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Abstract

From its very beginnings, regional science has been open to intellectual exchange with many other scientific disciplines. This has led to cross-fertilization, but also to problems concerning the intellectual identity of regional science. After half a century of history of the field, it is time to ask the question, whether or not regional science has developed into a scientific discipline in these decades.
In this paper we use cross-citation data between 464 journals in different disciplines to answer this question. With this data set we attempt to find out, how strongly regional science journals are interconnected by citations as compared to their citation links to journals in neighbouring disciplines. We find that when we consider the raw citation data, regional science becomes fragmented with its journals tied to those from economics, geography, planning, etc. When we standardize the citation information to take into account size differences between journals, however, regional science appears to form a strong and well connected dscientific discipline.

1. Introduction

From its very beginning, regional science has been a field of research with strong relations to others. In the very first meeting of the Regional Science Association the aim of the new organization was defined as follows: “to foster exchange of ideas and to promote studies focusing on the region and utilizing tools, methods and theoretical frameworks specifically designed for regional analysis as well as concepts, procedures, and analytical techniques of the various social and other sciences” (p.3). Regional science borrowed from various other disciplines and maintained close contacts to many related areas. Arguably most notable are economics, geography, sociology, demography, and planning (Maier, 2005).

This strong relationship to other areas of research on the one hand has been a constant stimulus for the development of regional science, but on the other hand has frequently plagued it because it questioned its very existence as a scientific discipline. Andrew Isserman, one of the most recognized authors in regional science even claimed “Regional science never became a science or a discipline” (Isserman, 1995, p.249). The diagnosis, however, did not prevent him from further publishing in regional science journals and on regional science topics.

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The close relationship to neighbouring disciplines led to discussions about the thematic focus and role of regional science in society (Mittelbach, 1975, Isserman, 1993, Nijkamp, 1994, Plane, 1994). Hägerstrand (1973) raised the question "What about people in regional science?" and in the 1990s the discussion culminated in a perception of crisis. Bailly and Coffey (1994) diagnosed "a lack of relevance" and "a narrow perspective" and triggered a heated discussion with contributions by Gibson (1994), Plane (1994), Stough (1994), Anas (1994), Vickerman (1994), Casetti (1995) and others.

With the turn of the century, the perception turned more to the positive side. Quigley (2001) in referring to the discussion of crisis a few years earlier talks about the "renaissance in regional research", and mainly attributes that to developments that took place outside of regional science and to "the contribution of regional science 'infrastructure' to this research enterprise" (p. 174). Bailly and Gibson (2004) suggest "directions for the future" and Kramsch and Boekema (2002) comment "on the status and the future of regional science" from the perspective of a European border region. Kind of following the tradition, they imagine regional science "a vital border-crossing discipline, located at the confluence of multiple research paths" (p. 1388). In conclusion they argue "that rather than view each research strand as an 'improvement' on its predecessor they should be viewed as the grounds for a potentially rich cross-fertilization between spatial science and various fields of nonorthodox economics" (p.1373).

A major element of this discussion irrespective of whether it leans more to the pessimistic or to the optimistic side is the issue of whether or not regional science is a scientific discipline by itself and what its relationship is to neighbour disciplines. With this paper we want to contribute to this discussion. We do this by use of a citation based social network analysis. We analyse the citation network of a large number of journals, among them the most relevant journals in regional science and the related areas mentioned above. Our basic hypothesis is that a scientific discipline is characterized by a set of journals which is related by citations to one another more intensively than to journals from other disciplines. What at first sight seems to be a rather simple empirical issue turns out to raise some rather tricky questions at closer inspection. Since journals vary in numbers of pages and articles, and disciplines differ markedly in their citation behaviour, the raw citation data may not give the definite answer. Standardizations are necessary that correct for these disturbances. Which method of standardization to use, however, is debatable. The choice will definitely influence the results of the analysis.

The paper is structured as follows: In the next section we provide a short overview of the existing literature of citation analyses, where the focus will be on the one hand on analyses of citations between journals, on the other hand on papers that deal with regional science and closely related fields. Section 3 briefly describes the data and the data collection strategy. The main results of the paper are given in section 4. After an overview of the structure of the data in section 4.1, in 4.2 we present the results for the raw citation data. Sections 4.3 and 4.4 give the corresponding results for standardized citation data, where in section 4.3 we use a standardization method developed by Pudovkin and Garfield, in section 4.4 the standardization is based on the logic of the gravity model. The paper closes with a summary in section 5.

2. Existing relevant literature

There exists a substantial amount of literature dealing with quantitative measurement of the relationships in science, cross-citations, the flow and spreading of knowledge, etc. For a recent review of the quantitative aspects of this field see Bar-Ilan (2008).

Also the more narrowly defined aspect of the mapping of journal-journal citations has a long history. In the 1970s Narin et al. (1972) and Carpenter and Narin (1973) have used this method to identify the clustering of scientific journals (see also Narin, 1976). Later contributions are by Doreian and Fararo (1985), Leydesdorff (1986), and Tijssen et al. (1987). More recent contributions concentrate more on specific aspects of the method. Leydesdorff (1994) discusses a method for generating aggregated journal-journal citation information from the CD-ROM version of the Science Citation Index, in a later paper he uses principal component analysis in an attempt to classify scientific journals based on such data (Leydesdorff, 2006). One issue in this discussion is which measures to use for the identification of the relatedness of journals. Boyack et al. (2005) use the full journal to journal citation matrix from both the Science Ciatation Index and the Social Science Citation Index to test various similarity measures. Klavans and Boyack (2006) also discuss these measures and propose a new framework for assessing their performance. A few years earlier Pudovkin and Garfield (2002) propose a procedure that takes into account varying journal sizes.

In regional science the number of publications that apply scientometric methods is limited. Moreover, most of them deal with internal aspects of the discipline and not with the relationship between regional science and its neighbours. An early example for the application of scientometrics in regional science is the paper by Kau and Johnson (1983) who rank regional science programs based on their publication performance. Allen and Kau (1991) and Strathman (1992) focus on just one journal in their discussion of the development of the discipline (or parts of it). The respective journals are the *Journal of Urban Economics* and the *Journal of Regional Science*. Florax and Plane (2004) make a similar analysis for the fifty years publication record of *Papers in Regional Science*.

Broader perspectives are taken by Rey and Anselin (2000), Surinach et al. (2003) and Isserman (2004). They all use not just one but a set of regional science journals as the basis of their analysis. While Rey and Anselin (2000) as well as Surinach et al. (2003) search for trends and developments in the topics of the respective publications, Isserman (2004) tries to identify the intellectual leaders in the discipline. He does this by use of a citation analysis.

To some extent, our analysis combines the two research traditions that we have discussed above. On the one hand we focus on regional science as a scientific discipline, while one the other hand we follow the tradition of scientometrics by taking into account a broad set of journals. In doing so, we use a much wider set of citation evidence than any of the earier studies in the discipline and thus provide unique insights into the position of regional science within the larger set of related scientific disciplines. On the other hand, we can use our knowledge and insights as regional scientists to gain a better understanding of the structures we analyse than is possible for most scientometrists.

3. Data and data collection

Our analysis is based on two data sources. On the one hand we use cross-citation information from the Journal Citation Reports (JCR) published by ISI Thompson based on the database of the Social Science Citation Index. Among other information, this data source shows how often articles published in a specific journal in one year have cited articles published in this or other journals. This allows for the generation of cross-citation matrices among journals. Our second data source is the results of the survey conducted by Gunther Maier among regional scientists investigating the reputation and importance of regional science journals (Maier, 2007). As described below, this data source is used as a starting point for the data collection and to identify the core regional science journals.

The JCR of the Social Science Citation Index contains information about a total number of 1768 journals. For each of them the dataset shows how many times in 2006 an article in that journal cited an article in any of those journals. The names of the two journals and the number of citations are reported, when the number of citations is at least two. Cross citations that occur only once are not reported in the data. To focus the analysis we applied the following procedure to select a subset of the journals.

1. We took the top ten journals in regional science from table 8 of Maier (2007). This table is based on a weighted index of the number of times a journal was named as the first, second, third, fourth, or fifth important journal for the respondent's work in regional science. A nomination as first is weighted by five points with the number of points declining linearly down to one point for a fifth place nomination. The resulting list of top 10 journals and their weighted index scores are given in Table 1.
2. ISI Thompson assigned every journal to one or more of 55 subject categories. In the second step we first identified the subject categories to which the top ten regional science journals are assigned by ISI Thompson. In a second step we identified all the journals in these subject categories.
3. For each of these journals we downloaded their citation tables, i.e. the names and numbers of citations of journals in these journals.
4. For every journal we identified the five most cited journals and, provided they were not yet downloaded and were included in the database, downloaded their citation tables.
5. Step 4 was repeated until we reached an almost closed set of journals. Since we did not want to include the extensive citation networks of medical and psychiatry journals, we stopped this procedure when the only new journals were in these areas.

This procedure led to a list of 464 journal names and a 464 by 464 square matrix of journal cross citations. The JCR provides more information about these journals than what is compiled into the cross citation matrix. The JCR assigns each journal to one or more subject areas, gives the numbers of active and passive citations, and the number of articles published in 2006.

4. Empirical results

In this section we present our empirical analysis that is intended to answer the question, whether or not regional science is a scientific discipline.

4.1. Structure of the data

As has been mentioned above, starting point of our analysis are the top ten journals of table 8 from Maier (2007). They are shown in Table 1. We will refer to this group of journals throughout the empirical part of the analysis.

Table 1: The 10 most important journals as indicated by regional scientists, weighted index

Rank	Journal title	Weighted index score
1	Regional Studies	1141
2	Journal of Regional Science	852
3	Papers in Regional Science	701
4	Regional Science and Urban Economics	651
5	Urban Studies	456
6	Annals of Regional Science	419
7	Journal of Urban Economics	381
8	Environment and Planning A	342
9	International Regional Science Review	206
10	European Planning Studies	201

Source: Maier, 2007

According to the regional scientists' assessments, *Regional Studies* received the highest score, well ahead of the *Journal of Regional Science* and the *Papers in Regional Science* which rank second and third. Except for *Environment and Planning A*, all top 10 journals have a clear regional science focus. So, nine of the ten most important journals for regional scientists are specifically dedicated to this field of science. The fact that there are specialized journals which are of central importance for these scientists underlines the disciplinary nature of regional science. That *Environment and Planning A* shows up in the top 10 ranking is a sign of the importance of environmental issues in the research work of many regional scientists. Furthermore it is interesting that there are three journals in the top 10 ranking that place a special focus on urban issues, showing the importance of the urban area in regional science.

