

International and domestic co-publishing and their citation impact in different disciplines

Hanna-Mari Puuska · Reetta Muhonen · Yrjö Leino

Received: 28 February 2013 / Published online: 22 November 2013
© Akadémiai Kiadó, Budapest, Hungary 2013

Abstract This paper studies disciplinary differences in citation impacts of different types of co-publishing. The citation impacts of international, domestic inter-organizational and domestic intra-organizational co-publications, and single-authored publications, are compared. In particular, we examine the extent to which the number of authors explains the potential differences in citation impacts when compared to the influence of different types of international and domestic collaborations. The analysis is based on Finland's publications in Thomson Reuters Web of Science database in 1990–2008. Finland is a small country, thus, it has fewer opportunities to find collaborators inside own country when compared to larger countries. Finland's science policy has underlined internationalization and research collaboration as key means to increase the quality and impact of Finnish research. This study indicates that both international and domestic co-publishing have steadily increased during the past two decades in all disciplinary groups. International co-publications gain on average more citations than domestic co-publications. In natural sciences and engineering, co-authorship explains only a small proportion of variability in publications' citation rates. When the effect of the number of authors is taken into account there are no big differences in citation impacts between international and domestic co-publications. However, international co-publications by ten authors or more gather significantly more citations than other publications. In humanities, the difference in citation impacts between co-authored publications in relation to single-authored publications is significant. However, international co-publications are not on average more highly cited in relation to domestic co-publications in humanities.

Keywords Co-publishing · Research collaboration · Research policy · Citation impact

H.-M. Puuska (✉) · R. Muhonen
University of Tampere, Kanslerinrinne 1, 33014 Tampere, Finland
e-mail: hanna-mari.puuska@uta.fi

H.-M. Puuska · Y. Leino
CSC - IT Centre for Science, P.O. Box 405, 02101 Espoo, Finland

Introduction

Several studies have shown that international co-publishing has increased rapidly and that international co-publications are cited more often than publications authored by scientists coming from one country only (Glänzel 2001; Glänzel and Schubert 2001; Katz and Hicks 1997; Muhonen et al. 2012; Narin et al. 1991; NordForsk 2010; van Raan 1998; Schmoch and Schubert 2008; Sooryamoorthy 2009). Furthermore, it has been demonstrated that also domestic inter-organizational collaboration increases citation rates compared to articles published by authors from one organization. Domestic co-publications are, on average, less cited than international co-publications however (Katz and Hicks 1997; Must 2012; Persson et al. 2004; van Raan 1998; Sooryamoorthy 2009).

The number of authors has a positive influence on the number of citations received by a publication (Baldi 1998; Goldfinch et al. 2003; Hsu and Huang 2011). The higher citation rates of international co-publications are in part explained by the fact that on average they have a higher number of authors than publications by authors from one country only. Goldfinch et al. (2003) argued that a co-publication allows access to a larger social network that consequently leads to increased visibility which in turn is reflected in higher citation rates. The causal relationship can also work the other way round: highly cited researchers and research groups are more attractive as collaborative partners (see also Schmoch and Schubert 2008).

The increase in co-publishing varies between scientific fields. Larivière and colleagues (2006) found that natural sciences and social sciences have witnessed a steady growth in the share of co-authored publications, both international and domestic, whereas the share of co-publication has stayed fairly low in the humanities between 1980 and 2002. Previous studies comparing different fields and countries show that co-authorship is not always positively associated with citation impact. Sooryamoorthy (2009) found that while in general co-authored papers receive more citations, in some natural sciences fields (psychiatry, biochemistry, agriculture and material sciences) single-authored papers are on average more highly cited. Goldfinch et al. (2003) found that the citation rates of New Zealander articles in 1998–2005 were negatively associated with the number of domestic institutions involved. Similarly, in forestry research, international collaboration did not lead to higher citation impact (Goldfinch et al. 2003). Leimu and Koricheva (2005) also found that international collaboration did not have a significant effect on the citation rates of papers in ecology. International co-publications of European ecology researchers received fewer citations on average than papers resulting from domestic collaborations.

There is lack of research exploring whether citation rates are influenced in the same way by international versus domestic collaborations across disciplines. Furthermore, there exists little research on whether the higher citation rates of international co-publications can be explained by the higher average numbers of authors in these publications.

This study looks at patterns in how international and domestic collaboration have influenced citation rates in six disciplinary groups (natural sciences, engineering, medicine and health sciences, agriculture and forestry, social sciences and humanities) between 1990 and 2008. The study focuses on Finnish publications in Thomson Reuters Web of Science (WoS) database. Disciplinary differences are examined in terms of the following subquestions:

- (1) How has the international and domestic co-publishing developed in various disciplinary groups during the past two decades?

- (2) Are the citation impacts between different types of collaboration (single-authored publications, domestic intra-organizational and inter-organizational co-publications and international co-publications) similar across various disciplines?
- (3) To what extent can the variation in citation rates be explained by type of collaboration, and to what extent by the number of authors?

Disciplinary cultures and variations in co-publishing

In natural and life sciences, international collaboration has been historically seen as a self-evident part of research. In these fields, research often requires access to expensive equipment or gathering a critical mass of colleagues working around the same problem and line of research. In social sciences and humanities, internationalization has rather been seen as a possibility for cross-cultural dissemination of research ideas (Hakala 1998). Therefore, co-publishing has been much more common in natural and life sciences. In social sciences and humanities, publications are often single-authored (Kyvik 1991; Larivière et al. 2006). As explained by Frame and Carpenter (1979), fields that deal with shared generally agreed-upon research interests and problems are more oriented towards the international scientific community. Researchers in fields working on creating solutions to national and local problems aim their publications to domestic forums and publications are more frequently authored by researchers from one country only.

Kaukonen et al. (2009) found that heads of Finnish university departments in all disciplines agreed that international collaboration is conducted to enhance the competitiveness of the unit in the own research field and to be able to seek for international funding. In the social sciences, however, international collaborative research was more often motivated by the wish to conduct international comparative research. In natural sciences, the international research collaborations were also seen as a means of gaining access to better research equipment and cutting edge technology. In engineering, international collaboration was seen as helpful for establishing contacts with international companies.

