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Co-Authorship and Co-Citation Networks in the Agricultural Economics Literature: The Case of Central and Eastern Europe

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This article analyzes co-authorship and co-citation networks in the agricultural economics literature on Central and Eastern Europe written during the last twenty-five years. It highlights the principal researchers in the field, together with their authorship and citation networks, on the basis of 238 articles written between 1990 and 2013. Most of the articles were written by a small number of researchers, indicating that clusters and central authors play an important role in scientific progress. Contrary to expectations, it turns out that number of articles and central role in network are not related. Finally, clusters are found to cite themselves more than the average, thereby boosting scientific progress for their members.

Keywords: agricultural economics, clusters, social networks

JEL Classification: A11, A12, Q10

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The analysis of co-authorship and co-citation networks has a strong theoretical background in the social network analysis literature. These networks have been analyzed extensively at both the network and the individual level to explore the various characteristics of scientific collaboration. Such networks not only show us an academic society but also represent the structure of our knowledge (Wagner and Leydesdorff 2005).

Despite the apparent importance of the topic, there has been little analytical research on co-authorship and co-citation networks in the field of agricultural economics. As Gazni and Didegah (2011, p. 253) states, the "association between scientific collaboration in a research and the impact of the research results [has] been investigated in just a small number of studies." The aim of the present article is to (1) apply social network analysis to agricultural economics, (2) focus on a region rather than a single country, and (3) make both authorship and citation networks in agricultural economics visible.

Information of this kind is important for researchers seeking to publish articles and apply for research funding or scholarships. It is essential for them to know what market they are entering, how and with whom they can cooperate, what strategy to use in publishing and citation, and what chances they have to be published. Our results will also be useful for decision-makers and funding bodies to see how agricultural economists are organized and structured around different topics, and what strategies they apply to obtain funding and increase their scientific progress.

The article is structured as follows. The next section provides a brief description of the theoretical background of social network analysis in general and, more particularly, in scientific collaboration. The third section details our methodology, with its descriptive statistics given in the fourth section. Co-authorship and co-citation networks are described in the fifth and sixth sections, followed by some concluding remarks.

LITERATURE REVIEW

A social network is formally defined as a set consisting of finite number of social actors and the relationships among them (Wasserman and Faust 1994). Actors are the nodes of the network, and their relationships are the edges, presented in the sociomatrices of sociographs (Marin and Wellman 2010). In other words, each edge in a network represents a co-authorship relationship. Actors can take various forms, from individuals to organizations, and relationships can be treated as a loop among the actors. In a social network, *actors* are represented by points, while *relationships* are given by lines. The lines can be directional or nondirectional, where the former measures the prestige of an author. A directional relationship can also be divided into symmetric and asymmetric parts, depending on whether or not the actors are conversely related (Hanneman and Riddle 2005). For an excellent review on the basics of social network graphic representation, interested readers are advised to consult Liu et al. (2005).

The role of social network analysis has been steadily increasing, because the field plays an important role in many disciplines (Liu et al. 2005). Originating in the three disciplines of psychology, anthropology, and sociology, network analysis is now influential in many areas of the social sciences, and most recently has begun to draw on other disciplines, such as mathematics, physics, and computer science (Knoke and Yang 2008). The theory is based on the recognition that social life is basically a set of interhuman relationships that can be described

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through the analysis of relationship networks (Marin and Wellman 2010). However, analysis of this type is much more than the simple gathering and description of data (Moed, Glanzel, and Schmoch 2005) and is, in fact, the base for a new theory of social structure (Scott 1987). The theory, in general, is very appropriate for analyzing and modeling complex social structures (Wasserman and Faust 1994).

With the help of graph theory (Wasserman and Faust 1994), social network analysis makes the web of social interactions visible at the global and individual levels. The global level seeks to describe the characteristics of a network as a whole (distance, clusters, etc.), while the individual level refers to the analysis of individual actors (status, position, etc.). The status of an actor can be well described by centrality, as is evident from the methodological section below.

With its increasing popularity, there has also been a growing interest in applying social network analysis to other areas, such as scientific collaborations (e.g., co-authorship) and citation networks between researchers within a specific discipline. Scientific collaboration (e.g., co-authorship) can be treated as a special social network, and research on this topic dates back to the 1960s (Glanzel and Schubert 2005). In the past, most scientific research was done by individuals who published single-authored articles; however, this has changed significantly in recent decades. Whereas in 1950, only 8 percent of the articles published in the *American Economic Review* were co-authored, the rate increased to 55 percent by 1993 (Hudson 1996) and was 81 percent in 2014. Science is now more accessible and free than ever before, and there is a growing interest in scientific collaboration in its various forms (e.g. research projects, publication in peer-reviewed journals, conference papers). According to Cabanac, Hubert, and Milard (2015), collaborations are most often facilitated by technological advances, geographical proximity, and similarity of research topics. Multidisciplinary, interdisciplinary, and transdisciplinary research and approaches are needed to tackle the key issues we face as a society, and this has led to collaborations of a higher order. Collaborations definitely boost research outcomes, as shown by the rising number of publications and of citations received. As Persson, Glänzel, and Danell (2004) have shown, the number of references increases with the number of co-authors, especially if the latter are from different institutions.

