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Long time series of highly cited articles: an empirical study

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Long time series of highly cited articles: an empirical study

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ABSTRACT

The study of how citations, received by scientific works, evolve with time is a relevant bibliometric topic. The present work aims at describing the evolution of received citations of highly cited scientific articles over a long time span (30 years or more). It tries to answer to the question on how such citation trends evolve, and on how much it is possible to assimilate them to a single model, by performing an empirical descriptive study. Thirty articles (the five most cited for each of the six Subject categories in two Research domains) are taken into account. Once obtained the citation received by the articles, their trends are traced and analysed. The empirical results show that received citations exhibit significantly different trends. Moreover, many articles are not affected by the phenomenon of aging. Such facts make it more difficult to generalize citation trends.

KEYWORDS

Received citations trends; empirical study; highly cited; long time series.

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INDICE/CONTENTS

1 INTRODUCTION 3
2 LITERATURE OVERVIEW 4
3 METHODOLOGY 5
4 RESULTS 6
5 DISCUSSION AND CONCLUSIONS 6
6 REFERENCES 7

Long time series of highly cited articles: an empirical study

UGO FINARDI

1 INTRODUCTION

One of the most relevant topics of bibliometrics and scientometrics is the study of the evolution of citation trends. Citations are commonly used as a means for the evaluation of scientific literature. In fact, several indicators have been built from citations in order to allow scholars to recognize the main features of scientific production (Waltman, 2016). In fact, studying how often scientific products are cited and how citations evolve over time allows us to better understand the features of the outcome of research activities.

It is in consequence of these facts that citation trends and citation dynamics are among the most relevant bibliometric topics. Two main perspectives have been adopted in the past by authors who did contribute to this debate. The first one, more theoretical, tries to build models describing the evolution of citations with them (see for instance Egghe and Rao, 1992). On the other side, the second one entails a more experimental/empirical point of view. Some papers in fact start from describing the evolution of citations over time in specific cases, in order to speculate on their nature (see for instance Finardi, 2014). Many works also combine the two approaches. For instance, some authors present a theoretical model and then apply it to the analysis of a more or less specific set of scientific products, deepening the nature of their citation trends.

Notwithstanding the above-mentioned facts, the study of long time series of highly cited papers is substantially underexplored. In addition, the following literature overview will show this lack of knowledge. Thus, the aim of the present work is to tackle this specific subject, using a descriptive methodology, in order to fill partly this knowledge gap and to raise the interest on the topic. Despite its simplicity, the obtained results are able to raise some questions on the nature of the evolution of citations for highly cited scientific products. As a consequence of its methodology, the present work should be inserted in the second stream of literature on citation analysis. In fact, it starts from an empirical perspective with the aim of realizing an analysis of the features of highly cited papers. In a sort of "preliminary overview", it tries to shed some light on the evolution of their received citations. It is substantially directed towards answering to the following research question: how do the trends of received citations of highly cited scientific articles evolve in the long term? Is it always possible to assimilate them to a single model, or do different types of trends coexist?

In order to respond to this question the present article selects and studies top five cited articles among those produced in the first half of the 1980s for six different subject categories in "Sciences" and in "Social sciences". After selecting the subject categories and then the articles, citations per year are collected and then plotted and arranged in tables. The results and their discussion show interesting properties that are partly in countertrend with past evidence.

The article is organized as follows: the following section presents a literature overview on the topics of highly cited articles and of long time series study; section three describes the methodology of the empirical activity at the core of this work; the last one is section four which presents and discusses the results of the activity, as well as some concluding remarks.

2 LITERATURE OVERVIEW

Several works have studied highly cited scientific articles in the past. The articles written by de Solla Price (1965; 1976) are among the earliest relevant contributions on this topic. They have soon been followed by other ones, focusing on the analysis of citation patterns, such as those by Oppenheim and Renn (1978), Smith Aversa (1985) and Vlachý (1985).

In their work Oppenheim and Renn (1978) study articles published in 1974-1975 and citing 23 very old (pre-1921) highly cited articles. They find that about 40 % of the citations were made purely for historical purpose, hence “they are relevant and valuable even to this day” (p. 230).

On the contrary, Smith Aversa (1985) analyses a sample of papers published in 1971 and follows their citation patterns until 1980. Two distinct patterns are found, and “a delayed rise in citedness is associated with less rapid aging and a higher number of total citations, and […] an early rise […] is associated with fewer total citations and a very rapid aging rate” (p. 387).

Lastly, the work of Vlachý (1985) offers a review of the literature on the topic of aging, also examining the time distribution models. Several models are reported from different sources and most of them confirm the phenomenon of citation aging, i.e. citations tend to peak and then decrease over time.

As introduced above, a considerable point in addressing the obsolescence of older scientific articles is that of building “obsolescence functions” able to model ageing. Among others, Egghe and Rao (1992) have studied this subject. They work on aggregate data to find that the function drops to a minimum at a certain time after the maximum number of citations is reached. The lognormal distribution best fits sets of citation data.