The need for research collaboration hence depends on the nature of the research in a field and the way the research work is organized. In certain types of experimental research, data collection requires a lot of human resources and the complexity of research methods or instruments requires several types of expertise (Kyvik 1991). In these areas, research cooperation also involves mutually exploiting well-equipped laboratories or the sharing of research data and materials between research groups. In areas such as high energy physics and astrophysics, dependence on large laboratories and expensive special and rare research equipment creates a prerequisite for international research collaboration (Glänzel 2001; Laudel 2001.)

Whitley (2000) describes such fields in natural and life sciences as fields in which the degree of mutual dependence between researchers is high. The development of science relies heavily on an accumulated knowledge base, and therefore the utilization of earlier and others' research results is mandatory. Collaboration is necessary for making progress and ensuring the novelty of results. Kyvik (1991) argued that in the fields sharing a common paradigm, that is, having a generally accepted theory linked to a common technology and methodology (see Kuhn 1970), researchers share a consensus on how research results must be presented. Collaboration and co-publishing is therefore easier than in the social sciences and humanities, where there are often multiple competing paradigms, where research is not based on shared and mutually agreed-upon theories and

methodologies, and where researchers often do not agree on what constitutes quality or relevance in research (Kyvik 1991).

Variation in international research collaboration between countries

The typicality of international collaboration as well as impact on citation rates varies significantly by country (Glänzel 2001; Gossart and Özman 2009; Larivière et al. 2006; Must 2012). Geographical, linguistic, cultural, political, and geopolitical factors as well as bilateral or multilateral agreements between countries or institutions have an effect on the degree and direction of international research cooperation (Frame and Carpenter 1979; Glänzel 2001; Schubert and Braun 1990). Frame and Carpenter (1979) argued that the scientific size of a nation determines the need for international collaboration. Countries with lower degrees of material and intellectual resources are more likely to look for research partners outside national borders than resource-rich countries (see also Schubert and Braun 1990, Luukkonen et al. 1992). Small countries have fewer opportunities to find collaborators inside their own country when compared to larger countries and they have a greater need for research partners from other countries (Narin et al. 1991). Differences in international collaboration patterns across countries can also be explained by their location either in the scientific centre or the periphery. Goldfinch et al. (2003) found that countries in scientific periphery benefit from international collaboration while domestic collaborations between institutions in these countries have a negative relationship with citation rates (see also Schubert and Sooryamoorthy 2010).

It has been shown that small countries are more active in international collaboration and the share of international co-publications is bigger in their overall scientific production than in big countries (Glänzel 2001; van Raan 1997). Finland is a relatively small country of 5 million inhabitants. The next subsection briefly describes Finland's science policy in relation to internationalization of research and research collaboration in the past decades.

The Finnish science policy and patterns of international research collaboration

The Finnish science policy turned towards favouring and supporting internationalization in the late 1980s. Internationalization was seen as a necessity for developing a competitive “national innovation system” (Hakala 1998). At that time Finland became a member of European cooperation networks, such as Eureka in 1985, CERN (the European Laboratory for Particle Physics; 1991) and ESA (the European Space Agency; associate membership in 1987, full membership in 1995). Finland joined the European Union in 1995. The full participation in EU research programs since the mid-1990s has reinforced European research collaborations. Since the beginning of the 2000s, research policy, for example, the policy statements of the Finnish Ministry of Education (2004) have underlined the support of internationally competitive units of excellence in research. Supporting collaboration networks at all levels (international, national and regional) is seen as an important means to achieve excellence.

Despite its small size, Finland is highly research intensive. It has heavily invested in research and the higher education R&D expenditure has grown remarkably since the mid-1990s (Hakala 1998; Himanen et al. 2009). In 2010, Finland's R&D expenditure measured as percentages of GDP was the second highest of all OECD countries: 3.9 %. The number of researchers per total workforce in Finland is the highest in all OECD countries: 17 researchers per thousand total employments in 2010 (OECD 2012). Moreover, Finland's

per capita ratio of publications in the WoS was higher than in any other OECD country: 1,259 publications (as a fractionalized count) per million inhabitants a year were produced in Finland in 2006–2009. In citation rates, Finland is of average level among OECD countries. Normalized to scientific fields, Finnish publications gained on the average 7 % more citations compared to all WoS publications in 1990–2008 (Finnish Ministry of Education and Culture 2012).

The share of Finland's international co-publications of all the Finnish publications in WoS increased from 25 to 49 % between 1990 and 2009 (Muhonen et al. 2012). Despite the steady growth in international co-publishing, Finland has a lower integration to international collaboration networks compared to other Nordic countries. The share of international co-publications has remained lower than in Sweden, Denmark, Norway, and Iceland each year during 1984–2008 (NordForsk 2010). Based on research collaborations funded by the EU framework programs, European research networks are concentrated within a triangle formed by England, Sweden and Switzerland and including Germany, Denmark and the Netherlands. Finland is located in between the centre and the periphery (European Commission 2008).

The development and citation impact of Finland's international co-publishing has been studied in a few studies (e. g. Muhonen et al. 2012; NordForsk 2010; Persson et al. 2000). These earlier studies show that international collaboration has a positive effect on the citation impact of publications by Finnish scholars. This study extends the understanding of the phenomenon by concentrating on disciplinary differences in co-publishing patterns and the citation impact of not just international but also domestic co-publications. Particularly, it provides new insight on to what extent the number of authors explains the potential differences in citation impacts between international and domestic co-publications.

Data and methods

The study analyses Finland's co-publishing patterns and citation rates between 1990 and 2008 based on publication and citation data provided by the Thomson Reuters WoS database. Finnish publications were identified on the basis of country codes given in connection with addresses. A publication was counted as Finnish when at least one author or research group had recorded a Finnish address for him/herself in the publication. *International co-publications* were defined as publications where, in addition to one or several Finnish organisations, at least one foreign organisation was recorded. In this study, a *domestic inter-organizational co-publication* refers to publications that include authors from several organizations with Finnish addresses. *Domestic intra-organizational co-publications* are authored by several authors from only one Finnish organization. A publication by only one author was counted as a *single-authored publication* even if the author had affiliations to several international or domestic organizations.