There is little doubt that high-quality published articles are crucial to academic progress (Acedo et al. 1995). Researchers who publish together with colleagues establish a scientific network, and the analysis of such networks provides a useful picture of the relationships among individual authors. However, scientific networks are usually based around prominent researchers who function as a hub in attracting a large number of scientists (Cabanac, Hubert, and Milard 2015). According to Katz and Martin (1997), research collaboration enhances the quality of research such that co-authored articles are cited more often. Narin, Stevens, and Whitlow (1991) found that internationally co-authored articles are cited twice as frequently as single-authored ones. Sooryamoorthy (2009) also found a significant positive correlation between the number of authors and the number of citations received by South African scientists. However, Zapata (2009) added that collaboration patterns in agricultural economics would rise in the future as the profession becomes more multidisciplinary in nature.

Journal rankings may also have an impact on scientific collaboration, because publishing in the more prestigious scientific journals has a higher value in most academic performance indicators. Several authors have analyzed discipline-specific journal rankings and quality (e.g., Axarloglou and Theoharakis 2003; Barrett, Olia, and Bailey 2000; Herrmann et al. 2011).

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Citation networks are a special type of social network first analyzed by de Solla Price (1965) in his seminal "Networks of Scientific Papers." Citation indices are widely used in scientometrics as a means of evaluating the quality and impact of scientific publications. However, although metrics based on citation indices remain a crucial component in evaluating research performance, they cannot alone reflect every aspect of scientific communication (Chen et al. 2015).

The number of citations, for instance, is usually lower in the first years, but since the quality of a published article surely does not change over time, the number of citations does not always reflect the visibility of a research study on the social web. Moreover, natural and social scientists have diverging publication records, which makes citation patterns even harder to compare. Therefore, many alternative measures have been proposed as compared to the Web of Sciences (WoS) or Scopus-based performance indicators (e.g., Chen et al. 2015; Palacios-Huerta and Volij 2004).

On the whole, co-authorship networks and citation networks are both social networks, but it should be noted that co-authorship implies a stronger social bond than citation (Liu et al. 2005). There need not be any direct relationship between researchers for citation to take place, whereas co-authorship implies a temporal and collegial relationship with all its social aspects.

DATA AND METHODOLOGY

In order to analyze co-authorship and co-citation networks in agricultural economics, we built a sample in two steps. First, using Cramon-Taubadel and Nivyevskyi (2012) and suggestions by colleagues, we compiled a list of the most relevant journals, based on number of articles focusing on the agricultural transition in Central and Eastern Europe (CEE), including countries that acceded to the European Union in 2004 and 2007: *Agribusiness, Agricultural Economics, American Journal of Agricultural Economics, Canadian Journal of Agricultural Economics, Eastern European Economics, Economics of Transition, European Review of Agricultural Economics, Food Policy, International Food and Agribusiness Management Review, Journal of Agricultural Economics, Journal of Agricultural and Resource Economics, Journal of International Agricultural Trade and Development, Post-Communist Economies, Review of Agricultural Economics, The World Economy, Quarterly Journal of International Agriculture*, and *World Development*. All the articles on the CEE agricultural transition published in these journals between January 1990 and December 2013 were systematically reviewed, and the references in these articles were searched for other relevant articles published elsewhere. Overall, 238 articles from thirty-one journals were selected for the analysis. The following criteria determined the selection of articles:

1. *Topics*. The selected articles interpreted agricultural transition in the widest sense available. Thus any article that treated the agri-food sector of at least one CEE country was selected regardless of the exact topic, whether efficiency, trade, or rural development.
2. *CEE in focus*. The selected articles focused on agricultural transition in the CEE countries; the former Soviet Union and any other countries were not part of the analysis.

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3. *High scientific standards*. Only journals published in the Thomson Reuters Journal Citation Reports were considered. No reports, books, or conference materials were selected.
4. *References*. Articles that did not include a list of references were not selected. Book reviews, comments, discussions, and reflections were not selected, even if they appeared in the journals listed above.

We are aware that our selection method has limitations. First, our sample is only valid for articles published in selected impact-factor journals, as discussed above. Second, since journal rankings were not the focus of our study, we did not weight the journals based on their different reputations (e.g., Axarloglou and Theoharakis 2003; Hermann et al. 2011; Liebowitz and Palmer 1984). However, an excellent review on the preference of authors to submit articles to agricultural economics journals based on their rankings can be found in Lusk and Hudson (2009). Third, our selection concentrated on a single region within a given timeframe. On the whole, as is always the case, we are aware that any change in our sampling method might have altered the results we obtained to some extent. Still, we believe that our results are not far from reality.

Various social network metrics are available for measuring the characteristics of a social network. Component size analysis measures different features of disconnected components and shows the structure of the network. Three common metrics are available for binary undirected co-authorship networks: degree centrality, closeness centrality, and betweenness centrality (Wasserman and Faust 1994). *Degree centrality* of a node is defined as the total number of edges related to it, representing the number of connections between an author and his/her immediate neighbors. Authors may be well connected to their immediate neighbors, but if they are a part of a scientific cluster, the overall centrality can be low. Therefore, *closeness centrality* expands the original definition and focuses on how close an author is to all other authors. By definition, closeness centrality is a node's shortest path distances to all authors, inverted to a metric of closeness. This enables the central author to have many short connections to other authors. However, *betweenness centrality* determines how often a node is found on the shortest path between any pair of nodes in the network, referring to a "bridging role" played by an author to reach the others (Wasserman and Faust 1994).

Third, a relatively novel method called PageRank is also available to analyze co-authorship and co-citation networks. Mimicking the popularity of web pages by counting how many clicks each receives, PageRank enables a measure of an author's prestige that differs from the centrality measures discussed above. Since its results are based on the hyperlink structure of a web, they can be applied to binary directed networks (Liu et al. 2005).