On their side, Glänzel and Schoepflin (1994) consider a stochastic model for the aging of scientific products, and then apply it to a group of articles to calculate the parameters of the model. They find out that, for instance, physics journals are affected by faster aging than psychology journals.

More recently, Bouabid (2011) and Bouabid and Larivière (2013) have proposed a further model to describe the distribution of citations. The model is then tested on specific sets of publications. In the first one of the two papers, the model is tested on a set of publications from the ‘Biochemistry & Molecular Biology’ ISI category. The articles under investigation show a peak in received citations two years after publication. In the second work, the model is applied to study changes in life expectancy of different groups of articles using a diachronous methodology. The results show that the life expectancy of scientific literature is increasing and that there are divergences among different sets of publications. Moreover, in some cases life expectancy might be infinite, which “assumes that the corpus would continue to attract scientific community’ interest for a very long time” (p. 708).

Lercher and Smolinsky (2016) exploit the model of Bouabid (2011) and Bouabid and Larivière (2013) to fit citation curves of older articles. Results confirm the overall trend of a growing use of older scientific literature in citations and demonstrate that the value of this kind of publications is increasing in libraries.

Another work on the modelling of trends is the one proposed by Onodera (2016), who performs an aggregate analysis based on several subject categories with a view to better defining an “index of citation durability” (yet described by Wang et al., 2015). His results support the use of the index and state “more highly-cited articles tend to concentrate in a region of higher and also narrower citation durability” (p. 1002).

An original perspective is that of Egghe (2000), who performs a study that is in some way accessory to the topic of the present work. In fact, the topic addressed in the article is about the study of first citation distribution, which is modelled in an apt way. The article describes the phenomenon called “aging rate” as “the decline from year to year of the number of citations a paper receives” (p. 345). The pattern created to model the distribution of the first citations combines “an exponentially decreasing aging function […] and a Lotka function”. The model is able to fit several types of distribution.

Another group of scientific articles proposes a more experimental/empirical point of view. For instance, Finardi (2014) studies the citation trends of several specific journals in two ISI categories, “Chemistry, multidisciplinary” and “Management”. He finds that, while most Chemistry journals reach a peak in received citations around two years after publication, Management journals, as well as some other Chemistry journals, do not.

Highly cited articles are instead the instrument used by Bornmann (2016) to evaluate the effects of the support to the German Clusters of Excellence. His findings show the growth with time of network inside the Clusters.

Van Nierop (2009) analyses the time series of received citations for what concerns statistics journals. Then, he analyses the diffusion patterns of articles in the field and finds that they are characterized by a slower citation diffusion than journals in other disciplines. Van Nierop states that, in this field, articles present a peak of citations at a more distant time since the publication than observed in other fields. Data are analysed with a specific model.

On their side Verstak et al. (2014) come forward with data on the citations received by older articles. Their major conclusion is that the impact of older articles has grown with time (at a faster pace in recent years) and that the growth of the impact is also true for older (more than 20 years) works, given that their fraction of citations has been growing since the 1990s.

Furthermore, Egghe and Rousseau (2000) provide definitions and describe properties for several terms used in the study of citations. Among such terms, there are “Aging” and “Obsolescence”. Then, they introduce a theoretical discussion on citation distribution and aging, showing their peculiarities. Ultimately, they present some examples of the application of the models.

This brief overview of the past literature does not claim to be exhaustive; however, it helps focusing on the topics of this work. Moreover, and most importantly, it shows that the topic of long time series of citation of highly cited scientific articles is substantially underexplored. As a result, even a simple empirical work like the present one – which explores the citation trends of a small group of highly cited, aged scientific publications in different research areas – is meaningful as to offer preliminary results on the subject.

3 METHODOLOGY

The present study performs a diachronous analysis of received citations. The methodology exploited to answer the research questions is the following. The first step of the procedure is the selection of six ISI Subject categories from the ISI-Web of Science. Three out of the six categories are from the “Science & Technology” database, while the other three are from the “Social Sciences” database. In order to select the three plus three subject categories, a main determinant has been taken in account. This is the heterogeneity of Subject categories, which means that a certain degree of heterogeneity among categories has been looked for. This has been done with the aim of ensuring representativeness of the sample at large. Thus, the three “Science & Technology” chosen categories are “Chemistry”, “Physics”, and “Agriculture”. On the contrary, the three subject categories chosen in “Social Sciences” are “Operations Research & Management Science”, “International Relations”, and “Business Economics”.

The data extraction was performed in May 2014 at the University of Toronto on the ISI-Web of Knowledge version resident at that institution. In order to choose the highly cited scientific articles object of the present work, the chosen time period was 1980-1985 (included) for all the six subject categories.

