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The Past and Future of Evolutionary Economics: Some Reflections Based on New Bibliometric Evidence

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ABSTRACT

The modern wave of 'evolutionary economics' was launched with the classic study by Richard Nelson and Sidney Winter (1982). This paper reports a broad bibliometric analysis of 'evolutionary' research in the disciplines of management, business, economics, and sociology over 25 years from 1986 to 2010. It confirms that Nelson and Winter (1982) is an enduring nodal reference point for this broad field. The bibliometric evidence suggests that 'evolutionary economics' has benefitted from the rise of business schools and other interdisciplinary institutions, which have provided a home for evolutionary terminology, but it has failed to nurture a strong unifying core narrative or theory, which in turn could provide superior answers to important questions. This bibliometric evidence also shows that no strong cluster of general theoretical research immediately around Nelson and Winter (1982) has subsequently emerged. It identifies developmental problems in a partly successful but fragmented field. Future research in 'evolutionary economics' needs a more integrated research community with shared conceptual narratives and common research questions, to promote conversation and synergy between diverse clusters of research.

Keywords: evolutionary economics; evolution of science; bibliometrics; co-citation analysis; Richard Nelson; Sidney Winter.

1. INTRODUCTION

After decades when the word was taboo in the social sciences, since 1980 the word 'evolution' and claimed 'evolutionary approaches' have proliferated, particularly in areas related to business and innovation research.[1] From economics (Boulding 1981; Nelson and Winter 1982, 2002; Friedman 1991; Hodgson 1993, 1998, 1999; Nelson 1995; Witt 2003), the terms 'evolution' and 'evolutionary' have spread to other disciplines including organizational, innovation and management research (Aldrich and Ruef 2006; Durand 2006). Some scholars (Aldrich 1999; Geroski 2001) have argued for a meta-theoretical 'evolutionary perspective,' to express the

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conceptual core and unite separate disciplinary approaches. But as yet there is no agreement on this core.

Modern ‘evolutionary economics’ of the Nelson-Winter variety has had more impact on research in business schools and departments of innovation studies than in departments of economics. This is confirmed by evidence (including some provided here) that it receives more citations from business and management journals than from core journals of economics. This is neither surprising nor necessarily alarming, as the analytical perspectives of mainstream and evolutionary economics are quite different. But this bibliometric study also confirms the fragmentation of developments in evolutionary economics, and highlights problems for this stream of research.[2]

Because of changes in the character of mainstream economics and the growth of interdisciplinary academic arenas, such as business schools, many practitioners of Nelson-Winter type ‘evolutionary economics’ emigrated from departments of economics. This migration was most pronounced in the United States and other Anglophone countries, where business schools expanded rapidly. But the development of business schools was not uniform globally, and other countries tell a different story. Notably, in Italy and Germany, for example, evolutionary economics retains a stronger footing in departments of economics.

Residence in business schools, departments of innovation studies, or departments of science policy, created both opportunities and problems for the theoretical development of this field. The opportunities and successes are apparent in the rapid impact of ‘evolutionary economics’ in empirical studies of technological change, national innovation systems, and science policy (Dosi et al. 1988). On the other hand, theoretical cohesion and communication are more difficult to develop with researchers located in multiple disciplines or sub-disciplines. In such contexts, a key developmental problem for evolutionary economics was that of enhancing its theoretical core through trans-disciplinary conversations.

These trans-disciplinary features (being partly located in business schools and other interdisciplinary institutions) give evolutionary economics a unique character. The lack of a consensus over a clearly-identified theoretical core, combined with the well-known communication barriers between disciplines, mean that the standard sociology of scientific disciplines (Whitley 1984, 1986) is inadequate to deal with evolutionary economics. As Anthony Van Raan (2000) argued, bibliometric analysis can at least have a preliminary diagnostic role in dealing with the problems of inter-disciplinarity, by making communicative ‘maps’, identifying key actors, works and research areas, and showing structural changes in the field through time.

Our analysis helps to assess the nature and scale of the problems for ‘evolutionary economics’. Its theoretical fragmentation has been noted by other authors, but our analysis is more extensive. We analyse published ‘evolutionary’ research in the fields of business studies,

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[2] Winter (2014) depicted evolutionary economics as occupying a ‘beachhead’ within economics. But Stoelhorst (2014) pointed out that the bibliometric and other evidence shows its greater presence within management and business.

economics, and sociology by combining co-citation analysis (Small 1973; Griffith et al. 1974) with cluster and document centrality analysis.[3]

No previous bibliometric study in this research area is as large and systematic as ours. Two earlier studies are confined to evolutionary economics (Dolfsma and Leydesdorff 2010; Silva and Teixeira 2009); Dolfsma and Leydesdorff (2010) addressed research linked to the *Journal of Evolutionary Economics* only; Witt (2008) built on an opinion survey of meanings of the word 'evolutionary' adopted by users in the field. Another study confined itself to innovation and technology research in the context of evolutionary economics (Verspagen, Bart and Werker 2003). Bhupatiraju et al. (2012) applied network analysis to a citation database confined to the fields of entrepreneurship, innovation studies, and studies in science and technology. While these three fields have links with 'evolutionary economics' they exhibit independent trajectories and are no more than segments of its whole field.[4]

Only two earlier systematic reviews take a longitudinal bibliometric approach and attempt to show the evolution of the field through time (Dolfsma and Leydesdorff 2010; Silva and Teixeira 2009). Dolfsma and Leydesdorff (2010) consider the years 2000-2005 and 7534 journals citing or cited by the *Journal of Evolutionary Economics.* Silva and Teixeira (2009) addressed the 1958-2008 period and use 2,510 journal articles for their survey.

In comparison, our study covers 1986-2010. We accessed 8,474 articles, which in turn cited 349,750 further usable works. This is by far the largest bibliometric study of the 'evolutionary' field to date. This is also the first systematic bibliometric analysis covering economics, sociology, management, and business. Because of its multi-disciplinary scope and timespan, it is able to address the development of such key problems as fragmentation and disciplinary division, to an unprecedented depth and degree. In particular, the nodal role and lack of development of immediate offshoots from Nelson and Winter (1982) is less clear in earlier studies.

