Laboratory of Economics and Management
Sant'Anna School of Advanced Studies

Piazza Martiri della Libertà, 33 - 56127 PISA (Italy)
Tel. +39-050-883-343 Fax +39-050-883-344
Email: lem@sssup.it Web Page: http://www.sssup.it/~LEM/

LEM
Working Paper Series

Mapping Evolutionary Economics in Europe

Bart Verspagen *
and
Claudia Werker *

* *Ecis, Eindhoven University of Technology*

2003/08 **June 2003**

MAPPING EVOLUTIONARY ECONOMICS IN EUROPE

by Bart Verspagen & Claudia Werker

Ecis
Eindhoven Centre for Innovation Studies

Ecis, Eindhoven University of Technology
b.verspagen@tm.tue.nl, c.werker@tm.tue.nl

We are indebted to Dao Nguyen for valuable research assistance. We also acknowledge the useful contributions of our students at the Tema MSc programma of Eindhoven University of Technology: Marcel Bogers, Loes Bonnemayer, Willem Bouman, Inge van Baardwijk, Olga Huizing, Judith van Laarhoven, Joffry Maltha, Liesbeth Nix, Rene van den Oetelaar, Anke Verhagen, and Bas de Vries. They prepared three reports on the invisible college, and these were a valuable input in the analysis undertaken for this paper.

1. Introduction

Evolutionary economics is a relatively new branch of the social science that is concerned with scarcity. The term is now used by an increasing number of scholars, not all of whom share a common understanding of what makes evolutionary economics different from 'normal economics'. The project described in this paper was aimed at mapping the intellectual interaction within the group of a particularly influential 'type' of evolutionary economics, i.e., the research community aimed at analyzing the role of technological change and innovation. This topic was not high on the agenda of most academic economists in the first, say, 80 years of the 20th century. The main exception to this trend of neglecting the role of technology in the economy was of course Joseph Schumpeter, the Austrian economist who viewed technology as the prime mover of economic dynamics. In his analysis, Schumpeter put much emphasis on 'out-of-equilibrium dynamics' rather than the description of the economy as a steady state. This, and other elements of his work has been a reason for followers of Schumpeter's work to regard him as an evolutionary economist. In the immediate postwar period, Schumpeter's legacy was picked up by a small number of economists, most notably Chris Freeman in Europe (UK) and Richard Nelson and Sydney Winter in the US.

It were the latter two scholars who introduced the term 'evolutionary economics' in their writings during the 1970s. The European work at the time was mostly concentrated at the Science Policy Research Unit (SPRU) of the University of Sussex, where Chris Freeman was the first director. Economists and other social scientists working at SPRU remained in close contact with their American colleagues Nelson and Winter, and this cross-Atlantic cooperation might be considered as the seed of what of the research community that we wish to study in this paper. With the publication of Nelson and Winter's book 'An Evolutionary Theory of Economic Change' in 1982, the term firmly settled in the

profession. SPRU managed to attract a wide international group of (PhD) scholars, such as Giovanni Dosi, Luc Soete, Pari Patel, Keith Pavitt, Nick von Tunzelmann and Roy Turner who were rather influential in setting the evolutionary agenda for the rest of the 20th century, also because these scholars established research centers in the evolutionary tradition all over Europe, such as the Maastricht Economic Research Institute on Innovation and Technology (MERIT), established by Luc Soete.

Evolutionary economics in the way these early scholars understood it, differs from mainstream economics in at least two important respects. In the first place, the behavioural assumptions are different. Where mainstream economics assumes fully rational behaviour, and builds its models on this, evolutionary economists argue that the strong uncertainty connected to technological change makes full rationality a particularly bad assumption if one is interested in analyzing the economic impact of technology and innovation. In practical terms, this implied that evolutionary economists do not have much trust in the equilibrium models that mainstream economists derive using the full rationality assumption. Instead, they put much more emphasis on economic dynamics and out-of-equilibrium situations. Secondly, and related to the first issue, the 'believe' in the analytic power of strict modeling approaches is much less than in mainstream economics. Thus, a more eclectic mode of analysis, in which there is a place for such diverse tools as simulation models, case studies, and biological metaphors is favoured in evolutionary economics.

This rather eclectic approach favoured by most 'evolutionary economists' also implies that an exact definition of what it means to be an evolutionary economists is hard to provide. As Giovanni Dosi put it:

> "[T]here is not likely to be an exact sharing within the concerned community of what such a programme ought to be ... A few close collaborators and I have some ideas of what it is ... but one should only expect a less than perfect sharing even by likeminded researchers".

Some observers even assert that the fuzzy boundaries of evolutionary economics extend into mainstream economics. Mainstream economists, evolutionary economists and other 'heterodox' economists meet at conferences, publish in similar journals and discuss the same issues. In a number of cases, similar methodologies are used between the different groups, and similar conclusions are reached. For example, Arnold Heertje (1983) argued:

> "neo-Schumpeterians [i.e., the evolutionary tradition] have been productive in their criticism of the neoclassical scheme on the basic of an evolutionary approach, but the questions they have raised have been addressed more or less successfully by many scholars, who have close links with the neoclassical tradition (…) I would not be surprised to see the present Schumpeterian mood to be part of mainstream economics before the end of this century" (p. 273-275).

The research project on 'The Invisible College' (a term that will be explained below) that was started at Ecis, Eindhoven University of Technology in the Netherlands in 2002, is

aimed at mapping the intellectual relations in this broad and diverse group of economists working in the field of the economics of innovation and technological change. The main tool of analysis is a survey that was done in the research community. The methodology of the survey will be described in Section 2.