Three types of publications in WoS have been taken into account in this study: *Article*, *Letter* and *Review*. In all statistical analyses of this study, whole counting of publications was applied, that is, each publication is counted as a whole independent of its number of Finnish authors or organizations. The alternative calculation counting method, fractionalization, is not used since we are not interested in Finland's publishing performance in relation to other countries but differences in publishing patterns and citation impacts between various types of collaboration within Finland.

The disciplinary group of an individual publication is determined by the journal in which the publication appeared. For the purposes of this study, each of the 260 WoS subject fields was classified into one of six disciplinary groups: natural sciences, engineering, medicine and health sciences, agriculture and forestry, social sciences and humanities. In WoS, each journal is assigned between one to six subject fields. Thus, a publication may belong to several subject fields. In this study, if a publication was categorized into subject fields representing more than one disciplinary group, it was counted into each group. Therefore, a single publication can belong to several disciplinary groups and the sum of publications exceeds the total number of Finnish publications in WoS. Some journals in WoS are classified into the category “Multidisciplinary Sciences.” This category includes journals as “Nature” and “Science” and it formed 0.6 % of all Finnish publications in WoS between 1990 and 2009. In this study, these publications were omitted from the analysis since they could not be unambiguously classified into any of the six disciplinary groups.

The amount of references in reference lists and consequently average citation rates vary significantly by scientific field, publication type and year of publishing (see e.g. Moed et al. 1995; Lancho-Barrantes et al. 2010; Lundberg 2007). In our analysis, we follow the established practice in bibliometrical analyses where the number of citations received by a publication between the year of publication and 2011 is normalised by comparing it to the average citation count from the equal time period of all WoS publications in the world in the particular subject field (out of WoS’s 260 subject fields) which were published in the same year and which represent the same publication type (Article, Review or Letter). To describe the citation impact of Finnish publications in comparison to the average citation rates of all WoS publications, we use the *item-oriented field normalized citation score average* (FNCS) introduced by Lundberg (2007):

$$\text{FNCS} = \frac{1}{P} \sum_{i=1}^P \frac{c_i}{[\mu_f]_i},$$

where c_i is the number of citations to publication i , P is the number of Finnish publications in the unit under scrutiny, $[\mu_f]_i$ is the average number of citations of all publications in the world of the same type, published in the same year and in the same subject area as publication i . If a publication belonged to several subject areas, the average of field normalized citation scores was applied.

FNCS was introduced by Lundberg (2007) as an alternative to the widely used “crown indicator” developed by Moed et al. (1995). While the crown indicator normalizes the average citation count of a group of publications in relation to all publications from the same year, in the same subject area and of the same document type, FNCS is calculated by dividing every single publication’s citation count by all publications in the respective subject field, year and publication type (Lundberg 2007). FNCS is more suitable for the purposes of this study, because it gives an equal weight to each publication, while the crown indicator gives a higher weight to publications with a higher number of citations received.

The distribution of the number of citations received by publications is highly skewed. In theory, the tail of distribution of number of citations can in some subsets be characterized by the power law distribution $p(x) = kx^{-\alpha}$ (e.g. Katz 2012). If such a power law distribution has a scaling exponent α less than 3, it has an infinite variance, the central limit theorem is no longer satisfied and the indicators based on average are not valid. This is especially the case when the group size is small (Katz 2012). In such cases, the possible

outliers, namely publications with an exceptionally high number of citations may have an increasing effect on the world average which consequently decreases the normalized citation scores of other publications. Therefore, the results from the smallest subfields should be interpreted with caution.

We use normal linear regression analysis to examine the effects of type of collaboration and number of authors on the citation impact. The distribution of the normalized citation scores of publications is highly skewed. For that reason, we used logarithmically transformed citation rates as the dependent variable in the regression model which induced to almost symmetric distribution. Lundberg introduced in his paper (2007) a normalized logarithmic-based field citation z-score which also takes into account the standard deviation in citation rates within subject fields. In order to achieve more interpretable statistics in the regression model we instead applied a simple logarithmic transformation of the field normalized citation score which was calculated by adding one to the citation score normalized to all publications of the same type, same year of publishing and same subject area:

$$\text{FNCS}_{[ln]i} = \ln\left(\frac{c_i}{[\mu_f]_i} + 1\right)$$

Through using $\text{FNCS}_{[ln]i}$ as the dependent variable in the regression model, the antilog transformation of regression coefficients, $\exp(B)$, gives the geometric mean ratio. In the regression model, the effects of (1) number of authors and (2) type of co-authorship were investigated both through a single-variable and a multiple regression model. For number of authors, the geometric mean ratio $\exp(B)$ describes the relative difference in the citation score in relation to addition of one author. As regards type of co-authorship, $\exp(B)$ gives the average citation score of the co-authorship type (international, domestic inter-organizational or domestic intra-organizational) in relation to single-authored publications.

The number of authors is also a highly skewed variable. Publications by 10 authors or more account for 5.4 % of the total publication count and only 1.6 % of publications have 20 authors or more. Some publications are co-authored by even thousands of scholars and these exceptions would have a remarkable effect on the results. If the number of authors exceeded 20 it was therefore recorded as 20 in our analyses.

The open citation window was applied; hence the accumulation period of the citations is not limited and all citations between the year of publication and 2011 from all WoS publications are included. This procedure gives a better coverage of citations cumulated by publications than the fixed citation window which takes into account citations only from a fixed period, for example, three or 6 years after publication year. The advantage of fixed citation window is that it is lesser subject to distributional effects. Nederhof and Visser (2004) found that, for example, a relatively large percentage of papers published in the later year of publication period leads to the field normalized citation scores below average because articles published in the early part of the period under scrutiny thus have had more time to gain citations. Nederhof and Visser (2004) argue, however, that the normalized indicators are free from such effects. In order to make citation scores of publications from different years more comparable, we applied normalization as regards publication year. That is, the citations received between the year of publication and 2011 by a Finnish publication are always compared to the citation count from the same period received by all WoS publications in the world published in the same year.

