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Topography and Dynamics of Co-author Networks¹

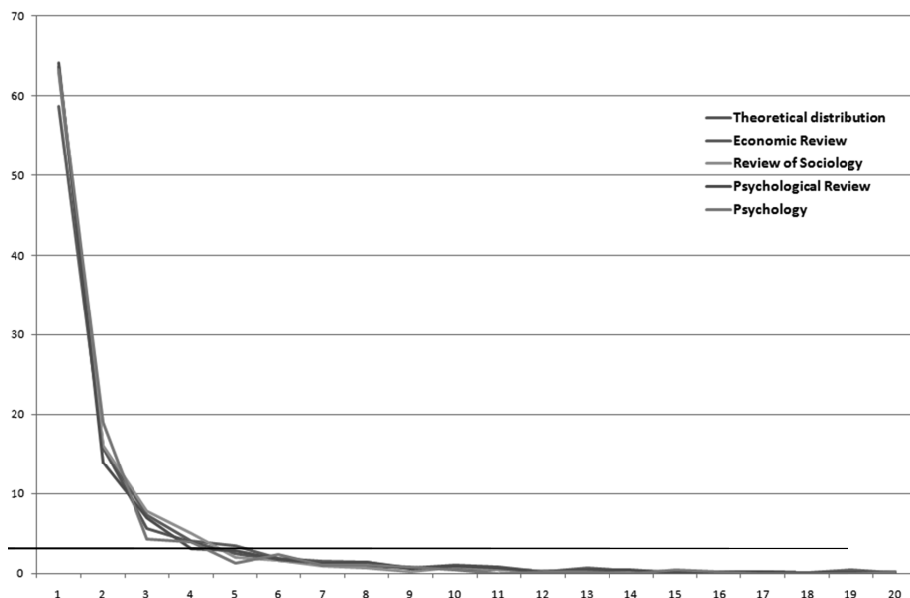
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ABSTRACT: Co-author networks have become the center of the attention of both scientometrics and network researches during the last decade. In this article I put more emphasis on the scientometrics side, I compare the actual and the international results related to my topic.

The outcome of the research is that the rate of co-authorship of the last fifty years in Hungary has no significant change. The number of the largest component of all publishing scientists in co-authorship covers only twenty-eight, thirty-three percent. The international co-operation shows surprisingly low number of articles and the distribution is uneven. The growth of networks - contrary to the 'mature' Western science - can be modeled easily by the logistic growth function.

Keywords: networks, co-authorship, scientometrics, logistic growth



¹ English revision by Evelin Szarka.

Introduction

After the emergence and success of the concept of scale-free law in the beginning of the new millennium many researches were conducted in the field of co-author networks. The growing scale of available databases provides an excellent background for its analyzation from a network and from a scientific historical perspective. Many articles were written in several areas (in physics: [Newman 2000, 2001a, 2001b]; about the Colombian science: Bernal-Llanos [2005]; psychology and philosophy in Cronin et al. [2003]; evolutionary computation: Merel-Cotta [2006]; sociology: Moody [2004]; Mapping the network of co-authors of the journal *Scientometrics* was carried out by [Hou et al 2006]. Hungarian scientometric analysis (distribution of numbers of publications, citation networks) was made in some journals. Researches about the *Economic Review* Such-Tóth (1989), the *Space and Society* Reisinger-Tóth (2007) and the *Political Review* Cselényi (2009) have been conducted.

Analyzing co-author networks raises some methodological questions: what is the significance of co-authorship of scientific operation? Can we use co-authorship for the analyzation of the functioning of science at all? If yes, in what sense? Has it always the same meaning for each connection?

Right from the beginning of the study I would like to state that besides the authorship of scientific publications there are other additional levels of scientific analysis. One of them is the well-known citation data (since 1960) and the citation networks. The following analysis of a potential level of involvement lies in the keywords: keywords indicate the directions of science, which are the most interesting for scientists. The presented aspects are interesting separately, without no doubt, however, their combination offers the greatest potential (Mutschke Quan-Haase 2001).

Before I proceed with the presentation of the causes of authorship, I go back to scale-free law for a while. The concept mentioned is widely used within a short time, great number of studies analyzed its validity but it should be noted that its history is not without precedent. In the field of scientometrics Alfred Lotka has carried out a research in the twenties about what proportion of articles could be found at n number of authors. Under the formula of Lotka's law ($1/n^2$ the ratio of n publications of researchers) the distribution is the same as in the Albert-Laszlo Barabási idea: there are many who have little and few have much.

I clarify the necessity of returning to the reasons of co-authorship: co-operation has both structural and emotional reasons. The availability of laboratory equipment has increased the level of co-operation in natural sciences; however, there is no need of laboratory application equipment in social sciences but in many cases large-scale data collection needs teamwork. The terms of payment systems will also promote cooperation in scientific work: its impact can be experienced in natural sciences.

To make it simple I consider the relations among co-authors symmetrical in this article. Yoshikane distinguishes (2006) two roles: leader and follower. Usually the first person of the authors is the leader of the research, who in most cases is also the main organizer of it. A very different approach can be found by Patel (quoted by Glänzel-Schubert 2004): the analyzation of scientific articles found that the publisher often indicates those who write the article indirectly: e. g. they have participated only with their ideas and critics. The term sub-authorship was introduced on this basis of this concept. Cronin (2001), however, found that an article has fifty or sixty or even more than hundred authors in certain areas of science, for example high-energy physics, so he introduced the concept of hyper-authorship in this context.

In the case of sociology, during the examination of the American sociology James Moody (2004) finds that within various science topics large differences can be observed. It goes without saying that theoretical issues can be explored independently, while empirical researches are increasingly common. According to the research, co-author articles are more likely to appear in health care and education issues than the already mentioned theoretical ones. The fact of co-authorship is under the influence of a researcher's career as well. The more one has been moving for a long time in science, it is more likely that they cooperate. Moody has shown that every single publication of the 1.28 percent increase the likelihood of participation in co-authorship. Although, in areas with low co-author articles rates compared to earlier periods in subsequent periods, this ratio was even lower. It can be concluded that specialization has become more important over time. In the field of gender studies the probability of co-author articles has an average value at the beginning of the examined period but later only half of them were written in co-operation. The same process can be observed in reverse: in the case of methodology the rate of co-author articles was also the average for the early period, in the future, however, a 1.21-fold increase can be seen in the likelihood. The number of writers for quantitative works the likelihood of co-author articles is five times greater. In Moody's view, works of co-authors become normative once they appear in an area, they become common.

The co-authorship has become normative and we know its importance from Brian Uzzi's writings (Uzzi et al. 2007). The ISI Web of Science database has been analyzed from the mid-fifties (the starting year of the data vary with different fields) until the millennium. During work it has been found that the authorship of all scientific disciplines (natural and engineering sciences, social sciences, humanities and patents are available from 1975) has increased significantly. This is also valid for mathematics (the level of authorship grew 19 percent to 57 percent in the period under review), which many have been seen as the field of solitary geniuses. These results are not new to those already mentioned but Uzzi and his team has taken another important step. During their study they compared the

received citation of the self-made and that of co-author articles. The surprising result is that co-author articles have much more citations than self-writings. In addition, the number of received citations grows at the same time: while in the fifties in natural sciences there were 1.7 times as many references in co-author articles as in those of single authors; this share was 2.1-fold in the 2000s. (The advantage remained even when self-citations were eliminated.)