The rest of this paper is aimed at analyzing the role of evolutionary economics in the broad research community working on the economic analysis of innovation and technological change. Three main research questions will be asked. The first is to identify the relative size of the evolutionary economics group in the larger research community, and to compare the structure of the evolutionary group to the broader group. Second, the question will be asked to what extent the notion of evolutionary economics diffused in Europe, and where the main research groups in this field are to be found. Thirdly, we will ask the question how evolutionary economists agree or disagree about certain academic standards, such as the importance of specific journals and research groups. The answer to the latter question will be interpreted to provide some clues about the 'identity' of evolutionary economics. Each one of these research questions will occupy a separate section of the paper. A final section will summarize the argument and draw conclusions.

2. Methodology – the survey

Our method of analysis follows in the footsteps of Crane (1972). In her treatment of a research community as an 'invisible college' (a term earlier used by Robert Merton), she viewed intellectual relations in the 'college' primarily as social relations between researchers. The term invisible college is used to signal that the group of researchers that is being studied works together closely. This cooperation depends not only on the strong relations that exist between people actually working together in a single institute, but also on cooperation between people who are distant in geographical space. Crane's interest was in explaining the development of a new field of research, for which she argued that it crucially depends on a number of pioneering scientists, and the circles of co-workers and students they create around them. Naturally, the structure of the invisible college changes over its lifetime, as the field evolves to a mode that Kuhn (1962) has dubbed 'normal science'.

Like Crane (1972), we set out a survey among scholars in the field of the economics of innovation and technological change and/or evolutionary economics. The survey was aimed at mapping the intellectual relations between people active in the field, in a way that has become popular in the field of social network analysis (e.g., Wasserman and Faust, 1994) and social capital (e.g., Lin, 1999). In particular, we interpret the invisible college that we are analyzing as a social network in which both strong and weak ties (Granovetter, 1973) play a role. Following Crane (1972), strong ties (e.g., between PhD student and supervisor, or between co-authors) may be important for the formation of intensive knowledge networks in which the main ideas of a new field are created. Weak ties (e.g., inspiration through the written literature) may be more important for the diffusion of these ideas to a wider research community.

Our survey was set up specifically to identify weak and strong ties. Respondents were asked to list people who had influenced them. Six categories of people were asked for: the respondent's PhD supervisor, his/her PhD students, his/her co-workers (defined as people working in the same institution), his/her co-authors (outside the respondent's main institution), his/her network contacts (defined as people who the respondent meets regularly at conferences, workshops, etc.) and, finally, his/her sources of inspiration (important scholars whose work the respondent knows, but whom he/she has never met, an important category of this are scholars from the past who are no longer active).

Respondents were asked to list at most five people in each category, with the exception of the PhD supervisor, which could only be one name. Names could be based on the entire career of an individual, not only the state of affairs at the time of the survey. If more than five people qualified for a category, only the five most important persons (in terms of the quality of their contribution) were asked for. The categories were presented in the above order, where our interpretation is that earlier categories imply stronger links. Our instructions said that if a person qualifies for one category, (s)he could no longer be filled in in a later category, even if (s)he was not listed because (s)he was not among the five most important people in the category. In this way, we wanted to force people to report on a broad range of contacts in the continuum of strong links to weak links. In general, the respondents understood these instructions, and listed different people under different categories. However, there were also a number of respondents who did not follow the instructions, and listed a single name in more than one category. We cleaned the database for this, and deleted all occurrences of people after the first time. Although this solves the immediate inconsistencies, it does not solve for the fact that the people for whom we deleted names did not have the opportunity to supply new names, and hence these people will generally have less 'weak links' to other people in the database.

The survey was sent to all people who appeared in the reference list of a recent overview paper of the field (Dosi, Orsenigo and Sylos Labini, 2002). We asked for the email address of the people listed, but indicated this was optional, and we still wanted to have a name when no email address was known or the respondent did not want to give it. For names that were reported without an email address, we did a search for the email address on the Internet. Everybody mentioned in the responses was also sent an invitation to fill in the survey (this corresponds to the name generator mechanism in Lin, 1999). The survey was kept running in this fashion, and the results reported in this paper correspond to the database at 3 March 2003. At this point, there were 2492 names in our database, of which we had sent out invitations to fill in the survey to 1597 persons (we don't have an email address for the remaining persons). 580 responses were obtained (36% of the invited people, 23% of the total).

The results reported in this paper are based on the database consisting only of the 580 respondents, plus 118 additional persons. The majority of the 118 persons consist of deceased scholars who contributed to the area. A few (less than 10) of the 118 persons concerns persons who indicated they did not want to participate in the survey. By excluding the people who did not (yet) respond to the survey, we miss an important part of the research community in the field. However, because these people did not respond,

they will, on average, have much less (compared to actual respondents) links to other people in the database, simply because they could not list, but only could be listed. This is why we decided to exclude these people from the database. The consequence is that our database does not give a complete mapping of the invisible college. However, with the response rate of 36%/23%, we still have a good sample of the field, and there seems to be no indication of a particular non-response bias. Thus we may consider a map of the invisible college based on our database as a reasonable approximation of the actual research community.

At the beginning of the survey, we asked people to answer yes/no to the questions "Do you consider yourself to be an evolutionary economist?"[1] and "Do you consider 'the economics of innovation and technological change' to be a field to which you have contributed or plan to contribute in the near future?". If the answer to both questions was No, the respondent was instructed to submit the survey without further answering. We consider these respondents as 'outsiders' to the invisible college we are investigating, although they obviously did have an impact on the field. Thus, we define the boundaries of the college on the basis of this question. The 'outsiders' are included in the analysis below (unless otherwise stated), but they were not able to generate new names on the list of respondents (and thus they can only be listed, and not list other people).