The development of publishing patterns is explored in four-year time blocks: 1990–1993, 1994–1997, 1998–2001, 2002–2005 and 2006–2008. Since publications that

came out from 2009 afterwards have had less than 3 years time to gain citations, all indicators were calculated only for publications published in or before 2008 and the last block is limited to the 3 years between 2006 and 2008.

To some extent, the higher citation rates of co-publications can be explained by the higher number of authors who potentially cite themselves (Herbertz 1995; Leimu and Koricheva 2005; van Raan 1998). As self-citations do not reflect the true impact of a publication, the citations from publications whose authors included at least one of the same names as the cited publication were discarded from our analysis.

The coverage of WoS varies greatly by discipline. The data cover publications in natural and life sciences most comprehensively. As for social sciences and humanities, only a small fraction of publications are represented in WoS, because the research results of these disciplines are frequently published in books and national forums. In engineering, where articles in conference proceedings are a typical form of publishing, the coverage of WoS is moderate (see e.g. Moed 2005). The majority of the 143,221 Finnish publications between 1990 and 2008 were published in journals belonging either to natural sciences (47.4 %) or medical and health sciences (42.1 %). Engineering accounts for 14.1 %, social sciences for 6.4 %, agriculture and forestry for 5.2 % and humanities 1.2 % of the publications (Table 1). The sum of these percentages exceeds 100 % since a single publication can belong to several groups.

Finland's publishing output has increased steadily in all disciplinary groups (Table 1). The publication counts in engineering and social sciences have, however, grown faster than the output for other disciplinary groups in Finland: the number of publications per year has increased by more than three times between the years 1990–1993 and 2006–2008. This is due to the overall improved coverage of engineering and social sciences journals indexed by WoS.

Results

Trends in international and domestic co-publishing

International co-authorship had become more common in all disciplinary groups during the past two decades (Fig. 1). The relative increase in international co-publishing between 1990 and 2008 was highest in agriculture and forestry (from 10 to 40 %). The degree of international co-publications was lowest in the humanities. There was a strong growth of international publishing also in the humanities, however, where the share went from 4 % up to 11. Yet in the latest period 2006–2008, publications involving authors affiliated only with Finnish organisations formed the majority of the publications in all disciplinary groups except natural sciences.

Along with the growth of international co-publishing, there has been an increase in the relative share of domestic inter-organizational co-publications in all disciplinary groups but especially in medical and health sciences and agriculture and forestry (Fig. 1). Consequently, the share of publications produced in domestic intra-organisational cooperation as well as the share of single-authored publications have decreased in all disciplinary groups. The share of domestic inter-organisational publications is highest in medical and health sciences where universities often collaborate with university hospitals. As an exception to other disciplinary groups, the share of intra-organisational co-publishing

Table 1 Number of Finnish publications in WoS in 1990–2008 by disciplinary group

	1990–1993	1994–1997	1998–2001	2002–2005	2006–2008	Total 1990–2008
Natural sciences	7,355 41.9 %	10,722 44.7 %	14,319 47.3 %	16,535 50.1 %	14,015 50.1 %	62,946 47.4 %
Engineering	1,909 10.9 %	2,970 12.4 %	4,176 13.8 %	5,080 15.4 %	4,523 16.2 %	18,658 14.1 %
Medical and health sciences	8,562 48.8 %	11,059 46.1 %	12,988 42.9 %	12,811 38.9 %	10,399 37.2 %	55,819 42.1 %
Agriculture and forestry	865 4.9 %	1,082 4.5 %	1,604 5.3 %	1,788 5.4 %	1,534 5.5 %	6,873 5.2 %
Social sciences	823 4.7 %	1,335 5.6 %	1,881 6.2 %	2,235 6.8 %	2,273 8.1 %	8,547 6.4 %
Humanities	223 1.3 %	205 0.9 %	351 1.2 %	374 1.1 %	423 1.5 %	1,576 1.2 %
Total	17,533 100.0 %	23,964 100.0 %	30,244 100.0 %	32,973 100.0 %	27,975 100.0 %	13,2689 100.0 %

The sum of percentages of all disciplinary groups exceeds 100 % since a single publication can belong to several groups

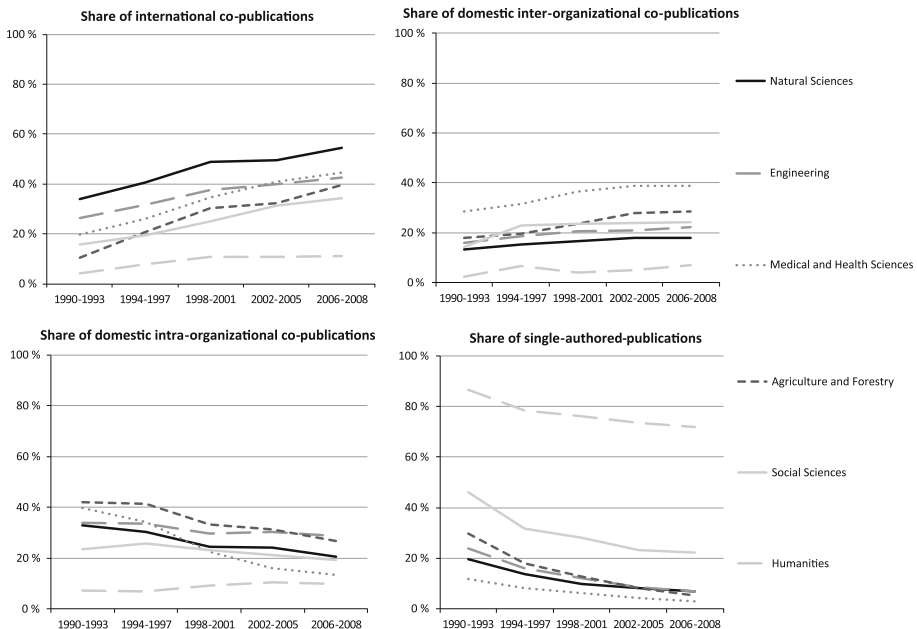


Fig. 1 Shares of different types of co-publishing of Finland's WoS publications in 1990–2008 by disciplinary groups

increased slightly in the humanities. Even though single-authorship has become less typical also in the humanities, it still clearly remained the most typical form of publishing. In 2006–2008, 72 % of Finnish humanities publications were single-authored.