The relationship between recognition and the authorship of the work also means that good work and creativity are linked closely. Subsequently Uzzi investigated this issue further and during the success and failure analysis of New York's Broadway musicals he found interesting relations (Uzzi 2005). Those cuts have become a success where teams were both heterogeneous and homogeneous. Homogeneous in the sense that staff members have previously worked together, heterogeneous meant that new members came up with new ideas.

The emergence of creativity in terms of structural analysis is indeed an interesting task. Finally, I mention the work of Randall Collins (Collins 1999) who examined the history of philosophy through the birth of the conditions for innovative ideas. Collins' theory of the innovative ideas was born in the heart of scientific networks.

Evolution of networks

Besides the topographic analysis of networks, the analysis of the growth dynamics of networks is also an important issue under the Barabási model (Barabási 2003) – “who is to be given” – that is the principle of preferential attachment: who has a large number of connections, new relationships can be obtained by them more easily.

According to Barabási, all points can acquire new ones on the basis of the already existing proportion of relations. According to this research the relations of the points will increase proportionally with the square root of time. If we consider the points in various co-author networks we can see that they have different lifetimes, and it reveals a more nuanced picture. Jose Mendez (2000) says points lose their ability to attract after a while and they cannot create new connections. Amaral (2000), Mendez take forward the idea, which is the logical consequence of this: if central points cannot create new connection points after a time (either outside networks), then centers will be of limited size.

The Barabási model – in order to explain the growth of dynamics – refines the existing model by the analysis of the spectacular success of Google and introduces the concept of fitness. Now we can imagine two kinds of networks: a scale-free network – the rich will be richer – but it also displays a newer kind of organization where the winner takes it all virtually (e. g. Microsoft). This, however, is no longer a scale-free network, the majority of the links points towards a central operator.

Barabási et al (2002) examined mathematical neuroscience and the development of networks of co-authors in the period of 1991–1998. The tested network proved to be scale-free. The average degree has increased over time; the initial value of around five in 1998 grew up to twelve points. Surprisingly, the diameter of the network declined. Two reasons explain this decline: one explanation is the increasing number of network connections within the reduced distance the other says that the diameter reduction is the result of the limited lifetime of the database. (The network density decreased slowly in time.) The study analyzed, inter alia, that what proportion of authors has the largest network. In the case of neuroscience from the initial fifty-five percent in 1991 it grew up to ninety percent until the end of the test period. The largest network of co-authors in Maths reached seventy percent from zero between 1991 and 1998, but has not reached saturation yet. The process of time, the average connection number is growing. In neuroscience the average number of connections is from five to twelve, in mathematical sciences it increased from two to four. Barabási recognizes that the number of authors of publications was ignored in their model, and due to a short-term view they also did not take in consideration the dynamics of players leaving the network.

II. Analysis

Co-author networks of three Hungarian social scientific journals – an economical, a psychological and a sociological one are presented in this study. The analysis focuses on the leading papers of these sciences: the *Economic Review*, the *Psychological Review* and the *Review of Sociology*. In the field of sociology there is no other paper that would have been published for a longer time. Although in the field of economics there are more reviews their profiles differ significantly from the leading one. Psychology constitutes the only exception: another paper appeared beside the official journal even before the change of regime.

I analyzed the co-author networks in each case from the very first issue to the last one in 2009. The *Economic Review* started in 1954, the *Psychological Review* in 1960 and the *Psychology* in 1981. The *Review of Sociology* started only in 1991, although its predecessor, the *Sociology* was published from 1972 to 1990. The *Economic Review* is published eleven times a year (with a double issue in summer). The *Review of Sociology* and the *Psychological Review* appear four times a year. It is important to note that the *Psychological Review* published six issues per year between 1975 and 1995 but there were certain years, in 1987–88 and in 1992–93, when only three double issues appeared.

During the collection of the names of authors I have faced the problem that the same person could also published under various names. In case of women after marriage their husband's name was partly or totally included and used in publications. Besides the different names of the same person, it also caused difficulty

when I might have considered two researchers the same but accidentally just their name was identical. Besides the previous mentioned problems, approximately one percentage of the data seems uncertain.

The *Economics Review* was published 608, the *Psychological Review* 200, the *Review of Sociology* 132, the *Psychology* 116 times during their history. The analysis includes book reviews, too. The number of book reviews refers to their role in scientific communication. Book reviews cannot be found in science journals, the speed of the development of knowledge does not allow researchers to publish their results in a book. On the contrary, in social sciences and humanities books constitute an important part of the scientific communication like journals.

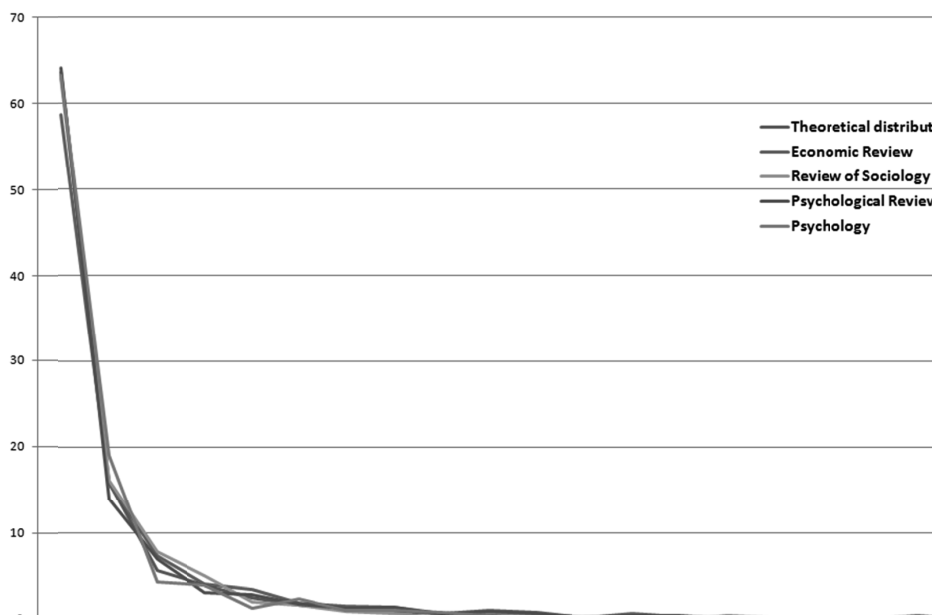
In Canada (Laviri re et al. 2004) book reviews represent 27 percent in social science journal articles and 57 percent in those of humanities. In case of Hungarian journals the ratio of book reviews are lower: it is seventeen percent in the *Psychological Review*, it is fifteen percent in the case of the *Economic Review* and it is also seventeen percent in the *Review of Sociology*. (Some co-authored articles can be found among them but their number is insignificant.) Differences between the ratios of book reviews can be found when we operate with time. In the case of the *Economic Review* it decreased by half (from nineteen to nine percent) from the initial period of 1956–1975 to the period of 1991–2009. In the initial phase of the *Psychological Review* (between 1960 and 1975) there is no book review: between 1976 and 1990 twenty, between 1991 and 2009 twenty-four percent of the articles were published as reviews. Book reviews represented 20 percent of the articles in the *Review of Sociology* in the first twenty years (1972–1990) while this number declined to seventeen percent in the period of 1991–2009.