3. The role of evolutionary economics in the respondents group

Table 1 reports on the answers to the two main introductory questions. Almost three quarters of the respondents (72.1%) reports to have an interest in the economics of technology and/or innovation. Since the survey was specifically aimed at this field, this high percentage is not surprising. One third of the respondents (33.8%) consider themselves as evolutionary economists. About one quarter of the respondents (24.1) falls in the 'outsider' category that we defined above.

Table 1. Interest in technology/innovation vs. evolutionary economics

	Interested in technology/innovation			
Evolutionary	Missing	No	Yes	Total
Missing	5 (0.9%)		9 (1.6%)	14 (2.4%)
No	2 (0.3%)	140 (24.1%)	228 (39.3%)	370 (63.8%)
Yes		15 (2.6%)	181 (31.2%)	196 (33.8%)
Total	7 (1.2%)	155 (26.7%)	418 (72.1%)	580 (100%)

In the third column, we see that within the broad research community on the economics of innovation and technology, the group of economists that considers themselves as evolutionary economists make up 43%. This is in fact a rather large minority. Although our sample of economists not particularly interested in technology (in the second column) is rather small (and biased), it is clear that evolutionary economists are well represented in the economics and 'technology field'. On the basis of the history of the field (briefly outlined in the introduction above), this is not surprising.

[1] We did not provide a definition of 'evolutionary economics', and left it to the respondent him/herself to define the concept appropriately.

The lists of people in the response to the questionnaire were used to build a network matrix. This matrix has the individuals in our group of 698 (see above) persons in the rows and columns. When a link between two people exists, i.e., they have mentioned each other in the survey, we add a 1 in the matrix cell, otherwise there is a 0. Although this matrix is in principle non-symmetric (person A may mention person B, but not vice versa), we make the matrix symmetric by taking the maximum of the cells (i,j) and (j,i). In other words, we assume that a network link between two people exists even if only one of them reports the links.

In this way, we can build various matrices, depending on which type of links (on the scale strong to weak ties) we take into account. In this paper, we will only work with *cumulative* links, as in Table 2. In the last column of this table, we have results for a network based on only links between PhD supervisor and PhD student. The second-last column includes all links in the previous (last) column, plus links between co-workers (colleagues in the same institution). The third-last column is based on a network including all links in the previous columns, plus links between co-authors (outside the respondent's own institution), etc., until in the first column we have a network based on all types of links between respondents.

Table 2. Size of the largest connected component at various network 'layers'

All relations	Excl. "Inspiration"	Excl. "Network"	Excl. "Co-authors"	Excl. Co-workers
Complete database (n=698)				
673	604	518	322	63
(100.0)	(89.7)	(77.0)	(47.8)	(9.4)
Only declared evolutionary scholars (n=196)				
179	166	144	109	28
(100.0)	(92.7)	(80.4)	(60.9)	(15.6)
Declared evolutionary scholars as a percentage of total network				
27	27	28	34	44

Between brackets is the size of the component as a percentage of the size of the component in the first column. The last line indicates the size of the largest component in the evolutionary network as a percentage of that in the total network.

Table 2 reports a rough measure for the connectedness of the network. It starts from the concept of a network component, which is defined as a subset of the network in which every network member 'can be reached' from every other network member by successive links between people. To see how this works, imagine a network respondent was asked to transmit a red piece of paper to all the people (s)he listed in our survey, plus the people who listed this respondent. The receivers of the piece of paper would be asked to do the same. The 'largest' component in Table 2 measures the number of people who would have received the red piece of paper after it has diffused completely.

In case of the complete database (top part of the table), we use all people in the group of 698. In the case of 'only declared evolutionary scholars', we delete from the network everybody who did not answer 'yes' to the question 'Do you consider yourself to be an evolutionary economist'. When we move left-to-right in the table, network links in a

specific category of ties (weak or strong) are deleted. Naturally, this makes it harder to 'reach' other people in the network, and hence the size of the largest component decreases. In fact, what happens is that the network breaks up in a number of smaller components. We report only the size of the largest of these. This largest component is in all cases significantly larger than the next-largest component, even in the rightmost column.

For the complete database, the largest drop in the number of respondents still in the largest component happens when we delete co-authors (outside the own institution) links (a drop from 77.0% to 47.8%) and when we delete co-workers links (47.8% to 9.4%). The size of the largest component at these levels is still rather large: of the 673 people in the largest component based on all links, about half are linked to each other, albeit often indirectly, through a co-worker relation. This shows that both strong and weak ties play an important role in holding together the invisible college.

For the subgroup of evolutionary scholars, what is most notable is that strong ties are relatively more important than weak ties, as compared to the network as a whole. At the level of PhD supervisor/student relations, 15% of the largest component based on all ties is still held together, which is almost twice as much as for the total network. At the level of co-workers, the difference is still striking: 60.9% of the evolutionary group is held together by relations of this type, vs. 47.8% for the network as whole. We may thus conclude that compared to the rest of the invisible college we are analyzing, the evolutionary subgroup is a (large) minority of which the members have invested heavily in strong links between them.

4. The network of evolutionary economics

The 698 individuals in the database together report 312 different institutions as their affiliation. In determining which units to choose as an institution, some arbitrary judgment had to be made. The procedures used to standardize the affiliations are described in the Appendix. We used social network analysis to determine the centers of activity of evolutionary economics in the invisible college. The networks that were used for this were constructed by aggregating links between individuals to links between the institutions they are affiliated to. The resulting networks are again binary (links exists or not) and symmetric.