Analysing the data on citation links between the journals in our database (described in section 3) results in a couple of key indicators for the top 10 regional science journals. At first we are going to deal with the basic bibliometric indicators citations and references, both in absolute terms and relative to the number of articles published by each journal (see tables 2 and 3). The term "citation" refers to an article being cited by another article, the term ''"reference" to an article citing another article. In the following two tables "citation" counts how often articles published in a specific journal X are cited by articles in the other journals (and the journal itself, if applicable) whereas 'reference' counts how often articles published in X are citing articles in the other journals (and the journal itself, if applicable).

Table 2: **Citations and references of the top 10 regional science journals**

Journal title	Citations Top 10	Citations All journals	References Top 10	References All journals
Regional Studies	385	1227	373	3903
Journal of Regional Science	197	565	173	1327
Papers in Regional Science	100	302	164	1077
Regional Science and Urban Economics	221	647	134	1092
Urban Studies	540	2079	541	6626
Annals of Regional Science	96	240	230	1331
Journal of Urban Economics	410	1320	228	1455
Environment and Planning A	414	2195	428	7728
International Regional Science Review	108	272	97	492
European Planning Studies	153	367	256	3371
All top 10 journals	2624	9214	2624	28402
All 464 journals	9482	788606	6845	1038454

Based on citation data from Thomson Scientific

Table 3: **Citations and references indicators of the top 10 regional science journals**

Journal title	Citations-References Ratio Top 10	Citations-References Ratio All journals	Top 10 to All Journals Ratio Citations	Top 10 to All Journals Ratio References
Regional Studies	1.03	0.31	0.31	0.10
Journal of Regional Science	1.14	0.43	0.35	0.13
Papers in Regional Science	0.61	0.28	0.33	0.15
Regional Science and Urban Economics	1.65	0.59	0.34	0.12
Urban Studies	1.00	0.31	0.26	0.08
Annals of Regional Science	0.42	0.18	0.40	0.17
Journal of Urban Economics	1.80	0.91	0.31	0.16
Environment and Planning A	0.97	0.28	0.19	0.06
International Regional Science Review	1.11	0.55	0.40	0.20
European Planning Studies	0.60	0.11	0.42	0.08
All top 10 journals	1.00	0.32	0.28	0.09

Based on citation data from Thomson Scientific

Of the top 10 regional science journals *Environment and Planning A* and *Urban Studies* are receiving most citations overall, followed by the *Journal of Urban Economics* and *Regional Studies*. From within the group of the top 10 regional science journals it is the same four journals, but switching the top position: *Urban Studies* is now first, *Environment and Planning A* second. The picture is very similar regarding references. Most references to the whole set of journals originate from *Environment and Planning A* and *Urban Studies*, followed by *Regional Studies* and *European Planning Studies*. References to the top 10 regional science journals concern most often *Urban Studies*, *Environment and Planning A* and *Regional Studies*. The number of references clearly surpasses the number of citations as far as the whole set of journals is concerned. Table 3 shows ratios calculated from the data in Table 2. The columns under “Citations-References Ratio” show the ratio of the number of citations received by each journal to the number of references originating from this journal. The respective number shows whether the journal is a net receiver (ratio below 1) or a net generator of citations (ratio larger than 1). For every top 10 journal it holds that it is referring more the other journals than it is being cited. All the “Citations-References-Ratios” under “All journals” are clearly smaller than one. Only for the *Journal of Urban Economics* this relation is above 0.9. *European Planning Studies* and the *Annals of Regional Science*, on the other hand receive only 11% and 18% respectively of the citations they generate as references.

Within the group of the top 10 journals, the numbers of citations and references are far more balanced, of course. Nevertheless, as the column “Top 10” under “Citations-References Ratio” shows, some journals are far more often cited than citing (*Regional Science and Urban Economics*, *Journal of Urban Economics*) while others are far more often citing than being cited (*Papers in Regional Science*, *Annals of Regional Science*, *European Planning Studies*).

By comparing the citation and reference data for the top 10 journals with those for all journals, we can get a first impression of the strength with which the regional science journals are tied together as compared to their ties to all the other journals (see Table 3, column “Top 10 to All journals ratio”). Regarding citations the journals’ shares of top 10 citations in all citations is up to 0.42 (*European Planning Studies*) and in most cases larger than the average of 0.28. Regarding references the shares are much smaller. The average is just 0.09, the highest ratio of 0.20 is achieved by the *International Regional Science Review*, the smallest by *Environment and Planning A* (0.055) and by *European Planning Studies* (0.076). This shows that some journals are less strongly tied to the group of top 10 regional science journals than others. This is particularly the case for *Environment and Planning A*, which reaches the lowest ratio for both citations and references.

If we consider references as indicators of an inflow of information and citations as an outflow, our analysis shows clearly, that regional science, when represented by our top 10 journals, receives more information from outside areas than it disseminates to them. The numbers of references exceed the numbers of citations for all journals. At the same time we also see that this inflow of information tends to be relayed to other journals within regional science, as can be seen from the higher “Top 10 to All journals ratio” for citations than for references.

Of course, absolute numbers of citations and references are also depending on the number of articles published in the respective journals. Therefore it is neccessary to look at the respective relative numbers too (see Table 4).

Table 4: Relative citations and references per article of the top 10 regional science journals

Journal title	Articles	Citations per paper Top 10	Citations per paper All journals	References per paper Top 10	References per paper All journals
Regional Studies	68	5.66	18.04	5.49	57.40
Journal of Regional Science	37	5.32	15.27	4.68	35.86
Papers in Regional Science	29	3.45	10.41	5.66	37.14
Regional Science and Urban Economics	36	6.14	17.97	3.72	30.33
Urban Studies	116	4.66	17.92	4.66	57.12
Annals of Regional Science	49	1.96	4.90	4.69	27.16
Journal of Urban Economics	52	7.88	25.38	4.38	27.98
Environment and Planning A	117	3.54	18.76	3.66	66.05
International Regional Science Review	15	7.20	18.13	6.47	32.80
European Planning Studies	69	2.22	5.32	3.71	48.86
All top 10 journals	588	4.46	15.67	4.46	48.30
All 464 journals	23394	0.41	33.71	0.29	44.39

Based on citation data from Thomson Scientific

The *Journal of Urban Economics* receives the most citations per paper, both from the whole set of journals and the top 10 regional science journals. Within the top 10 citations, the *International Regional Science Review* and *Regional Science and Urban Economics* have similar ratios. Referring to the whole set of journals most top 10 journals have similar ratios, only the *Annals of Regional Science* and the *European Planning Studies* lie clearly behind. As far as references to all journals are concerned, *Environment and Planning A*, *Regional Studies* and *Urban Studies* are top. The journals that refer most frequently to other top 10 journals per article are the *International Regional Science Review*, *Papers in Regional Science* and *Regional Studies*. It is interesting that there is a considerable difference in the ranking of the top 10 regional science journals depending on the assessment of the importance by the survey respondents (see Table 1) or on relative citations and references. This indirectly confirms the analysis presented by Maier (2006) who reports a lack of significant correlations between the survey results and journal impact factors.

When we l'ook at the 20 journals most frequently citing and being cited by the top 10 journals (see Tables 5 and 6) the results of our analysis thus far are confirmed. As far as references are concerned (Table 5), the top 10 regional science journals perform very prominently on this list. They occupy the first four positions, and only two of the journals (*Papers in Regional Science* and *Annals of Regional Science*) are not among the top 20 ranks.

Table 5: The 20 most important journals being cited by the top 10 regional science journals

Journal title	References
Urban Studies *	540
Environment and Planning A *	414
Journal of Urban Economics *	410
Regional Studies *	385
American Economic Review	380
Journal of Political Economy	277
Regional Science and Urban Economics *	221
Quarterly Journal of Economics	204
Journal of Regional Science *	197
International Journal of Urban and Regional Research	172
Review of Economics and Statistics	159
European Planning Studies *	153
Progress in Human Geography	142
European Economic Review	139
Journal of Economic Geography	137
Econometrica	131
Economic Journal	122
Annals of the Association of American Geographers	121
International Regional Science Review *	108
Transactions of the Institute of British Geographers	108

* Top 10 regional science journals according to the assessment of survey respondents (Maier, 2007)

Based on citation data from Thomson Scientific

Table 6: The 20 most important journals citing the top 10 regional science journals

Journal title	Citations
Urban Studies *	541
Environment and Planning A *	428
Regional Studies *	373
European Planning Studies *	256
Annals of Regional Science *	230
Journal of Urban Economics *	228
Journal of Regional Science *	173
Papers in Regional Science *	164
Geoforum	162
Growth and Change	161
Housing Studies	147
Progress in Human Geography	142
Regional Science and Urban Economics *	134
International Journal of Urban and Regional Research	127
Urban Geography	120
Journal of Economic Geography	119
Environment and Planning C	110
Environment and Planning B	97
International Regional Science Review *	97
Economic Geography	93

*** Top 10 regional science journals according to the assessment of survey respondents (Maier, 2007)**

Based on citation data from Thomson Scientific

Regarding the citations (Table 6), the internal cross-citing becomes even more obvious. All top 10 regional science journals are in the list of the 20 most frequently citing journals. They occupy the first eight positions. Overall, we can conclude that the top 10 regional science journals are strongly interlinked regarding citations and references.