Publication Activity

Scientometrics research started in the early twentieth century with the works of Alfred Lotka. Although Lotka was a chemist, he analyzed the distribution of the publications' number in scientific journals and found that all number of authors who have written n articles average with $1/n^2$. Lotka's law is, therefore, that during a specified period of 100 publications with one author there are 25 articles with two and 11 articles with three authors. I have examined the data until twenty publications and I present the theoretical distributions in this light. In percentage terms this means that articles which represented the 63.56 percent have authors with one publication, another 15.89 percent has authors with two and finally, 5.72 has authors with three publications. We can group authors in three different ways: all members of a co-authored article can be handled the same way (single authorship), or co-authors get the proportion of authorship according to the number of authors (fractional authorship), and finally, only the first author is considered. In this study all authors were considered equal. The percentages of authors of the

studied journals are shown in the *first figure*. The *Economic Review* and the *Psychological Review* differ from the theoretical distribution. In the case of the former it is five percent lower (it is fifty-eight percent instead of sixty-three), in the case of the latter one, the number of authors with two articles is higher, while those with three publications represent a lower percentage than the expected theoretical value. The overall results can be said to correspond with the expected theoretical distribution.

Figure 1: Distribution of authors according to the number of articles and Lotka's law



Researchers having the most publications in different journals can be seen in the first table. The first number in the parenthesis is the number of self-authored publications the second one is that of the co-authored articles. Except for Kolosi Tamás, Angelusz Róbert, Tardos Róbert in the field of sociology, Molnár Márk and Csépe Valéria in that of psychology, there are no more researchers among the top ten most publishing authors who co-authored more than wrote independently. Six or more co-authored articles were written by only fourteen researchers from the forty, therefore the emphasis is clearly on independent publications.

Table 1: Researchers with the highest number of publications

Economic Review		Review of Sociology	
Name	Number of publications	Name	
Bródy András	64 (60+4)	Bertalan László	
Kornai János	53 (43+10)	Némedi Dénes	
Erdős Tibor	39 (38+1)	Andorka Rudolf	
Pócs Ervin	35 (33+2)	Kulcsár Kálmán	
Csikós-Nagy Béla	33 (30+3)	Tamás Pál	
Simonovits András	33 (26+7)	Kolosi Tamás	
Török Ádám	33 (31+2)	Sik Endre	
Csaba László	31 (30+1)	Szántó Zoltán	
Falusné Szikra Katalin	31 (29+1)	Tardos Róbert	
Mátyás Antal	31 (31+0)	Angelusz Róbert	
Psychological Review		Psychology	
Name	Number of publications	Name	
Pléh Csaba	81 (56+25)	Marton Magda	
Buda Béla	51 (48+3)	Halász László	
Klein Sándor	47 (40+7)	László János	
Hegedűs T András	36 (33+3)	Cziegler István	
Kardos Lajos	25 (15+10)	Pléh Csaba	
Kozeki Béla	24 (22+2)	Csépe Valéria	
Forray Katalin	23 (22+1)	Farkas András	
Szegál Borisz	23 (18+5)	Vargha András	
Salamon Jenő	22 (21+1)	Pataki Ferenc	
Feuer Mária	21 (20+1)	Molnár Márk	

(The first number in parentheses is the number of self-authored articles; the second indicates the number of co-author publications.)

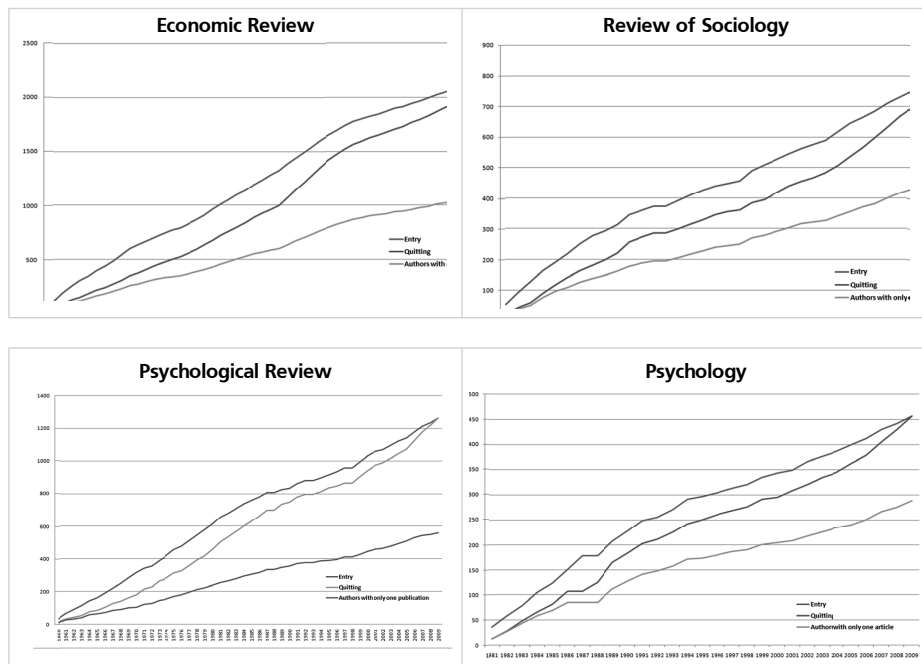
Measurement of entering and quitting

In table two the dynamics of the emergence of new authors can be seen. New authors were considered as those who had not previously published in the journals studied. Similar to the newcomers I aggregated the numbers of authors who published their last article in that year. As I have previously demonstrated, the highest proportion is of the one-article authors for whom the entry and the exit date are the same, so I marked this group for all three journals. (The authors create a group in which everyone has two articles published in the same year and later did not have any. Despite the entry and the exit number is the same in their case; I considered them a separate group.) The proportion of authors with one article is 44 percent in the *Psychological Review*; which is 51 in the *Economic Review* and 59 percent in the *Review of Sociology*.

In all of the four journals the entry and the exit dynamics follow each other. The starting growth of dynamics in psychology and sociology diminishes and stabiliz-

es in eight to ten years after its first issue. In case of the *Economic Review* a decline can be observed in the dynamics of entry before 1965 and around 1990. In the *Psychological Review* the above-mentioned difficult period between 1987 and 1998 reduced the number of new entrants but then the previous growth rate returned.