The average number of authors in Finnish WoS publications has increased steadily in all disciplinary groups since the beginning of 1990s (Fig. 2). The increase in the number of authors concerns both international and domestic co-publications. There are no big differences in the growth rate of author numbers for the three types of co-publications with the exception of the humanities where the number of authors in international co-publications increased from 2.6 to 4.0 between early 1990s and late 2000s. At the same time, the average number of authors in humanities domestic co-publications did not increase significantly.

Co-authorship and citation impact

A positive relationship between international cooperation and citation scores can be found in all disciplinary groups (Table 2). The citations received by Finnish international co-publications exceeded the average level of all WoS publications throughout the studied period 1990–2008. However, Finnish single-authored publications were cited less often compared to the world average in all disciplinary groups. There was no systematic pattern in terms of growth or decrease of citation impact of Finnish publications during the studied period 1990–2008 in either international or domestic co-publications or single-authored publications (See also Muhonen et al. 2012).

Domestic inter-organizational collaboration has not led to a significantly higher citation impact compared to intra-organizational publishing collaboration (Tables 2, 3). Humanities make an exception since there are no remarkable differences between international and domestic inter-organizational co-publications in the average citation impact but publications with authors coming from several organizations gathered significantly more citations than publications authored by scholars from one organization.

Compared with single-authored publications both domestic inter- and intra-organizational cooperation is associated with higher citation impact in all disciplinary groups. The difference is biggest in the humanities where publications with authors from several organizations get as much as 73 % and intra-organizational co-publications 37 % more citations than single-authored publications. As stated earlier, single-authored publications are far more typical ($n = 1,200$) in the humanities than domestic ($n = 226$) or international co-publications ($n = 150$).

The number of authors has a positive effect on the citation impact of a publication in all disciplinary groups. Medical and health sciences and humanities express the most linear association between number of authors and citation scores in logarithmic scale (Fig. 3). The influence is strongest in the humanities where the augmentation of one author increases the publication's normalized citation score by 18 % on the average (Table 3). In other disciplinary groups, one additional author raises the citation score by only 3–6 % on the average. In the humanities, the number of authors explains almost 10 % of the variance in citation scores. In natural sciences and engineering, only a small portion (2.1 and 1.3 %) of the variation in citation scores is explained by the type of co-authorship.

When the effect of the number of authors is taken into account there are no longer big differences between international and domestic co-publications in other disciplinary groups except social sciences and humanities (see multivariate model in Table 3). Figure 4 shows that the number of authors is positively related to citation impact of both international and domestic co-publications. When comparing publications with the same number of authors in natural sciences, engineering, and agricultural sciences, the citation scores are almost equal regardless of whether all authors are from Finland or whether there are international co-authors. However, international co-publications with more than ten authors get far more citations than other types of publications in all disciplinary groups.

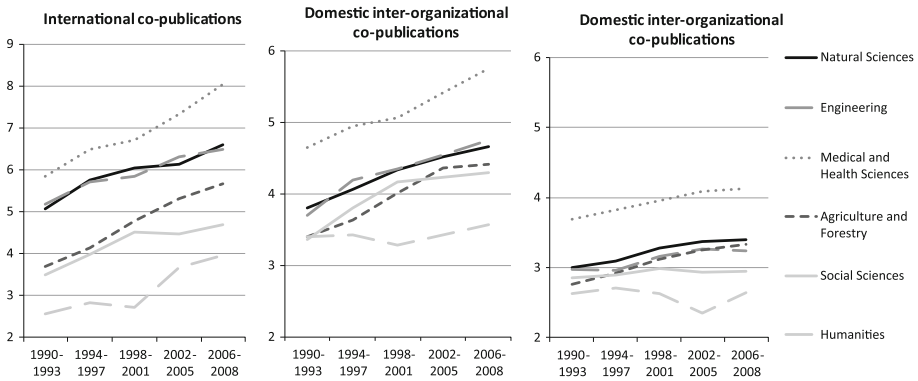


Fig. 2 Patterns in the number of authors in international and domestic co-publications of Finland’s WoS publications in 1990–2008 by disciplinary group

Table 2 Field normalized citation score (FNCS) of Finland’s WoS publications in 1990–2008 by type of co-authorship and disciplinary group

	Type of co-authorship			
	International	Domestic inter-organizational	Domestic intra-organizational	Single-authored
Natural sciences	1.19	0.98	0.98	0.83
Engineering	1.35	1.03	1.07	0.94
Medicine and health sciences	1.64	1.09	0.96	0.73
Agriculture and forestry	1.74	1.34	1.15	0.89
Social sciences	1.33	0.98	0.91	0.66
Humanities	2.26	2.28	1.73	0.74

The potential interaction effect between the number of authors and type of co-authorship was analyzed, but there were no significant effects. That is, the effect of the number of authors is by and large the same within both internationally and domestically co-authored publications.