There are several indicators which describe the position of nodes in networks. In our case the nodes are journals in the network of a large set of scientific journals (464 overall) linked by citations and references. Being interested in the position of the 10 most important regional science journals we have calculated the following three basic network indicators (see Table 7):

- Degree centrality, dichotomous ties: This degree equals the number of other nodes to which a specific node is connected. The higher the value, the higher the number of other nodes the node under consideration has relations with. In our context the degree shows the number of other journals a specific journal X is linked with by at least one citation and reference.
- Degree centrality, valued ties: The valued degree is the sum of all links of one node to other nodes considering the value of each tie. Contrary to the dichotomous degree, where there is either a citation link between two journals or not, for calculating this degree each link is weighted by the number of citations and references.
- Betweenness: This indicator measures the extent to which a node is directly connected only to those other nodes that are not directly connected to each other. The higher the value, the larger the number of nodes being linked up by the node under consideration. In

our context betweenness measures the bridging function of a journal, linking parts of the network which would be separate otherwise.

Table 7: Network indicators for the 10 most important regional science journals - degree centrality and betweenness

Journal title	Degree (dichotomous ties)	Degree (valued ties)	Betweenness
Regional Studies	155	1530	2695
Journal of Regional Science	95	840	660
Papers in Regional Science	87	551	318
Regional Science and Urban Economics	99	828	626
Urban Studies	172	2004	6830
Annals of Regional Science	81	583	215
Journal of Urban Economics	119	1215	905
Environment and Planning A	201	2398	7358
International Regional Science Review	56	319	132
European Planning Studies	104	735	554

Based on citation data from Thomson Scientific

Environment and Planning A has the highest number of citation links (the highest degree), followed by *Urban Studies* and *Regional Studies*. Most other top 10 journals are rather close, only the *International Regional Science Review* has a clearly smaller degree. The picture is very similar regarding the valued degree, the first four ranks are occupied by the same journals.

Regarding the bridging of otherwise separate parts of the journal network (measured by the indicator "betweenness"), the same journals are most important: *Environment and Planning A*, *Urban Studies* and *Regional Studies*. The other journals have far smaller values and are, therefore, much less important mediators. For *Environment and Planning A* this can be seen as another indicator of its relatively strong connection to areas outside the core of the top 10 regional science journals.

Even from this first analysis we can already draw some important preliminary conclusions. Although we find that regional science journals are strongly connected to journals outside its own core, particularly as far as references are concerned, we also see considerable connections among the top 10 regional science journals. Some of the journals, like *International Regional Science Review*, seem to be more strongly integrated into the group than other, like *Environment and Planning A*.

So far we have only looked at summary indicators of the citation data and at the most important citation links. In the remainder of this section we will take a more detailed look at the full set of ciation information.

4.2. Raw citation data

To answer the question whether or not regional science is a discipline, we investigate the strength of the connection between the regional science journals in our dataset and compare it to that between other groups of journals as well as that between those journals and the various regional science journals. We apply the same research method to three related but somewhat different data sets: first, the raw citation data, and then to the same citation data standardized in two different ways.

The raw citation data can be organized in a 464x464 citation matrix. This matrix is quite sparse. Of its 215,296 elements over 90 per cent is zero because there are less than two citations between the respective two journals. Only 21,333 elements contain non-zero entries. The largest numbers of citations are journal self-citations and therefore on the main diagonal of the citation matrix. Of the fourteen largest elements in the citation matrix only one is not a self citation and therefore not on the main diagonal (*Personality and Social Psychology Bulletin -> Journal of Personality and Social Psychology*). The largest number in the citation matrix is 1969. That number of times the *Journal of Personality and Social Psychology* cited itself.

When ordered by size, the cross-citation numbers decline rapidly. With 805 the tenth largest number (self-citations by *Ecological Economics*) is only 40 per cent of the largest one. This suggests a distribution following a power law. This hypothesis is supported by the analysis. A double logarithmic regression of the number of citations on the rank in the distribution yields $\log(X) = 11.39 - 1.07 * \log(Rk)$ with X being the number of citations and Rk being the rank in descending order. The r-square is computed as 0.97.

While the analysis of the citation matrix as a whole can generate some valuable insights, we are mainly interested in the mutual connection between two journals. Two journals are strongly connected, when journal A cites journal B and journal B also cites journal A. If the citation link is strong only in one direction, we do not consider this a connection. To take this into account, we transform the citation matrix in such a way that

$$\tilde{X}_{ij} = \tilde{X}_{ji} = \min(X_{ij}, X_{ji})$$

where X represents the values of the original citation matrix and $\tilde{X}$ those of the transformed citation matrix. In other words, we derive a symmetric matrix, where the value of each element is the smallest value of this element and that of its corresponding element mirrored on the main diagonal. In this new matrix only those pairs of journals show large values that strongly cite each other in both directions.

We use this transformed citation matrix as the basis for the social network analysis. The matrix is transformed into a graph with the journals being the nodes and the non-zero citations (elements of the transformed citation matrix) being the links between them. To find out which journals are strongly connected and whether regional science journals are more strongly connected to each other or to other groups of journals, we apply the following procedure.

1. We select a threshold level and eliminate all links with values below the threshold level.
2. We eliminate all nodes that became isolated in the previous step.
3. We identify the components of the graph. These components give groups of journals that are connected with values higher than the threshold to each other and with values below the threshold – or not at all – to other journals.

4. We identify the regional science journals and find out, whether any of them became isolated and whether they belong to the same component or to different components.

Table 8: network indicators for threshold levels 0-20, raw data

threshold	no of nodes	isolates	components	largest	second largest
0	455	9	2	452	3
1	455	0	2	452	3
2	440	15	2	437	3
3	425	15	4	419	2
4	415	10	6	404	3
5	403	12	8	387	3
6	392	11	8	366	12
7	382	10	8	356	12
8	369	13	8	342	12
9	358	11	12	306	11
10	342	16	14	288	10
11	329	13	18	268	10
12	318	11	22	244	10
13	305	13	22	233	10
14	296	9	22	208	19
15	284	12	21	199	18
16	277	7	20	196	17
17	268	9	20	190	17
18	262	6	21	185	16
19	252	10	19	181	15
20	248	4	20	153	26

Table 8 shows the results when this procedure is applied with threshold levels from zero to twenty. For each threshold level the table gives the number of connected nodes, the number of nodes that are deleted at isolates at this level, the number of components in the network and the size (number of nodes) of the largest and the second largest of the components. As we see, when we use a threshold level of zero, we start off with two components of very different size; one with 452 nodes and one with just three. With the exception of the three journals of the second component and the nine journals that are isolated even at the lowest threshold level, all journals in the data set are directly or indirectly connected by mutual citation links. When we increase the threshold level, more and more journals are eliminated as isolates and the initially large component breaks up into smaller and smaller ones. At the threshold level of zero the ratio of the size of the largest to that of the second largest component is 150. With the increasing numbers of isolates and components this ratio declines to a value of 4.68 at the threshold level of 22. At a threshold of 23 the largest component breaks apart, pushing this ratio to a value under two.

Of the ten core regional science journals that we identified, four become isolated and thus eliminated in this early stage. The first one is *Papers in Regional Science* which is eliminated at a threshold of 13. This implies that this journal is connected with no other journal by more than 13 mutual citations. The next one eliminated is the *International Regional Science Review* (14), then *Annals of Regional Science* (15), and finally the *Journal of Regional Science* at a threshold level of 16.

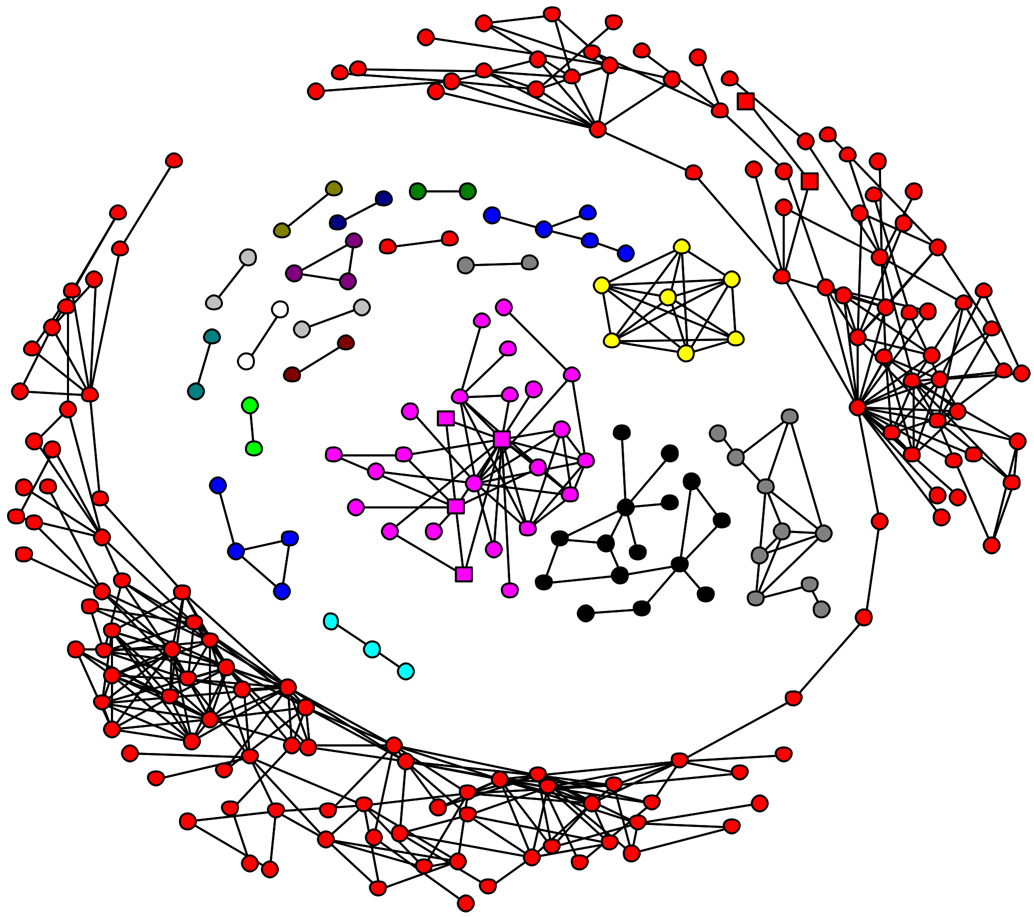

Figure 1: Components of the citation network at a threshold of 20

This leaves us with six regional science journals remaining in the analysis. Their position in a graph derived from a threshold level of twenty can be seen in Figure 1. The top 10 regional science journals are identified by squares. Two of them, representing *Journal of Urban Economics* and *Regional Science and Urban Economics* belong to the largest component that surrounds the others in the figure. The other four, representing *Environment and Planning A*, *Regional Studies*, *European Planning Studies* and *Urban Studies*, belong to the second largest component of the graph, which in the picture is displayed in the centre. It is important to note that these two sets of regional science journals are more strongly connected to the other journals (from other disciplines) of their component than to each other.