Our analysis maps the research field, including the most influential authors, publications and research areas. It identifies a diversity of 'evolutionary' research clusters, of which few cross disciplinary boundaries. A crucial problem highlighted by our study is for this 'evolutionary' field to maintain a common research agenda and momentum across these boundaries. Loose and vague terms such as 'evolution' and 'selection' are insufficient to retain connectedness and

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[3] The widening our focus of research to additional disciplines (such as politics and history) would have limited our ability to study the structure of the field effectively. Increased heterogeneity would have made the identification of different research streams trickier. Also our software restricts the number of articles and the number of cited pieces of work. With about 350,000 potential citation objects we are already near the current performance limits of the Sitkis software. As shown in Figure 1, by a good margin the most important areas using 'evolutionary' terminology are management, business and economics.

[4] Bhupatiraju et al. (2012) found that citations between the fields of (i) entrepreneurship, (ii) innovation studies, and (iii) studies in science and technology are scarcer than citations within the fields. Although the three fields share research topics and themes, they have developed largely on their own and in relative isolation from one another. This further confirms the problem of spanning different research communities.

interdisciplinary conversation, while enhancing theoretical development, across a highly diverse field of study.

This essay has three further sections. Section two gives an overview of our bibliometric analysis of the 'evolutionary' field and draws out implications for 'evolutionary economics'. Section three addresses the problems of identity and strategy for 'evolutionary economics'. Section four offers a further discussion and concludes the argument. The Appendix outlines the bibliometric techniques employed.

2. RESULTS OF THE BIBLIOMETRIC ANALYSIS

Figure 1 portrays the rapid rise since 1980 in research employing 'evolutionary' terminology. It reveals its particularly strong usage in management, business, and economics. This 'evolutionary' upsurge reflects the growing influence of the sets of ideas to which the term was attached. We do not claim that all uses of 'evolutionary' terminology can be described as 'evolutionary economics'. We cast the net widely to capture the broader context. Within this we show the supreme nodal significance of Nelson and Winter's (1982) work.

An important institutional factor to take into account is the rapid growth of business schools after 1980, particularly in the US but also elsewhere.[5] Our co-citation analysis shows how the seminal and nodal work of Nelson and Winter (1982) has been linked most strongly to areas of business-related research. As discussed in the following section, its success is partly due to its implantation in business schools and other multi-disciplinary milieux.

Figure 1**Error! Reference source not found.** about here

Our bibliometric analysis covered five five-year sub-periods, from 1986 to 2010. For brevity we present figures relating to the 1986-1990 and 2006-2010 sub-periods, omitting those intervening. But we do also present results for the whole 1986-2010 period. We use the following nomenclature to refer to clusters:

[5] In the US, for example, the number of graduate degrees (masters and doctorates) in business increased from 55,775 in 1980 to 77,769 in 1990, 112,726 in 2000, and 170,498 in 2009. By comparison, the number of US graduate degrees in 'social sciences and history' were 15,406, 14,644, 18,161 and 23,474 in those same years (US Census Bureau 2012). *The Economist* (1996, p. 54) reported that 'the number of business schools in Britain has risen from 20 in the early 1980s to 120' by 1996.

Cluster A	Industrial evolution and product life-cycles
Cluster B	National innovation systems
Cluster C	Economic sociology
Cluster D	Endogenous growth theory
Cluster E	Qualitative research methods
Cluster F	Socio-genetic evolution
Cluster G	Evolutionary game theory
Cluster H	Genetic algorithms
Cluster I	Organizational ecology
Cluster J	Evolution of technology and dominant designs
Cluster K	Resource and capability-based views
Cluster L	Organizational learning and behavioural approaches
Cluster M	New institutional sociology
Cluster N	Transaction cost economics

The clusters were formed via our bibliometric algorithm. (See the Appendix.) The choice of titles for the clusters was based on the nature of the key works that dominate each cluster, often using standard terminology. Note that relatively few of the clusters span established disciplinary boundaries. Clusters C, I and M are largely if not entirely confined to sociology. Clusters D and G are almost entirely, and Cluster N is largely, confined to economics. Other clusters relate to specialist groups of researchers with their own institutional niches in academia. So Clusters A and J relate to technology studies, Clusters I and L to organization science, and Cluster K to business strategy.

Figure 2 about here

Figure 2**Error! Reference source not found.** maps clusters for 1986-1990, when modern evolutionary approaches were just emerging.[6] Only one cluster, Cluster F on socio-genetic evolution, was well-formed. The field was dominated by two classic and nodal works: Nelson and Winter (1982) and Axelrod (1984). Axelrod (1984) explores conditions under which self-interested agents will spontaneously cooperate. It fell inside Cluster F and was linked to related works in socio-biology (Wilson 1975), evolutionary biology (Darwin 1859; Dawkins 1976; Trivers 1985), and evolutionary anthropology (Boyd and Richerson 1985).

By comparison, works around Nelson and Winter (1982) were more loosely connected, and its ties with other documents were weaker. This group was populated by older classics such as Alchian (1950), Cyert and March (1963), Friedman (1953), Keynes (1936), Schumpeter

[6] In Figures 2-4, the size of the node represents the relative citing frequency of the document. The thickness of the line connecting two documents indicates the strength of the link between the documents.

(1934), Simon (1969), and Veblen (1899). Adjacent were a few emerging nodes of research, particularly transaction cost economics around Williamson (1975), and organizational ecology around Hannan and Freeman (1977). Evolutionary ideas had not yet become strong in organizational and management research.

Moving forward to the later sub-period for comparison, by 2006-2010, the popularity of evolutionary views had increased considerably. Still frequently cited, Nelson and Winter (1982) stood near the centre of a heterogeneous constellation of clusters and research areas.

In the later sub-period, management and organization related research streams had much gained in influence. The largest and most central clusters – Cluster K on resource and capability-based views, Cluster J on the evolution of technology and dominant designs, Cluster I on organizational ecology, Cluster M on new institutional sociology, plus Cluster L on organizational learning and behavioural approaches – all remained part of management and organizational research tradition. Relatedly, Cluster C on economic sociology (Granovetter 1973, 1985; Burt 1992), which included work on networks, also emerged as a clear unit, but now remote from the similarly sociological Cluster I. The increasing popularity of network-related research is also visible.

Figure 3 about here

On the fringes of this constellation were several other economics research streams. As in preceding sub-periods, Cluster G on evolutionary game theory remained remote from the main streams of evolutionary research, with the exception of its slight links with Cluster F. Cluster N on transaction cost economics (Coase 1937; Williamson 1975, 1985) endured on the fringes of the evolutionary research field.