Conclusions

This study supports results from earlier research indicating that both international and domestic co-publishing has increased in the studied period 1990–2008 in all disciplinary groups. The amount of Finnish scientific publications conducted in international or domestic inter-organisational collaboration has increased more than the intra-organisational publications. The average number of authors involved in a publication has similarly increased in all disciplinary groups. Similar to earlier results on the positive effect of international co-authors on publication’s citation impact (e. g. Glänzel 2001; Katz and Hicks 1997; Muhonen et al. 2012; Narin et al. 1991; NordForsk 2010; Schmoch and

Table 3 Normal linear regression analysis on the effects of type of co-authorship and number of authors on logarithmically transformed field normalized citation score of a publication (FNCS_{[m]*i*})

	Simple model ^a				Multivariate model ^a				
	B	exp(B)	(95 % CI) ^a	R ² ^b	B	exp(B)	(95 % CI) ^a	R ² ^c	
Natural Sciences									
Number of authors	0.028	1.028	(1.027–1.029)	3.2 %	0.022	1.022	(1.021–1.023)		3.7 %
Type of co-authorship				2.1 %					
International	0.242	1.274	(1.263–1.285)		0.126	1.134	(1.123–1.145)		
Domestic inter-org.	0.166	1.181	(1.170–1.192)		0.083	1.087	(1.076–1.097)		
Domestic intra-org.	0.120	1.128	(1.117–1.138)		0.067	1.069	(1.059–1.080)		
Single-authored ^d	0	1			0	1			
Engineering									
Number of authors	0.029	1.029	(1.027–1.031)	2.8 %	0.026	1.026	(1.023–1.029)		3.0 %
Type of co-authorship				1.3 %					
International	0.196	1.216	(1.184–1.249)		0.065	1.068	(1.036–1.100)		
Domestic inter-org.	0.104	1.110	(1.078–1.143)		0.016	1.016	(0.986–1.048)		
Domestic intra-org.	0.094	1.098	(1.069–1.129)		0.039	1.040	(1.011–1.069)		
Single-authored ^d	0	1			0	1			
Medical and health sciences									
Number of authors	0.039	1.040	(1.038–1.041)	6.1 %	0.032	1.033	(1.031–1.034)		6.7 %
Type of co-authorship				3.6 %					
International	0.327	1.387	(1.362–1.412)		0.130	1.139	(1.116–1.162)		
Domestic inter-org.	0.181	1.198	(1.177–1.220)		0.044	1.045	(1.026–1.065)		
Domestic intra-org.	0.121	1.129	(1.108–1.150)		0.027	1.028	(1.009–1.047)		
Single-authored ^d	0	1			0	1			
Agriculture and forestry									
Number of authors	0.058	1.060	(1.055–1.066)	6.5 %	0.054	1.055	(1.049–1.062)		6.7 %
Type of co-authorship				2.9 %					
International	0.278	1.320	(1.265–1.377)		0.059	1.060	(1.010–1.113)		
Domestic inter-org.	0.174	1.190	(1.139–1.243)		0.007	1.007	(0.961–1.055)		
Domestic intra-org.	0.102	1.108	(1.063–1.155)		-0.010	0.990	(0.949–1.033)		
Single-authored ^d	0	1			0	1			

Table 3 continued

	Simple model*				Multivariate model*			
	B	exp(B)	(95 % CI) ^a	R ² ^b	B	exp(B)	(95 % CI) ^a	R ² ^c
Social sciences								6.5 %
Number of authors	0.045	1.046	(1.042–1.050)	5.0 %	0.030	1.030	(1.025–1.036)	
Type of co-authorship				4.8 %				
International	0.303	1.354	(1.317–1.393)		0.201	1.223	(1.183–1.264)	
Domestic inter-org.	0.178	1.194	(1.160–1.230)		0.085	1.089	(1.053–1.126)	
Domestic intra-org.	0.141	1.151	(1.118–1.186)		0.083	1.087	(1.054–1.121)	
Single-authored ^d	0	1			0	1		
Humanities								11.0 %
Number of authors	0.168	1.182	(1.153–1.212)	9.8 %	0.101	1.106	(1.065–1.149)	
Type of co-authorship				9.5 %				
International	0.519	1.680	(1.514–1.864)		0.281	1.324	(1.155–1.518)	
Domestic inter-org.	0.551	1.734	(1.512–1.989)		0.304	1.355	(1.149–1.598)	
Domestic intra-org.	0.318	1.375	(1.237–1.528)		0.161	1.175	(1.041–1.325)	
Single-authored ^d	0	1			0	1		

* In the simple model, only one variable, either type of co-authorship or number of authors is included as independent variable whereas in multivariate model both effects are included

^a Exp(B) gives the geometric mean ratio. For number of authors, exp(B) describes the relative growth in the citation score in relation to addition of one author. In case of type of co-authorship, exp(B) describes the average citation score of the co-authorship type under scrutiny in relation to the reference group, namely single-authored publications. 95 % CI is the 95 % confidence interval for exp(B)

^b R² of the simple model describes the proportion of the variation in FNCS explained by a single predicting variable (either number of authors or type of co-authorship)

^c R² of the multivariate model describes the proportion of the variation in FNCS explained by both predicting variables simultaneously (number of authors and type of co-authorship)

^d Reference group

Schubert 2008; Sooryamoorthy 2009) we found that in almost all disciplinary groups international co-publications are on average more highly cited than publications by only Finnish authors. Especially in medical and health sciences as well as humanities the straightforward positive association between number of authors and average citation score supports the view presented by, for example, Goldfinch et al. (2003) that co-publishing enables access to larger scholarly networks and consequently leads to higher impact of co-publications.

Despite the fact that citation impact varies between types of collaboration, in natural sciences and engineering only a small portion of the variation in citation rates is explained solely by international or domestic collaboration. The higher average number of authors in international co-publications when compared to domestic co-publications explains most of the differences in citation rates between these two types of collaboration. In the social sciences, however, international co-authorship has a strong positive impact on citations