When we investigate the smaller components we see that they contain journals which clearly belong to the same group. Within this paper we cannot analyze them all. To illustrate this argument, we just give examples: *Social Work* and *Journal of Social Work Education* form one component, *Transportation*, *Transportation Science*, *Transportation Research A* and *Transportation Research B* form another component. The strongly interconnected component of seven nodes in the upper right hand side of the centre of Figure 1 consists only of university law reviews (Columbia, Harvard, Michigan, Stanford, Yale, U.Chicago and U.Pennsylvania).

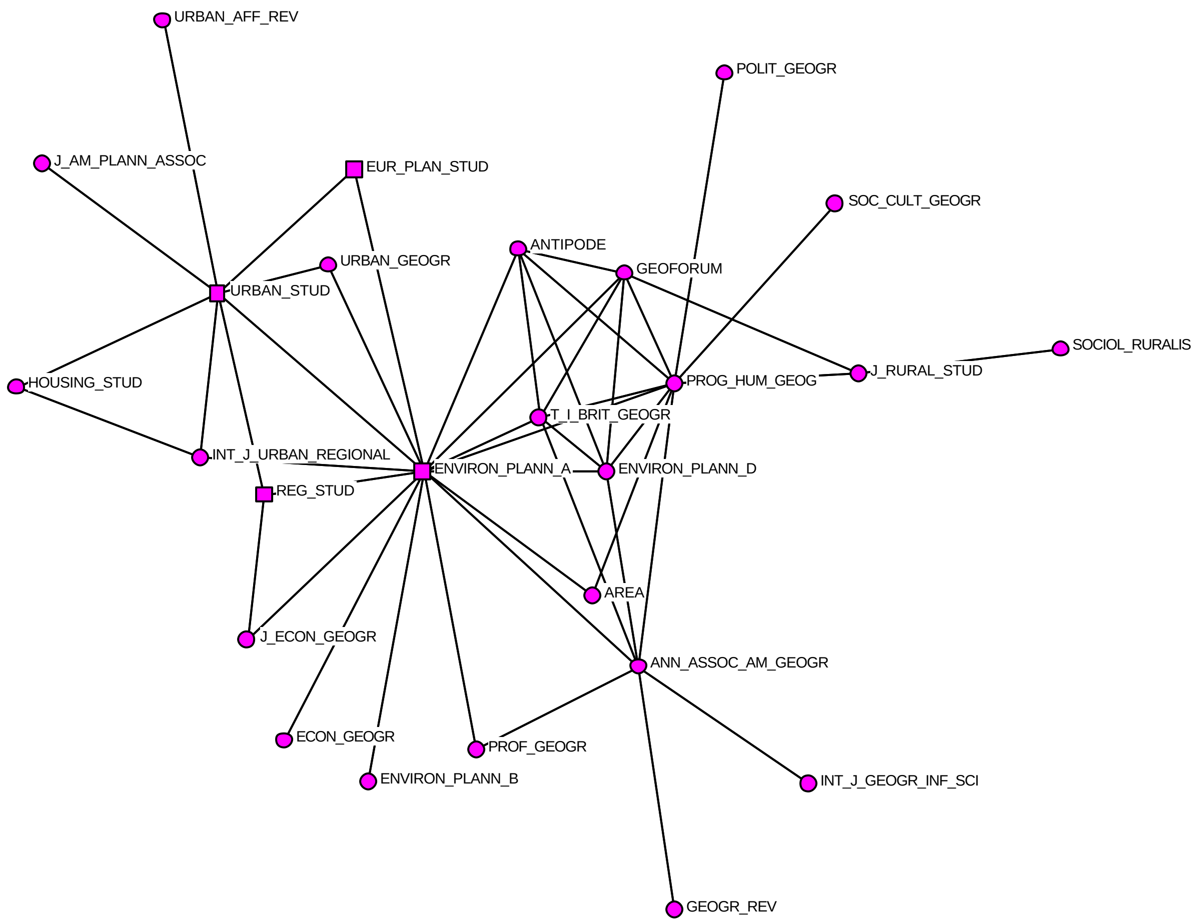

Figure 2: The second largest component of Figure 1 (detail)

The second largest component with the above mentioned regional science journals consists of 26 journals. Their connections and abbreviated names are shown in Figure 2. As we can see, this component contains space related journals with urban and planning oriented journals on the left hand side and geography journals on the right. *Environment and Planning A* is an important cutpoint[4] linking the two sides. *Environment and Planning A* is directly connected to *Regional Studies* and *European Planning Studies*, where the latter are connected via *Urban Studies*.

[4] A cutpoint is a node the removal of which would disconnect the graph.

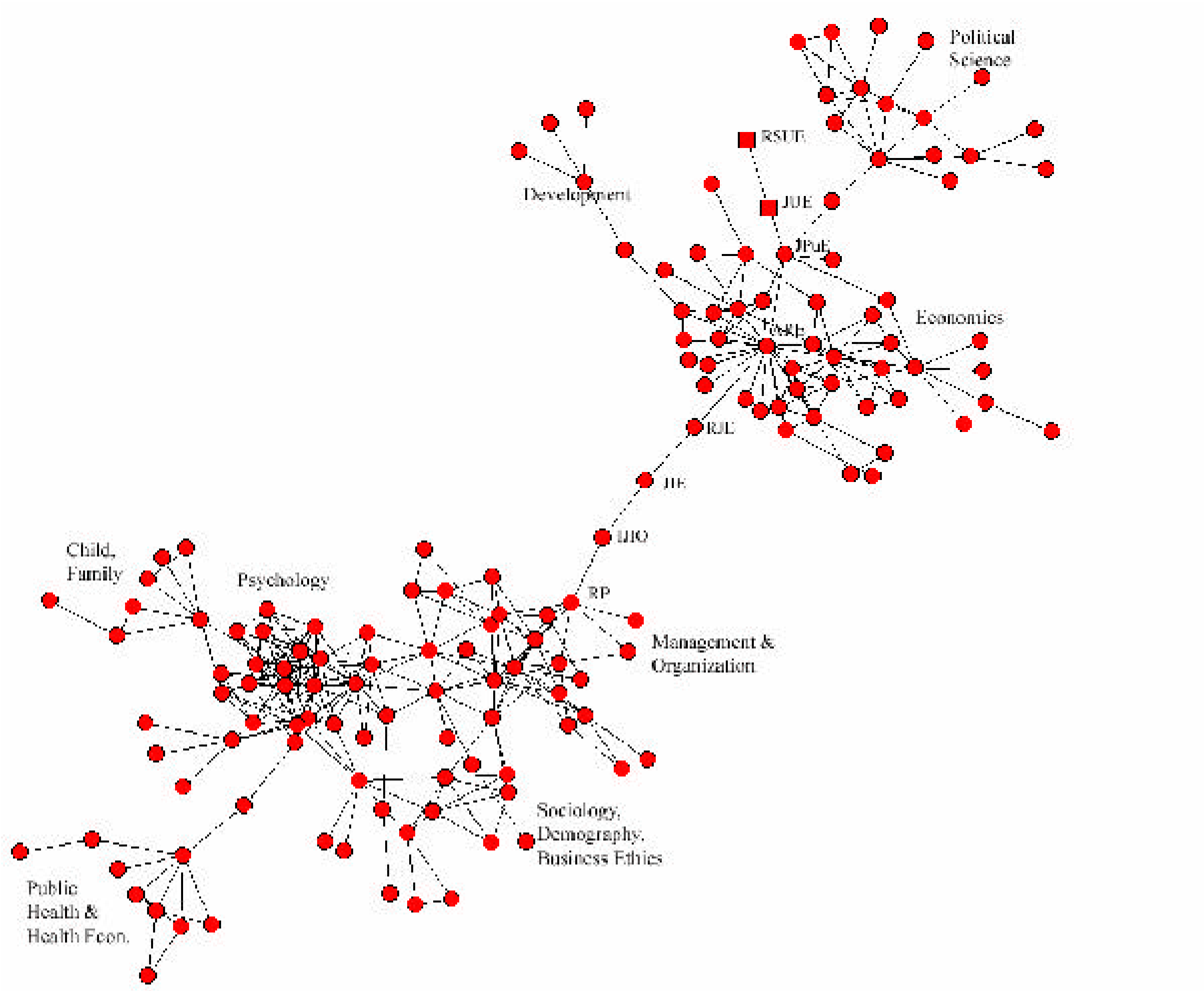

Figure 3: The largest component of Figure 1 (detail)

The largest component at this threshold level is shown in Figure 3. A very significant feature of this component is the large sequence of bridges connecting two more interrelated sub-parts. The one to the top right consists of journals from economics, political science and development studies. The one to the bottom left is relatively heterogeneous and consists of journals in areas like management and organization, sociology, psychology, and public health. The respective areas in the sub-network are marked in the figure. The sequence of bridges linking the two parts is formed by *American Economic Review* (AER), *Rand Journal of Economics* (RJE), *Journal of Industrial Economics* (JIE), *International Journal of Industrial Organization* (IJIO) and *Research Policy* (RP). The two regional science journals in this component, *Journal of Urban Economics* (JUE) and *Regional Science and Urban Economics* (RSUE) are connected to the core of the economics journals via the *Journal of Public Economics* (JPuE).

