Patterns of research collaboration in a digital library for Economics[1]

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Abstract

RePEc (Research Papers in Economics) has been conceived and developed to promote scholarly communication and to enhance the dissemination of research findings in the field of economics. RePEc offers the RePEc Author Service (RAS) where economics authors can claim authorship of the research papers that are described in RePEc archives. The data from this service forms a high-quality authorship database. We investigate the structure of research collaborations within RePEc by applying social network analysis to the co-authorship network formed by the RAS registrants. We perform a component size analysis and calculate centrality metrics. Our findings imply that the RAS registrant population is made up of highly active academics that are well connected to each other. In addition, RAS registrants appear to have a broad range of coauthors, with most individuals having only a few coauthors, whereas a few have many. We compare and contrast results from a number of recent studies of similar scope on co-authorship networks.

Introduction and motivation

Even though the roots of present day digital libraries may be traced to the information retrieval systems of the 1960s, digital libraries, as we know them today, have emerged only in the past decade to serve different constituencies and communities (Fox & Urs, 2002). RePEc (Research Papers in Economics), one of the earliest digital libraries in existence, has been conceived and developed to document scholarly communication and enhance the dissemination of research findings in the field of economics (Walshe, 2001). RePEc[2] is a collaborative effort of hundreds of volunteers in 51 countries. As of this writing, RePEc describes over 362,000 items of interest such as working papers, journal articles, software components, and instructional datasets. All RePEc data, freely available online, are contributed by academic departments, institutions involved in economics research (e.g. central banks), publishers, and individuals. Barrueco Cruz and Krichel (2001), early pioneers of RePEc, provide a detailed discussion of their approach towards building the digital library and summarize the basic principles.

RePEc is based on three concepts: “archive,” “site,” and “service.” A service is defined as a “rendering of RePEc data in a form that is available to the end user.” The definition can be expanded to include activities such as mining the archive data, discovering potentially useful information about the users, and presenting it in a form that is meaningful to the research

[1] We are grateful to the Open Society Institute for funding to support the ACIS software system, see http://acis.openlib.org. The data used in this study has been gathered through a running version of the software.
[2] http://repec.org

community. To facilitate some of these activities, RePEc provides several innovative user services:

- "NEP: New Economics Papers," at http://nep.repec.org, is a human-mediated current awareness service.
- "LogEc," at http://logec.repec.org, gives detailed access statistics for RePEc items and authors.
- "CitEc," at http://citec.ier.hit-u.ac.jp, gives citations from items in the RePEc database.
- The "RePEc Author Service," at http://authors.repec.org, is an author registration service.

This study focuses on the RePEc Author Service (RAS), a user service that maintains personal data, which enables analysis related to the association between authors and documents.

In all bibliometric studies, the availability of complete and correct authorship data remains a significant obstacle in obtaining statistically accurate results. Although bibliographic data contain author names, a name does not necessarily identify an author uniquely. A number of factors contribute to the variety of ways author names appear in standard bibliographic data. Several authors may share the same name, a name can be written in various forms and the use of initials, accents or capitalizations may be inconsistent. To illustrate, here is an example of three names referring to the same author:

Phillips, P C B
Peter C.B. Phillips
Peter Phillips

Additional problems are introduced by the transliterations from non-Roman to Roman alphabets. (e.g., Chaykovskiy, Tchaikovsky). In general, raw author name data have to be put through a long and arduous cleaning process before they can be used for authorship analyses. The RAS provides utilities for an author to register, provide a profile and codify his/her own authorship data in its database. The RAS database, therefore, contains high-quality authorship data for analysis.

This paper analyzes the patterns of authorships and incidence of collaborative relationships among all RAS registrants. The remainder of the paper is organized as follows. In section two we discuss the RAS in more detail. In particular, we assess its completeness. In section three we study co-authorship among RAS registrants using social network analysis (SNA) methodology. In section four we provide our conclusions and suggest future work.