The extraction entailed retrieving data on citations received by highly cited scientific articles. To this end, from each of the six subject categories the list of scientific articles published in the chosen years was retrieved. Once the list of scientific articles published in each Subject category was compiled, the five most cited articles were identified for each one of the six. Eventually, a list of thirty articles was considered in the analysis. Relevant data on each of the thirty articles are presented in table 1: Database (Science & Technology vs. Social Sciences), Subject Category, Publication Year, Journal, Total Received citations.

For each one of the thirty articles, the complete list of citing articles was retrieved, again from the ISI-WoS.

The list covers the entire period from publication to 2014. At last, the number of citing articles per year was calculated and plotted against the year of publication.

The values of received citations per year are presented in tables 2 to 7, which report the number of citations received per year by each paper of the six groups. Figures 1 to 6 show instead the citations trends in graphic mode. Each figure consists of two graphs showing the data for each specific Subject category. The first one of the two graphs refers to citation trends per year, while the second one illustrates cumulative citations. Each graph contains five different trends (Citations 1, Citations 2, etc.), each referring to the received citation trends of one of the five papers in the subject categories (first, second etc. highly cited). It is further submitted that, the years 2013 and 2014 are included purely for the sake of completeness and the numbers of citations referring to these years are either unavoidably incomplete (2014) or possibly incomplete (2013).

4 RESULTS

This paper starts from an empirical point of view, as it aims at highlighting and discussing the trends of citations received by a set of highly cited articles over a long time series (30 years or more). To the best of my knowledge, a similar study has never or seldom been performed to date. The trends, presented in Figures 1-6, clearly show that the citation aging profiles of highly cited scientific articles of older age can have very different shape. In some cases, very different trends are present within the same Subject category. Some trends display a peak, growing after publication (in a more or less pronounced and sudden way) and then decreasing more or less steadily. Other trends grow rather steadily since the publication year onwards, and do not show any peak. Some others, lastly, grow but change slope more or less pronouncedly and at a more or less distant time since their publication. What is even more relevant is the fact that, within both Research domains and within each Subject category, the various trends are difficult to identify under a common model.

In this regard, Chemistry and Physics are the most interesting Subject categories. In fact, the aging trends of the articles in such Subject categories display either a peak at n years after publication, or a continuous growth, or a sort of “quasi-bimodal” distribution, with a period of growth, a sudden stop, and then another period of growth. Conversely, all five “Agriculture” articles are characterized by a steady increase in received citations from publication onwards. No article in this category presents a peak of citations. The same is true for all “Management” and “Business Economics” articles, although their trends are very dissimilar. In fact, in some cases paper start receiving an overwhelming number of citations only many years (around 20) after their publication. “International Relations” articles, instead, either grow steadily or exhibit a peak in citations. As also cited literature reports, most past works (with some relevant exception) report the phenomenon of “ageing” for scientific literature, which refers to the usual growth of the received citations of articles (or set of articles) over the first period after the publication and their subsequent, steady decrease.

5 DISCUSSION AND CONCLUSIONS

The aim of this article is to perform an empirical analysis of the trends of received citations and of aging of Highly Cited Papers. The description of the trends tries to shed light on their nature. In particular, by analysing a specific sample, it tries to explore whether it is possible or not to detect a generalized behaviour for the citation trends of the analysed sample.

To this end, a specific sub-group of articles is considered, i.e. articles that are highly cited and aging. This makes it possible to extend the analysis to longer time series (30 years or more) including a relevant number of received citations.

The analysis of the empirical results shows some aspects that are in countertrend with some “stylized facts” of bibliometric analysis. First of all, the data show that many of the papers analysed here are not affected by the phenomenon commonly described as “obsolescence” or “aging”, as they keep being cited despite the passing of time. Such articles, in fact, suggest a steady growth in the number of received citations per year and do not present any “peak of citation” at some years after their publication. Thus, in many cases, citations tend to grow over time. This fact is mirrored in some way in the results of Finardi (2014) who shows that the average citation trends of some specific journals do not peak.

Another relevant fact is to be found in the strong heterogeneity of citation trends, both between and inside scientific fields and subject category. In fact, only some of the studied subject categories present a common behaviour. It is the case, for instance, of agriculture. However, in several cases the trends are extremely heterogeneous. This result has an important consequence. Very different citation trends are more difficult to be described by a common model. This raises a question on how much general models of citation ageing can be applied to any field, subject category and time span.

Surreptitiously, it is necessary to note the heterogeneity of scientific articles in some of the subject categories (in particular International relations, and one case in Business Economics). These facts further instill doubts on the structure of subject categories, at least in less recent times. Actually, some of the selected fields are extremely heterogeneous regarding the subject of considered (most cited) articles and journals. This is true not only regarding their bibliometric features (number of journals per field, number of published articles, number of received citations, etc.), but also for their thematic consistency: thus, it is possible that most cited papers may receive a (considerable) part of their citations from papers published in other subject areas. This means that considering aggregate data for articles published in less recent time might introduce biases due to the presence of journals that belong also to other subject categories.