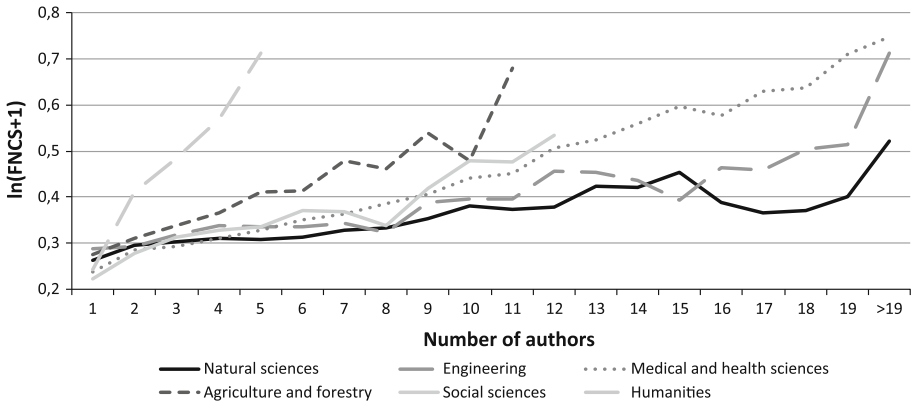


Fig. 3 Logarithmically transformed field normalized citation score, $\ln(\text{FNCS} + 1)$, of Finland's WoS publications in 1990–2008 by number of authors and disciplinary group. *Note* Citation score is not displayed when publication count is less than 25

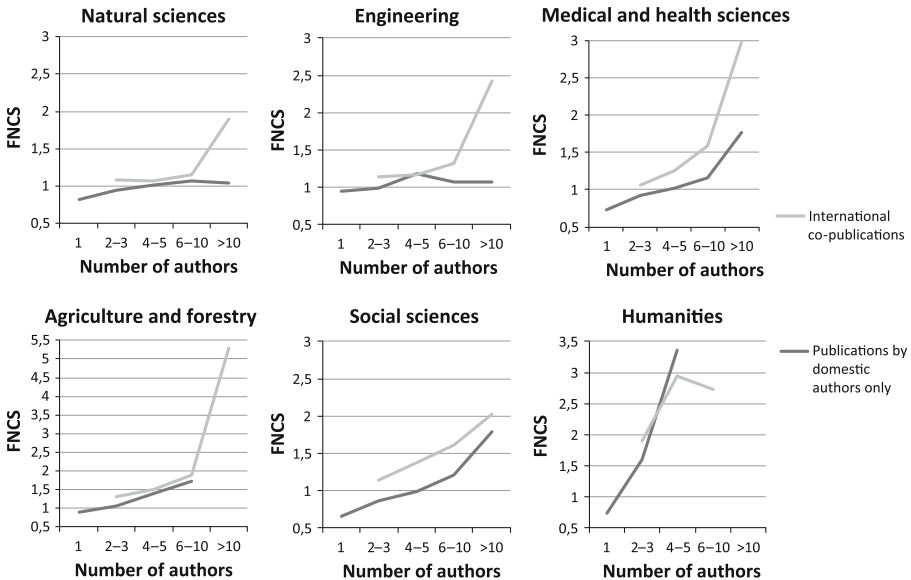


Fig. 4 Field normalized citation score (FNCS) of Finland's WoS publications in 1990–2008 by number of authors and by disciplinary group. *Note* Citation score is not displayed when publication count is less than 25

even when the higher average number of authors is taken into account. This is possibly due to the nature of research in social sciences where research topics are often nationally or locally oriented. Publications which have a national aspect receive fewer citations than publications in WoS on average. International co-publications are likely to deal with more universal topics or contain international comparisons and are thus of interest to a wider international audience. In natural sciences, research topics are universal by nature also in domestic co-publications. International co-publications by more than 10 authors, however, gather significantly more citations than similar publications by Finnish authors only in

almost all disciplinary groups. The higher impact of these publications can result from the fact that scholars and research groups participating in large international research projects already have an established and recognized status in their scientific community.

The number of authors has the strongest effect on citation scores in the humanities. The humanities differ from other disciplinary groups in that there is no difference between the average citation scores between domestic inter-organizational publications and international co-publications. There is a big difference between single-authored and multi-authored publications in the amounts of citations received. As most humanities publications are single-authored, co-authorship thus has an important role in increasing the visibility and citation impact of humanities research. Since humanities and social sciences fields are often multi-paradigmatic and produce arguments and interpretations, it may be that a publication's perceived credibility increases when there are several authors. It must be noted that the number of publications in social sciences and humanities is low and the possible outliers may affect the results. A more in-depth analysis considering the citation distribution of publications would be needed in order to validate the results.

The increase of international collaboration is a global trend in science. It is also a result of strong promotion of collaboration networks and internationalization of research within the EU and in national science policies. Finnish science policy has emphasized international research collaboration as the key means to increase the quality and impact of Finnish research. The results reached in this study show, however, that international collaboration is not the only factor that would in itself necessarily produce more impactful research. Hakala (1998) argues that from researchers' point of view, externally imposed internationalization directs towards particular types of research and particular geographic directions in collaboration and contacts. Without a basis on existing genuine international collaboration networks imposed collaborations may have unwanted implications, for example, increased homogenization of science. There are also contradictions in the aims of science policy which underlines internationalization, and national innovation policy emphasizing societal impact. Research conducted in international context may not always meet the national needs and interests.

The findings of this study indicate that citation impact of a publication may be related to other influencing factors not scrutinized in this article. These include the interdisciplinarity, universality or locality of the research topic, the scholarly positions of co-publishing authors, and the level of application. Further studies should take into consideration the influence of also these factors on the impact of international and domestic co-publications.

References

- Baldi, S. (1998). Normative versus social constructivist processes in the allocation of citations: a network-analytic model. *American Sociological Review*, 63(6), 829–846.
- European Commission. (2008). *A more research-intensive and integrated European Research Area. Science, Technology and Competitiveness*. Luxembourg: European Commission.
- Finnish Ministry of Education. (2004). *Management and Steering of Higher Education in Finland*. Publications from the Finnish Ministry of Education 2004:20.
- Finnish Ministry of Education and Culture. (2012). *Report from the Finnish Citation Index Working Group II. Finnish research organizations' publications and citations in the Web of Science, 1990–2009*. Publications from the Finnish Ministry of Education and Culture 2012:18.
- Frame, J., & Carpenter, M. P. (1979). International Research Collaboration. *Social Studies of Science*, 9(4), 481–497.
- Glänzel, W. (2001). National characteristics in international scientific co-authorship relations. *Scientometrics*, 51(1), 69–115.