Figure 4 presents the structure of evolutionary research during the whole period of 1986-2010. The enduring nodal role of Nelson and Winter (1982) is impressive. There is a significant connection with Dosi's (1982) seminal essay on technological paradigms plus various works on organizational learning and behaviouralism (March and Simon 1958; Cohen and Levinthal 1990; March 1991). Rather than creating an immediate cluster of closely related and spin-off research, the seminal role of Nelson and Winter (1982) has been to serve as a point of reference for other clusters. It seems that Nelson and Winter's work stimulated a dispersed array of related but detached enquiries, but did not lead to the further development of a closely-related and distinctive evolutionary theory in that genre (Witt 2008; Silva and Teixeira 2009).

Overall, in 1986-2010 the work of Nelson and Winter (1982) was most closely linked with Cluster L on organizational learning and behavioural approaches, Cluster I on organizational ecology, Cluster M on new institutional sociology, and (more remotely) Cluster B on national innovation systems. Strikingly, this work is taught infrequently in departments of economics and it is much more prominent in business schools. Further evidence of the detachment of Nelson-Winter style evolutionary economics from its originating discipline is the absence of any significant interchange between evolutionary economics and evolutionary game theory (Hodgson and Huang 2012). There are links between Nelson and Winter (1982) and the work of Coase (1937) and Williamson (1975, 1985), but transaction cost economics has also moved its centre of gravity away from economics and towards business schools, as evidenced by a detailed longitudinal analysis of references in Williamson's work (Pessali 2006).

While Nelson and Winter's pioneering work remained relatively marginal in its source discipline of economics (particularly because of the increasing emphasis on mathematical theory in mainstream economics), it became very popular in management. Nelson and Winter (1982) became a central work for a while in clusters J and L; much of the research in these clusters is produced in business schools.

Figure 4**Error! Reference source not found.** about here

In the years 1983-1989 inclusive, there were 142 citations to Nelson and Winter (1982) from journals listed under 'economics' compared to 82 citations from journals in business and management. In 1990 the number of citations to this book from economics was equal to those from business and management journals. Subsequently citations from business and management increased rapidly, while the number of citations from economics grew much more slowly. In the years 2006-2012 inclusive, there were 515 citations to this work from journals listed under 'economics' compared to 1766 citations from journals in business and management.

In sum, in the 1980s the main arena for discussion of Nelson and Winter (1982) was in economics, but by 2006 citations to it from journals in business and management were more than three times greater than those from economics. As the evolutionary economics of Nelson and Winter (1982) has become more influential, it has become detached from mainstream economics while being cited much more in the business school sector.[7]

But the loss of a single home discipline has in turn created severe problems of unity and conversation across multiple clusters and research programs. Analysis of curricula in business schools have long noted very limited success in linking separate disciplines, except for the use of common mathematical and statistical tools (Dunning 1989, Starkey and Madan 2001).

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[7] But further evidence suggests an even deeper divergence. The three journals citing Nelson and Winter most often since 1983, which are listed under 'economics' in the Thomson-Reuters database, are *Industrial and Corporate Change* (accounting for 3.0% of all citations to Nelson and Winter (1982)), the *Journal of Evolutionary Economics* (2.6%), and the *Journal of Economic Behavior and Organization* (2.2%): none of these is by any account a mainstream journal of economics. In the top ten, the seven other journals citing Nelson and Winter most since 1983 are *Research Policy* (5.7%), the *Strategic Management Journal* (5.7%), *Organization Science*, (3.7%), *Management Science* (2.1%), the *International Journal of Technology Management* (1.9%), and the *Journal of Management Studies* (1.8%).

Both individual sub-periods and 1986-2010 overall provide strong evidence that the disciplinary boundary between economics and sociology has affected the linkages. In particular, work in Clusters I and M was not as close to Nelson and Winter's nodal work as it could be, despite the strong evolutionary theme to much work in organizational ecology (Hannan and Freeman 1989) and the work on the evolution of organizations by Aldrich (1999) and others.

All sub-periods show an enduring disconnection of research gathered around Nelson and Winter (1982), on the one hand, from evolutionary developments in anthropology (Boyd and Richerson 1985), evolutionary psychology, work on the evolution of cooperation (Axelrod 1984), and from Darwin (1859) himself, on the other. Given that the core theory of Nelson-Winter style evolutionary economics may benefit from further development, these lively, theoretically-rich and relevant evolutionary literatures would be obvious places to turn. So far this has not happened to any great degree.

While our analysis identifies Nelson and Winter (1982) as an enduring nodal point in the evolution of the field, our bibliometric diagnosis suggests that this work has not inspired major subsequent development of the core evolutionary theory. Instead it serves as an historic 'concept marker' (Case and Higgins 2000) with 'conceptual symbolism' (Small 2004, p. 71) for a diverse, inter-disciplinary and fragmented field of specialized 'evolutionary' studies of particular economic and business phenomena. This also suggests that this 'evolutionary' field lacks an integrated, developing meta-theoretical perspective, which can help to generate shared ideas and research questions for empirical investigation.

3. PROBLEMS OF IDENTITY AND STRATEGY

Any viable discipline or school of thought must have a *raison d'être*. This can be defined in terms of

(a) the study of a specific zone of enquiry or a set of phenomena,
(b) the promotion or development of a particular theoretical approach (such as utility maximization and equilibrium),
(c) the promotion or development of a set of analytical techniques (such as econometrics or game theory), or
(d) the promotion or development of policies in a defining problem area (such as the environment, peace, or economic development).

The *raison d'être* may consist of one of these, or a combination of more than one.

Starting with the first option, 'evolutionary economics' has not made a major effort to define itself in terms of (a) – a specific zone of enquiry or a set of phenomena in the real world. While it has emphasized innovation and technological change, this is because they are often side-lined in mainstream theory – not because this zone of enquiry is regarded as sufficient to define the essence of 'evolutionary economics'. Indeed the term 'evolutionary economics' has been promoted by protagonists in many other contexts.

Turning to (d), although Nelson-Winter type 'evolutionary economics' has made important policy contributions, particularly in regard to science and technology, contributions to policy development do not themselves define 'evolutionary economics'. Hence (d) alone does not provide a *raison d'être,* even if it has been a major area of contribution.