We concentrate in this paper on the subset of individuals who answer "Yes" to the question "Do you consider yourself to be an evolutionary economist?". We take into account all links reported by these individuals, i.e., we also include links to people who did not answer "Yes" to this question. In other words, the 'originator' of the link is known to be evolutionary, but the 'target' of the link does not necessarily have to be evolutionary. Furthermore, we aggregate the various types of links (weak-strong) into two main categories: all links and all links excluding "inspiration" and "network contacts" (the two last layers). We interpret the network based on the smallest category of links as the "strong ties network" and the total network as the "strong and weak ties" network.

In the case of the strong ties network, the largest component of the network of institutions has 212 members (institutions). In order to determine the centers of activity, we use three different measures for network centrality.[2] The first of these, closeness, measures the distance between network members as the number of links that separates them. For example, if institutions A and B are linked (because one or more of their members reported links between them), their distance is one. If institutions A and C are not linked (directly), but both A and C are linked to B, the distance between A and C is two. For each network member (institution), one may calculate the average distance to all other members in the network. This is called closeness centrality.

Table 3. Centers of activity in evolutionary economics in Europe

University of Aalborg, Denmark
University of Athens, Greece
Austrian Research Centers Seibersdorf
Bocconi University / CESPRI, Milan, Italy
Chalmers University, Gothenburg Sweden
CNR, Rome, Italy
Copenhagen Business School, Denmark
CRIC, University of Manchester, United Kingdom
University College Dublin, Ireland
Ecis, Eindhoven University of Technology, Netherlands
European Commission, Brussels
INRA/SERD, University of Grenoble, France
IPTS, Seville, Spain
ISEG, Technical University of Lisbon, Portugal
University of Jena, Germany
University of Leuven, Belgium
University of Manchester, United Kingdom
Manchester Metropolitan University, United Kingdom
Merit, University of Maastricht, the Netherlands
Catholic University of Milan, Italy
Open University, Heerlen, Netherlands
University of Rome, La Sapienza
Sant'Anna School of Advanced Studies, Pisa, Italy
SPRU, University of Sussex, United Kingdom
TIK Center, University of Oslo, Norway
University of Twente, Netherlands
University of Utrecht, Netherlands
University of Zurich, Switzerland

The second type of centrality measure, betweenness, measures the extent to which a network member (institution) is a link in indirect relations between other institutions. More precisely, it measures how often a network member is on the shortest path between two other institutions. The final measure of centrality, Bonacich centrality, starts from the idea that it is important to have many links to other network members. However, it also takes into account the centrality of the institutions to which links exist, where the

[2] Formal definitions of the measures we use can be found in Wasserman and Faust (1994).

hypothesis is that it is more important to have links to other central institutions. This leads to an eigenvalue problem on the network matrix, which is why this measure is also known as eigenvalue centrality.

We calculate the centrality score of each institution on the three centrality measures, and then rank the institutions for each of the measures. The average rank obtained for each institution is then used to make an overall ranking. Table 3 reports the top-20 European institutions derived in this way for the strong ties network, plus the first ranked institution for countries that do not have an institution in the top-20. The institutes are ranked alphabetically.[3]

It is notable that evolutionary economics, in terms of institutions, is mostly a European affair. In the statistics used for the construction of Table 3, only three non-European institutes ranked in the global top-20 of centrality measures. These were all three US-based institutions, and for two of these, their performance was solely based on one individual scholar in each case (the performance of most of the institutes in Table 3 is based on multiple individuals). In fact, European institutions dominate the complete list of centrality measures for the strong ties network. Diagram 1 outlines the (strong) ties between the institutions in Table 3.

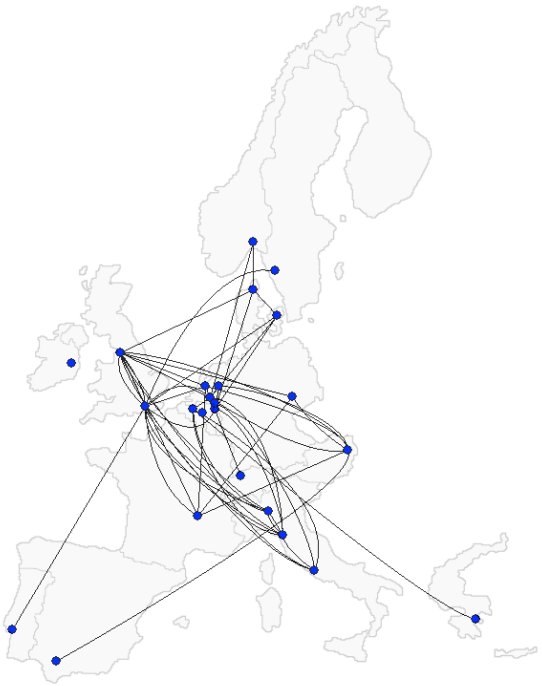

Diagram 1. Strong links between the European centers of activity in evolutionary economics

[3] It is important to realize that our ranking cannot be interpreted as a measure of quality. While it seems reasonable to assume that the institutes on the list generally perform high-quality research, this may also hold for institutes not featured on the list.

However, also within Europe there is considerably concentration in certain countries. Specifically, Italy and the Netherlands (both 5 institutions), the United Kingdom (4 institutions) and Denmark (2 institutions) are strongly represented. These countries seem indeed to be the ones in which evolutionary economics is strongest in Europe. Diagram 1 outlines the strong links that exist between the institutions. This visual impression confirms the dominance of the axis Italy-Netherlands-United Kingdom as the main focus of interaction.