The main limitation of this work obviously lies in its empirical nature and limited scope. In order to understand properly the phenomena described here, it ought to be enlarged upon through an experimental approach. Nevertheless, the key purpose of this contribution is to stimulate the debate on the topic.

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Table 1. Most relevant data for the 30 articles in the database.

Research domain	Subject Category	Pub. Year	Journal	Rec. cit
SCI. & TECH	CHEMISTRY	1983	JOURNAL OF IMMUNOLOGICAL METHODS	22,387
		1983	ANALYTICAL BIOCHEMISTRY	21,459
		1985	JOURNAL OF BIOLOGICAL CHEMISTRY	19,456
		1985	ANALYTICAL BIOCHEMISTRY	15,666
		1985	JOURNAL OF THE AMERICAN CHEMICAL SOCIETY	13,595
	PHYSICS	1983	JOURNAL OF CHEMICAL PHYSICS	13,172
		1980	CANADIAN JOURNAL OF PHYSICS	12,231
		1984	JOURNAL OF CHEMICAL PHYSICS	11,364
		1981	PHYSICAL REVIEW B	10,704
		1984	PROC. OF THE NAT. ACAD. OF SCI. OF THE USA-BIOL. SCI.	8,532
	AGRICULTURE	1980	SOIL SCIENCE SOCIETY OF AMERICAN JOURNAL	6,798
		1980	CANADIAN JOURNAL OF FISHERIES AND AQUATIC SCI.	3,594
		1984	PROC. OF THE NAT. ACAD. OF SCI. OF THE USA-BIOL. SCI.	2,613
		1980	WATER RESOURCES RESEARCH	2,149
		1982	JOURNAL OF SOIL SCIENCE	1,929
SOC. SCI.	OPERATIONS RESEARCH & MANAG. SCIENCE	1984	MANAGEMENT SCIENCE	2,647
		1981	MANAGEMENT SCIENCE	876
		1982	OPERATIONS RESEARCH	718
		1983	OMEGA-INTERNATIONAL JOURNAL OF MANAGEMENT SCI.	714
		1983	MANAGEMENT SCIENCE	584
	INTERNATIONAL RELATIONS	1983	PAIN	4,146
		1985	ANNALS OF INTERNAL MEDICINE	1,813
		1985	ANNALS OF INTERNAL MEDICINE	659
		1985	PEDIATRIC RADIOLOGY	501
		1982	INTERNATIONAL ORGANISATION	396
	BUSINESS ECONOMICS	1985	CRITICAL CARE MEDICINE	7,729
		1981	JOURNAL OF MARKETING RESEARCH	7,464
		1980	ECONOMETRICA	7,170
		1982	ECONOMETRICA	4,329
		1984	STRATEGIC MANAGEMENT JOURNAL	3,488

Table 2. Chemistry

YEAR	1	2	3	4	5
1980	-	-	-	-	-
1981	-	-	-	-	-
1982	-	-	-	-	-
1983	0	0	-	-	-
1984	3	7	-	-	-
1985	24	77	13	0	3
1986	58	241	113	24	25
1987	91	688	296	87	68
1988	146	1239	490	249	152
1989	230	1812	667	349	246
1990	291	2200	727	523	358
1991	342	2258	945	629	476
1992	441	2251	979	665	601
1993	550	2005	1072	706	664
1994	644	1795	1243	802	742
1995	657	1494	1126	804	785
1996	697	1189	1165	866	817
1997	672	964	1048	698	826
1998	676	781	960	781	738
1999	700	541	966	657	764
2000	664	412	896	630	652
2001	678	348	785	634	618
2002	681	257	715	613	571
2003	777	197	621	612	549
2004	853	142	613	537	560
2005	901	140	576	544	521
2006	954	82	532	551	469
2007	1157	72	485	498	407
2008	1224	74	429	532	407
2009	1339	48	403	539	382
2010	1563	38	441	481	329
2011	1570	45	358	523	292
2012	1524	30	362	491	284
2013	1784	25	343	499	216
2014	496	7	87	142	73

Table 3. Physics

YEAR	1	2	3	4	5
1980	-	0	-	-	-
1981	-	16	-	7	-
1982	-	20	-	30	-
1983	1	24	-	58	-
1984	21	28	1	65	14
1985	29	38	9	88	67
1986	35	49	14	67	133
1987	52	44	21	93	219
1988	54	54	25	103	277
1989	69	57	44	138	353
1990	108	73	61	129	395
1991	123	106	87	151	502
1992	137	121	107	174	507
1993	182	172	129	200	560
1994	224	249	191	250	574
1995	220	295	232	258	537
1996	283	460	209	311	508
1997	272	507	201	354	503
1998	300	490	228	346	485
1999	324	525	276	363	451
2000	353	530	259	366	360
2001	356	547	279	406	357
2002	377	556	363	423	308
2003	459	556	392	430	267
2004	522	623	455	439	230
2005	600	608	579	457	182
2006	662	636	658	460	151
2007	736	589	713	508	122
2008	800	653	819	539	120
2009	896	695	817	619	112
2010	928	610	861	585	80
2011	1123	695	914	639	67
2012	1246	717	1040	691	46
2013	1324	694	1082	705	35
2014	356	194	298	252	10