The RePEc Author Service (RAS)

Overview and operation

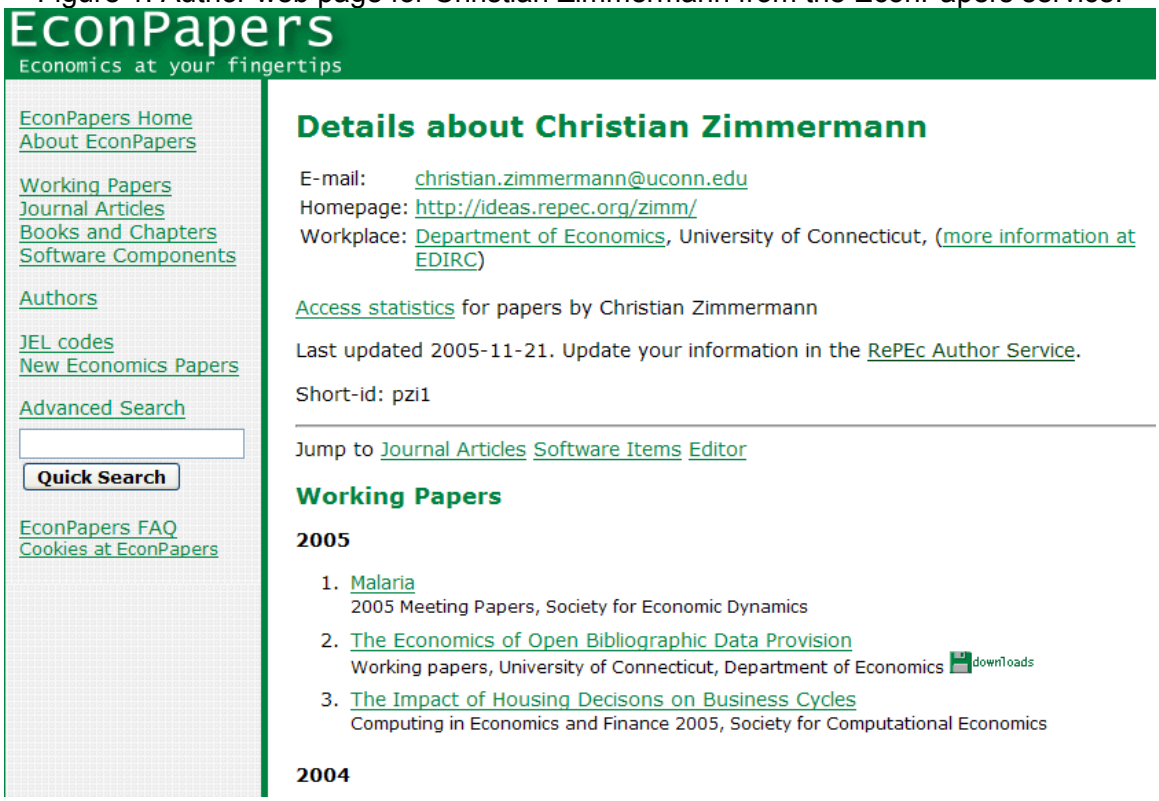
To the best of our knowledge, the RAS is a one-of-a-kind service with much potential in cultivating collaboration and cooperation among "digital library" users, promoting information sharing and creating a sense of community in a digital environment. Each author registers himself/herself voluntarily and creates a professional profile. Then, the author provides contact information, affiliation, and publications. Following is an extract of a record from the RAS database:

```
Template-Type: ReDIF-Person 1.0
Name-First: Christian
Name-Last: Zimmermann
Name-Full: Christian Zimmermann
```

Workplace-Organization: RePEc:edi:deuctus
Email: christian.zimmermann@uconn.edu
Homepage: http://ideas.repec.org/zimm/
Author-Paper: repec:cre:crefwp:33
Author-Paper: repec:mtl:montde:2000-05
Author-Software: repec:dge:qmrbcd:99
Author-Software: repec:dge:qmrbcd:97
Author-Paper: repec:uct:uconnp:2005-01
Author-Article: repec:eee:jcecon:v:33:y:2005:i:1:p:88-106
Author-Article: repec:eee:jmacro:v:26:y:2004:i:4:p:637-659
Author-Paper: repec:sce:scecf5:372
Author-Paper: repec:red:sed005:561
Short-Id: pzi1
Handle: repec:per:1964-12-14:christian_zimmermann
Last-Login-Date: 2005-11-21 15:25:20 -0500
Registered-Date: 2004-02-29 17:36:09 –0600

Figure 1 provides a screenshot of a web page that renders this data on the web.