The selection of centers of activity in Table 3 and Diagram 1 is based on relations between respondents to the survey. The survey database also allows for a different selection of centers of activities, based on the following question: "In case you regularly (on average at least once every two years) visit other institutes (in your own country or abroad) supporting the research areas 'the economics of innovation and technological change' and /or 'evolutionary economics', please list the names of the institutes (universities, research centres, etc,) and countries in which they are based (most important first)."

It is quite possible that a selection of institutions based on the answers to this question differs from the selection in Table 3 and Diagram 1. One possible source of difference relates to the organization of conferences, workshops etc. If such an event is organized at a specific institution, this institution could be listed as an answer to the above question. At the same time, however, one could meet people from different places at this conference, and these people could be listed as contacts in the survey questions that were used in the construction of Table 3 and Diagram 1. We therefore also analyze the answers to the above question.

Each respondent could list at most five different institutions in the answer to this question. We select here only the answers from the 196 respondents who answered that they considered themselves evolutionary economists. All their answers to the question were pooled together, without taking account at which rank an institution was listed. Figure 1 reports the number of times an institution was mentioned.[4]

[4] Again, the results in Figure 1 should not be taken as an institute of quality of research. Like before, it seems reasonable to assume that the institutes on the list generally perform high-quality research, but this may also hold for institutes not featured on the list.

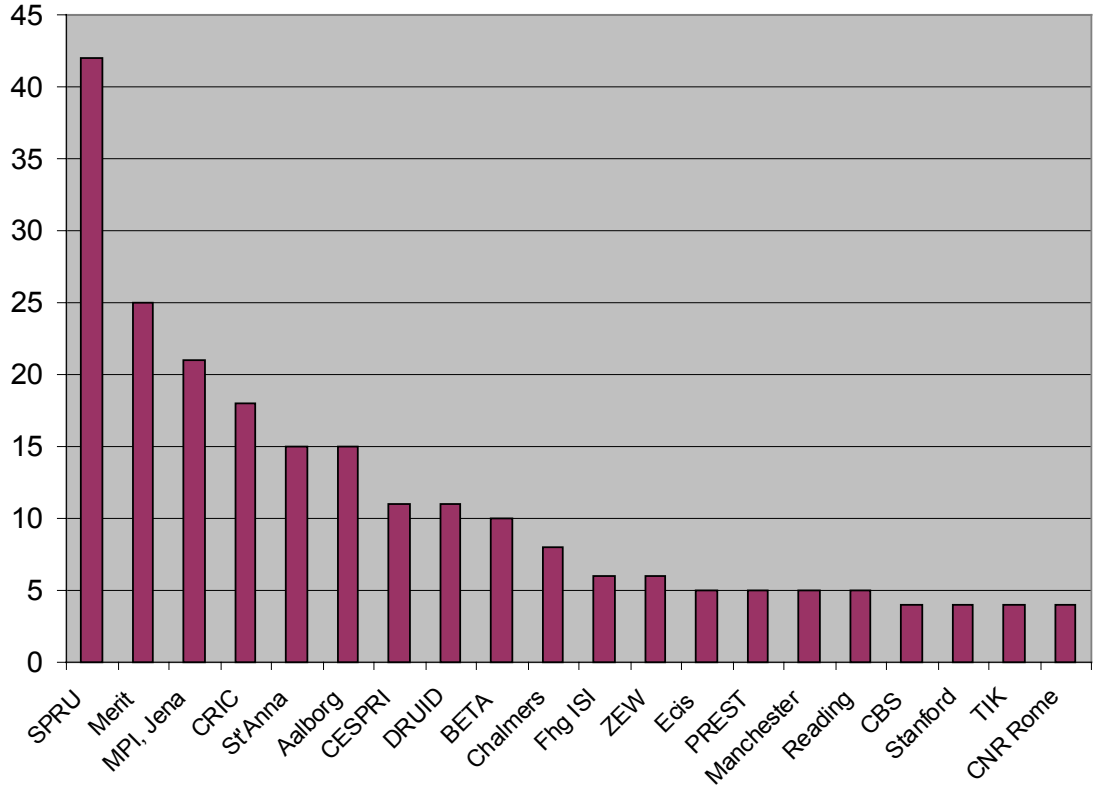

Figure 1. Regularly visited institutions (number of times an institution appears as an answer by evolutionary scholars)

Many of the institutes listed in Figure 1 also featured in Table 3. European institutes dominate again. However, there are also a number of institutes in Figure 1 not present in Table 3. Interestingly, this mostly concerns a number of German institutes: the Max Planck Institute in Jena, the Fraunhofer Institute ISI in Karlsruhe, and the ZEW in Mannheim. These are all non-university institutes (although they have close links with nearby universities), and they are indeed all known to regularly organize well-known conferences and workshops. By these activities, they have clearly established a strong reputation. The other, non-German, institutes not on the list in Table 3 are Beta (Strasbourg, again well-known for organizing workshops and conferences in the field), PREST and the University of Reading.

Summarizing, it emerges clearly from the database that in terms of institutions, Europe is the leading world region in terms of evolutionary economics. The European research area contains the leading institutions in the world in this field, as measured by different approaches. Which approach is used (one based on network relations between scholars, or one based on the answers to the question which institutions are often visited by evolutionary economists) does not seem to matter very much for the overall picture. A major exception to this conclusion are a number of mostly German institutes, which are often visited, but do not emerge so clearly as centers of activity from the network based approach.

5. The identity of evolutionary economics

Is the evolutionary economics community a homogenous research group? Based on an informal impression of the field, the answer to this question is not straightforward. Evolutionary economics entails a broad range of research approaches and methodologies. It certainly does not (yet) have a standard toolbox that characterizes, for example, mainstream economics. In the final part of our analysis, we use the results from the survey to try to answer the above question.