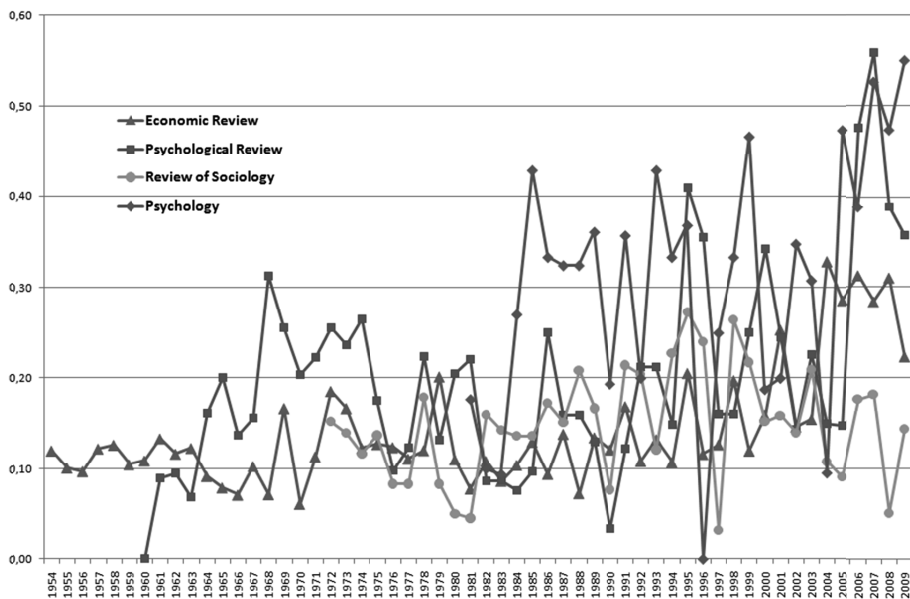
Figure 2: Measurement of entering and quitting



The proportion of co-authors

The third table shows the annual rate of co-author articles. The proportion of co-author articles was around ten percent in the *Economic Review* from the start until the nineties (with smaller fluctuations), then it slowly decreased to twenty until 2000, and now this ratio is around thirty percent.

Figure 3: *The proportion of co-author articles*



In the *Psychological Review* thirty percent of the articles were written in co-operation as far back as in the sixties but in the mid-eighties and early nineties it fell with ten percent. A new growth started in the mid-nineties. In the last year co-authored articles represented more than fifty percent. (The increase is partly explained by the fact that thematic issues have been published from 2006 and more research results made in co-operation were accepted.)

The proportion of articles co-authored has no significant change from the start in the case of the *Review of Sociology*. The values range between five and twenty-five percent. In 2004 and 2005 only ten percent of the articles were co-author ones.

Besides co-operation rate the average number of authors is also useful information. Only in the case of the *Psychological Review* can changes be observed in the last few years. It reached a value above three many times during its history, what's more, it was 3.5 in the last year studied. Among psychologists, it can be stated that in recent years both the rate of co-authorship and the average number of authors has increased.

The biggest co-author networks

The most interesting part of the research is the analysis of the networks of co-authors but it also raises several methodological questions. Two journals have more than fifty and one of them nearly forty years' history. If a chart shows the total connections – those who had published in the seventies but after died or those who have finished academic activity – it can be misleading as these researchers could not contact today's publishing authors because of their age. The investigation of the whole period is indispensable regarding the growth of networks. Therefore the following pages present the networks from the very beginning. I indicate the last decades with the data when the last article was published.

Table 2: Size of components

	Economic Review	Review of Sociology	Psychological Review	Psychology
Biggest component	280 (27%)	74 (24%)	240 (34%)	69
2ndbiggest component	31	10	19	61
2 persons	161	61	69	23
3 persons	41	13	16	11
4 persons	15	6	15	5
5 persons	9	7	10	5
6–10 persons	15	4	20	6
11+ persons	5	0	1	0

Two researchers can publish together more times as well. In the *Review of Sociology* 93 percent of the relations, in the *Economic Review* and the *Psychological Review* 89, in the *Psychology* 85 percent are simple-weighted relations (they have only one common article). In the field of sociology the biggest weight of a relation is seven (between Angelusz Róbert and Tardos Róbert), in the field of economics it is six (between Galasi Péter – Kertesi Gábor; Köllő János – Kertesi Gábor). In the *Psychological Review* and the *Psychology* the same pair (Márton Magda – Szirtes József) have published the most articles (eight in the former and seven in the latter.)

Biggest networks

In the *Economic Review* the size of the biggest component is 280, which is 240 in the *Psychological Review* and 74 in the *Review of Sociology*. Two bigger components can be found in the *Psychology*: a network with 69 persons and a little smaller one with 61 people. The economist Balázs Sándor has the most connections within different fields (twenty-two), he is followed by the psychologist Pléh Csaba (thirty-four) and the sociologist Kolosi Tamás (thirteen).