Figure 1. Author web page for Christian Zimmermann from the EconPapers service.



Registered authors receive a monthly notification, which includes statistics on abstract views and downloads of their works.

Assessment of RAS Data

In order to assess document and author coverage in RAS, we perform basic statistical analysis on two databases: RePEc and RAS. RePEc contains 362,080 documents. RAS contains 124,447 documents that have been claimed by at least one registered author. This observation indicates that roughly one in three papers in RePEc is included in the

RAS database. Furthermore, the number of authorships in RAS is 152,072, whereas the corresponding number is 609,225 in RePEc, suggesting that about one in four authorships in RePEc are covered in the RAS.

At a disaggregated level, we examine how many registered authors have claimed to be an author of a paper. Table 1 furnishes a list of the number of authors on a paper and the corresponding number of papers in the entire RePEc database vs. RAS database. RePEc contains 180,716 (49.91%) documents with a single author, whereas RAS contains 99,562 (80%) documents with one registered author. It is quite possible that a document may have more than one author, but only one may have registered in the RAS. In RePEc, there are 1.68 authors per document whereas in RAS, there are 1.22 authors per document. While the maximum number of authors for a single document reaches 24 in RePEc database, this number remains at a maximum of 8 in the RAS database.

Table 1. Distribution of the number of authors per paper in RePEc and RAS

Number of authors	**Number of papers**	
	RePEc	RAS
1	180716 (49.91%)	99562 (80.00%)
2	129638 (35.80%)	22315 (17.93%)
3	42427 (11.72%)	2425 (1.95%)
4	7021 (1.94%)	130 (0.10%)
5	1338 (0.37%)	9 (0.01%)
6	425 (0.12%)	4 (0.00%)
7	193 (0.05%)	1 (0.00%)
≥ 8	99 (0.03%)	1 (0.00%)

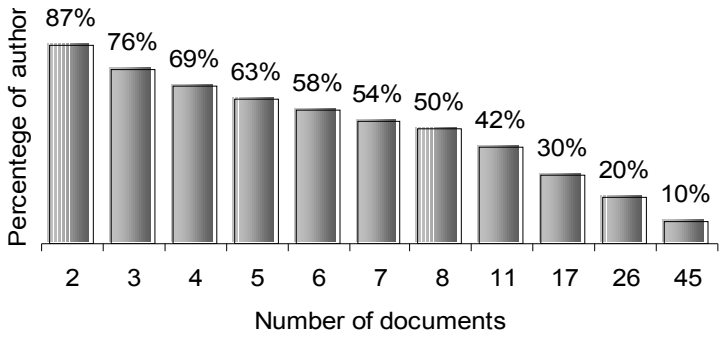
Table 2 provides basic statistics for RAS registrants. Of the 12,381 registrants in the RAS database, 8,666 have claimed at least one document while the remaining 3,715 have claimed none. It is difficult to explain why some individuals have registered for the RAS but not claimed any papers. Therefore, such records are excluded from further analysis. The average number of papers per registered author is 17.55, which is significantly higher than the average number of papers per author in various academic fields reported in other similar studies. For example, Newman (2004b) reports that the average number of papers per author is 6.4 in biology, 5.1 in physics, and 6.9 in mathematics based on the number of authors in Medline, Physics E-print archive, and Mathematical Reviews, respectively. There are possible explanations for the difference. First and foremost, RAS registrants are likely to be active in research and publication, evidenced by their interest in the service, and hence more prolific than an average author found in an indexing and abstracting database. Second, RePEc covers both journal articles and working papers, and might contain both the working version(s) and formally-published form of a document. Finally, it is likely that the prior studies underestimated the averages due to the difficulties outlined above in reliably distinguishing variations of the name of the same author.