This leaves us with (b) or (c) as potential *raisons d'être* for 'evolutionary economics'. Different opinions may exist on this. A core theoretical approach is evident in Nelson and Winter (1982). On the other hand, some evolutionary economists have adopted and promoted specific techniques, such as Stuart Kauffman's (1995) NK model. But in neither case does our bibliometric evidence point to extensive post-1982 development of these theories or techniques. Whatever the *raison d'être* of 'evolutionary economics', our bibliometric analysis fails to detect its broad, generic, developmental traces in post-1982 publications.

This does not mean that there have been no core theoretical developments in this field since 1982. Several important ones come to mind. But none of these have established strong bibliometric traces in the citation record. Unfortunately, no development has yet created strong and enduring resonance.

The complete explanation of this lacuna would require a major research project, beyond the compass of a single paper. Consider one possible reason among others. We hypothesize that the migration of 'evolutionary economics' from departments of economics to business schools and other multi-disciplinary institutes, has exacerbated its ongoing fragmentation and thwarted the development of its identity, in terms of theory or technique ((b) or (c)). This migration also created great opportunities, particularly on the policy front. But policy influence simply helped to postpone the development of a core identity.

Success in these inter-disciplinary milieux has been a major blessing, but also in part a curse. Akin to oil-rich countries enjoying prosperity but failing to invest revenues in long-lasting and productive assets such as infrastructure and education, 'evolutionary economics' has failed to invest in a viable theoretical core or provide another suitable *raison d'être*. Over thirty years since the publication of Nelson and Winter (1982), and without adequate further theoretical development or other reinvigoration, there are diminishing marginal returns in an inexorably fragmented and specialist field.

Science is a social process and it works partly through the creation and ongoing amendment of established positions in a scientific community (Kuhn 1962, Kitcher 1993). It is a social process involving 'epistemic communities' and institutionalized 'machineries of knowing' (Knorr-Cetina 1981). Sufficient variety of opinion in this community is also necessary for advance, so that inadequate or flawed beliefs can be challenged by alternatives. Variety and contestation are essential for progress.

Some sufficient (but not absolute) consensus is also required to avoid endless criticism and unceasing demolition of core beliefs (Kitcher 1993). It is impossible for individual scientists to challenge everything effectively. There are far too many theories and publications. Many things have to be taken on trust. Judgments of others have to be relied upon, often without detailed inspection. Lots of things have to be taken for granted. Otherwise science cannot progress.

But consensus has difficulties in academic communities that are trained to be sceptical and critical. To the extent that some consensus is necessary, it requires incentives to be sustained (Kitcher 1993). The leaders in the scientific community must have sufficient power over career opportunities, academic promotions, academic journals, and grant-awarding bodies to provide reputational, pecuniary, and other rewards for individuals to respect many existing scientific claims, and not to be overly-critical of its consensus. The obvious danger here is that the group becomes overly-conservative, rebuts much sensible criticism, and stifles innovation. This has happened in some disciplines. But the complete absence of consensus is also damaging: endless criticism and unrestrained innovation would inhibit cumulative advance in the healthiest areas of research. Hence, to a degree, institutionalized incentives for maintaining some consensus matter.

The Nelson-Winter wave of 'evolutionary economics' established some conversational forums and consensus-preserving institutions. They include the International Joseph Schumpeter Society formed in 1986. There are allied or sympathetic journals such as the *Journal of Evolutionary Economics* and *Industrial and Corporate Change.* These provided important, international, consensus-preserving incentives and helped to keep 'evolutionary economics' together, especially on a global scale.

But otherwise, and within particular universities, reputational and other incentives were underdeveloped. Having failed to capture major citadels of mainstream economics, 'evolutionary economics' took hold in multi-disciplinary environments with multiple incentive-providing academic networks and institutions. In such environments, most 'evolutionary economists' had to advance their individual careers in compartmentalized research fields such as innovation studies, business economics, science policy, or organization studies. Quite reasonably, no-one attempted to set up academic departments labelled 'evolutionary economics' with their own qualifications and teaching programs. But this consigned evolutionary economics to multiple environments, where incentives and structures were less aligned to its mission or interests.

As it moved into business schools and other interdisciplinary institutions, 'evolutionary economics' faced the crucial additional problem of establishing *interdisciplinary* mechanisms to generate fruitful conversation and sustain sufficient scientific consensus. But the necessary degree of consensus is more difficult to sustain in such contexts. Researchers have vested interests based on time investments and incentives – including those of promotion, status and publication – that are largely compartmentalized by the institutional and departmental structures of academia (Weingart and Stehr 2000). Specialisation within disciplines compounds this problem further. Any interdisciplinary research program has to provide additional incentives – including common questions of interest – to escape multiple, narrow, specialist confinements.

The success of 'evolutionary economics' in maintaining fruitful conversation among its practitioners has been very much against the stream. It is down to the enduring vitality of several international networks (including the International Schumpeter Society and allied journals) and some national associations. But the bibliometric evidence presented here reveals insufficient further development of a theoretical core. Studies of academic activity from the sociology of science suggest that additional institutionalized incentives are necessary.

4. FURTHER DISCUSSION AND CONCLUSION

This study charts the diversification and spectacular growth of 'evolutionary' research from 1986 to 2010. It reveals a combination of growth, diversification and deepening fragmentation, caused in large part by disciplinary boundaries that cannot be dissolved simply by the use of vague words such as 'evolution', 'evolutionary' or 'selection'. This diverse 'evolutionary' field has been described as an 'invisible college' (Verspagen and Werker 2003). But it has striking differences from 'invisible colleges' studied elsewhere. Classically the term applied to 'an elite of mutually interacting and productive scientists within a research area' (Crane 1972, p. 348). Although the 'evolutionary' field in economics, sociology and management has an elite group of highly-cited researchers, their works are also divided by disciplinary and sub-disciplinary frontiers. The identity and boundaries of its 'research area' are unclear. It is a peculiarly diverse and segmented elite, making relatively few shared references to core theoretical works appearing after 1982.