Figure 4: The biggest network of the *Economic Review*

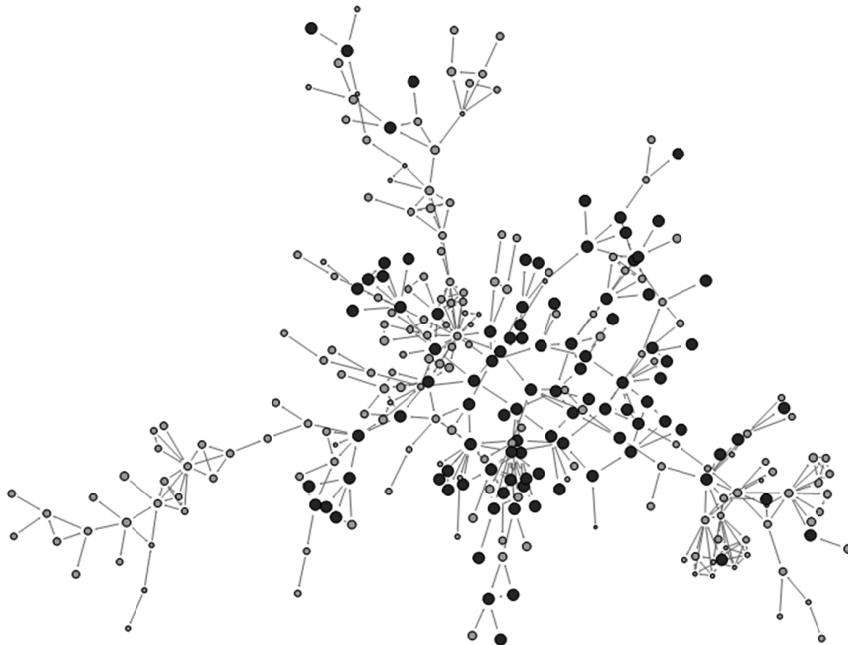


Figure 5: *The biggest network of the Psychological Review*

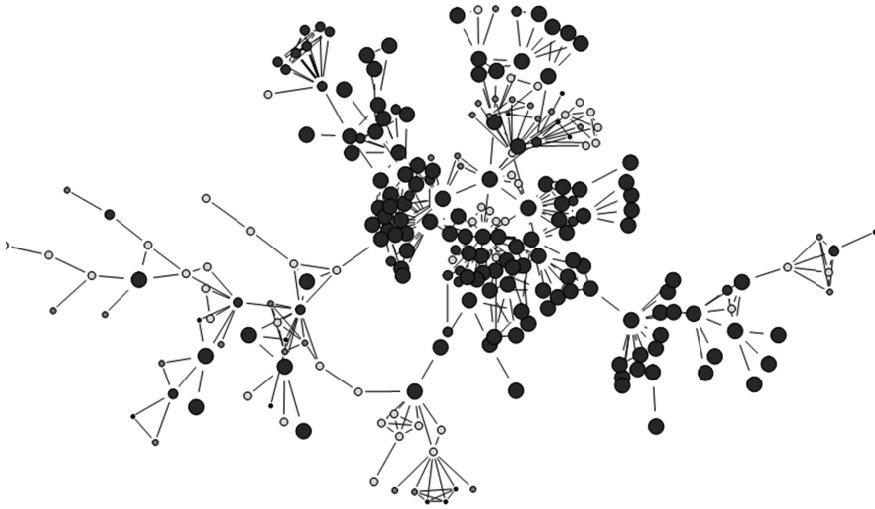
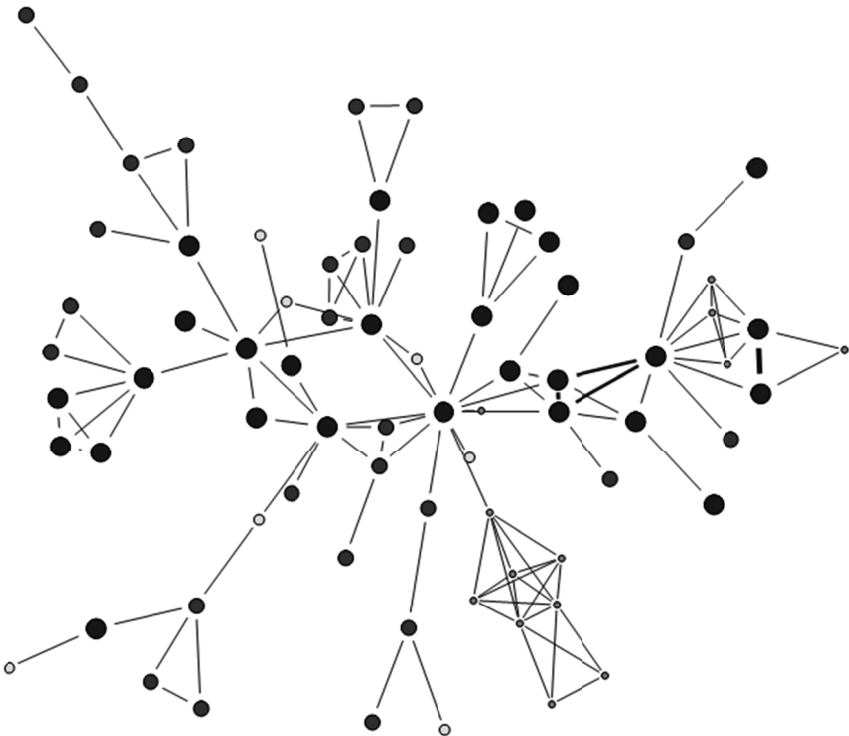


Figure 6: *The biggest network of the Sociology and the Review of Sociology*

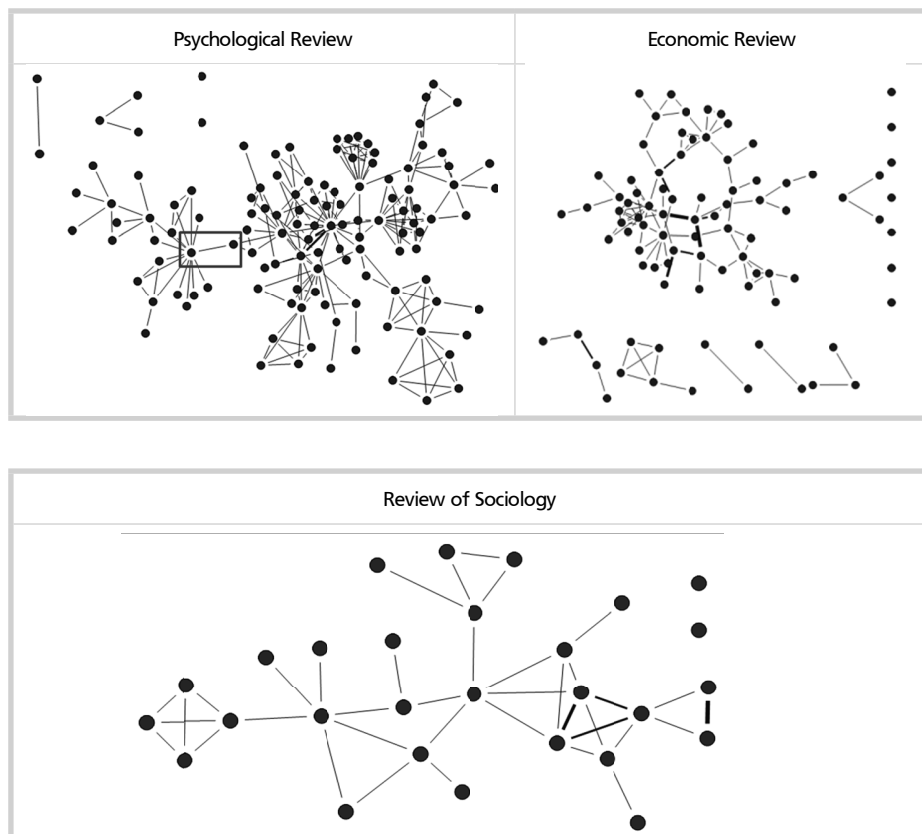


I mentioned that the networks presented here a forty- or fifty year span. This implies that authors who had published in an earlier period could not write together with researchers who entered scientific life later. The *following figures* show the decade of the last (single or co-authored) publications, their various sizes are marked according to the decade. In the case of all three journals it can be seen that publishing authors within the same decade are closer to each other. In order to ensure that these data are comparable, I collected them in *table 3* in various decades according to the date of the last publications. Networks based on the publications from the last ten years (2000–2009) can be viewed separately in the *seventh figure*.

Table 3: According to the last publications

	Economic Review	The Review of Sociology	The Review of Psychology
1950–1959	12 (4,3%)	–	–
1960–1969	20 (7,2%)	–	12 (5%)
1970–1979	30 (10,7%)	13 (18%)	28 (12%)
1980–1989	83 (29,6%)	7 (9%)	48 (20%)
1990–1999	35 (12,5%)	26 (35%)	28 (12%)
2000–2009	100 (35,7%)	28 (38%)	124 (51%)
Sum	280	74	240

Figure 7: The network of authors publishing between 2000–2009



It turns out from the networks made from publications over the past ten years that the largest network of co-authors can be found in the *Psychological Review*. The second is in the *Economic Review* and only the third is in the *Review of Sociology*. The filtered sub-networks based on the last publications (the last decade) show that while there are only six people in the *Psychological Review* who are not involved in the largest component, in the case of the *Economic Review* twenty-seven people were missed. A spectacular case of cluster can be observed, a connection (cutting point, rectangle marked in the figure) can be seen, if this was removed, the network would split in two parts. The left cluster is a good example of how a particular subject might be important. The key player here is Dull Andrea who is a recognized researcher in the area of environmental psychology and other researchers working on the same topic can be found around her.