Table 2. Summary statistics for RAS registrants

Number of RAS registrants	12381
Number of registrants who did not claim a paper	3715
Number of registrants who claim at least one paper	8666
Number of authorships	152072
Average number of papers/author	17.55

Figure 2 provides the frequency distribution of authors by number of documents they claim. A close examination of data reveals a tendency for authors who have claimed a large number of documents to register with RAS. In particular, three RAS registrants claim over 300 documents, fifteen registrants claim between 200 and 300 documents, and so on. It can be seen from the data that the percentage of authors with two or more articles is 87%, the authors with three or more articles is 76%, the authors with four or more articles is 69%.

Figure 2. Frequency distribution of authors by number of documents



According to the well known Lotka's Law of scientific productivity, about 60% of the authors publish only once (Egghe, 2005), which is not the case here. Using the software program LOTKA (Rousseau and Rousseau, 2000), we test whether Lotka's Law is valid for RAS registrants. We find that:

$$f(y) = \frac{0.3174}{y^{1.3927}}$$

where *f(y)* denotes the relative number of authors with *y* publications. According to Kolmogorov-Smirnov statistic (D_{max}=0.2022), the observed author publication frequencies cannot be described by the Lotka distribution. This indicates that interest in RAS is more wide spread among researchers who are highly productive. Prolific authors also act as hubs in the co-authorship network, as we will demonstrate in our analyses.

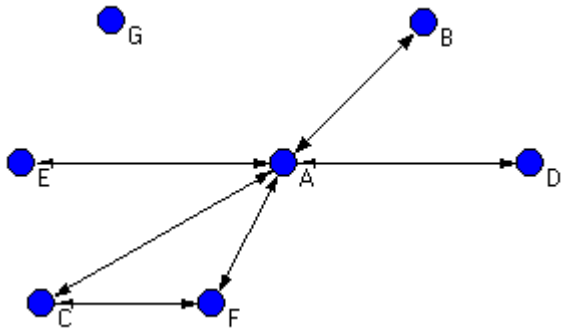
RAS co-authorship analysis

In this section, we investigate the structure of research collaborations within the co-authorship network of RAS using social network analysis methodology.

Introduction to social network analysis

Social network analysis is concerned with understanding the linkages among social entities and the implications of these linkages (Wasserman & Faust, 1994). A social network consists of a set of social entities and the relations defined on them, referred to as "actors" and "ties" respectively. A network can be presented as a graph, which consists of points (or nodes) to represent actors and lines (or edges) to represent ties or relations. An example of a social network diagram is given below.

Figure 3. A social network diagram



Co-authorship network studies

In recent years, there has been a vivid interest in the co-authorship networks to examine the patterns of collaborations within an academic community and determine the status and influence of individual researchers. Recent studies of research collaboration in a number of academic fields demonstrate that social network analysis plays a critical role in determining how well-connected a research community is. The academic fields range from physics, biomedical research, mathematics, computer science (Newman, 2004a; Newman, 2004b), neuroscience (Barabasi, Jeong, Neda, Ravasz, Schubert, & Vicsek, 2005), to digital library research community (Liu, Bollen, Nelson, & Van de Sompel, 2005) and economics (Goyal, van der Leij, Moraga-Gonzalez, 2004) and information sciences (Otte & Rousseau, 2002)

RAS co-authorship network

In the co-authorship network model for this study, nodes represent authors and an edge connects two authors if they coauthored one or more papers. We build a binary graph representing a nondirectional dichotomous relationship, that is a tie is either present or absent between each pair of authors. In this study, we do not take the frequency of co-authorship between authors into account. We plan to investigate weighted co-authorship networks in the future. Table 3 shows the summary statistics for RAS co-authorship networks.

Table 3. Summary statistics for RAS authors and co-authorship networks

Number of authorships by co-authors	137550
Number of authors with at least one co-author	5661
Number of authorships with at least one co-author	109924
Average number of collaborators/co-author	2.05
Size of the largest component	4659
Number of components	382
Network Diameter	22

To better understand the nature of collaboration patterns both on a micro- (i.e., immediate connections between authors) and a macro-scale (i.e., connections to the larger network), we first consider a number of basic statistics. The average number of collaborators per author is 2.05, which is smaller than the numbers observed in other disciplines. For example, Newman (2004b) reported, on average, 18.1 collaborators for biology, 9.7