DESCRIPTIVE STATISTICS

Figure 1 shows the number of articles published in the most relevant journals. The majority (68 percent) of articles were published in six journals: *Post-Communist Economies* (PCE), *American Journal of Agricultural Economics* (AJAE), *Food Policy* (FP), *European Review of Agricultural Economics* (ERAE), *Eastern European Economics* (EEE), and *Agricultural Economics* (AE).

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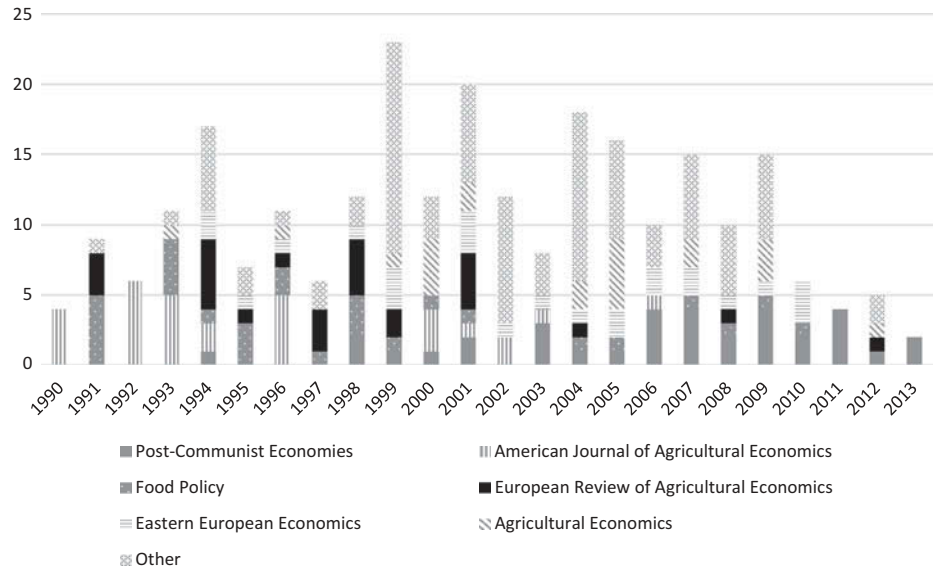

FIGURE 1 Number of Articles on CEE Agricultural Transition, 1990–2013.
Source: Own calculations.
Note: "Other" includes journals with less than 12 articles in the whole period.

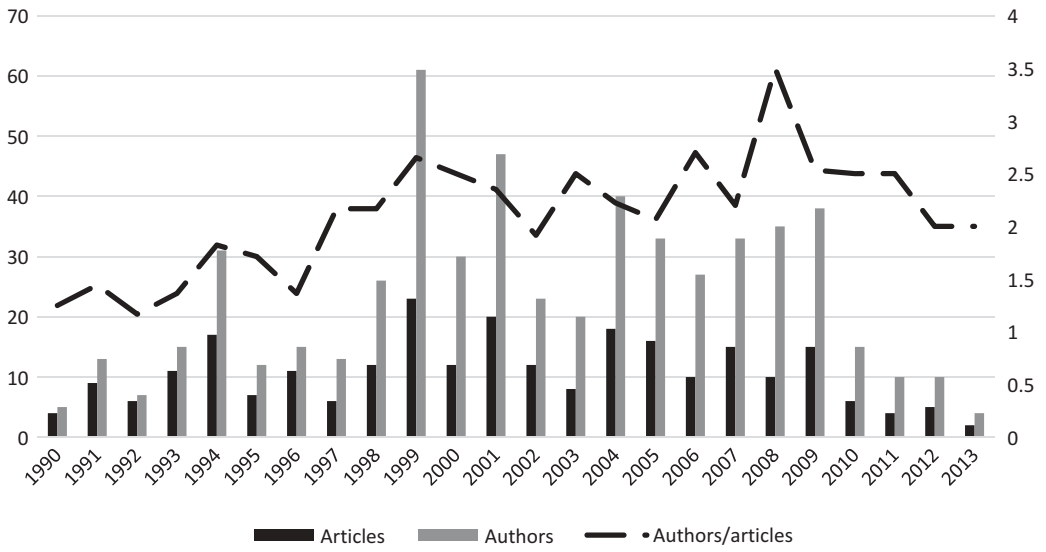

FIGURE 2 Articles and Authors by Year, 1990–2013 (percent).
Source: Own calculations.
Note: Bars are on the left axis, while the line is on the right.

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The importance of research on agricultural transition seems to have increased from the beginning of the 1990s and reached a peak in 1999, when twenty-three articles were published on this topic. After some decline, the eastern enlargement of the European Union proved to be a renaissance for the issue, with the number of articles increasing right after the 2004 and 2007 accessions. However, by 2013, the topic of transition seems to have lost its importance, with only two articles published in *Post-Communist Economies*.

The selected 238 articles were written by 564 authors (with repetition), resulting in an average of 2.2 authors per article. There is an upward trend in collaboration, from 1.5 authors/article in 1990 to 2 authors/article in 2013 (Figure 2), in line with the literature (Acedo et al. 1995). As many authors have written more than one article, the real number of authors (e.g., without repetition) is 277. Consequently, an average individual author published less than one full article (0.94) per year.