Since from the area of psychology two journals can be found in the analysis, I examined their shared network, too. The common networks of the two journals

from 240 grew to 424. 176 authors from the *Psychology* (36.5%) can be found among the authors of the *Psychological Review*. A lot of interesting questions arise by merging the two networks. Both networks has a number of authors of ninety-five but only 59 people are members of the largest component of the *Psychological Review*, so only thirty-six persons become part of the largest component, if authors of both journals were taken into account (57 people are authors who just wrote in the Review and they were not previously members of the largest network). In the case of authors of both journals the average numbers of articles are evidently much higher than in the case of the other members of the network (average number of articles is 9.54 and 1.84).

Analyzing the networks

During the descriptive analysis of networks basic centrality measures are used. The first indicator is density which is the rate of possible and completed connections as a percentage. (The statistical analysis of the networks was made by the program UCINET). The data consists of the strength of the relationship which slightly changes the method of preparation of metrics. Regarding density, this means that not the number of connections but the weight of the amount is allocated by the program, divided with number of possible connections. The average degree number shows the number of connections per capita, while the diameter indicates the largest distance that can be found between the members of the network. The geodesic distance shows the average distance within the network. This is calculated by connecting every node with each other and then dividing by the number of roads. The fifth indicator is the betweenness centrality value which provides the number of trips crossing the nodes of the network.

Table 4: Centrality measures

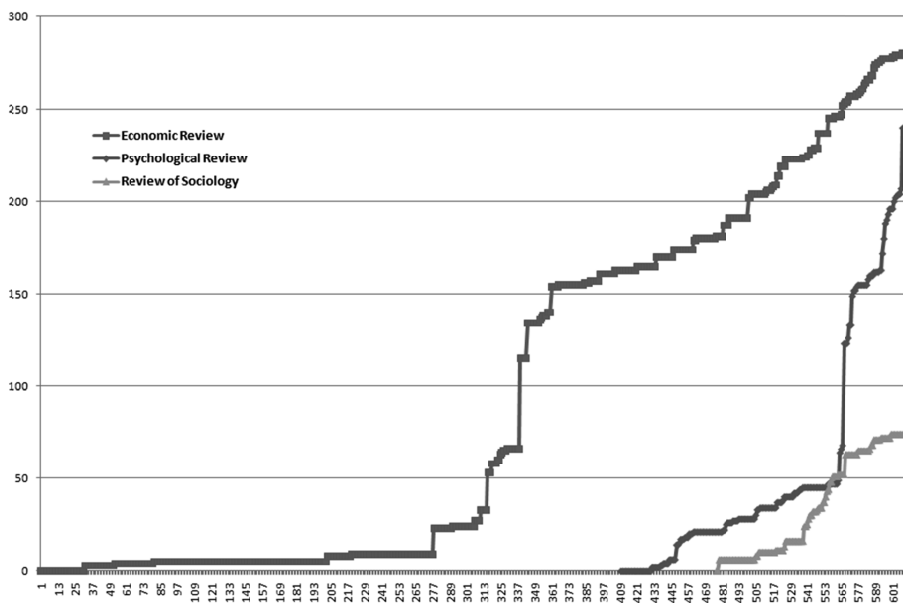
	N	Density	Average degree	Diameter	Geodesic distance	Betweenness centrality
<i>Economic Review</i> 1956–2009	280	0,011	3,193	23	8,136	0,026
<i>Hungarian Psychological Review</i> 1960-2009	240	0,016	3,767	18	5,94	0,021
<i>Review of Sociology</i> 1972–2009	74	0,044	3,180	10	4,38	0,047
<i>Economic Review</i> 2000–2009	68	0,046	3,08	10	4,8	0,058
<i>Hungarian Psychological Review</i> 2000–2009	117	0,035	4,05	10	4,439	0,030
<i>Review of Sociology</i> 2000–2009	26	0,117	2,93	7	3,3	0,103

Evolution of networks

Network analysis can focus both on topography and on dynamics. The 8th figure shows the growth of dynamics of the largest networks. During the interpretation of the data, it should be noted that the growth of networks were adjusted to the latest issues released. As the three journals appeared first in different years and they are published in different months of the year, I did not want to sacrifice the details. So I chose it instead of the aggregation of growth data.

The network size can be read firstly from the diagram. This information is already known so I do not return to it again. The interesting part of the diagram is that the sizes of the network of the *Economic Review* and the *Psychological Review* show a sudden increase at the same size after a slow initial growth phase. The previous one grows from sixty-six to 114 and the latter grows suddenly from sixty-seven nodes to 120. In the case of the *Review of Sociology* a similar dynamic growth cannot be observed.

Figure 8: Evolution of the biggest components



A question arises during the analysis of the growing of networks: what kind of dynamics do networks follow? Social and natural sciences often describe the dynamics of networks with logistic growth (Fokasz 1999). In social sciences it can be used for analyzing demographic data, how widespread technological innova-

tions are (e. g. mobile phones). The canonization of Saints in the middle ages, the number of rockets sent to the Moon during the Cold War shows similar dynamics, more recently the dynamics of topics in the media is in the focus from this aspect (Fokasz 2004). The *Review of Sociology* also released a more detailed specification about this type of growth (Fokasz 2006), so I do not want to deal with it in more detail.

The use of logistic growth is based on the fact that different waves can be observed already from the raw data, while the entry data revealed that the appearance of new researchers is essentially linear. At the same time, however, I may not say that the model suits other scientific fields. In “mature” science, where a high degree of co-authorship and a higher average number of authors can be observed, other approaches may be used, as in the period under review.