Table 4. Agriculture

YEAR	1	2	3	4	5
1980	0	4	-	0	-
1981	0	15	-	3	-
1982	0	29	-	4	1
1983	5	21	-	3	3
1984	4	40	0	5	16
1985	16	51	2	9	15
1986	8	45	14	4	12
1987	15	36	25	4	18
1988	21	37	24	10	16
1989	28	38	27	12	23
1990	35	41	55	16	22
1991	51	33	52	14	32
1992	66	43	81	30	38
1993	83	42	77	29	38
1994	79	57	96	32	32
1995	80	58	83	39	46
1996	126	67	83	59	47
1997	167	79	111	66	53
1998	176	100	80	84	57
1999	208	77	77	89	59
2000	231	120	93	98	74
2001	207	136	84	75	68
2002	238	143	82	94	76
2003	281	135	109	108	62
2004	313	132	103	113	84
2005	320	185	115	138	78
2006	359	221	124	109	113
2007	371	229	132	97	113
2008	431	197	138	136	113
2009	479	179	140	118	131
2010	456	225	128	122	111
2011	590	225	141	122	121
2012	562	233	155	151	133
2013	652	248	148	129	100
2014	140	73	34	27	24

Table 5. Operat. Res. Manag. Sci.

YEAR	1	2	3	4	5
1980	-	-	-	-	-
1981	-	1	-	-	-
1982	-	4	0	-	-
1983	-	15	5	0	0
1984	0	9	9	0	1
1985	2	20	11	0	0
1986	4	15	13	2	5
1987	1	21	19	0	8
1988	11	16	17	0	7
1989	7	21	23	2	5
1990	12	28	13	6	12
1991	10	18	20	5	3
1992	8	29	17	2	2
1993	20	17	14	9	7
1994	16	29	16	10	6
1995	34	33	22	8	5
1996	65	29	12	19	11
1997	48	22	25	10	11
1998	60	21	20	15	5
1999	71	37	25	16	6
2000	50	33	26	10	8
2001	55	23	15	18	12
2002	50	25	11	17	5
2003	56	23	18	19	9
2004	71	36	20	32	8
2005	92	31	26	25	27
2006	123	39	19	37	28
2007	112	38	39	42	31
2008	156	45	56	69	44
2009	281	45	35	73	50
2010	278	43	36	58	63
2011	285	33	34	62	68
2012	301	36	49	67	57
2013	274	34	37	64	64
2014	94	7	16	17	16