When we increase the threshold further, at the level of 30 *European Planning Studies* becomes isolated and drops from the picture. At the same threshold level, the two regional science journals that were connected to economics, *Journal of Urban Economics*, and *Regional Science and Urban Economics*, become cut off from economics journals together with the *Journal of Public Economics* and – surprisingly – the *National Tax Journal*. This small component of four journals breaks apart at a threshold level of 34 with the two regional science journals forming their own component. The remaining five regional science journals are allocated to two different components, one which includes also geography and planning journals and one which contains only the two regional science journals.

With a further increase of the threshold to 41, this latter component breaks up and the two regional science journals (*Journal of Urban Economics* and *Regional Science and Urban Economics*) become isolates. This leaves us with just one component containing regional science journals. From this component the regional science journals break away step by step: *Regional Studies* at a threshold level of 48 and *Urban Studies* at a threshold of 62. At this level (threshold 61) the component has already been reduced to just four connected journals: *Progress in Human Geography, Environment and Planning A*, *Urban Studies*, and *International Journal of Urban and Regional Research*, the second and third of which we identified as core regional science journals. From the threshold level of 62 onwards the component consists only of two connected journals, *Progress in Human Geography*, and *Environment and Planning A.*

At the threshold level of 84 the link between these two journals also breaks and the last regional science journal disappears from the analysis. At this level only 70 journals are left in the citation network, subdivided into 19 components. In average these components have 3.68 nodes. The largest component has size 17, the second largest size 7. Most components are small. Eight have size two and seven size three. These small components show a clear thematic proximity between the involved journals. They are specialised, for example, in finance, tourism, political science, econometrics, and science teaching and education. Larger components are specialized in law and in psychology and cognition. The largest component contains journals covering a wide set of topics: from psychiatry to psychology, organizational behaviour and management sciences. It is interesting to note that economics is broken up into at least three small components.

The analysis of the raw citation data showed that in this case our top 10 regional science journals are torn apart at fairly low threshold values. Four of the ten of them become isolated at levels below 20. At that threshold level the remaining six journals are divided between two separate components. One regional science journal, *Environment and Planning A*, remains longest in the analysis, because it forms a component with another journal, *Progress in Human Geography*, which is not one of the top 10 regional science journals. In the respective table it shows up only on position 36.

Based on this analysis we have to reject the hypothesis that regional science is a scientific discipline. The journals which are identified by regional scientists as the important ones are less strongly connected by citations to other journals than those in other disciplines and are in most cases more strongly connected to other journals than to one another.

One weakness of the raw data, however, is that different journal sizes, publishing traditions and citation habits influence the analysis. The smaller journals tend to become eliminated from the analysis fairly early on. To correct for these distortions, in the following sections we will use two alternative forms of standardization of the raw citation data.

4.3. Citation analysis based on Pudovkin/Garfield standardization

Pudovkin and Garfield (2002) recognize the problem of the raw citation data and suggest an index of journal relatedness that standardizes the number of citations from one journal to the other by the number of articles published by the cited journal and the total number of citations in the citing journal. Without any theoretical justification they use the following definition, where *R* is the journal relatedness, *X* the number of citations, *Pap* the number of papers and *Rf* the number of references $R_{ij} = 10^6 * X_{ij} / (Pap_j * Rf_i)$. Instead of the arbitrary scaling factor used by Pudovkin and Garfield, we set it such that the sum of all elements in the raw citation matrix equals the sum of all elements in the relatedness matrix resulting from this standardization.

Although the sum of all the elements in the standardized matrix is the same as for the matrix of the raw citation data, the largest element in the standardized matrix is only 12 per cent of that of the raw matrix. Consequently, the double logarithmic regression yields a smaller intercept and less steep slope: $\log(R) = 8.04 - 0.63 * \log(Rk)$. The estimated r-square is only 0.86. Obviously, by scaling down the citations of large journals, the standardization leads to a more evenly distributed matrix of citations.

We apply the same procedure as before. First, we make the matrix symmetric by setting every element to the minimum of this element and its corresponding one across the main diagonal. Then, we increase the threshold level step by step. Although the matrix elements now contain real numbers, we use only integer values as threshold levels.

Table 9: network indicators for threshold levels 0-20, Pudovkin/Garfield standardized data

Threshold	no of nodes	isolates	Components	largest	second largest
0	455	9	2	452	3
1	455	0	2	452	3
2	455	0	2	452	3
3	455	0	2	452	3
4	455	0	2	452	3
5	455	0	2	452	3
6	453	2	2	450	3
7	451	2	2	448	3
8	444	7	3	439	3
9	440	4	3	435	3
10	436	4	4	427	4
11	436	0	9	415	4
12	426	10	9	404	4
13	417	9	13	379	11
14	406	11	16	346	16
15	386	20	17	311	16
16	366	20	21	288	14
17	348	18	22	274	11
18	332	16	23	241	18
19	311	21	26	217	18
20	296	15	33	185	18

Table 9 shows again the results for threshold levels up to 20. Only one regional science journal, *European Planning Studies*, is eliminated (at threshold 17). At threshold level 20 all the remaining regional science journals belong to the same, the largest component. The composition of the smaller components makes good sense. The more important ones connect journals in the fields of Political Science (18 nodes), Social Work, Violence, Family Issues (11), Anthropology (7), Marketing, Consumer Research (6), Transportation (6), Public Administration, Governance (4).

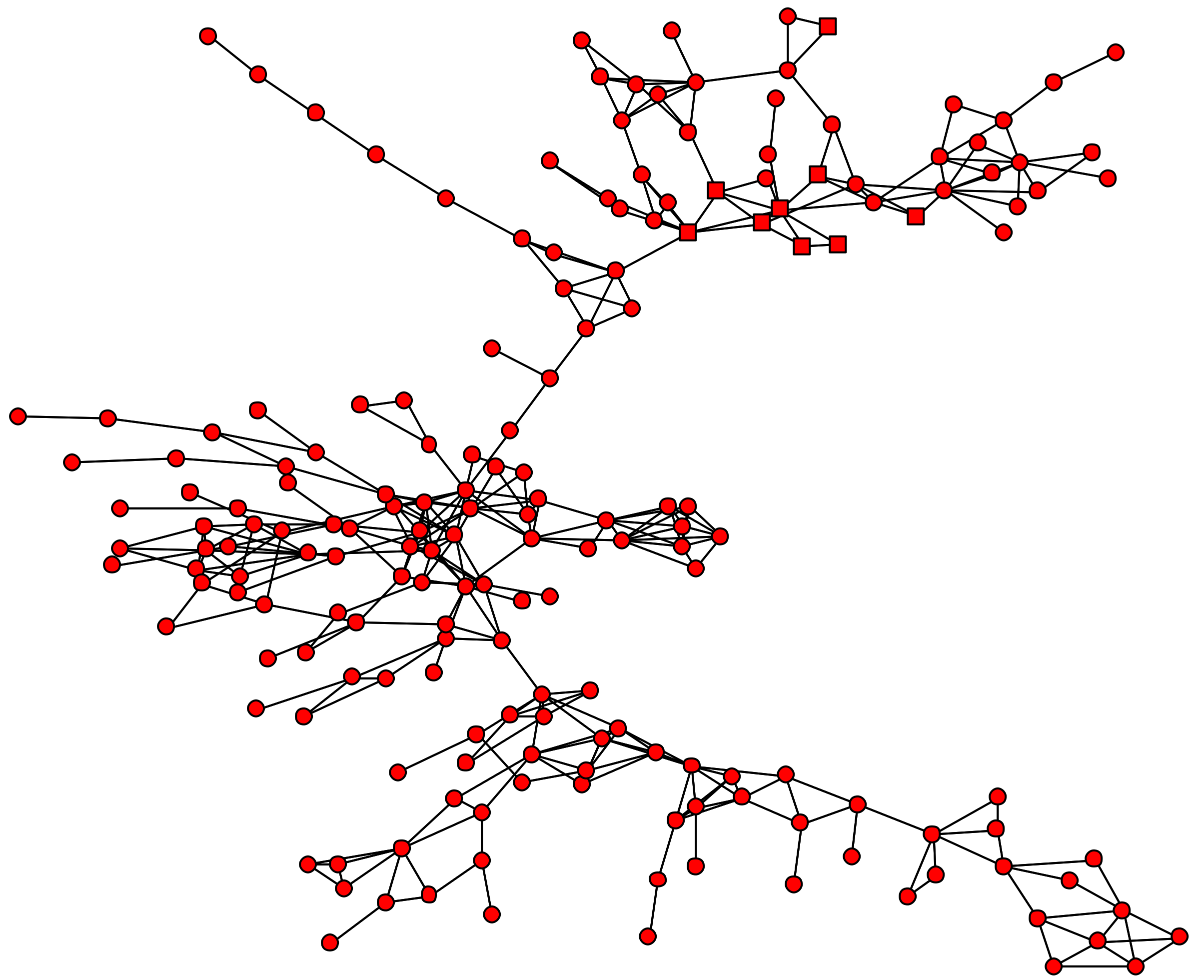

Figure 4: network Pudovkin/Garfield-standardization, threshold 20, largest component

When we look more carefully at the largest component at threshold level 20 (Figure 4), we see that all the nine remaining regional science journals (marked by squares) are in the same part of the component which is connected via a line of bridges to the rest. Seven of the nine journals have direct connections to at least one other regional science journal. Only two, *Environment and Planning A* and *Urban Studies* are only indirectly connected to other regional science journals. These two journals are the next ones from the regional science journals to become isolates: *Urban Studies* at threshold level 21 and *Environment and Planning A* at threshold level 23.