Consequently, 'evolutionary' work in economics, sociology and business has not generated enduring, trans-disciplinary questions for successful empirical or theoretical research. In this diverse context, the narrower stream of 'evolutionary economics' lacks an adequate theoretical 'hard core' in the sense of Imré Lakatos (1970). The bibliometric analysis clearly establishes that the work of Nelson and Winter (1982) is a dominant node in economics, management, and business, but there is a lack of subsequent identifiable literature developing a core theoretical framework. Its enduring presence among the citations in the field seems as much a ceremonial and 'symbolic payment of intellectual debts' (Small 2004, p. 71), as anything else.

Each individual cluster in the field manifests a high degree of historical path dependence and a good measure of isolation. Path dependence is itself susceptible to bibliometric study (Lucio-Arias and Leydesdorff 2008). The silo effect (Lewin and Volberda 1999) refers to an outcome of specialization and fragmentation, where sub-fields become less capable of reciprocal operation with related sub-fields. Our evidence suggests that evolutionary economics may be moving dangerously in this direction. Consequently, if evolutionary economics is to develop in the future it needs to find ways to (1) further facilitate inter-cluster communication, (2) promote complementary integration between clusters, and (3) generate prominent research questions with potential answers that are superior to those produced by rival approaches.

It is a longstanding claim that much innovation in science comes from the synthesis of ideas from different topics or disciplines (Peirce [1882] 1958, Koestler 1964, Laudan 1977). But scientific innovation requires not only diversity, but also a sufficiency of consensus and community, with a shared conceptual language, to make such synergy possible. Some consensus is also necessary to avoid continually overturning every established assumption or result.

One of the key problems is not lack of diversity but fragmentation and specialization. All scientific fields face the unrelenting challenge of what Eli Noam (1995, p. 248) calls the 'inexorable specialization of scholars' as research digs deeper and deeper into specific, separate problems (Blau 1994, Wenger 1998). Within the field of evolutionary economics, fragmentation and specialization have not been matched by fruitful development of over-arching theory, a common conceptual vocabulary, and common research questions promising answers that demonstrate the superiority of the approach.

Communication is inhibited by insufficient shared terminology. Organizational ecologists use some specialized vocabulary that differs from that of evolutionary economists. There is also the lack of a shared over-arching 'evolutionary' theoretical framework. Words such as 'evolution', 'co-evolution', 'evolutionary' or 'selection' are used in very different ways, with grossly insufficient attempts to establish shared meanings (Hodgson 2013; Dollimore and Hodgson 2014; Hodgson and Stoelhorst 2014).

An obvious longstanding candidate for a shared theoretical evolutionary framework, deploying sharper meanings of these terms, is the generalization of Darwinian principles to the socio-economic domain (Veblen 1898, 1899; Campbell 1965; Hull 1988). But work in this area has had little presence within Nelson-Winter type 'evolutionary economics' until recently and it is far from universally accepted (Aldrich et al. 2008; Stoelhorst 2008, 2014; Hodgson and Knudsen 2010; Breslin 2011; Hodgson and Stoelhorst 2014).[8]

Without such integrative developments, 'evolutionary economics' is likely to suffer further fragmentation, albeit with innovation and progress within the individual fragments. A core theoretical framework is necessary to show that the approach has improved answers to pressing research questions, to claim its superiority over rival approaches.

Some links have yet to be developed between evolutionary economics and other streams of evolutionary research. While evolutionary economists, organizational ecologists and institutional economists have often distanced themselves from narrow versions of rationality, and have been influenced by behaviouralists such as Herbert Simon (1957), much less attention has been given to evolutionary psychology (Cosmides and Tooby 1994; Buss 1999) and the evolution of cooperation (Hammerstein 2003; Bowles and Gintis 2011). The missing links with earlier classic works in this area such as Axelrod (1984) and Boyd and Richerson (1985) are clearly evident from our bibliometric analysis.

We offer no recipe for success, but 'evolutionary economics' needs a much clearer identity and *raison d'être.* Our bibliometric analysis identifies the failure to develop a prominent and widely-cited theoretical core. This is not to belittle the many achievements of evolutionary economics, but to point to gaps that may need to be addressed in the future.

[8] Murmann et al. (2003) is a symptomatic millennial reflection on the state and future of 'evolutionary' research in management and organization theory. This article illustrates the problems as well as the potentialities. Its authors mention the concept of 'selection' many times but fail to give it a sufficiently clear meaning. There is little elaboration of what is being selected, what are the selection mechanisms, and what kind of selection outcomes need to be identified. While pointing to the importance of empirical work, the key concepts to be deployed in analyzing reality remain vague. Immersion in empirics itself cannot serve as a research program, especially if it is conceptually blind.

APPENDIX: BIBLIOMETRIC METHODOLOGY

Bibliometrics involves the analysis of patterns that appear in the publication and use of documents, to shed light on the nature and development of a discipline.[9]

Citation analysis is a powerful tool for the identification of intellectual bases and underlying research streams (Usdiken and Pasadeos 1995; Pasadeos et al. 1998; Schildt and Mattsson 2006). Citation analyses divide into 'macro' approaches that focus on the overall structure of disciplines, and develop principles governing the evolution of science, and 'micro' approaches that describe retrospectively the structure and historical development of schools of research and their interdependencies (Gmür 2003). This study fits with the micro stream of research.

Criticisms of the use of citation analysis concern citation biases, a focus on only published articles and books, and the technical limitations and imperfections of citation indices and bibliographies (Macroberts and Macroberts 1989; Osareh 1996). With improved databases, some of these limitations have been ameliorated (Sillanpää 2006). Important limitations remain, but we have done our best to address possible biases and to remove errors from our extensive database.

Our approach combines co-citation and cluster analysis (Schildt et al. 2006; Sillanpää 2006; Schildt and Mattsson, 2006). Co-citation analysis reveals the closeness of two pieces of work in a common discourse. Cluster analysis and network analysis enable further structuring the research field under study. Our approach of highlighting the structure of the field by the means of both cluster analysis and network analysis (which produce highly similar results) mitigates the biases in any individual research method.

Data

We used data from the Social Science Citation Index (SSCI) of the Thomson-Reuters Web of Science, which is a massive multidisciplinary index to social sciences journals. It indexes over 1,720 journals across 50 social science disciplines; and individually-selected, relevant items from over 3,300 of the world's leading scientific and technical journals.