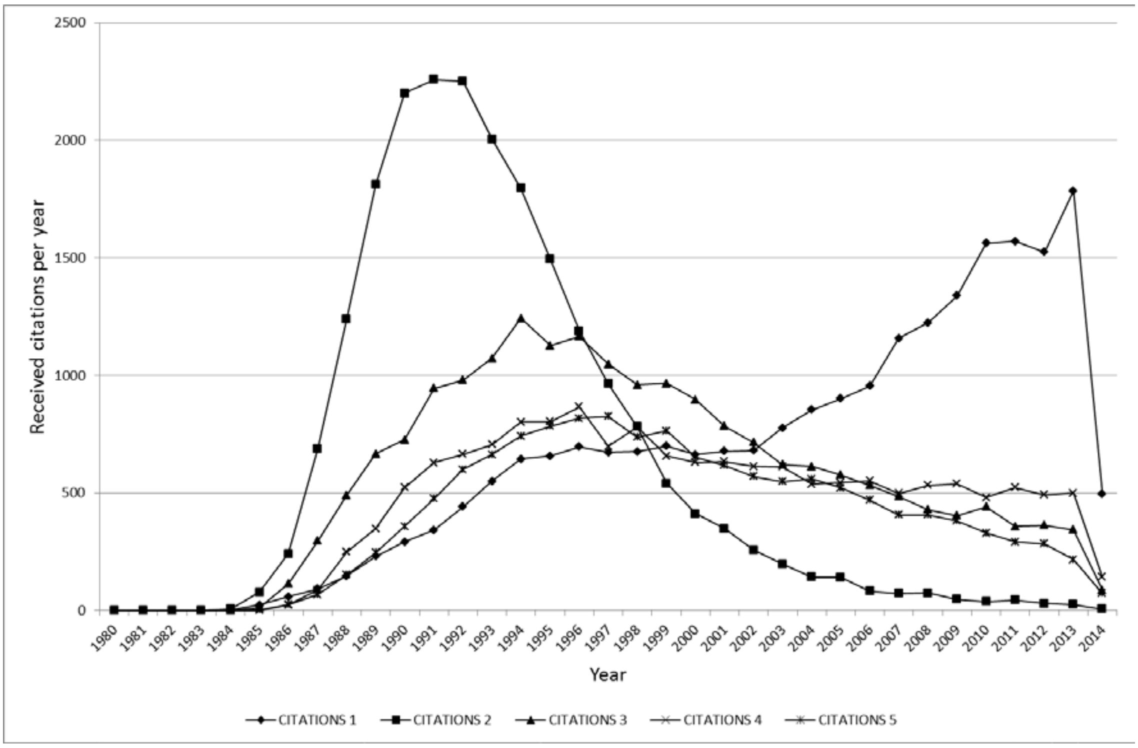
Table 6. International Relations

YEAR	1	2	3	4	5
1980	0	0	0	0	0
1981	0	0	0	0	0
1982	0	0	0	0	0
1983	0	0	0	1	0
1984	1	0	0	5	0
1985	2	1	2	1	0
1986	6	7	20	2	1
1987	4	21	38	1	3
1988	6	47	35	3	1
1989	12	47	39	7	6
1990	14	47	36	5	1
1991	22	61	36	2	1
1992	34	70	36	9	12
1993	31	64	35	5	6
1994	49	67	23	5	3
1995	67	92	34	7	6
1996	67	91	40	5	13
1997	74	66	24	13	15
1998	106	84	25	16	12
1999	114	86	22	9	20
2000	154	81	28	8	24
2001	166	80	19	9	18
2002	156	98	27	7	28
2003	195	83	25	20	27
2004	211	78	18	16	32
2005	219	82	20	17	16
2006	240	71	15	18	31
2007	240	70	14	16	31
2008	285	52	10	24	26
2009	288	57	8	20	33
2010	304	52	7	28	31
2011	318	59	8	25	27
2012	347	57	11	48	33
2013	328	36	4	33	35
2014	86	6	0	11	9

Table 7. Business Economics

YEAR	1	2	3	4	5
1980	-	-	0	-	-
1981	-	3	1	-	-
1982	-	7	17	3	-
1983	-	7	19	6	-
1984	-	11	25	11	0
1985	0	7	19	19	0
1986	21	2	42	14	1
1987	41	12	65	34	1
1988	84	11	79	51	2
1989	90	10	101	54	1
1990	150	19	114	60	3
1991	159	15	163	74	14
1992	153	12	176	91	20
1993	206	13	180	88	11
1994	203	17	190	66	27
1995	237	24	180	77	29
1996	280	23	227	119	47
1997	243	44	232	99	49
1998	281	40	216	117	82
1999	278	54	260	116	86
2000	293	62	265	136	74
2001	282	99	251	143	120
2002	279	83	251	130	112
2003	306	114	319	127	146
2004	333	126	288	169	143
2005	333	204	283	178	151
2006	384	287	314	204	196
2007	400	402	331	237	215
2008	411	535	352	314	285
2009	389	648	396	315	312
2010	417	835	429	286	347
2011	440	1035	409	314	326
2012	461	1127	402	316	302
2013	454	1205	446	284	312
2014	121	371	128	77	74