Figure 9: The dynamics of growth of the *Review of Sociology* (left), the result of Fisher transformation (right)

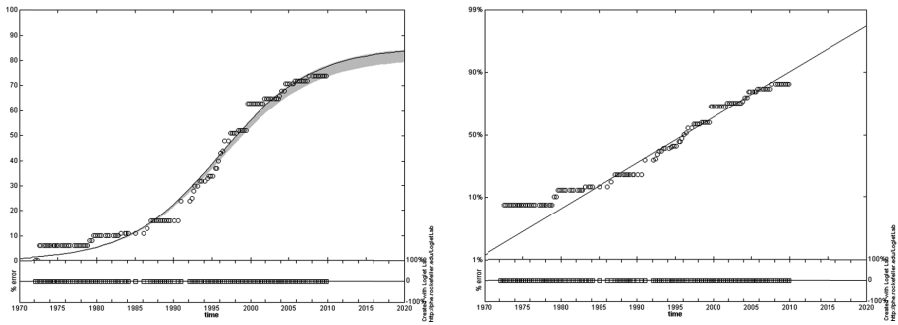


Figure 10: The dynamics of growth of the *Psychological Review* (left), the result of Fisher transformation (right)

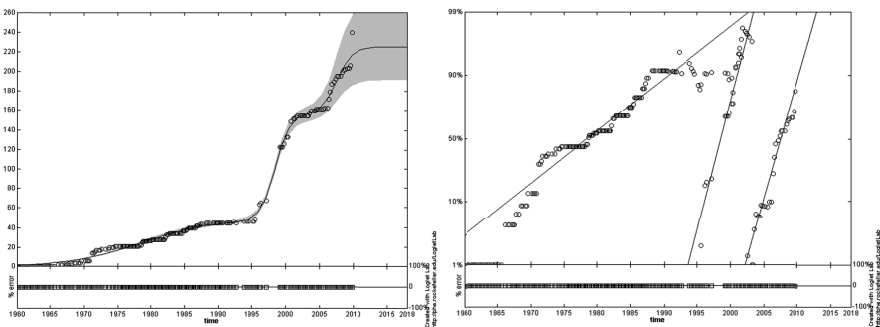
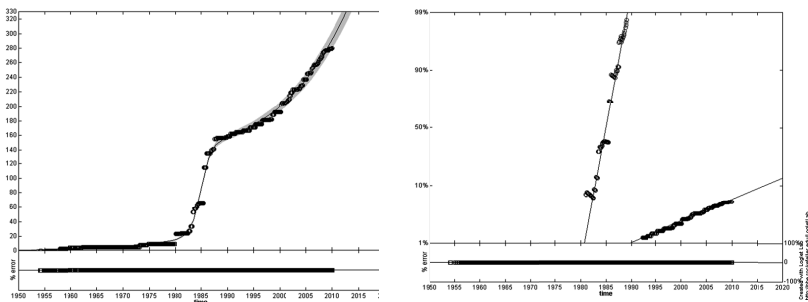


Figure 11: The dynamics of growth of the Psychological Review (left), the result of Fisher transformation (right)



Figures 9–10–11 show the dynamics of growth of the largest networks analyzed with the help of the logistic fit (this was made by the program Loglet Lab²). The figures on the left include the fittings, while the Fisher–Pry transformation results can be seen on the right side. (The essence of the transformation is that values of the logistic function are shown on a logarithmic scale which result a straight line. A relationship of successive waves of growth can be seen after data conversion.)

The fittings verified my conjectures; the dynamics of co-author networks grow logistically. More series of successive waves of growth: a bi- or tri-logistic growth is concerned in two cases. It can be assumed from the data in the 8th figure that if the network has a logistic growth, it has more series of successive waves of growth.

One growing wave can be fit on the largest network of the Sociological Review which is 90 percent full. Taking into account the data of recent years, it seems that the growth process is of a slow pace and even a few years are expected to pass until it reaches complete saturation. Considering that the number of co-author articles is low and there is no bigger-size network beside the largest component, we cannot expect major changes in the near future.

In the case of the Economic Review the fitting of two curves was necessary. On the basis of the current data it can be also shown that the increase of the largest network arrives at saturation point in the near future, however, this transitional period can take almost three to five years. The logistic growth is represented by consecutive waves; the slope of the second wave of growth is smaller than the first one. While interpreting the growth of the first wave, we should note that a sudden increase in size is due to the merger of parallelly growing smaller networks. But this does not appear during the analysis of the dynamics of growth; it seems that it was actually a single process.

The Psychological Review’s network analysis needed three logistic fittings. In this case the logistic processes do not follow each other sequentially but we can

2 The program can be found on the following site: <http://phe.rockefeller.edu/LogletLab/>

observe two logistic processes peaking at the same time and a start-up of a new wave can be seen, too.

Let's compare the growth of the largest network of the Economic Review and the Psychological Review. We can see that in the initial period, during which the growth of networks was due to similar-sized networks connecting to each other and substantially increasing in size, this happened in twenty-five or thirty years. In case of the Economic Review this dynamic growth began in 1985. I have already quoted the Such-Tóth article in the introduction – they stated that a significant change had happened in the mid-eighties when the Economic Review had become independent from politics. The first logistic growth saturated this time. Of course, I can't prove the relation between the two facts; a possible explanation could be policy revision with the professional aspect coming to the fore, which resulted in the fact that researchers who had had less publishing possibilities could benefit from the situation. However, further analysis should be needed to test the hypothesis. The initial growth period was approximately thirty years in the Psychological Review. The transitional period has not already finished and a dynamic new growth began in the meantime.

The similar length of the initial period is surprising particularly because the Economic Review is published eleven times a year while the Psychological Review only six times in its initial period. This points to the fact that not the number of the issues but the calendar time influences more the dynamics of growth of networks. I consider it important to mention that during this important period of evolving networks approximately 600 authors published in the Economic Review and 450 in the Psychological Review. The difference is significant so I think that besides time the growth of networks are determined by the number of potentially available authors besides time. The growth of the network of the Review of Sociology shows that it is still in its early days.

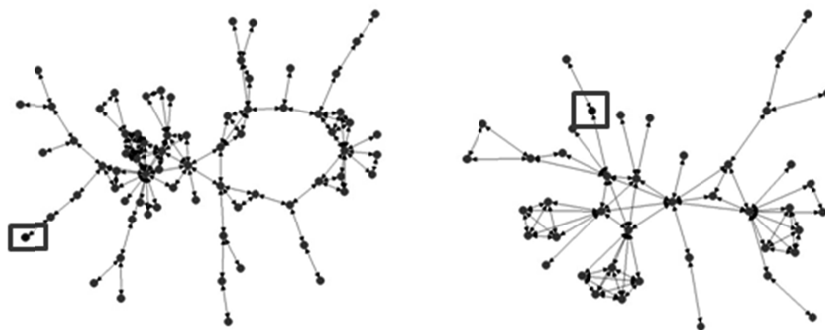
I return to the growth of the largest network of the Psychological Review for a while. The overall resolution of the initial phase passed through three locked wave of growth. Jumping a level in the analysis and considering different waves as the basic unit, it is possible to compare the duration of waves and their size (number of members of the network). I devote specific attention to the period of transformation. The network size of the Psychological Review has grown increasingly during the series of waves of growth. The first wave has increased with 18, the second with 26 and the third with 111 people. (The latter is debatable as it is not a continuous growth but another network is involved in the merger process.) The time of growth of the first two waves is fifteen to seventeen years and the transition period was approximately ten years. The Economic Review started with low initial numbers and suddenly there was an increase to one hundred and seventy. In the second phase (which is not complete yet) it continues to grow with approximately hundreds of people. The first and second stages are/were fifteen years.

The structure of the networks before the transition

The points marked with a square connect the two networks. In case of the *Economic Review* the relations of certain authors merge the two networks: Gábor R. István's in the larger network and Kővári György's in the smaller network. Regarding the *Psychological Review* the cooperation of Csibra Gergely and Csepeli György connects the two networks. It is true for both journals – except for the member Csepeli György – that the collaboration of these networks is established by the cooperation of authors with few connections on the periphery (Gábor R. István and Csibra Gergely have one, Kővári György has two).

