best performance of environmental governance in a very uncertain context. Given that this is a continuous challenge as ecosystems and associated human activities co-evolve and responses to management practices also change (Holling, 1998), (distinct and complementary) methodologies are needed for a myriad of processes (e.g., planning, discovery of new tools, new ways to define the problem, as well as policy instruments and a time frame for implementation, and their impacts on income and welfare distribution). Methods are also needed to assess alternative models of individual behavior and to operationalize sustainability (Illge and Schwarze, 2009), as well as new insights on the links between behavior, environment and policy (van den Bergh et al., 2000). Additionally, the trend observed in 'Methodological

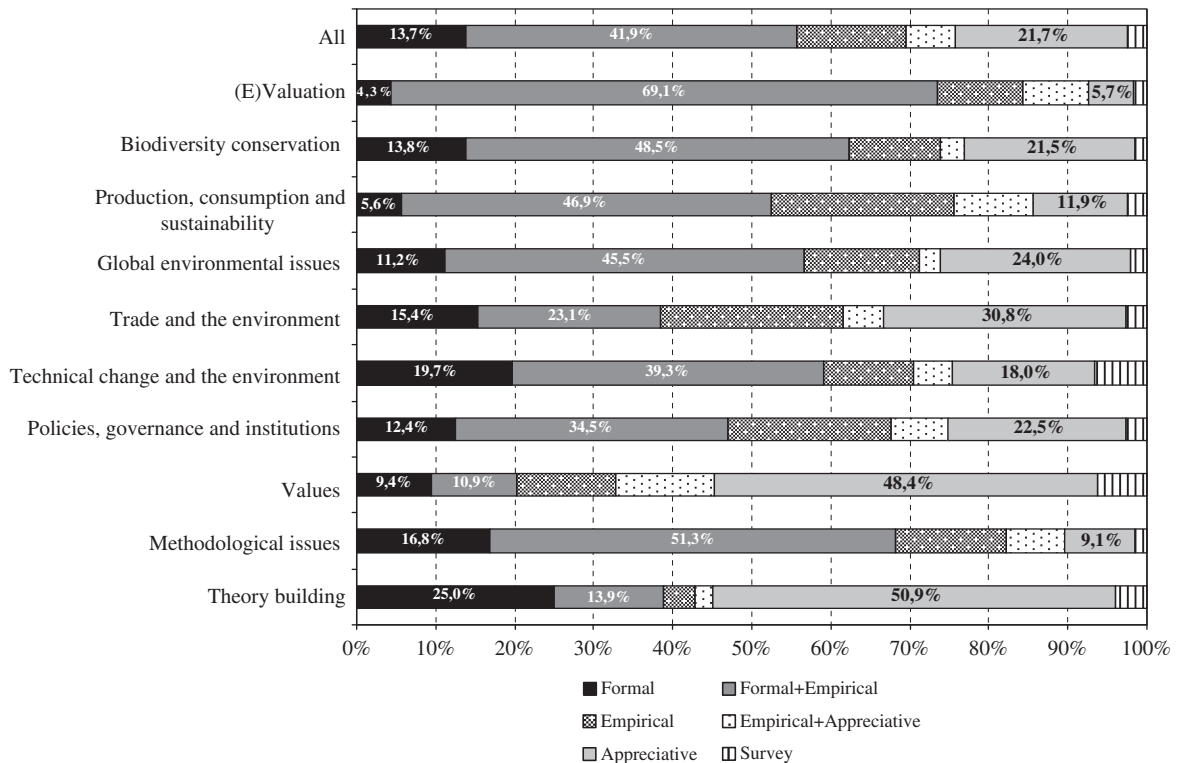
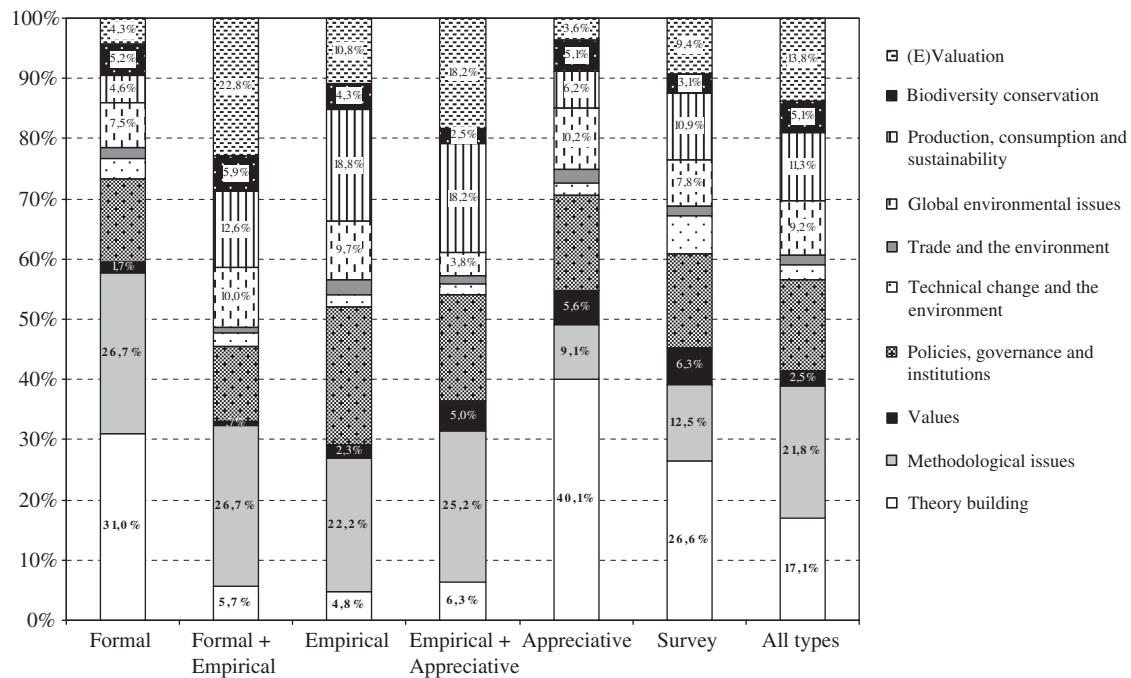