Within the database we conducted searches for the word *evolution* and its derivatives. Further searches confirmed the result of Dachs et al. (2001) that related search words (e.g. *Schumpeter*, *biological*, *biology*, *genes*) yielded a much smaller number of retrieved articles, compared to 'evolution' and 'evolutionary'. To narrow down the number of hits (over 20,000), and confine our study to business-related issues, we refined the search to cover documents related

[9] Bibliometric methodology has been employed in strategic management (Martinsons et al. 2001; Ramos-Rodriguez and Ruiz-Navarro 2004); economics (Cahlik 2000; Pieters and Baumgartner 2002); entrepreneurship (Ratnatunga and Romano 1997; Busenitz et al. 2003); organization studies (Usdiken and Pasadeos 1995); inter-organizational relationships (Sobrero and Schrader 1998; Parvinen 2003); marketing (Hoffman and Holbrook 1993; Pasadeos et al. 1998); management information systems studies (Culnan 1986); and research and development studies (Tijssen and Van Raan 1994).

to the following fields only: management, business, economics, and sociology. The search was further refined to cover articles only, thus excluding book reviews, notes and editorial announcements.

The start date of the searches was 1 January 1986 (the first accessible year on the Thomson-Reuters database) and the end date was 31 December 2010. Before 1986 much fewer articles discussing 'evolution' were published in the social sciences (Hodgson 1998). To identify changes. For the whole period we retrieved 8,474 articles. 217 were published during 1986-1990, 954 during 1991-1995, 1,637 during 1996-2000, 2,172 during 2001-2005, and 3,494 during 2006-2010. These were all possible citation sources.[10]

Sitkis computer software (Schildt 2004) was used to download data on possible citation objects from the Web of Science to a Microsoft Access database. The articles in the whole period cited another 373,848 texts, of which 24,098 were discarded by the program.[11] The program reported disregarded citations and all of these were checked manually. Most referred to newspapers, trade journal articles or statistics and were deemed tangential to this analysis. A small number of corrections were made.

Thomson-Reuters data are not entirely accurate. In the first 5-year sub-period, we went through all the citations manually and made any required corrections. But because the total number of references in other sub-periods exceeded 20,000, going through all of these was impossible. Schildt (2002) argued that correcting citation data for the top 20-50 authors or documents is sufficient to provide reliable and usable results. But we imposed higher standards.[12]

References made to reprints and book-editions were combined as references to one, original article or book. But citations to compiled book editions were left unaltered (Sillanpää 2006).

Analysis

A co-citation involves a link between two documents that is created by a later document (Griffith et al. 1974). A co-citation measures 'the frequency with which two documents are cited together' (Small 1973: 265). If two articles are cited in the same text, then they may be closely related to each other either because they are part of the same topic area or because their topic areas are closely connected (Small 1973; Cawkell 1976). Although some co-citations are between

[10] Data and charts for the 1991-1995, 1996-2000 and 2001-2005 sub-periods are available from the authors.

[11] The respective figures for the first sub-period were 5,700 with 384 discarded; for the second period 27,184 and 2,963; for the third period 45,774 and 2,974; for the fourth period 62,460 and 4,315, and for the fifth period 232,730 and 13,462.

[12] In the database covering the first 5-year period, the 512 documents that received at least 29 citations were checked and corrected. The level in the sub-database for the second 5-year period was set to five citations (top 463 documents), seven for the third period (top 575 documents), nine for the fourth (top 568 documents), and 12 for the fifth period (top 512 documents).

unrelated references, a sufficiently large sample of cited articles enables researchers to mitigate this problem (Schildt and Mattsson 2006).

Using Sitkis software, we produced a co-citation network for each sub-period. A threshold level, based on the frequency the citing articles cited the references, was used to exclude references that did not have a serious impact on the study (Schildt et al. 2006). A series of two dimensional (citer-cited) networks were then produced in order to determine the best threshold level. In a two-dimensional network, the citing articles were the first dimensions, and the cited texts acted as their affiliations. When the threshold was raised, the number of remaining cited documents decreased, and the number of citing articles also declined. After testing the series of networks, the threshold was set to a point at which lowering the threshold level by one would bring the maximum marginal increase in the number of cited articles. Below this threshold the heterogeneity of the cited documents increased considerably, leaving additional documents outside the core of the field.[13]

Next we normalized co-citation data in order to emphasize proximate relationships between similar references that are not cited as often as the most common references (Gmür 2003). The normalized co-citation strength measure, S, for individual pairs was calculated by means of the Jaccard index (Small and Greenlee 1980). The co-citation link strength *S(A,B)* between papers *A* and *B* is defined as follows

$$S(A,B) = \frac{a \cap b}{a + b - a \cap b}$$

where *a* represents the number of citations to document *A*, *b* the number of citations to document *B* and $a \cap b$ the number of co-citations of *A* and *B*.

We employed cluster analysis to classify objects into clusters that maximize homogeneity within clusters and heterogeneity between clusters (Culnan 1987; Hair et al. 1998).[14] We employed Johnston’s average-link hierarchical algorithm, as in the Ucinet 6 software (Borgatti 2002), to produce clusters from the co-citation network data. In the average-link algorithm, the distance between two clusters is the average dissimilarity between members (Borgatti 2002). According to Sillanpää (2006), the average-link method produces clusters more continuously than other hierarchical methods.

Ucinet Netdraw software was used to draw network figures from the co-citation network data for the sub-periods. To make reading of the networks easier, we reduced the number of

[13] Following Small and Greenlee (1980), we set thresholds with regard the popularity of references contained in the analysis, omitting information on cited documents that have a lower impact. Consequently, for the whole period, articles or books with at least 90 references were included in the analyses. For the first sub-period, the threshold level was set to five references, for the second to 15 references, for the third to 24 references, for the fourth to 28 references, and for the fifth to 40 references. The networks resulting from these analyses are available from the authors upon request.

[14] There are many different cluster methods and algorithms (Jain et al. 1999). The two most popular clustering approaches are ‘hierarchical agglomerative’ and ‘iterative partitioning’ (McCain 1990).

visible links by imposing an arbitrary cut-off level of co-citation strength. The links below the cut-off level were left out of the figures, as well as documents isolated by the procedure.[15] The Netdraw software then arranged the remaining documents according to geodesic distances.