At this time Cziegler István can be found in the center of the larger network of the *Psychological Review*. B. Kakas Gizella, Kardos Lajos, Barkóczy Ilona or Klein Sándor have more connections but they are on the edge of the network. Popper Péter stands in the heart of the smaller network. His central role in this network is indisputable. Csepeli György and Füredi János have more connections but this does not change the fact that basically the network has a chain structure.

Figure 12: The bigger (left, N=66) and the smaller (right, N=48) part of the network of the *Economic Review* before the merging in 1985*



* Networks merge after the formation of the relationships between the points marked by squares

Figure 13: The bigger (left, N=67) and the smaller (right, N=53) part of the network of the *Economic Review* before the merging in 1999*



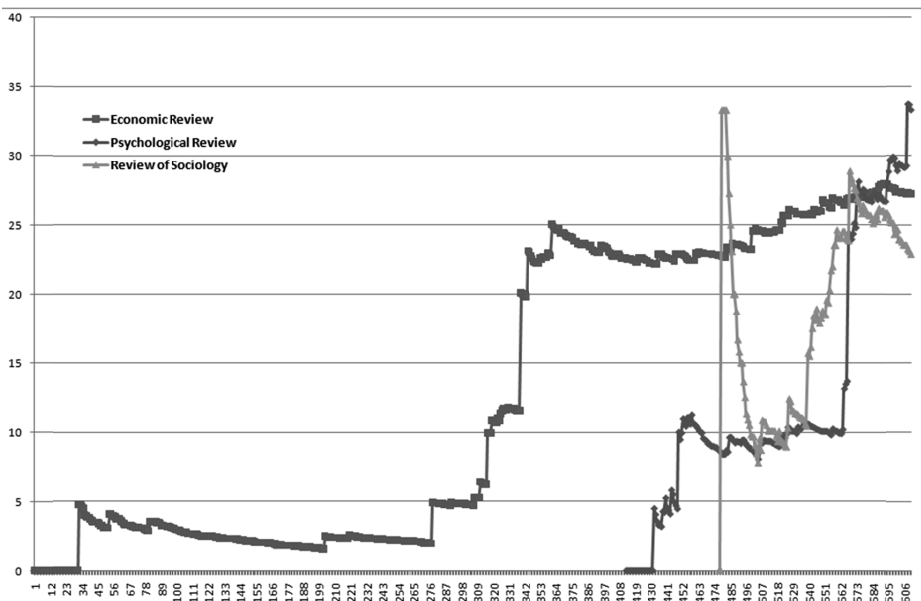
* Networks merge after the formation of the relationships between the points marked by squares

The place of the biggest components within the whole scientific community

The 14th figure shows the proportion of researchers who published their articles in co-authorship within the largest networks. The sizes of the three networks are significantly different from each other thus it is surprising that about twenty-five to twenty-eight percent of the co-authors are integrated in all three cases.

In the case of the *Economic Review* and the *Psychological Review* it can also be observed that they show not only a similar dynamics of growth, but also a similar dynamics of the number of authors integrated in their largest networks. Initially the first two networks include five percent of the authors, which doubled to ten and then it stagnates around twenty-five percent.

Figure 14: The proportion of the largest networks compared to the number of writers of co-author articles



Inter-journal connections

These journals focus on the fields of social sciences but is there a connection between them? Only Csepeli György, Garai László and Varga Károly published their work in all of the four papers. The number of the common publishers of the *Review of Sociology* and the two psychological journals is eleven; this number is seven regarding the *Economic Review* and the two psychological journals.

The number of pairwise connections can be found in table five. The strongest link can be observed between economic and sociological journals, and between psychological ones. (The numbers are somewhat biased upwards, several common names can be found in the overlapping relationships among which it is conceivable that different persons are behind the names.)

Table 5: Number of researchers who have published in two journals

	Economics Review	Review of Sociology	Psychological Review	Psychology
Economics Review	–	150	25	9
Review of Sociology		–	26	7
Psychological Review			–	146
Psychology				–

In the case of the biggest networks except for the *Economic Review* and the *Psychological Review* there is a connection. Between sociology and economics the brokers are: Kertesi Gábor (two in the *Economic Review* and five in the *Review of Sociology*), Kiss István (five and two), Kovách Imre (seven and four), Kuczi Tibor (four and three), Sik Endre (two and seven). The *Review of Sociology* and the *Psychological Review* have also five common members: Csepeli György (six in the sociological and eight in the psychological one), Kóczán György (seven and seven), Neményi Mária (four and two), Rudas Tamás (two and one), Váriné Szilagyfi Ibolya (one in both journals).

The brokerage role of sociology between the different fields of social sciences is consistent with the results of Moody (Moody 2006). In his citation network analysis of social science journals he found that economics, law, political science and psychology have the most stable boundaries and they are seated on the edge of the network, while sociology journals refer less to themselves so they can be found in the middle of the network. (The American Sociological Review is the most central journal and also seven from the ten most central reviews belong to sociology.) Thus I was led to the conclusion that sociology can convey ideas between different disciplines and it can easily borrow new ideas as well.

Summary

I focused on two aspects of co-author networks in this article: topography and dynamics. The results showed that the level of cooperation in domestic social science is very low in comparison with the American which is twice as much. This raises several interesting questions: what can influence the low cooperation rate while it is clear that scientific work can benefit from collaboration? Is it due to the individualism of society, or other structural causes stand behind this?

The question remains unanswered in this article as the methodology used here is inappropriate to find this out.

The analysis revealed that logistic curves can describe the growth of the largest components of co-author networks effectively; what's more, it is possible to fit more curves on the networks. In the case of two or three waves we can talk about bi-logistic or tri-logistic growth. Regarding the *Review of Sociology*, however, only one wave can be identified. If we extrapolate this wave, it can be seen that a significant change cannot be expected in the coming years in the level of cooperation. It is a major and serious recognition for sociology that it has a linkage role between psychology and economics, so in this sense it has the same role as in American science in this sense.

The dynamics of networks was approached several ways but there are still more possibilities for further analysis. The centrality measures presented here can be applied not only for a moment, but also for all moments of the life of networks. This becomes particularly interesting if both entering and leaving the network become part of the analysis. How does dynamic look like? Does network have a state of balance? What processes can be observed when an important person leaves a network? However, these questions could be interesting for scientific networks and for network studies, too. As for co-author networks there are further possibilities of analysis if additional data are available. These mean for example: connecting the network results with citation- and topic networks, but we can also focus on the situation³ of women and men within science, too.

The analysis of co-author networks shows the skeleton of the working process of science. This is one of the different levels of cooperation which connects researchers, where new ideas are born and various thoughts spread. I believe that creativity is a social phenomenon which will provide several new results during the research of innovation.

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³ I wrote about the network positions of women and men in these three journals in a previous article. (Micsinai 2007).

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