Fig. 6. Papers published by theme and type in Ecological Economics (EE), 1989–2009. Note: The classification of the topic of each article was based on the analysis of the full article available from Science Direct. 'Seminal' papers are those that have 100 or more citations; 'Widely-cited papers' are those that have 30 or more citations (it includes 'Seminal' papers). Source: Authors' computations based on the all the articles published in EE gathered from Scopus in February 2010.



**Fig. 7.** Papers published by type and theme in Ecological Economics (EE), 1989–2009. *Note:* The classification of the topic of each article was based on the analysis of the full article available from Science Direct.

Source: Authors' computations based on the all the articles published in EE gathered from Scopus in February 2010.

issues' is not detached from the broader perspective of ecological economics on the relation between the environment and human behavior in itself, which also has implications on the interaction between 'valuation issues' and methodological reflections, due to the openness of new approaches to the appropriate methodology to value biodiversity and environmental goods and services. 'Valuation' also emerges as a prominent issue in ecological economics research, comprising a central issue in environmental economics (Perkins, 2003). The evolution of the 'Valuation' topic had captured growing interest in developing better frameworks and methods to tackle valuation with new approaches. For instance, estimates associated to the value of ecosystem services that can be used in benefit-cost analyses give more support to policies regarding environmental protection. Thus, as Ehrlich (2008) notes, such research is of great practical and political importance.