To this end, we use the answers to three questions. The first of these is the questions about which institutions are regularly visited (see above). The two other questions concern the importance of scholarly journals. These questions were phrased as follows: "Which academic journals do you consider CURRENTLY to be the best outlet for work on 'evolutionary economics' or 'the economics of innovation and technological change' (most important first)?" and "Which academic journals did you consider to be the best outlet for work on 'evolutionary economics' or 'the economics of innovation and technological change' (most important first) BEFORE 1985? (If you feel too young to have an informed opinion, please leave open this question)". Each question allowed up to five possible answers.

We express the agreement of two respondents on the answer to each of the above three questions as the number of answers they both listed. This yields an integer number in the interval [0..5]. These numbers can be expressed in a square symmetric matrix, of which we exclude the diagonal from the analysis. The matrix is used in a statistical analysis using the so-called QAP regression technique (Krackhardt, 1988). In this technique, the above constructed agreement variable is the dependent variable. A number of other variables are entered in the regression as predictors of the agreement variable.[5] We use the survey data on ties (weak or strong) between people as one independent variable. Five different regressions will be documented, for the five different network layers (weak to strong ties). Two additional explanatory variables are dummy variables based on the distinction between evolutionary and non-evolutionary respondents. One dummy equals 1 if both respondents report to be evolutionary economists, and another one equals 1 if both respondents report to be non-evolutionary economists. Because we do not have any answers on the agreement questions for respondents who filled in "No" to our two initial questions, we have to exclude these respondents from the analysis. This leaves us 433 respondents that can be included in the QAP regressions.

Based on informal theorizing, we expect that all independent variables have a positive sign. For the network ties variables, this is based on the expectation that interaction between people will increase the likelihood that they share opinions. More specifically, we expect that stronger ties have a higher impact (larger coefficient). For the dummy variables, we expect that these capture a common broad perspective (evolutionary vs.

[5] QAP regression differs from OLS in the calculation of the standard errors of the estimated coefficients, which have to be obtained through simulation based on permutations of rows and columns in the dependent variable matrix. We perform 2000 permutations in each regression.

non-evolutionary) on economics, which is also expected to increase the likelihood of agreement.

Table 4. QAP regressions, dependent variable shared opinion on current important journals (mean of dependent variable = 0.62)

	(1)	(2)	(3)	(4)	(5)
Intercept	0.564	0.565	0.567	0.567	0.569
All ties	0.768 (0.000)				
Ex Refr		0.849 (0.000)			
Ex Netw			0.803 (0.000)		
Ex Coaut				0.829 (0.000)	
Ex Cowo					0.808 (0.000)
ShEvol Y	0.580 (0.000)	0.582 (0.000)	0.584 (0.000)	0.586 (0.000)	0.588 (0.000)
ShEvol N	-0.234 (0.000)	-0.235 (0.000)	-0.235 (0.000)	-0.234 (0.000)	-0.234 (0.000)
R2	0.106	0.106	0.103	0.102	0.100

p-values in brackets.

The results for shared opinions about current academic journals are in Table 4. All three explanatory variables are highly significant as indicated by the p-values. The network variables all have positive signs, as expected: ties between two respondents increase the likelihood of agreement in opinions. However, there are no very systematic differences between weak or strong ties. The highest coefficient is found for all ties included except "frame of reference". This result makes sense: the frame of reference category of people is defined as people whom the respondent does not know (very well) personally, so a link of this nature is unlikely to have an impact on shared opinions.

The dummy variable that indicates that both people are evolutionary economists has a positive sign, as expected. This indicates that evolutionary scholars tend to share opinions about journals. The sign for the other dummy variable is negative, however, which is against expectations. This seems to indicate that the group of non-evolutionary scholars in the survey is indeed a rather heterogeneous group, in which opinions differ more than within the homogenous group of evolutionary economists. The result could also be due to the fact that there are only a few specialized journals that serve the evolutionary community, while there is a larger set of journals to choose from if one is not committed to evolutionary analysis. Finally, it is notable that both the network variables and the "evolutionary Yes dummy" have high explanatory power as compared with the mean value of the dependent variable.

Table 5 reports the same regressions for shared opinions on the academic journals important before 1985. Here the mean of the dependent variable is much lower than for current journals. This is mainly due to the fact that many respondents do not list any journals for the period before 1985. Still, all variables are significant. The signs of the coefficients and the other patterns are the same as in Table 4. Again, two evolutionary respondents agree to a relatively large extent, while to non-evolutionary respondents tend to disagree more. The network variables again have a positive impact, with the highest coefficient resulting for all ties expect the "frame of reference" category.

Table 5. QAP regressions, dependent variable shared opinion on important journals before 1985 (mean of dependent variable = 0.02)

	(1)	(2)	(3)	(4)	(5)
Intercept	0.020	0.020	0.020	0.020	0.021
All ties	0.081 (0.000)				
Ex Refr		0.088 (0.000)			
Ex Netw			0.068 (0.000)		
Ex Coaut				0.071 (0.000)	
Ex Cowo					0.061 (0.000)
ShEvol Y	0.029 (0.000)	0.030 (0.001)	0.030 (0.000)	0.030 (0.000)	0.030 (0.000)
ShEvol N	-0.011 (0.005)	-0.011 (0.006)	-0.011 (0.006)	-0.011 (0.004)	-0.011 (0.004)
R2	0.010	0.010	0.009	0.008	0.008

p-values in brackets.