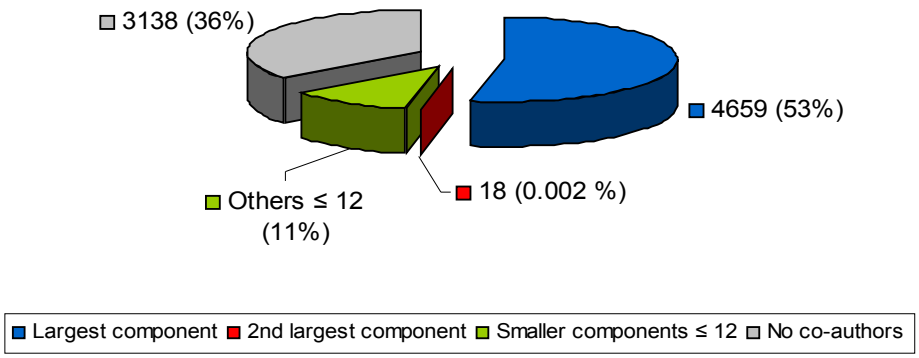
collaborators for physics, and 3.9 collaborators for mathematics. The most highly connected RAS author has 27 collaborators, which is lower than the number reported in other studies. For example, the Goyal et al. study reports that, for the 1990-1999 period in EconLit database, the average number of collaborators is 1.67 while the maximally connected economist has more than 50 collaborators. Table 4 furnishes a list of the 25 highest ranking economists according to the number of their collaborators found in RAS. A quick visual scan of Table 4 demonstrates wide differences among the authors. For example, Randall Wright has the most number of collaborators with 27 co-authors, and has claimed 106 documents. On the other hand, Barry Eichengreen has fewer collaborators with 19, but has claimed almost three times more documents (i.e., 323). A further ad hoc search reveals similar observations. For example, Gert Wagner ranks within the top 25 with 19 collaborators, but has claimed only 46 papers, whereas Jeffrey Frankel (who does not appear among the top 25 in Table 4) has 15 collaborators but has claimed 234 papers.

Table 4. Authors ranked according to the number of co-authors

Rank	Author	Co-authors	Papers
1	Randall Wright	27	106
2	Joseph Stiglitz	26	320
3	Clive Granger	25	165
4	James Stock	23	111
5	Pierre Chiappori	23	91
6	Martin Feldstein	22	259
7	Philip Franses	22	163
8	Robert Hubbard	22	116
9	Francis Diebold	21	189
10	Stephen Jenkins	21	138
11	Ronald MacDonald	21	137
12	Costas Meghir	21	86
13	Peter Phillips	20	315
14	Thomas Sargent	20	128
15	Fabio Schiantarelli	20	81
16	Barry Eichengreen	19	323
17	Hashem Pesaran	19	272
18	Andrew Rose	19	179
19	Olivier Blanchard	19	144
20	Edward Prescott	19	110
21	Carlo Favero	19	80
22	Gert Wagner	19	46
23	Eric Ghysels	18	195
24	Robert Engle	18	157
25	Francesco Giavazzi	18	80

The RAS co-authorship network is not a single connected graph but partitioned into one large component and many smaller components (i.e., groups of authors who are collectively linked by collaboration paths). The entire co-authorship network is composed of 382 components. The largest component has 4,659 authors (82% of the network, 53% of the population), the second largest component has 18 authors, the third largest component has 12, and so on. Figure 4 gives the component size distribution.