Collaboration patterns have also changed, as shown by analysis of the origin of the authors (Figure 3). In the 1990s, CEE agricultural economists worked with Western European colleagues, but by the end of the period researchers from the CEE were the only ones working on this topic. Moreover, after EU accession, there was no collaboration between CEE researchers and colleagues outside Europe. However, Western European co-authors played an important role in publications with CEE researchers in the period analyzed.

These trends demonstrate two important points. On the one hand, researchers from the CEE region now seem much more capable of publishing in internationally recognized journals by

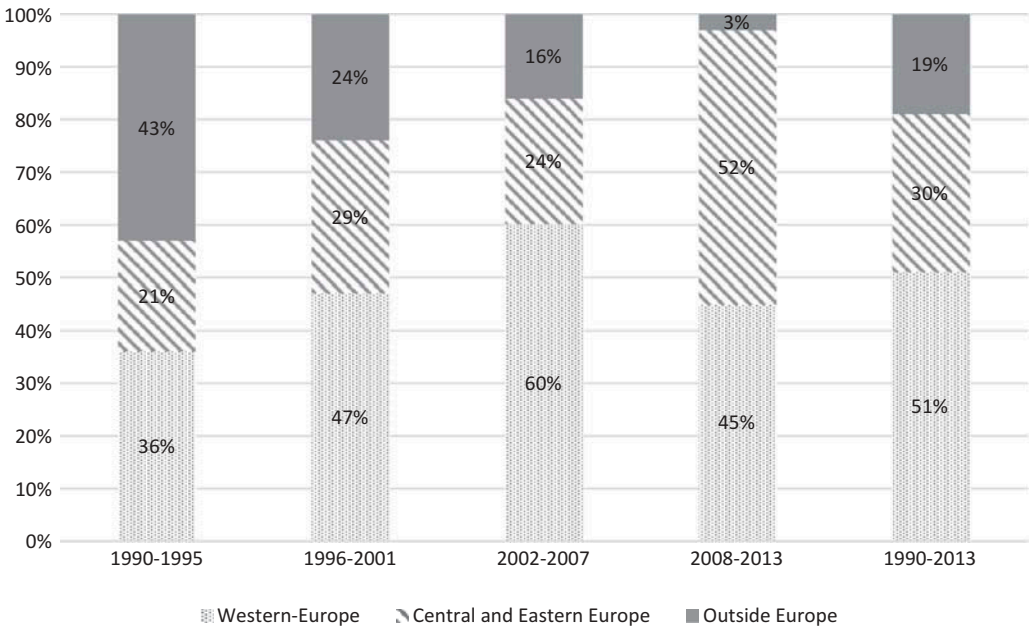

FIGURE 3 Collaboration by Region, 1990–2013 (percent).
Source: Own calculations.
Note: Origins of authors are based on the country where they were born.

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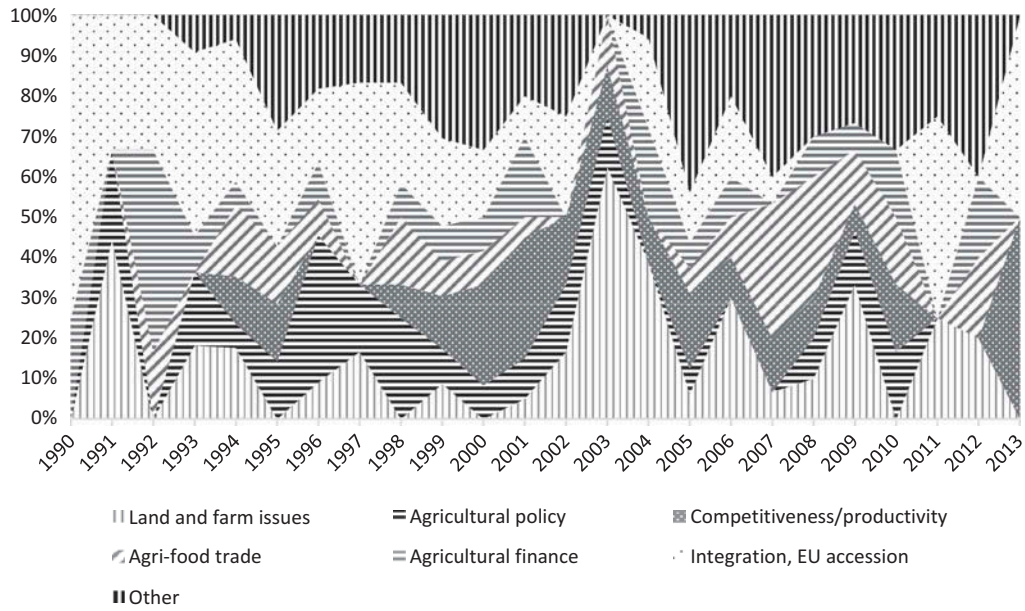

FIGURE 4 Changes in Topics of Articles, 1990–2013 (percent).
Source: Own calculations.

themselves. On the other hand, the CEE seems to be less interesting to agricultural economists globally, as there has been a shift toward developing countries in geographical terms (e.g., the considerable change in the topics of articles published by researchers with central positions in our network). However, as the scope of agricultural economics is about to expand, more emphasis is given to multidisciplinary approaches where collaboration is essential (Zapata 2009).

Research topics have also changed considerably in the period analyzed (Figure 4). The most important topic in the sample was integration and EU accession, with fifty-three articles (20 percent). Land and farm issues were the second most investigated topics, followed by competitiveness/productivity issues, agricultural policy, agri-food trade, and finance. These six topics accounted for 80 percent of the sample.