Figure 1. Chemistry



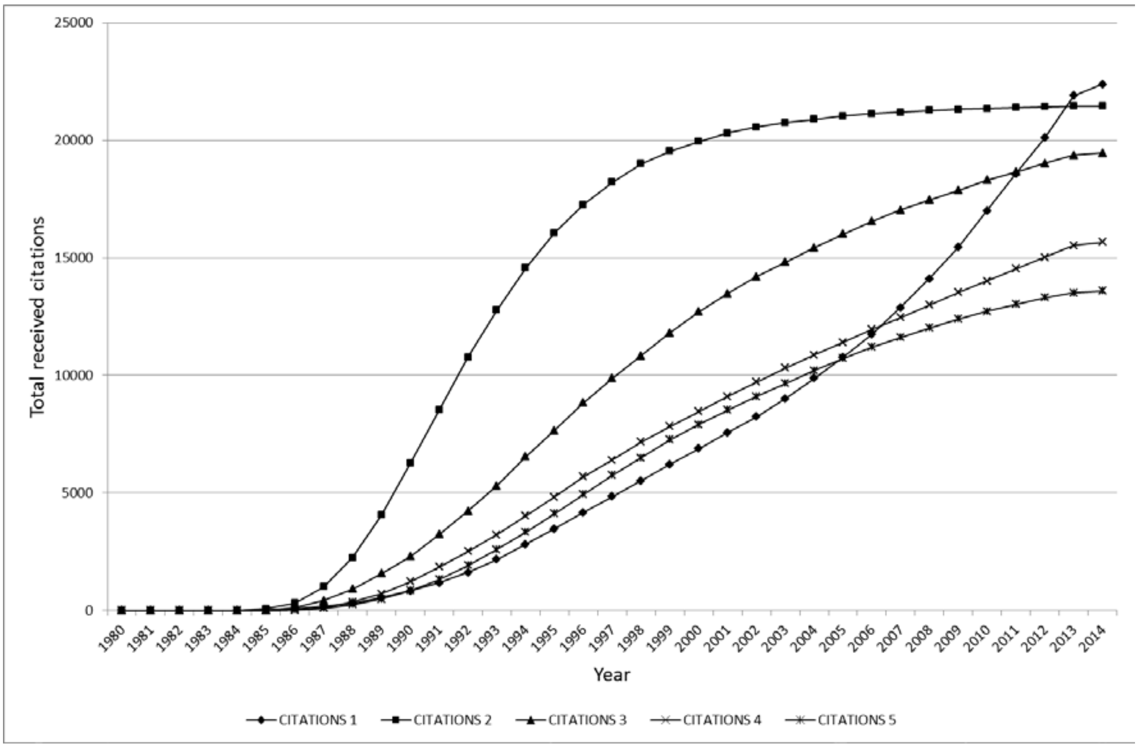
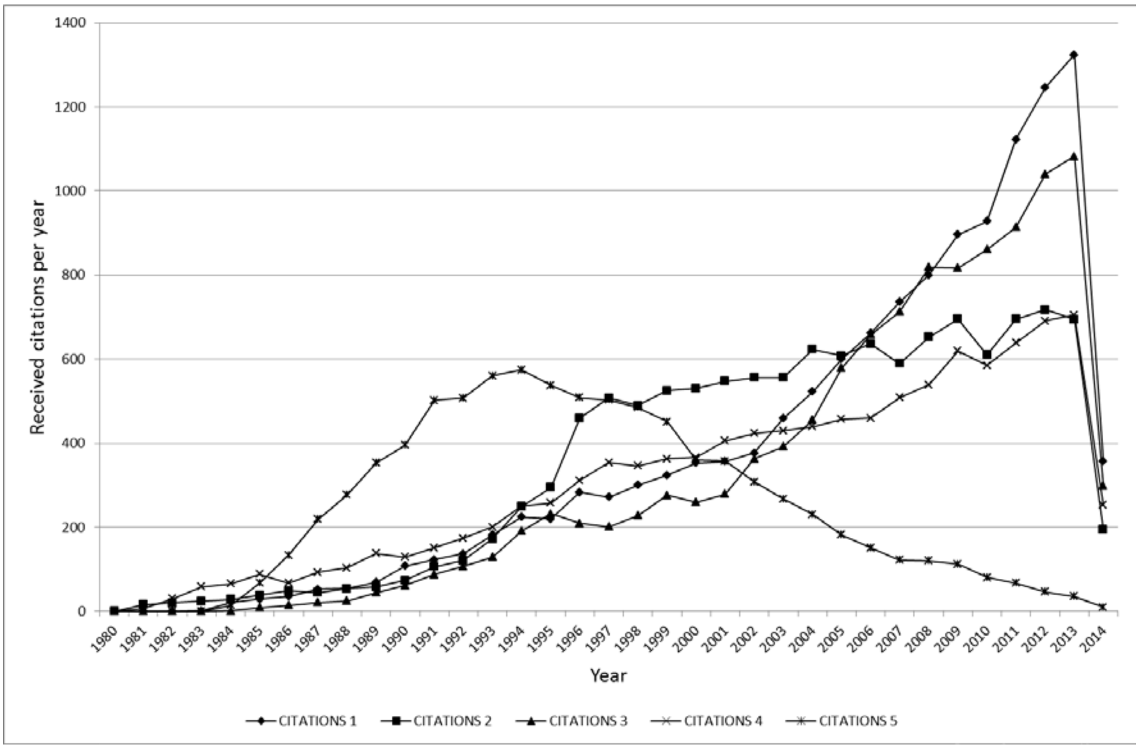