We performed the cluster analysis for documents in co-citation networks for the sub-periods, and for the 1986-2010 period as a whole. As there is no unique way to identify clusters, their identification involves some interpretation: we used similarity levels calculated by the algorithm as guidelines. We set two rules for the identification of clusters from the tree diagrams. First, an independent cluster or sub-cluster must consist of at least two documents. Second, main clusters were separated at a similarity level that produced a moderate number of clearly identifiable clusters.[16]

[15] The cut-off level was set to 0.1 in the whole period, and in the two sub-periods discussed in the text.

[16] This procedure produced five clusters at a similarity level of 0.063 for the period 1986-1990. We divided two clusters into four sub-clusters, excluding four documents. For the period 2006-2010, we identified 11 clusters at a similarity level of 0.045 and five of them we divided into 12 sub-clusters. Three documents were excluded. For the whole period 1986-2010, we identified 10 clusters at a similarity level of 0.04 and three of them were further divided into nine sub-clusters. Six documents were excluded.

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Figures

Figure 1: ‘Evolutionary’ Publications in Management, Economics, Sociology and Politics

Number of publications in Thomson-Reuters Web of Science with ‘evolution’ or derivative in the title, abstract or keyword.

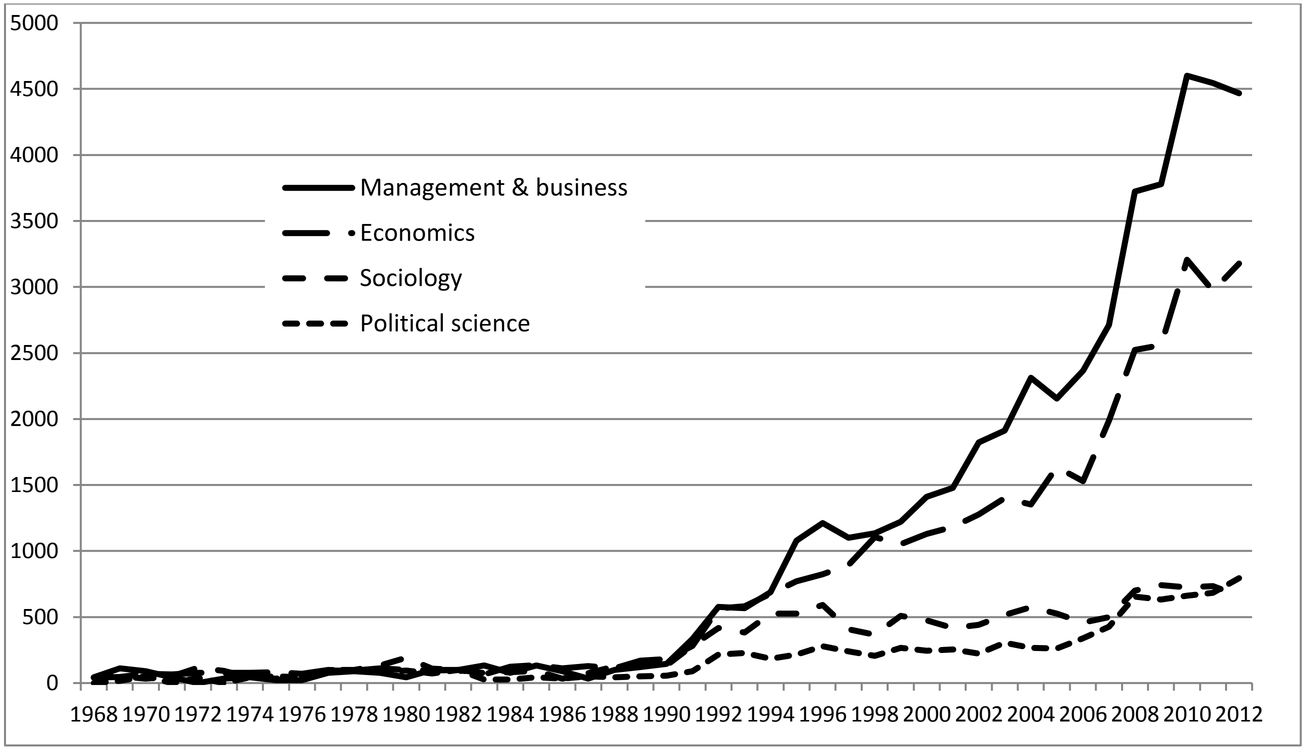

Figure 2: Clusters and Co-citations 1986-1990

In figures 2-4, the size of the node represents the relative citing frequency of the document. The thickness of the line connecting two documents indicates the strength of the link between the documents