Integration and EU accession was a popular topic at the beginning of the 1990s and just after EU accession, but its importance has significantly decreased. Land and farm issues were very popular at the beginning of the 2000s, accounting for every second article, while the importance of agri-food trade issues seems to have significantly increased after EU accession. The changes over time in the importance of topics mirror the concerns of policymakers and funding bodies. After the change in political systems, for instance, transitional issues were the focus of agricultural economics research in the region, with a vast amount of projects and funding. A similar situation occurred at the beginning of the 2000s, when EU politicians and funding bodies were interested in the possible impact of EU accession on agriculture both in the old and the new member states. It is also evident that researchers who focus on "popular" topics have become central in co-authorship networks (see details below).

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TABLE 1
Top Ten Authors of Agricultural Transition Articles

Other		*Degree centrality*		*Betweenness centrality*		*Closeness centrality*	
Author	*Score*	*Author*	*Score*	*Author*	*Score*	*Author*	*Score*
Swinnen, J. F. M.	28	Gorton, M.	25	Gorton, M.	1,817	Swinnen, J. F. M.	4.67
Davidova, S.	15	Mathijs, E.	15	Latruffe, L.	1,650	Gow, H. R.	4.61
Fertő, I.	14	Davidova, S.	14	Fogarasi, J.	1,182	Dries, L.	4.52
Gorton, M.	14	Swinnen, J. F. M.	12	Davidova, S.	1,165	Ivanova, N.	4.37
Bojnec, S.	13	Fogarasi, J.	11	Mathijs, E.	938	Turk, J.	4.37
Dries, L.	9	Erjavec, E.	10	Erjavec, E.	893	Mathijs, E.	3.83
Latruffe, L.	8	Fuller, F. H.	10	Zawalinska, K.	587	Lingard, J.	3.67
Mathijs, E.	8	Beghin, J.C.	10	Turk, J.	391	Erjavec, E.	3.54
Bakucs, L. Z.	7	Fabiosa, J. F.	10	Lingard, J.	373	Fertő, I.	3.53
Csáki, Cs.	7	Dries, L.	8	Falkowski, J.	336	Bakucs, L. Z.	3.53

Source: Own composition.

CO-AUTHORSHIP NETWORKS: WHO IS PUBLISHING WITH WHOM?

Before we make the co-authorship networks visible, we will present the authors with the highest number of publications, thereby indicating the leaders (nodes) of our social research networks (Table 1). Over the period of the study, Swinnen has published the most articles (28), followed by Davidova (15) and Fertő (14) as well as Gorton (14). Note that the top ten authors co-authored 123 articles out of the total 238, suggesting a high level of concentration (52 percent) and indicating that a small number of authors write the majority of the articles.

However, as is also evident from Table 1, those who publish the most are not necessarily the most important actors in network terms, which suggests that centrality ends up with a significantly different list of authors. Based on degree of centrality, Gorton, Mathijs, and Davidova, respectively, published most frequently with co-authors. Taking the number of pairwise relationships, this means that Gorton has worked with more co-authors than any of the others. Gorton's highest-degree centrality value, for instance, is almost double Swinnen's, while Swinnen wrote twice as many articles as Gorton. Similarly, Mathijs shows a relatively high value for degree centrality but relatively low for number of articles, indicating the publication of few articles with many co-authors.

Gorton also seems to have the highest "bridging role" in the sample, as is evident from his betweenness centrality. By definition, Gorton could be reached the easiest if we consider the pairwise relationships between authors, suggesting that he acted as a "central hub" in working with others. Latruffe and Fogarasi also had high values for betweenness centrality, suggesting that they also work with many co-authors. As for closeness centrality, Swinnen leads the line, followed by Gow and Dries. They have acted as central players and were the most easily reached by other authors. Note that Gorton is missing from this list, indicating fewer but a stable list of co-authors.

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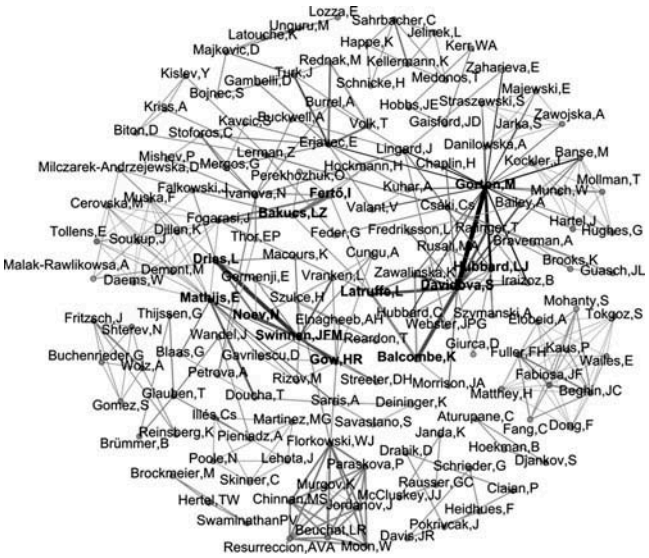

FIGURE 5 Co-Authorship Network of the Sample.
Source: Own composition using Gephi.

On the whole, the number of articles published is not in line with the centrality of the authors, as was *a priori* expected. Some authors publish a lot but with only a few co-authors, while others have extended their research networks but with relatively few publications. This situation can be explained by different motivations—some researchers like to work in small groups with more intensive relationships, others prefer working in larger teams. However, it seems evident from our results that small-group-based intensive research is more productive (at least in terms of quantity; as mentioned earlier, quality of journals and articles is not analyzed in this article).