Table 6. QAP regressions, dependent variable shared opinion on places often visited (mean of dependent variable = 0.05)

	(1)	(2)	(3)	(4)	(5)
Intercept	0.039	0.039	0.039	0.040	0.040
All ties	0.233 (0.000)				
Ex Refr		0.254 (0.000)			
Ex Netw			0.242 (0.000)		
Ex Coaut				0.228 (0.000)	
Ex Cowo					0.199 (0.000)
ShEvol Y	0.064 (0.000)	0.065 (0.000)	0.066 (0.000)	0.066 (0.000)	0.067 (0.000)
ShEvol N	-0.020 (0.001)	-0.020 (0.000)	-0.021 (0.000)	-0.020 (0.002)	-0.020 (0.001)
R2	0.027	0.026	0.023	0.021	0.018

p-values in brackets.

Table 6 reports the results for the question about which places are often visited. The results are in line with the questions on academic journals. Network variables are all positive and significant, with the highest value again for the category of links that excludes the weakest links. Evolutionary economists tend to agree more, non-evolutionary economists less.

Concluding, the results indicate that the subset of evolutionary scholars in our database is a relatively homogenous group in terms of their opinions about important academic journals, or which places are important to visit often. This indicates that there is indeed such a thing as an 'identity' of the evolutionary community within the invisible college.

6. Conclusions

In this paper, we have reported on a survey undertaken among economists interested in the economics of innovation and technological change and/or evolutionary economics. The main aim of the survey was to outline the intellectual relations that exist between scholars in the field. We have used the data to describe the (European) research community of evolutionary economists from an analytical perspective. Several conclusions emerge.

First, evolutionary economists emerge as a community in which the individuals have invested relatively strongly in strong ties between them. As compared to the non-evolutionary part of our respondents database, evolutionary economists span a relatively wide circle based on co-worker relationships.

Second, we were able to identify a number of European-wide centers of activity in evolutionary economics, based on the data on strong ties in the survey. These centers were most often found in Italy, the United Kingdom, the Netherlands and Denmark, which emerge as the most active countries in evolutionary economics. When centers of activity are based on what respondents consider important places to visit, the results change somewhat as compared to the network-based measures. The most striking difference is the emergence of a number of German institutes in the list of important places to visit.

Finally, we investigated what determines shared opinions on important academic journals and important places to visit. The findings indicate that evolutionary economists have a higher level of agreement on these matters than non-evolutionary economists. In addition, whether or not two respondents reported links with each other seems to matter for shared opinions (having links leads to a higher agreement in opinions). Although these results are in accordance with our expectations, they have important implications. For example, in research assessment exercises used in various countries, the 'quality' of journals is still based on mainstream opinions. For evolutionary economists, this implies that they are assessed on the basis of journals in which they themselves may have little confidence.

References

Crane, D (1972) *Invisible Colleges. Diffusion of knowledge in scientific communities.* Chicago & London: The University of Chicago Press

Dosi, G, Orsenigo, L., and M. Sylos Labini, 2002, Technology and the Economy, LEM Working Paper Series 2002/18.

Granovetter, M.S. (1973). 'The strength of weak ties.' *American Journal of Sociology*, 78, pp. 1360-1380.

Heertje, A. "Neo-Schumpeterians and Economic Theory." In: *Evolutionary Approaches to Economic Theory*, edited by Magnusson, 265-276. Dordrecht: Kluwer, 1993.

Krackhardt, D.(1988) .Predicting with networks: Nonparametric multiple regression analysis of dyadic data, *Social Networks*, 10, 359-381.

Thomas Kuhn (1962): *The Structure of Scientific Revolutions*. Chicago and London: The University of Chicago Press

Lin, N. 1999, Building a Network Theory of Social Capital, *Connections*, 22 (1): 28-51

Wasserman, S & K. Faust (1994). *Social network analysis: methods and applications, Cambridge*: Cambridge University Press

Appendix. Survey questionnaire (Word version, the large majority of results was obtained through an identical online web survey)

1. YOUR BACKGROUND

We would like to know a few details about your academic background.

1a. Which country do you consider to be your native country from a SCIENTIFIC point of view (e.g., if you are Italian by nationality, but pursued your entire scientific career in the UK, fill in "United Kingdom" here)?

Country:

1b. What is your current (main) affiliation?

Affiliation:

Country:

1c. In case you hold a PhD Degree, at which academic institution did you get it, who was your (main) supervisor, what is his/her current email address, and when did you obtain the degree (year)? In case you hold more than one PhD degree, please list the one most relevant to 'the economics of innovation and technological change' or 'evolutionary economics'.

Institute:

Supervisor:

Email:

Year:

1d. In case you are currently prepearing a PhD Dissertation, at which academic institution do you plan to receive the PhD degree, who is your (main) supervisor, and what is his/her current email address?

Institute:

Supervisor:

Email:

Year:

1e. Do you consider yourself to be an evolutionary economist?

Answer: Yes/ No (Please delete the option that does not apply)

1f. Do you consider 'the economics of innovation and technological change' to be a field to which you have contributed or plan to contribute in the near future?

Answer: Yes/ No (Please delete the option that does not apply)

If you answered 'No' to both of the previous questions, you may now save the file and submit your results without answering the remaining questions. It is important for our research that you submit your results! You may submit your results by sending the saved file as an attachment to b.verspagen@tm.tue.nl. Thank you for your cooperation!