Figure 4. Component size distribution



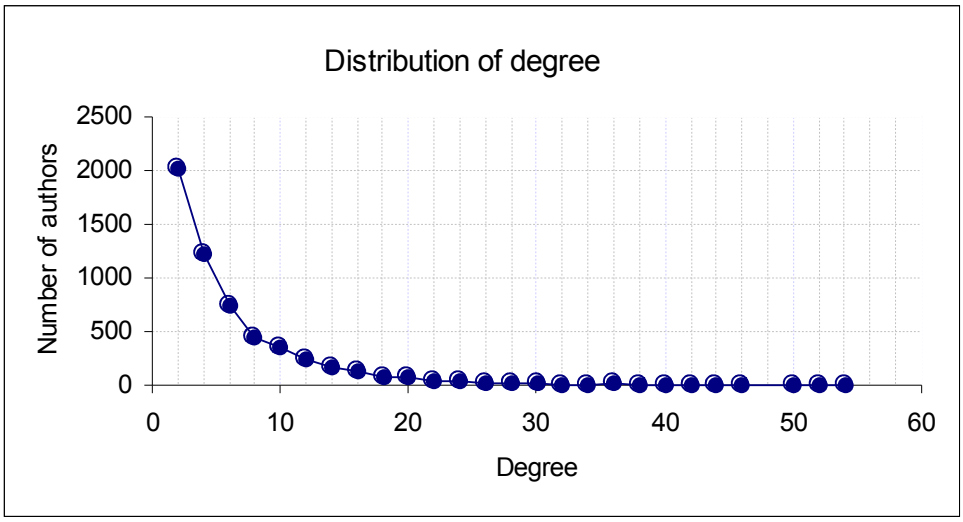
Centrality metrics

To examine the structural position of authors within the network, we calculate three centrality metrics for the network: degree, betweenness, and closeness. Table 5 gives the ranking of top 25 authors based on each of the metrics.

Degree: The degree centrality is the number of adjacent edges a node (i.e., an author) has, and can be considered a measure of "activity." We used the ***sna*** package of R[3] to obtain degree centrality (using Freeman's approach) for our network. It turns out that Randall Wright has the highest number of immediate edges. Appendix A shows the local network for Randall Wright drawn with Pajek[4] (Package for Large Network Analysis). He is followed by two winners of the Bank of Sweden Prize in the memory of Alfred Nobel (henceforth Nobel prize): Joseph Stiglitz, recipient of Nobel prize in 2001, and Clive Granger, the recipient Nobel prize in 2003. The degree centrality distribution, as shown in Figure 5, indicates that only a few authors have a high degree of connection while many others have a low degree.

[3] http://www.r-project.org/
[4] http://vlado.fmf.uni-lj.si/pub/networks/pajek/

Figure 5. Degree centrality distribution



Closeness: Closeness indicates an author's connection to all others through the length of a path in the corresponding social network. If we call the length of the shortest path between two authors the "distance," then the average of the distance between an author and all other authors in the same component measures the "closeness" of an author. To calculate the path length, we wrote a Perl script that implements the shortest-path algorithm by Newman (2001). Please note that, in any given network, there may be several shortest paths, albeit of equal length. In our network, Nobel prize winner Joseph Stiglitz ranks highest in closeness measure. This is not surprising given his prominent standing in the field.

Betweeness: While the degree is a measure of direct connectedness within the immediate network, betweenness is a measure of indirect connectedness to the larger network. Betweenness is measured by the number of times an author appears on the shortest paths between two other authors. If n designates the number of all shortest paths between authors A and B, and the author C may appear on p of them ($p \leq n$), then the fraction p/n indicates the betweenness of author C between authors A and B. Therefore, betweenness measure of the author C is the sum of betweenness measures among all author pairs A and B. Therefore all authors who have only collaborated with one other registered author have a betweenness of 0. In our study, Joseph Stiglitz has the highest betweenness measure, and it is dramatically larger than everyone else.

It is noteworthy that there are the differences between closeness and betweeness measures among the authors. Some authors rank high on both counts. These are the scholars who have written a lot of papers with a lot of collaborators. There are also authors who score high on betweeness but relatively low on closeness. These are the authors who act as a bridge between sub-communities and the larger collaboration group. Such sub-communities may be regional in character. For example, Gert Wagner appears to act as a bridge for Latin American authors. Sub-communities can also be discipline-based. For example, Hashem Pesaran's work straddles macroeconomics and econometrics. Similarly, Andrew Postlewaite's work bridges game theory and microeconomics.

For this particular network, we observed that the diameter (i.e., the largest geodesic distance between any pair of nodes in the graph) is 22 which is smaller than 29 reported in Goyal et al study based on articles in EconLit for the 90's period.