These findings are also observable on the graphical representation of the co-authorship networks. As can be seen in Figure 5, there are many strong relationships among authors (indicated by the thickness of the lines), but the strongest relationship is definitely the one between Gorton and Davidova. The hub function of Gorton, Mathijs, Swinnen, and Davidova is visible in Figure 5. It can also be seen that there are two large scientific clusters in our sample (Clusters 1 and 2; see Table 2). Note that many groups either do not have links to these largest clusters or are linked pretty loosely. Latruffe seems to have been the most important "intermediary" between the two largest scientific clusters; this was also evidence of her high betweenness centrality value shown above.

The members of the largest clusters are also worthy of analysis. Almost half of the authors worked in a cluster consisting of at least three researchers, but only 10 percent of the authors became part of the two largest clusters identified above, suggesting that these clusters were surrounded by high barriers. This suggests that collaboration among clusters is rare. Table 2 shows the members of the six largest scientific clusters, each of which consisted of more than ten authors. Note that only seventy-three authors (26 percent of the total) were part of these clusters,

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TABLE 2
Members of Six Largest Clusters of Network

Cluster 1	*Cluster 2*	*Cluster 3*	*Cluster 4*	*Cluster 5*	*Cluster 6*
Gorton, M.	Falkowski, J.	Erjavec, E.	Fogarasi, J.	Lingard, J.	Brooks, K.
Latruffe, L.	Swinnen, J. F. M.	Turk, J.	Mathijs, E.	Ivanova, N.	Braveman, A.
Davidova, S.	Bakucs, L. Z.	Majkovic, D.	Sarris, A.	Hubbard, L. J.	Guasch, J. L.
Zawalinska, K.	Fertő, I.	Mergos, G.	Doucha, T.	Szymanski, A.	Csaki, Cs.
Banse, M.	Dries, L.	Stoforos, C.	Deininger, K.	Zaharieva, E.	Lerman, Z.
Balcombe, K.	Gow, H. R.	Rednak, M.	Savastano, S.	Hubbard, C.	Kislev, Y.
Bailey, A.	Bojnec, S.	Volk, T.	Blaas, G.	Webster, J. P. G.	Biton, D.
Morrison, J. A.	Noev, N.	Gambelli, D.	Demont, M.	Thor, E. P.	Kriss, A.
Ratinger, T.	Vranken, L.	Kuhar, A.	Cerovska, M.	Petrova, A.	Feder, G.
Chaplin, H.	Reardon, T.	Valant, V.	Daems, W.	Buckwell, A.	
Fredriksson, L.	Streeter, D. H.	Lozza, E.	Dillen, K.	Burrel, A.	
Iraizoz, B.	Macours, K.	Latouche, K.	Muska, F.	Giurca, D.	
Danilowska, A.	Cungu, A.	Unguru, M.	Soukup, J.	Rusali, M. A.	
Jarka, S.	Malak-Rawlikowsa, A.	Mishev, P.	Tollens, E.		
Straszewski, S.	Milczarek-Andrzejewska, D.	Kavcic, S.			
Zawojska, A.	Germenji, E.				
Majewski, E.	Hockmann, H.				
Hartel, J.	Perekhozhuk, O.				
Hughes, G.	Rizov, M.				
Kockler, J.	Gavrilescu, D.				
Mollman, T.					
Munch, W.					

Source: Own composition.
Note: Only those clusters are listed where authors have published more than once together.

meaning that the vast majority of researchers are working in smaller (and peripheral) groups. It is also worth noting that 40 percent of the articles were written by the two most important clusters (and 60 percent by the six largest), also suggesting a high concentration of knowledge and capacity.

It is important to see the specific role that universities and research institutions have played in fostering co-authorship networks. Just to cite some examples, Swinnen, Mathijs, Dries, and Gow are, or were, based at the University of Leuven, while Gorton and Davidova were based at Wye College, where Latruffe was also a visitor. For those who know the background of many of these researchers, it seems evident that Cluster 1 has very strong connections to Wye College, Cluster 2 is mainly Leuven-oriented, while Cluster 6 has a strong World Bank flavor.

The role of funding institutions like the European Commission or the World Bank has also been essential in creating clusters. For instance, Swinnen, Buckwell, Davidova, Gorton, and Gow cooperated on an EU Fair and many FP projects together; Davidova, Buckwell, Swinnen, Ivanova, and Lingard worked on an EU technical assistance project in Bulgaria; Csaki had a leading role at the World Bank and had strong links with Brooks, Feder, and Lerman. On the whole, many co-authorship patterns are based on common workplaces as well as specific research projects, as is also suggested by Cabanac, Hubert, and Milard (2015).