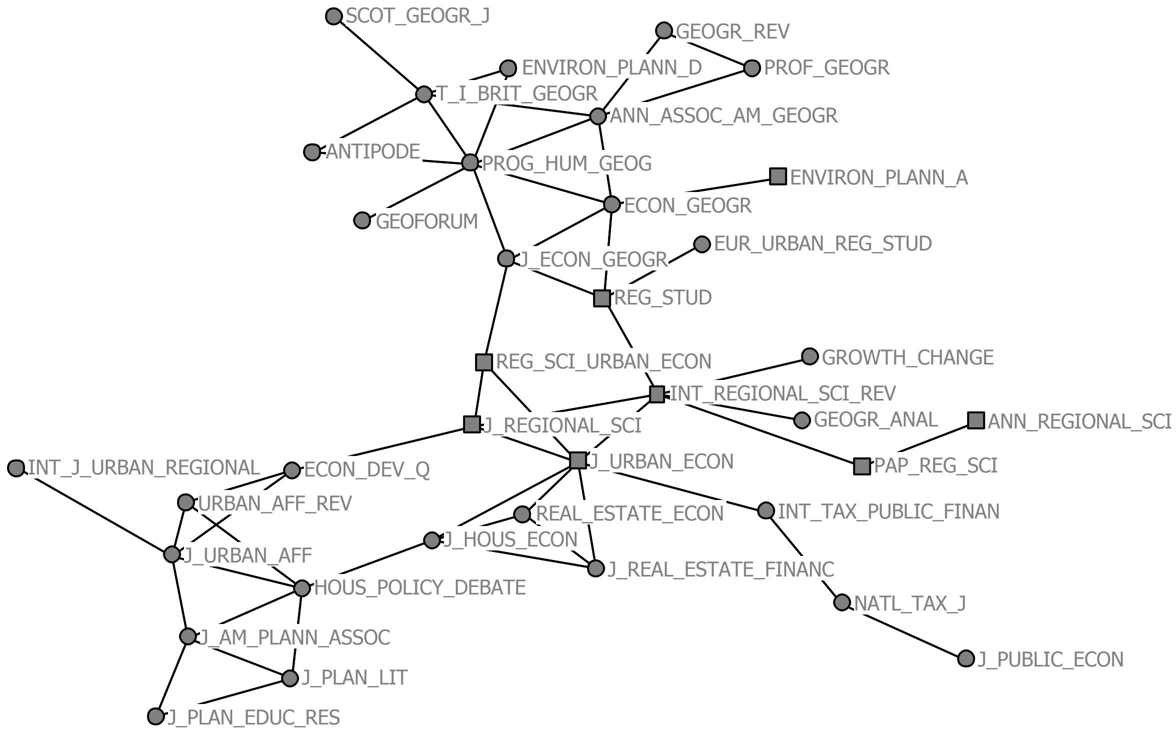

Figure 5: Component containing all regional science journals (threshold 22)

At threshold level 22 all the remaining regional science journals break away from the largest component to form the second largest component with 36 nodes. This component with the abbreviated names of the journals is shown in Figure 5. We see that all the journals in the component are thematically related. Seven of the eight regional science journals in the component are directly connected.

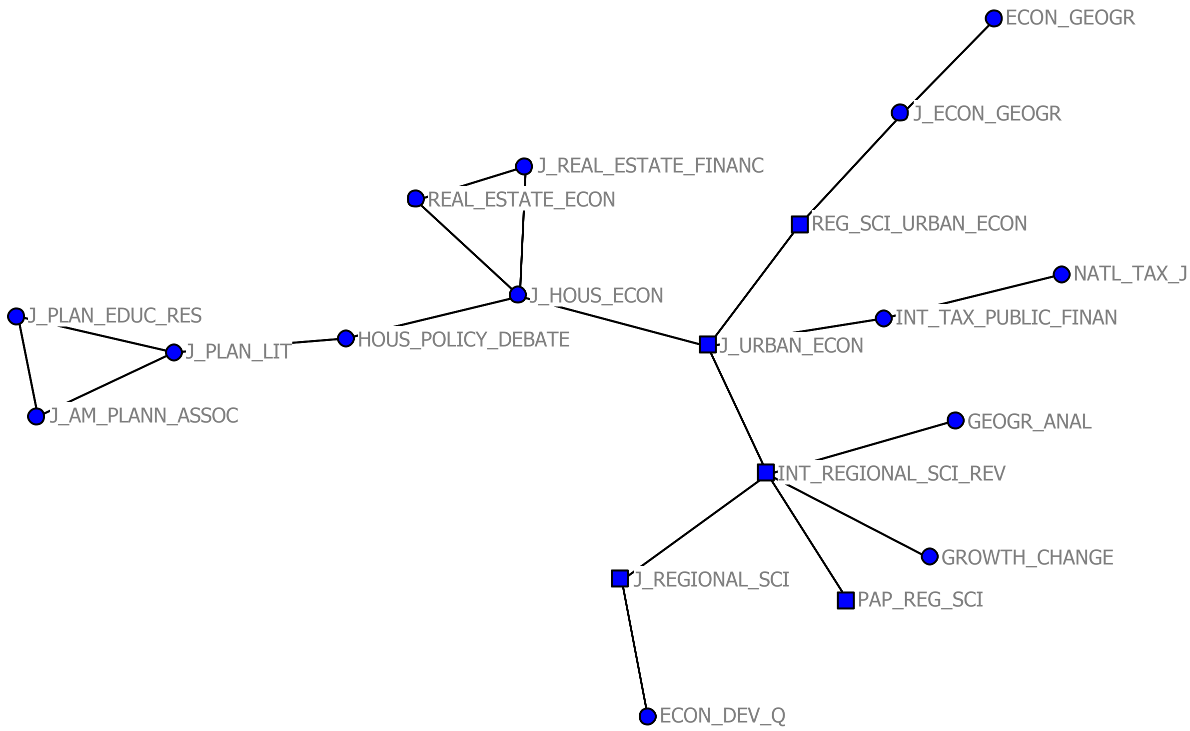

Figure 6: Component containing all regional science journals (threshold 27)

When we increase the threshold level further, *Environment and Planning A* is eliminated at 23, *Annals of Regional Science* at 24, *Regional Studies* at 27. At that threshold level the remaining 5 regional science journals all belong to a component of 19 journals (Figure 6). The regional science journals form a backbone of this component. Based on degree centrality *International Regional Science Review* and *Journal of Urban Economics* are the most central journals in the component. Via the regional science journals some journals with a different thematic focus are tied to the component. Areas are planning, housing, real estate, economic geography, taxation, geography and economic development. This composition of the component reflects the interdisciplinary nature of regional science.

When we add the threshold level further, this component breaks apart. At 28, the *Journal of Urban Economics* loses its connections on the one hand to the *Journal of Housing Economics* and on the other hand to the *International Regional Science Review*. At threshold 29 the regional science journals are isolated in two small components: One consists of *Journal of Urban Economics* and *Regional Science and Urban Economics*, the other of the remaining three regional science journals. At this step five of the ten regional science journals in our analysis are connected to each other, but not to any other journal. So, at this level we see a strong connection between these journals, suggesting that there exists a strong thematic relationship.

When we move the analysis further, *Papers in Regional Science* becomes isolated at 31, and *Journal of Regional Science* and the *International Regional Science Review* separate at level 32. The remaining component formed by *Journal of Urban Economics* and *Regional Science and Urban Economics* remains intact up to a threshold level of 41. At this level there are only 58 nodes left. They form 22 components.

The analysis with the standardized data shows a much stronger cohesion of the regional science journals than the previous analysis. The weighting of the standardization procedure increases the importance of the links between the relatively small regional science journals and decreases that of the links to larger journals outside the discipline. Therefore, the analysis with Pudovkin/Garfield standardized citation data suggests that regional science is a discipline, despite the relations to related fields that became apparent in the analysis as well.

4.4. Citation analysis based on gravity model standardization

One of the weaknesses of the Pudovkin/Garfield standardization is the fact that it is based on an ad-hoc formulation and lacks a conceptual basis. When we deal with interaction data in regional science, often the gravity model is applied. This model is based on Newton's law, but has been related to a number of behavioural concepts (Haynes and Fotheringham, 1988, Sen and Smith, 1995). In our context it provides a basis for an alternative form of standardization.

The gravity model is characterized by the relation

$$I_{ij} = a \frac{M_i^b N_j^g}{d_{ij}^d}$$

where in a spatial interaction context *I* is some form of interaction between spatial units *i* and *j*, *M* and *N* are some mass terms measuring the respective size of the spatial unit and *d* is some measure of distance between *i* and *j*. The Greek letters denote parameters, which are usually estimated. In the Newtonian form of the gravity model beta and gamma are equal to one and delta equals two. Alpha is just a scaling factor that can be set accordingly.

When we use the Newtonian parameter values, we can transform this relationship to

$$P_{ij} = \frac{1}{d_{ij}} = \sqrt{\frac{I_{ij}}{aM_i N_j}}$$

where P represents "proximity", the inverse of distance between two units. Since we know all the elements under the square root on the right hand side, we can compute proximity and thus use it as an alternative standardization to that of Pudovkin and Garfield. The scaling factor alpha will again be set such that the sum of all elements in the matrix is equal to the sum of all elements in the raw citation matrix. The main difference between the gravity model and the Pudovkin/Garfield standardization is the use of the square root which follows directly from the gravity formula.

Alternatively to Pudovkin and Garfield we use the total numbers of references and citations within our 464 journal citation matrix as mass terms. This is motivated by the constrained versions of gravity models (e.g., Haynes and Fotheringham, 1988, Sen and Smith, 1995). The following analysis which applies the same strategy as before will be based on this form of standardization.
With the gravity model standardization the largest value in the citation matrix reaches 16 per cent of the corresponding value in the raw citation matrix, although the sum over all the matrix elements is again the same. Similar to the situation of the raw data, the largest elements of the gravity model standardized matrix are elements on the main diagonal. The top 18 elements are self-citations of journals and 88 per cent of the largest 100 elements fall into this category. This follows from the form of standardization where we use the row and column sums as mass terms. Therefore, the more a journal cites only its own articles and is only cited by its own articles, the larger the standardized value becomes. Note, however, that the values on the main diagonal do not enter the network analysis.

Again, we estimate a double logarithmic regression of the proximity on the rank. This yields a relationship quite similar to that of section 4.3: $\log(R) = 8.45 - 0.68 * \log(Rk)$. The estimated r-square is 0.81 and thus slightly smaller than that of section 4.3.