Table 5. Authors ranked according to centrality measure

Rank	Degree		Betweenness		Closeness	
1	Randall Wright	54	Joseph Stiglitz	903758.86	Joseph Stiglitz	4.8199
2	Joseph Stiglitz	52	Fabio Schiantarelli	700949.47	Olivier Blanchard	4.8952
3	Clive Granger	50	Juergen von Hagen	699927.26	James Stock	4.9594
4	Pierre Chiappori	46	Costas Meghir	626284.35	Fabio Schiantarelli	4.9972
5	James Stock	46	Clive Granger	587076.57	Martin Feldstein	5.0004
6	Martin Feldstein	44	Gert Wagner	579692.04	Juergen von Hagen	5.0453
7	Philip Franses	44	Mark Taylor	551873.68	Costas Meghir	5.0459
8	Robert Hubbard	44	Olivier Blanchard	541855.20	Barry Eichengreen	5.0711
9	Francis Diebold	42	Pierre Chiappori	530045.41	Marcus Miller	5.0805
10	Stephen Jenkins	42	Klaus Zimmermann	504285.85	Alison Booth	5.0893
11	Ronald MacDonald	42	Thierry Verdier	468907.77	Robert Hubbard	5.0910
12	Costas Meghir	42	Friedrich Schneider	446818.87	Michael Rothschild	5.0988
13	Peter Phillips	40	James Stock	442058.12	William Brock	5.1136
14	Thomas Sargent	40	Alison Booth	440886.92	Mark Gertler	5.1166
15	Fabio Schiantarelli	40	Harald Uhlig	429068.93	Mark Taylor	5.1280
16	Olivier Blanchard	38	Hashem Pesaran	423172.90	Randall Wright	5.1353
17	Barry Eichengreen	38	Martin Feldstein	419839.19	Pierre Chiappori	5.1361
18	Carlo Favero	38	Andrew Postlewaite	410989.36	Paul Beaudry	5.1533
19	Hashem Pesaran	38	John List	410771.01	Michael Devereux	5.1569
20	Edward Prescott	38	Stephen Jenkins	409343.06	Lars Svensson	5.1651
21	Andrew Rose	38	Ronald MacDonald	400140.56	Thierry Verdier	5.1707
22	Gert Wagner	38	Paul Beaudry	396126.25	Andrew Rose	5.1730
23	Robert Engle	36	Francis Diebold	394494.57	Francesco Giavazzi	5.1730
24	Eric Ghysels	36	Eric Ghysels	385767.44	Gregory Mankiw	5.1748
25	Francesco Giavazzi	36	Randall Wright	384312.69	Michael Woodford	5.1767

Conclusion and Future Work

In this paper, we take a broad look at the patterns of research collaboration in RePEc, a large digital library for Economics. The data used to construct the co-authorship network for this study is not complete due to those authors who have not documented all their papers in their profiles and/or their co-authors are not RAS registrants. However, the database from RePEc yields high-quality authorship data from 8,666 registrants who claim at least one paper, and 152,072 corresponding authorship records.

In general we observe that authors who have written a large number of papers tend to register with RAS. In terms of information productivity, the 80/20 Rule (i.e., 80% of the information productivity is generated by 20% of the information resources), does not apply to RAS authors. In addition, RAS registrants appear to have a broad range of coauthors, with most having only a few coauthors, whereas a few having many. Although the average number of collaborators per author in RAS appears to be lower compared to other disciplines, it is observed to be higher when compared with another similar study in economics. Our findings imply that the RAS population is made up of highly active academics that are well connected to each other.

Although the author profiles maintain valuable information at an individual level (e.g., the number of downloads, references to citing articles, etc.), they lack information at a broader level (i.e, the co-authorship relations within the research community). The latter information can be extracted from the archive and incorporated into the profiles. We believe this will add significant

value to the service as we analyze the social dimension of scholarly research which can be best understood by examining it within a network context. Consequently, insights gained from this study will help RePEc team in developing a strategic plan to expand and improve the service in the near future. Ultimately, our goal is to make this source of information available for the RePEc digital library community and others interested in the phenomenon of research collaboration in the field of economics. One possible direction for future work is to build a user service where authors examine the paths that lead them to other authors.

Finally, the results reported here represent only a small portion of what can be done with this data. The RePEc database not only identifies the authors but their affiliations (e.g., universities, research institutions) as well. In order to understand the nature of connectedness better, we propose to study author affiliations.

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Appendix A. Local network for Randall Wright