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TABLE 3
Top Ten Cited Articles in Sample with PageRank Scores

Author	*Title*	*Year*	*Journal*	*Citations received*	*PageRank score*	*Article number in Figure 7*
Gow, H. R.–Swinnen, J. F. M.	Up- and downstream restructuring, foreign direct investment, and hold-up problems in agricultural transition	1998	ERAE	11	1	99
Brümmer, B.	Estimating confidence intervals for technical efficiency: The case of private farms in Slovenia	2001	ERAE	10	7	298
Sarris, A.–Doucha, T.–Mathijs, E.	Agricultural restructuring in Central and Eastern Europe: Implications for competitiveness and rural development	1999	ERAE	9	2	132
Deininger, K.	Collective agricultural production: A solution for transition economies?	1995	WD	8	5	241
Mathijs, E.–Swinnen, J. F. M.	The economics of agricultural decollectivization in East Central Europe and the former Soviet Union	1998	EDCC	8	3	249
Tangermann, S.	Aspects of integration between Western and Eastern Europe: West looks East	1994	ERAE	8	9	274
Munroe, D.	Economic efficiency in Polish peasant farming: An international perspective	2001	RS	8	8	306
Brooks, K.–Guasch, J. L.–Braverman, A.–Csaki, Cs.	Agriculture and the transition to the market	1991	JEP	7	4	169
Brooks, K.–Meurs, M.	Romanian land reform, 1991–1993	1994	CES	6	6	933
Mathijs, E.–Blaas, G.–Doucha, T.	Organizational form and technical efficiency of Czech and Slovak farms	1999	MOCT-MOST	5	10	713

Source: Own composition.
Notes: ERAE (*European Review of Agricultural Economics*), WD (*World Development*), EDCC (*Economic Development and Cultural Change*), RS (*Regional Studies*), JEP (*Journal of Economic Perspectives*), CES (*Comparative Economic Studies*), MOCT-MOST (*Economic Policy in Transitional Economies)*.

CO-CITATION NETWORKS

In addition to the co-authorship networks, co-citation networks are also worth analyzing for a better understanding of relationships. The logic for using co-citation networks is based on the assumption that it is at least as important to have good citations as to publish articles with colleagues.

The reference lists of the sample of 238 articles contain 1,983 citations, indicating an average of eight citations per article. Of the total citations, 509 refer to original articles in the sample, implying that 18 percent of the total citations were "inner" citations (this also means an average of two "inner" citations per article).

Table 3 shows the top ten most cited articles in the sample.

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TABLE 4
Top Ten Cited Authors in Sample, with Citation Rates

Author	*Number of authors cited*	*Number of citations received*	*Average citation per article*	*Average citation per author*
Swinnen, J. F. M.	83	155	1.39	1.87
Mathijs, E.	42	83	1.48	1.98
Davidova, S.	28	38	1.31	1.36
Gow, H. R.	27	49	1.20	1.81
Gorton, M.	27	43	1.47	1.59
Csáki, Cs.	27	34	1.06	1.26
Lerman, Z.	26	33	1.18	1.27
Doucha, T.	20	26	1.17	1.30
Brooks, K.	19	23	1.08	1.21
Brümmer, B.	15	32	1.09	2.13

Source: Own composition.

Each of the three most cited articles was published in the *European Review of Agricultural Economics*, receiving at least nine citations per article. As is evident from the PageRank scores, the number of citations received is not equal to the importance of the citations—what actually matters is who cites an article. When this phenomenon is also taken into account, the list changes significantly. Either way, the most important cited articles are products of the second and fourth clusters identified above. Note the central role Swinnen plays in these articles, even though he did not write any of them alone. It should also be emphasized that the top ten cited articles are all from before 2004, which implies that articles written before EU accession acted as a basis of "common knowledge" in our sample.

The citations can also be analyzed by author (Table 4). The most cited authors and the most published authors are very often the same. Swinnen, Mathijs and Davidova received the highest number of citations, although Swinnen alone got twice as much citations as the second most important author in this regard. However, the average citation per article is the highest for Mathijs, while Brümmer was cited the most by a single author. Note that the top ten cited authors are all members of a scientific cluster.

The co-citation network for authors is observable in Figure 6. As can be clearly seen, Swinnen stands at the core of this network, which implies that he is the most cited author. The strength of the lines in Figure 6 suggests that members of the largest clusters cite Swinnen the most, while the authors in the clusters also cite one another with more than average frequency. Aside from self-promotion, this pattern reflects the fact that authors in a cluster are more familiar with one another's works (i.e., the works of the colleagues with whom they interact). However, it is important to note that those who do not cite the major authors are not members of any cluster.

Analysis of the co-citation networks by article makes further patterns of our social network become apparent (Figure 7). First, it can be clearly seen that those who cite the leading authors have more central positions than those who cite marginal authors. In other

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FIGURE 6 Co-Citations Network in the Sample by Author.
Source: Own composition.

words, leaders cite leaders more, either because they know their works better and/or because of scientific "traditions." Second, according to the results of the PageRank method, it definitely matters who exactly cites a single article—citations received by leading authors seem to be valued more. Third, it is interesting that those articles with the highest number of citations given (indicated by ellipses in Figure 7) are located relatively far from the center, meaning that authors retain their "marginal" positions if not citing their leading colleagues. Fourth, note that all the most cited articles were written by members of scientific clusters, and none of the "marginal" articles was written by members of large clusters. This shows the important role of clusters in citations.

Finally, a regression was fitted on the number of received citations in order to reveal the determining factors. It is obvious from Table 5 that PageRank score and closeness centrality are positively related to the total number of citations received, whereas betweenness centrality is negatively related. In other words, an author's central position in a co-authorship network significantly and positively determines the number of received citations. However, it seems that authors who play an intermediary role among clusters actually receive fewer citations. Results are significant at 5 percent, and our model meets all the important regression assumptions.