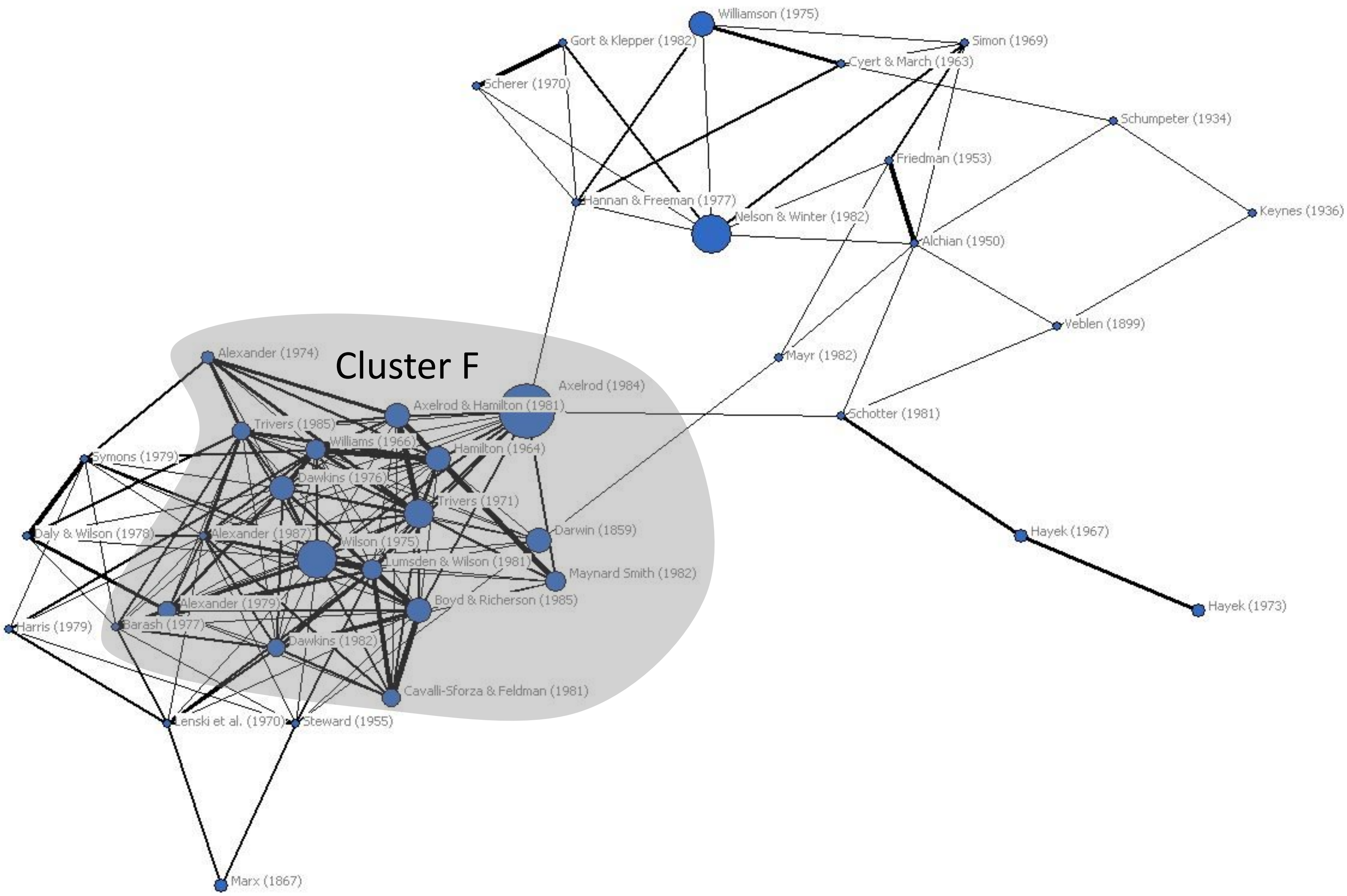

Figure 3: Clusters and Co-citations 2006-2010

In figures 2-4, the size of the node represents the relative citing frequency of the document. The thickness of the line connecting two documents indicates the strength of the link between the documents

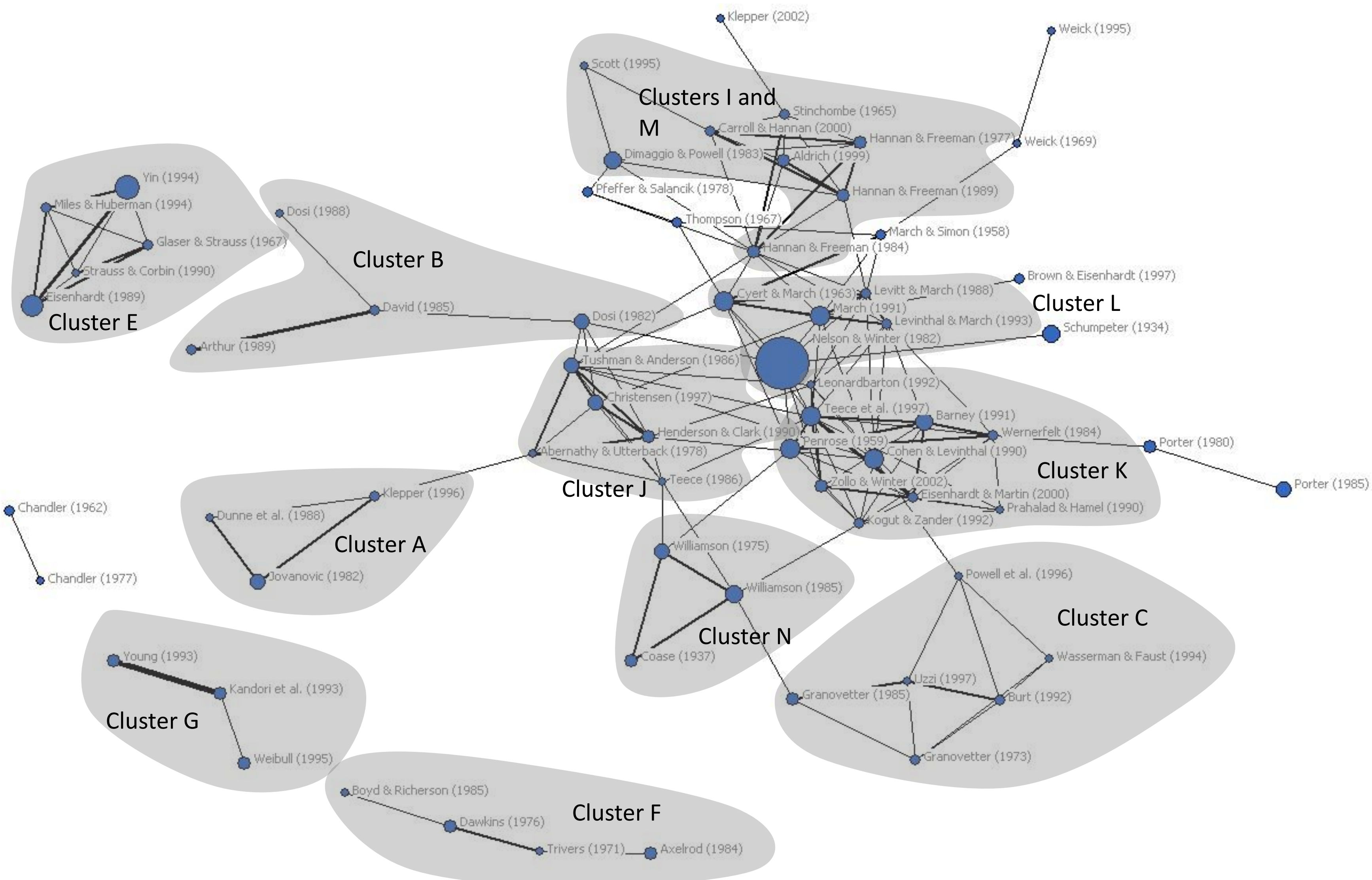

Figure 4: Clusters and Co-citations 1986-2010

In figures 2-4, the size of the node represents the relative citing frequency of the document. The thickness of the line connecting two documents indicates the strength of the link between the documents