2. YOUR NETWORK

The following questions will ask for names of people. We would like to give you a few general directions for answering these questions:

- **Our questions refer to EXCLUSIVE groups of people. This means, for example, that a person who would qualify as a possible answer to the first question below, is not a valid answer for any of the following questions. This even holds if you decided not to fill in the name of this person in the first question, because the person did not rank among the five most important people in the category. Also, never fill in your PhD supervisor as listed in Question 1.**

- **Only consider those people relevant to YOUR work on "the economics of innovation and technological change" and/or "evolutionary economics", although the people you list may themselves not specialize in these areas.**

- **Always use the quality of the input of a person as a measure rather than the quantity.**

- **List most important people in a category highest, least important people last.**

- **A few directions for formatting the names. Please do not use any academic titles, so write "J. Lennon" rather than "Prof. J. Lennon" or "dr. J. Lennon". Also, please write names in the order FIRST NAME - LAST NAME, e.g., "M. Jagger", rather than "Jagger, M.". Finally, please give us as much detail as you reasonably can, i.e., provide full first names (if you know them) rather than initials (e.g., "Elvis Presley" rather than E. Presley"), and also provide middle initials if you know them (e.g., "Elvis A. Presley" rather than "Elvis Presley").**

- **The questions will ask for current email addresses of the people you list. If you do not have these available, please leave this field empty, but complete the rest of the answer.**

- **If there are less than five people who qualify the description given in the question, simply leave the appropriate number of rows empty.**

2a. YOUR PhD STUDENTS

In case you ever supervised PhD students, we would like to know who you consider to be the most influential of these. Please list up to five PhD students from those who have completed their dissertation.

	name	Email address
1		
2		
3		
4		
5		

2b. YOUR CO-WORKERS

We would like to know who you consider to be the most important co-workers with whom you have worked over your entire career. We define a co-worker as a person employed in the same organization as yourself, and who is/was a source of inspriration in the form of formal and informal discussions, exchange of ideas, commenting on papers, etc.

	name	Email address
1		
2		
3		
4		
5		

2c. YOUR CO-AUTHORS

We would like to know who you consider to be the most important co-authors (working outside your own organization at the time of the joint work) whom you have worked with over your entire career. Please include also work outside scholarly journals, such as reports for contract research, etc., in your definition of a co-author.

	name	Email address
1		
2		
3		
4		
5		

2d. YOUR NETWORK

We would like to know who you consider to be the most important people in your network. Define your network as people you are in regular contact with, by face-to-face contact, meeting at conferences, paper correspondence, email, etc.

	name	Email address
1		
2		
3		
4		
5		

2e. YOUR FRAME OF REFERENCE

We would like to know who you consider to be the most important people in your frame of reference. We define the frame of reference as those people who have inspired your own work, but do not fit in the above categories. A good example of this could be a classic author who lived before your time

(e.g., Adam Smith), but this category can also include living people, for example those authors you reference in your own work, but you have never been in contact with.

	name	Email address
1		
2		
3		
4		
5		

2f. INSTITUTIONAL SETTING

In case you regularly (on average at least once every two years) visit other institutes (in your own country or abroad) supporting the research areas 'the economics of innovation and technological change' and /or 'evolutionary economics', please list the names of the institutes (universities, research centres, etc,) and countries in which they are based (most important first).

	Institute	country
1		
2		
3		
4		
5		

3. RESEARCH INFRASTRUCTURE

Please indicate the level of support for research in the area 'the economics of innovation and technological change' and /or 'evolutionary economics' you have experienced from the following institutions (1=no support, 5=strong support). Indicate your answer by putting a 'x' under the appropriate level of support.

1. **Your own institution (university, research institute, etc.)**

1	2	3	4	5

2. **2. National and/or regional research funding agencies in the country you work in**

1	2	3	4	5

3. **3. European research funding agencies (please answer this only if you are employed in Europe)**

1	2	3	4	5

4. JOURNALS

Which academic journals do you consider CURRENTLY to be the best outlet for work on 'evolutionary economics' or 'the economics of innovation and technological change' (most important first)?

	Journal
1	
2	
3	
4	

5	

Which academic journals did you consider to be the best outlet for work on 'evolutionary economics' or 'the economics of innovation and technological change' (most important first) BEFORE 1985? (If you feel too young to have an informed opinion, please leave open this question)

	Journal
1	
2	
3	
4	
5	

This is the end of the survey. Please save the file and submit your results by sending the saved file as an attachment to b.verspagen@tm.tue.nl. Thank you for your cooperation!

Appendix. Rules to standardize affiliations

Some general cases emerge. The first of these is when a research institute is part of a larger institution, such as a university. In this case, the classification used was based on what the majority of respondents filled in. This resulted in a number of research institutes being listed separately, while a number of other institutes were merged into the "mother institutions" (university). The most important research institutes that remained separately are the following ones:

- Merit, Maastricht University: the majority of respondents listed "Merit", possibly in combination with "Maastricht University" or "Maastricht". Almost never was "Maastricht University" mentioned without "Merit". The few cases (<5) in which this happened were classified as "Merit".
- CESPRI, Bocconi University. Most respondents mentioned "Bocconi University", without CESPRI, a minority mentioned also "CESPRI". We noticed, however, that a large number of the "Bocconi" respondents were indeed associated with CESPRI, and hence we label the entire category as CESPRI.
- DRUID. This Danish institute is a "join venture" between two universities: Aalborg University and the Copenhagen Business School. Many variants were found in this case. Most often people mentioned either one of the two "mother institutes". Some times this was done in combination with the word "DRUID". Also, sometimes just "DRUID" was mentioned. We decided to treat the two mother institutes and the joint venture as three separate units. Whenever one of the two mother institutes was mentioned, this was used, if only DRUID was mentioned, we used this.
- The Manchester institutes: CRIC, PREST, UMIST and their mother institute the University of Manchester, and the Manchester Metropolitan University. These occurred all five, in about equal numbers. This is why we treated them all separately.