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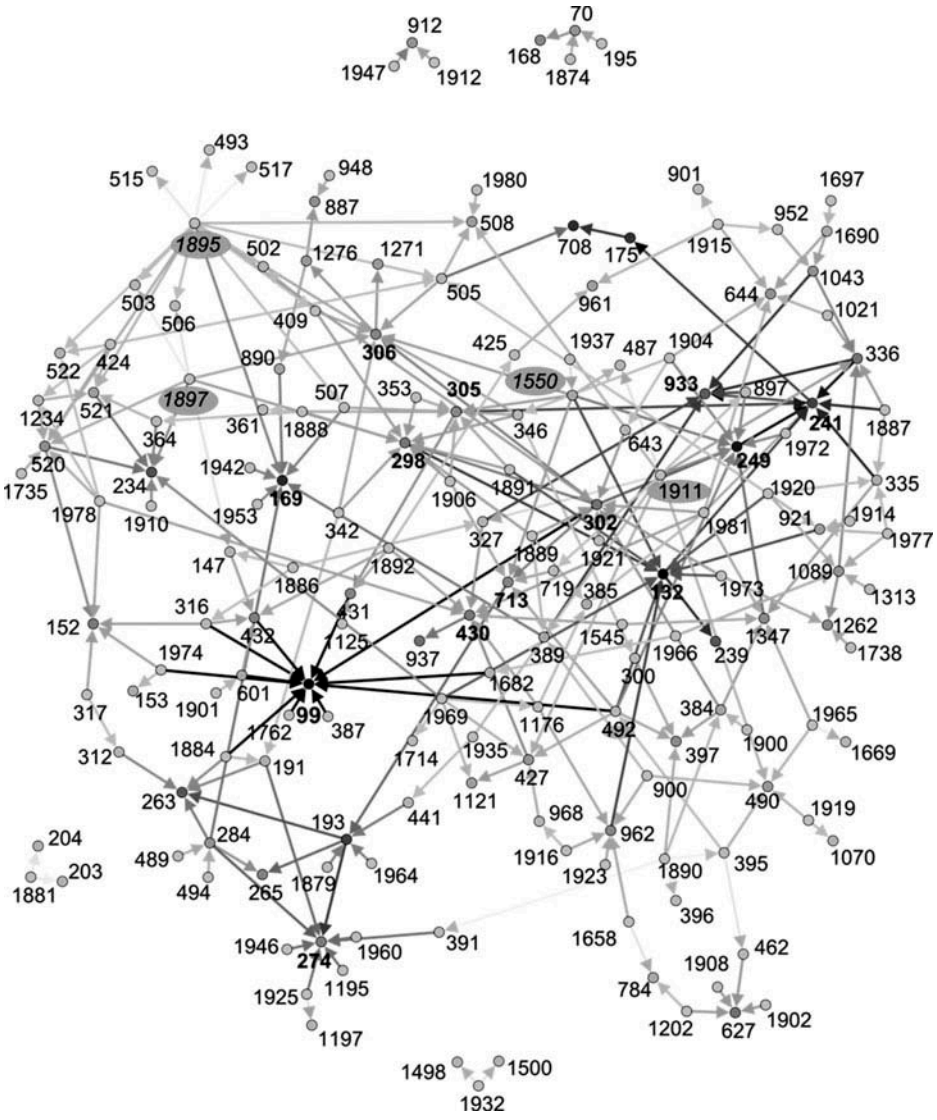

FIGURE 7 Co-Citation Networks in the Sample by Article.
Source: Own composition.
Notes: Importance is denoted by darker arrows according to PageRank score.The number of most cited articles is given in Table 3.

On the whole, our results confirm that most of the articles were written by a small group of authors. This result is mainly in line with the majority of contributions in the literature (Acedo et al. 1995; Cabanac, Hubert, and Milard 2015) show the important role of clusters and central persons in scientific publications. However, our results do not indicate a positive relationship

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TABLE 5
Determinants of Number of Received Citations

	Unstandardized coefficients		*Standardized coefficients*			*Collinearity statistics*	
Variable	*B*	SE	*Beta*	t	*Significance*	*Tolerance*	*VIF*
Constant	−10.588	1.844		−5.741	0.000		
PageRank	1768.713	220.826	0.745	8.010	0.000	0.458	2.183
Betweenness	−0.006	0.003	−0.180	−1.960	0.050	0.460	2.175
Closeness	1.232	0.330	0.245	3.733	0.000	0.919	1.088
R^2	0.637						
Durbin-Watson	1.671						

Source: Own composition.

between the number of articles published and the role played in co-authorship networks. Moreover, authors in clusters definitely cite each other more than average, as also indicated by Katz and Martin (1997) and Persson, Glänzel, and Danell (2004). Finally, our results show a positive correlation between number of citations received and an author's closeness centrality value, while betweenness centrality turned out to be negatively related to received citations. This contradicts the finding in previous literature that all centrality values are positively related to citations (Chen et al. 2015); Fischbach, Putzke, and Schoder 2011).

CONCLUSION

This article analyzes co-authorship and co-citation networks in the CEE agricultural transition literature during the time frame of 1990–2013. Our analysis of the descriptive patterns of the sample led to several conclusions. First, the majority of the articles were written by a small number of researchers, indicating that clusters and central authors play an important role in scientific progress. Second, number of articles written and central role in the network are not related, indicating that quantitative and qualitative indicators cannot be directly compared.

Third, the clusters cite themselves more than average, thereby boosting scientific advance for their members. Authors in close relationships cross-cite their respective works and cite articles by their co-authors more than the average. Fourth, centrality values significantly determine the number of citations received, meaning that central authors are cited more frequently. Paraphrasing Knoke and Yang (2008, p. 1), "everyone is linked to everybody else through a few highly connected intermediaries."

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