Table 10: network indicators for threshold levels 0-20, gravity based standardized data

Threshold	no of nodes	isolates	Components	largest	second largest
0	455	9	2	452	3
1	455	0	2	452	3
2	455	0	2	452	3
3	455	0	2	452	3
4	455	0	2	452	3
5	455	0	2	452	3
6	455	0	2	452	3
7	455	0	2	452	3
8	454	1	2	451	3
9	452	2	2	449	3
10	450	2	3	445	3
11	444	6	4	437	3
12	440	4	4	432	3
13	436	4	4	428	3
14	432	4	7	412	8
15	427	5	8	404	8
16	424	3	10	394	8
17	419	5	13	383	7
18	410	9	21	337	22
19	402	8	22	327	19
20	390	12	27	299	14

Table 10 shows again the results of our threshold analysis up to a threshold of 20. After the elimination of the initial nine isolates, the network remains unchanged up to a threshold level of 7. As compared to the analyses in sections 4.2 and 4.3, under gravity model standardization much fewer journals become isolates in these early steps of the analysis. At a threshold level of 20 we have almost 100 journals more remaining than under Pudovkin/Garfield standardization and almost 150 journals more than with the raw data. With 27 the number of components is between the two alternatives. Because of the higher number of journals remaining, the size of the largest component is also much larger than in the other cases.

All our top-10 regional science journals remain in the analysis at this threshold level and they are all members of the largest component. When we investigate the other components that were spun off, their composition generally makes good sense. The second largest component contains only journals targetted toward education, the two next largest components (size 7) cover finance and accounting on the one hand and a cluster of law journals similar to the one already mentioned in section 4.2. Also the smaller components contain related journals.

With respect to the regional science journals the situation remains qualitatively the same up to a threshold level of 27. At threshold 28 the first regional science journal, *Environment and Planning A*, becomes isolated.

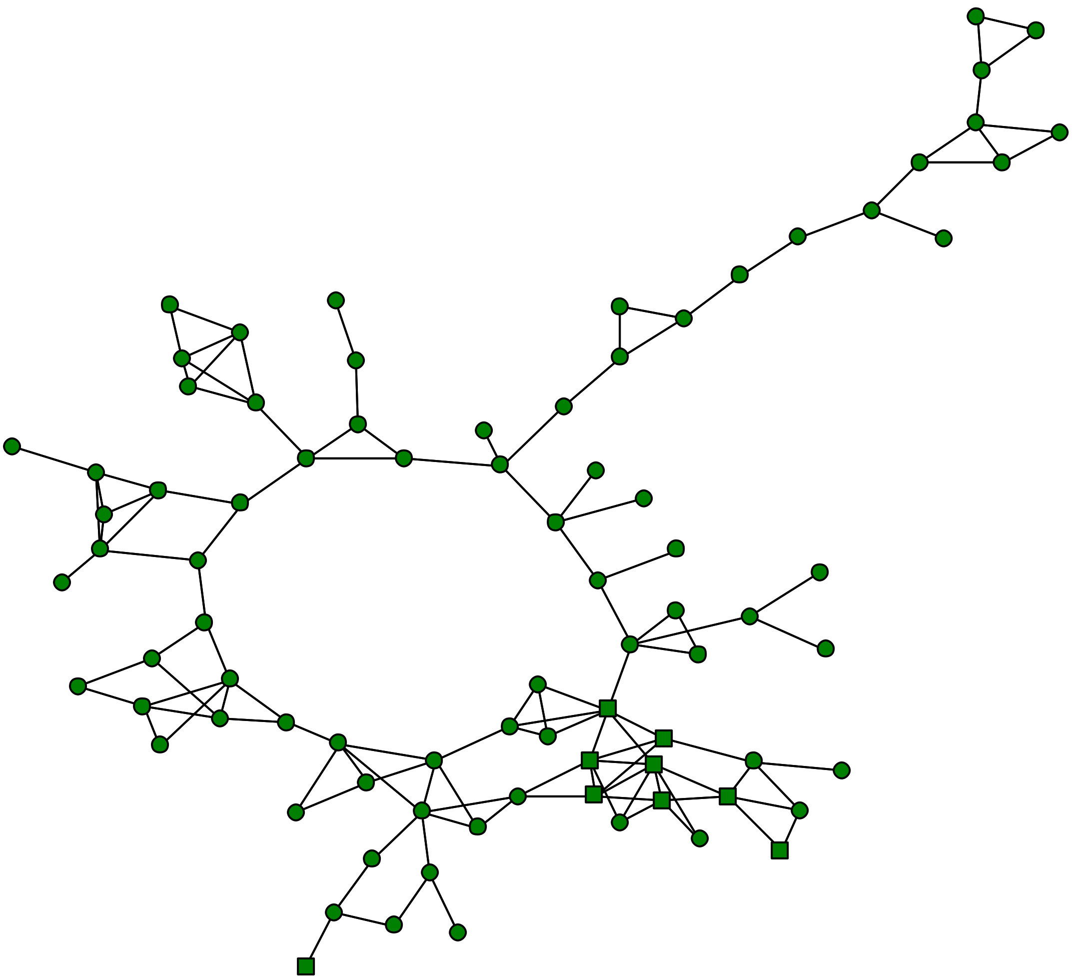

Figure 7: Network, Gravity based standardization, threshold 28, largest component

At this threshold level the network has been broken up into 51 components, the largest of which still has a size of 83 and contains all the remaining regional science journals. This component is shown in Figure 7. Characteristic are the large ring that the journals form and the large branch in northeast direction. The ring is formed by journals specialized in different aspects of business and economics in a broad sense. Examples of journals that function as cutpoints for this ring are *Energy Economics*, *IMF Staff Papers*, *Journal of Urban Economics*, *Journal of the American Planning Association*, and *Review of Industrial Organization*. The large branch is formed by political science related journals.

Eight of the nine remaining regional science journals are clustered together in one part of the component. They are all directly linked to at least one other regional science journal. The one separated from this cluster is *Urban Studies* which is only connected to *Housing Studies*.

At the next threshold level (29), the ring breaks apart at three places and the largest component becomes fractured. The regional science journals still remain in one, the largest component which reduced in size to 42. At a threshold level of 31, one of the regional science journals, *European Planning Studies*, breaks away from the component to form its own component with *European Urban and Regional Studies*. The situation at this level is shown in Figure 8. Noteworthy is the strong connection among six of the eight regional science journals, *Journal of Urban Economics*, *Regional Science and Urban Economics*, *Journal of Regional Science*, *International Regional Science Review*, *Papers in Regional Science* and *Annals of Regional Science*. *Papers in Regional Science* and *Journal of Regional Science* occupy a central position as they both are connected to at least four other journals from this group. We also see that this cluster consists of thematically closely related journals. Besides regional science they are from areas like economic geography, planning, urban economics, housing economics, real estate and public economics. The only potential outliers are contained in the branch to the north of the Figure, which includes journals oriented toward taxation.

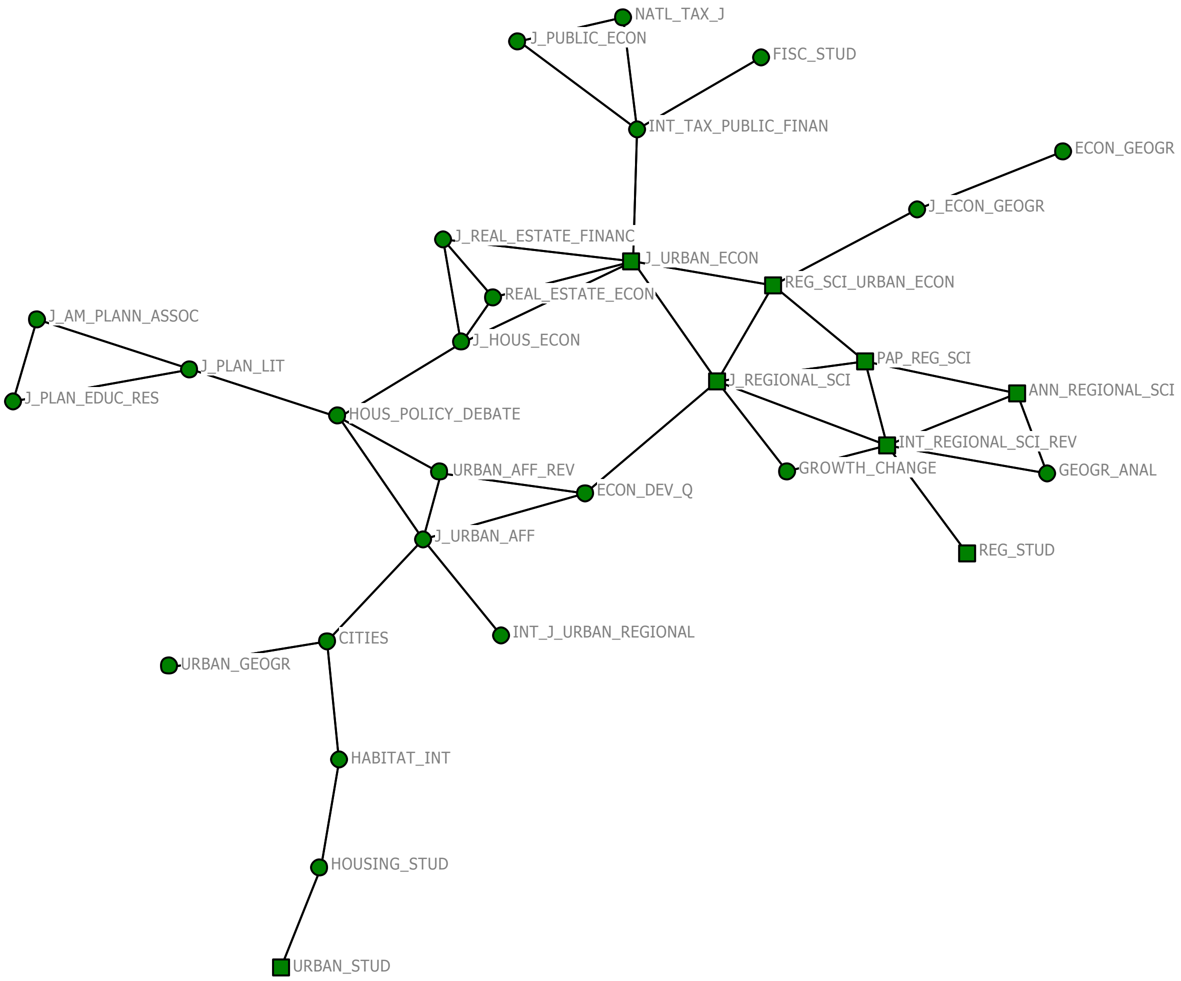

Figure 8: Network, Gravity based standardization, threshold 31, largest component

At a threshold level of 33, a second one of the regional science journals, *Urban Studies*, is spun off into its own component consisting of the branch of the five journals between *Urban Studies* and *Urban Geography* in Figure 8. At threshold level 34 *Regional Studies* becomes isolated and is eliminated from the analysis, at threshold level 35 the same happens to *Urban Studies*. At threshold level 39 *European Planning Studies* is eliminated.