A second core result is concerned with the 'emergent' themes of research within ecological economics. Although, as mentioned earlier, 'Policies, governance and institutions' is a prominent topic within the field over the time period in analysis, its subtopic, 'Collective action', can be considered an emergent theme. The awakening of ecological economics to issues regarding participatory governance and collective action is in line with the emphasis on this topic in other scientific fields with emerging literature on community empowerment, and the outcomes and constraints of participation (Fung and Wright, 2001). Given the newness of research on this matter, we have only limited knowledge on its outcomes when related with environmental and ecosystems management. This provides a new foundation for exploring and incorporating new scientific information on bottom-up participation, adaptive management participation, based on both conceptual and empirical research within ecological economics. As Ramos-Martín (2003: 392) underlines "... in ecological economics, as a post-normal science, policy is ... seen as a social steering mechanism implying the need to engage all stakeholders in reaching consensus", that is, involves a participatory process. Further research however is needed to highlight the conditions for participation as an efficient solution to resource allocation problems, its effects on equity and social justice, and its

effectiveness in reaching the goals of public policy or sustainable development.

Other emergent topics in ecological economics are 'Technical change and the environment' and 'Values'. 'Values' may be considered an 'expectable' emergent topic, since ecological economics claims to be grounded on a value-commitment to rethink the relationship between nature and humans, and to know how to live sustainably within the limits of the global ecosystem (Söderbaum, 1999), having arisen as "[a] framework for the ethical analysis of intertemporal and interspecies choice" (Proops, 1989: 62). This commitment raises meaningful issues related to human thoughts, feelings, actions and behaviors in light of eco-ethics (Kinne, 2002). Indeed, compared to the neoclassical environmental view, the ecological economics perspective is found to be more concerned with considerations of intergenerational justice, and value-related issues showing that economics cannot be a value-free science (Illge and Schwarze, 2009). Albeit the modest weight in terms of published papers in EE, 'Technological change and the environment' is fertile ground for growth due to its relation with sustainable development and the role it plays in anticipating consequences of implementing innovations. Moreover, it is an unavoidable issue in the relationship between ecological economics and the needs of public policy management.

A third and final core result is linked to the issue of formalism and empiricism. We observe that exclusively 'Formal' papers lose relevance, not because formality has decreased, but because ecological economics is attempting to couple scientific rigor with knowledge of reality, reflected in the increase of 'formal and empirical' type papers mentioned previously. Contrary to other scientific fields where the evolution is towards an increase in appreciative (e.g., regional – Cruz and Teixeira, 2010) or exclusively formal (e.g., evolutionary economics – Silva and Teixeira, 2009) type papers, ecological economics revealed an 'empirical turn', with a marked increase in 'formal and empirical' type papers. The increased importance of papers based on 'Formal and empirical' methods of analysis, allied to the growing weight of 'Methodological issues', reveals that ecological economics has sought to broaden its methodological body to support



the progress of the field and not lose sight of the reality it intends to study. Moreover, the increased importance of policy- and values-related research mirrors the specificity of the field, which conveys the interdependence of the economic, biophysical and social worlds, thus comprising a relativist and formal/empirical approach to science.

A good theory encompasses, among other aspects, 'breath', 'analytical utility', 'depth', 'relevance', and 'innovation' (Gerring, 2001: 89–117). Seen in this light, the evolution of 'Values', 'Technological change', 'Methodological issues', 'Policies, governance and institutions' (and 'Collective action' within this), and 'Valuation', in addition to the noticeable increase of 'Formal and empirical' type papers, indicate that ecological economics is finding a masterful way to improve its standing as a 'good theory', a science towards action, "a tool at the service of knowing" (Cook and Brown, 1999: 388), with a pragmatic focus on enabling action and developing reliable competences for decision-making.

Summing up, ecological economics is evolving unambiguously towards a post-normal science, at least through the lens of EE. A final remark, however, is required. The avid debate on the status of ecological economics should not detract from the need for further research to broaden our understanding of some of humankind's most pressing problems. A single yet quite compelling example suffices here. According to our exploratory bibliometric exercise, the issue of poverty is only tackled in 1.4% of the papers published in EE. As Ehrlich (2008) insightfully observes, more research is needed on ways to avoid the apparent perpetuation of the 'vicious cycle' between population, poverty and environmental degradation.

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