- Glänzel, W., & Schubert, A. (2001). Double effort = Double impact? A critical view at international co-authorship in chemistry. *Scientometrics*, 50(2), 199–214.
- Goldfinch, S., Dale, T., & DeRouen, K. (2003). Science from the periphery: Collaboration, networks and 'Periphery Effects' in the citation of New Zealand Crown Research Institutes articles, 1995–2000. *Scientometrics*, 57(3), 321–337.
- Gossart, C., & Özman, M. (2009). Co-authorship networks in social sciences: The case of Turkey. *Scientometrics*, 78(2), 323–345.
- Hakala, J. (1998). Internationalisation of Science: Views of the Scientific Elite in Finland. *Science Studies*, 11(1), 52–74.
- Herbertz, H. (1995). Does it pay to Cooperate? A bibliometric case-study in molecular-biology. *Scientometrics*, 33(1), 117–122.
- Himanen, L., Auranen, O., Puuska, H.-M., & Nieminen, M. (2009). Influence of research funding and science policy on university research performance: a comparison of five countries. *Science and Public Policy*, 36(6), 419–430.
- Hsu, J., & Huang, D. (2011). Correlation between impact and collaboration. *Scientometrics*, 86(2), 317–324.
- Katz, J. S. (2012). Scale-Independent Measures: Theory and Practice. Paper presented at the 17th International Conference on Science and Technology Indicators, September 5–8, Montreal, Canada.
- Katz, J., & Hicks, D. (1997). How much is a collaboration worth? A calibrated bibliometric model. *Scientometrics*, 40(3), 541–554.
- Kaukonen, E., Miettinen, M., Piirainen, T., Puuska, H.-M., & Vuolanto, P. (2009). Internationalisation of university research: Practices and problems, in: Ahonen, P.-P., Hjelt, M., Kaukonen, E., & Vuolanto, P. (Eds), *Internationalisation of Finnish scientific research*. Publications of the Academy of Finland 7/09, pp. 91–122.
- Kuhn, T. S. (1970). *The Structure of Scientific Revolutions*. Chicago: The University of Chicago Press.
- Kyvik, S. (1991). *Productivity in academia: Scientific publishing at Norwegian universities*. Rådet for samfunnsvitenskapelig forskning, NAVF.
- Lancho-Barrantes, B. S., Guerrero-Bote, V. P., & Moya-Anegón, F. (2010). What lies behind the averages and significance of citation indicators in different disciplines? *Journal of Information Science*, 36(3), 371–382.
- Larivière, V., Gingras, Y., & Archambault, E. (2006). Canadian collaboration networks: A comparative analysis of the natural sciences, social sciences and the humanities. *Scientometrics*, 68(3), 519–533.
- Laudel, G. (2001). Collaboration, creativity and rewards: why and how scientists collaborate. *International Journal of Technology Management*, 22(7–8), 762–781.
- Leimu, R., & Koricheva, J. (2005). Does scientific collaboration increase the impact of ecological articles? *BioScience*, 55(5), 438–443.
- Lundberg, J. (2007). Lifting the crown: Citation z-score. *Journal of Informetrics*, 1(2), 145–154.
- Luukkonen, T., Persson, O., & Sivertsen, G. (1992). Understanding patterns of international scientific collaboration. *Science, Technology and Human Values*, 17(1), 101–126.
- Moed, H. (2005). *Citation analysis in research evaluation*. Dordrecht: Springer.
- Moed, H., de Bruin, R., & van Leeuwen, T. (1995). New bibliometric tools for the assessment of national research performance: Database description, overview of indicators and first applications. *Scientometrics*, 33(3), 381–422.
- Muhonen, R., Puuska, H.-M., & Leino, Y. (2012). International co-publishing in Finland. Reports of the Ministry of Education and Culture, Finland 2012:19.
- Must, U. (2012). Alone or together: Examples from history research. *Scientometrics*, 91(2), 527–537.
- Narin, F., Stevens, K., & Whitlow, E. (1991). Scientific cooperation in Europe and the citation of multi-nationally authored papers. *Scientometrics*, 21(3), 313–323.
- Nederhof, A. J., & Visser, M. S. (2004). Qualitative deconstructions of citation impact indicators. Waxing field impact but waning journal impact. *Journal of Documentation*, 60(6), 668–672.
- NordForsk. (2010). *International Research Cooperation in the Nordic countries. A Publication from the NORIA-net "The Use of bibliometrics in research policy and evaluation activities"*.
- OECD. (2012). *Main Science and Technology Indicators. Key Figures*. Volume 2012/1. OECD.
- Persson, O., Glänzel, W., & Danell, R. (2004). Inflationary bibliometric values: The role of scientific collaboration and the need for relative indicators in evaluative studies. *Scientometrics*, 60(3), 421–423.
- Persson, O., Luukkonen, T., & Hälikkää, S. (2000). *A bibliometric study of Finnish science*. VTT, Group for Technology Studies Working Papers No. 48/00.
- Schmoch, U., & Schubert, T. (2008). Are international co-publications an indicator for quality of scientific research? *Scientometrics*, 74(3), 361–377.
- Schubert, A., & Braun, T. (1990). International collaboration in the sciences, 1981–1985. *Scientometrics*, 19(1–2), 3–10.

- Schubert, T., & Sooryamoorthy, R. (2010). Can the centre-periphery model explain patterns of international scientific collaboration among threshold and industrialised countries? The case of South Africa and Germany. *Scientometrics*, 83(1), 181–203.
- Sooryamoorthy, R. (2009). Do types of collaboration change citation? Collaboration and citation patterns of South African science publications. *Scientometrics*, 81(1), 177–193.
- van Raan, A. (1997). Science as an international enterprise. *Science and Public Policy*, 24(5), 290–300.
- van Raan, A. (1998). The influence of international collaboration on the impact of research results: Some simple mathematical considerations concerning the role of self-citations. *Scientometrics*, 42(3), 423–428.
- Whitley, R. (2000). *The Intellectual and Social Organization of the Sciences* (2nd ed.). New York: Oxford University Press Inc.