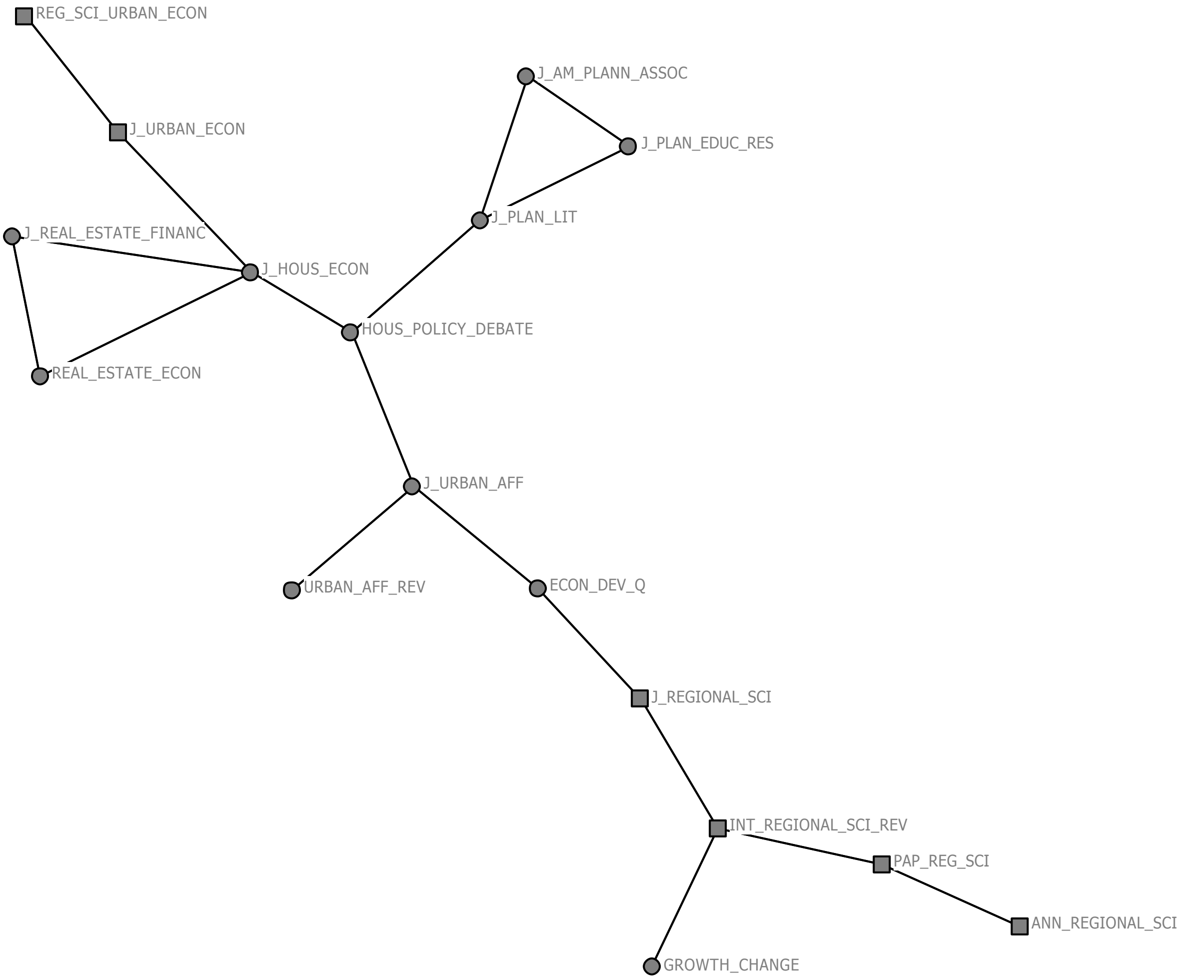

Figure 9: Network, Gravity based standardization, threshold 39, largest component

The regional science related component resulting from threshold level 39 is shown in Figure 9. When we compare it to Figure 8, we see that most of connections between the regional science journals were eliminated and that the group is split up into two sub-groups; one formed by *Journal of Urban Economics* and *Regional Science and Urban Economics*, the other by *Journal of Regional Science*, *International Regional Science Review*, *Papers in Regional Science* and *Annals of Regional Science*. When we raise the threshold level to 40, this distinction becomes even more evident, as the connections between the *Journal of Urban Affairs* and both *Housing Policy Debate* and *Economic Development Quarterly* disappear so that they now belong to different components. At threshold 41 the link between the *Journal of Regional Science* and the *International Regional Science Review* breaks, leaving the *Journal of Regional Science* form one component with *Economic Development Quarterly*.

At threshold level 44 also the link between the *Journal of Housing Economics* and the *Journal of Urban Economics* vanishes. This leaves us with three components containing regional science journals. One of them is formed by a regional science journal, Journal of Regional Science, and a journal that was not classified as one of our top-10 regional science journals, *Economic Development Quarterly*. The other two components contain only regional science journals, one *Journal of Urban Economics* and *Regional Science and Urban Economics*, the other one *International Regional Science Review*, *Papers in Regional Science* and *Annals of Regional Science*. This are three of 46 components that contain a total of 117 journals.

At threshold level 45 the *Journal of Regional Science* gets eliminated, at 51 the *International Regional Science Review*. At threshold 53 the component consisting of *Journal of Urban Economics* and *Regional Science and Urban Economics* breaks apart leaving the two journals isolated. The last two regional science journals, *Papers in Regional Science* and *Annals of Regional Science* disappear at threshold level 56, when the link between them breaks. At this stage there are only 43 journals left, which form 20 components, 17 of size two and just 3 of size three.

The analysis of the gravity model standardized citation data supports the observation made in section 4.3 of stronger cohesion among the regional science journals. They stay in the analysis fairly long as part of the largest component and most of them form an important block in this component. As a result of this connectedness they tend to form separate components at higher threshold levels. The analysis of this section supports the hypothesis that regional science forms a discipline.

4.5. Comparison of the results

The three analyses we made with our data, based on the raw data, Pudovkin/Garfield standardization and gravity model standardization, produced results that were similar in some respects, but dissimilar in others. The similarity is mainly in the way the method worked. First, the number of components increased as the network became more fractured, and then decreased as more and more small components broke up. This process started at low threshold levels with the raw data, with the standardized data at higher levels.

As we have noted above, we find much stronger cohesion among regional science journals from the standardized data. This makes sense as regional science journals tend to be smaller in terms of articles published and in terms of references and citations so that the standardization emphasizes the connections between those journals and downscales those connections that these journals have with larger journals. The differences in the standardization are on the one hand the different mass terms by which we standardized and on the other hand the fact that we took the square root in the case of the gravity model based standardization.

When we look at the performance of individual journals, we see marked differences. *Environment and Planning A*, for example, is the journal that stays connected longest in the raw data analysis, but is the first one to drop out from the gravity based analysis. For *Papers in Regional Science* we observe the contrary: it is the first to drop from the raw data analysis and the last one to drop from the gravity based analysis. Intuitively, this makes sense as *Environment and Planning A* is a relatively large journal with connections to many other areas. When we correlate the threshold levels at which the journals become eliminated in the three versions, we find a negative correlation between the raw data analysis and the other two (-0.23 and -0.78 for Pudovkin/Garfield and gravity, respectively), but a positive correlation between the two standardized versions (0.61). This provides some weak evidence that the two standardized versions yield similar results that differ from the raw data analysis.

5. Summary and conclusions

In this paper we raise the question, whether regional science is a scientific discipline and try to answer it on the basis of citation networks between journals. The question is motivated by the traditionally strong relationships of regional science to other scientific disciplines and by the discussions this situation has triggered in the past about what regional science is and what it should be.

Our analysis combines citation analysis on the one hand with techniques of network analysis and applies it to regional science journals. The most important regional science journals are identified by use of the results of a survey of regional scientists (Maier, 2007). Starting from the top 10 journals in this ranking we develop a dataset of journal-journal cross citations of 464 different journals in the social sciences. This cross citation matrix is the basis of our analysis.

The method used in the analysis is the following: first, we symmetrize the citation matrix by setting every cell to the minimum value of itself and the corresponding cell on the other side of the main diagonal. This is done because we define two journals to be closely related, when each one cites the other. Then, we appy thresholds of increasing size, filter out all connections that fall below the threshold level, and look for components of closely related journals. With this technique we step by step filter out the less important connections among journals and thus identify the more and more strongly connected journals.

When we apply this method to the raw citation matrix, we find that because of its intellectual proximity to some other disciplines, regional science cannot form a strong component and becomes torn apart between these other, typically larger, disciplines. This result raises the question of possible bias in the data because of differences in size and publishing traditions. We therefore apply two different forms of standardization, one suggested by Pudovkin and Garfield (2002), the other one motivated by the gravity model of regional economic analysis. In both cases we find that since the connections to other disciplines are scaled down by the standardization, regional science forms a strong component that remains intact up to relatively high threshold levels. We see this result as indicator of cohesion among regional science journals and as support for the hypothesis that regional science is a scientific discipline that is centered around a core set of journals and somewhat distinct from neighbouring disciplines and their publication outlets.

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