Figure 2. Physics



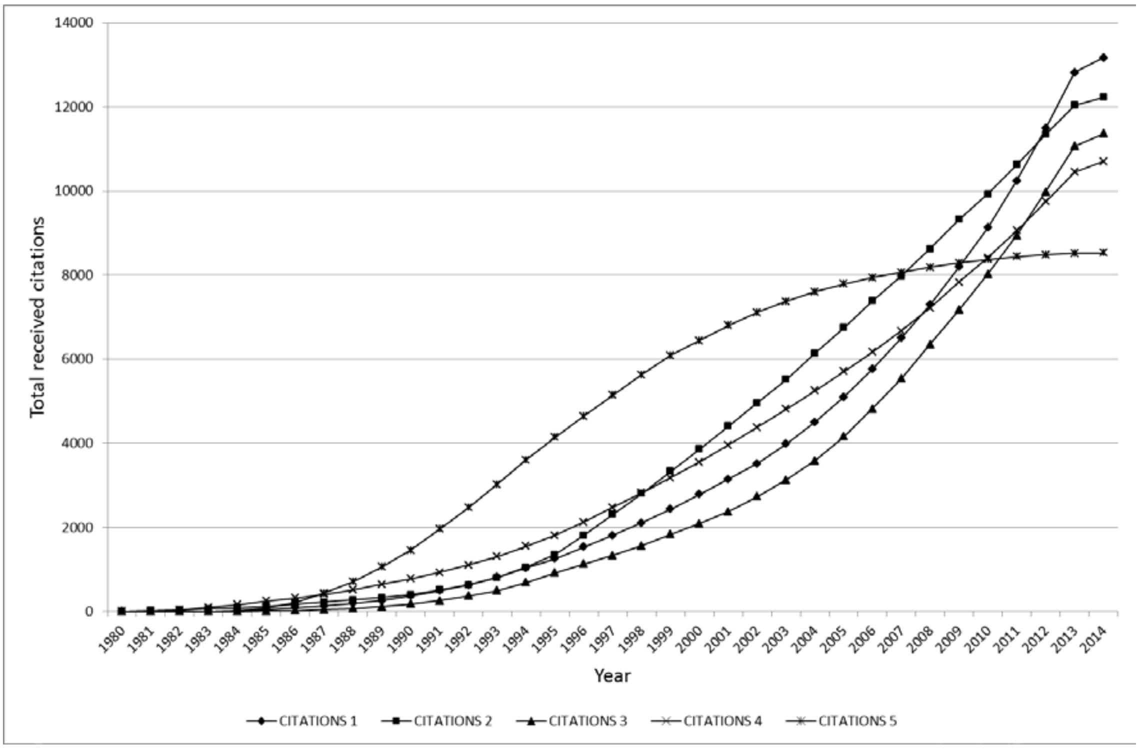
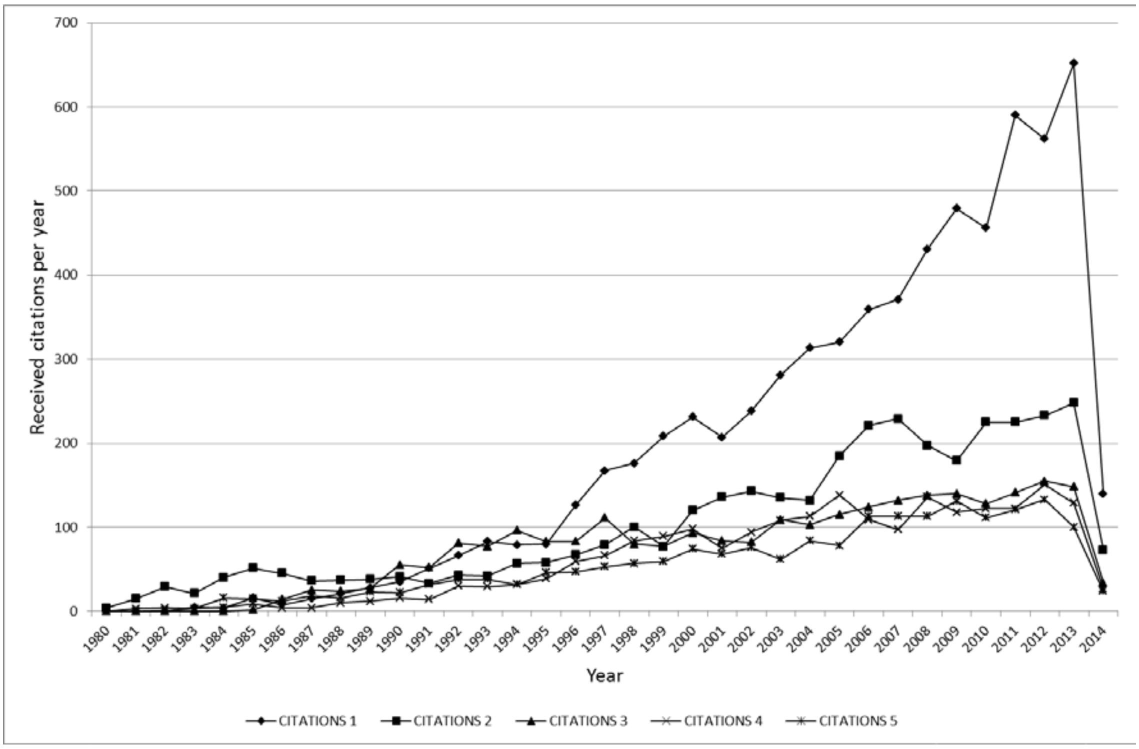


Figure 3. Agriculture



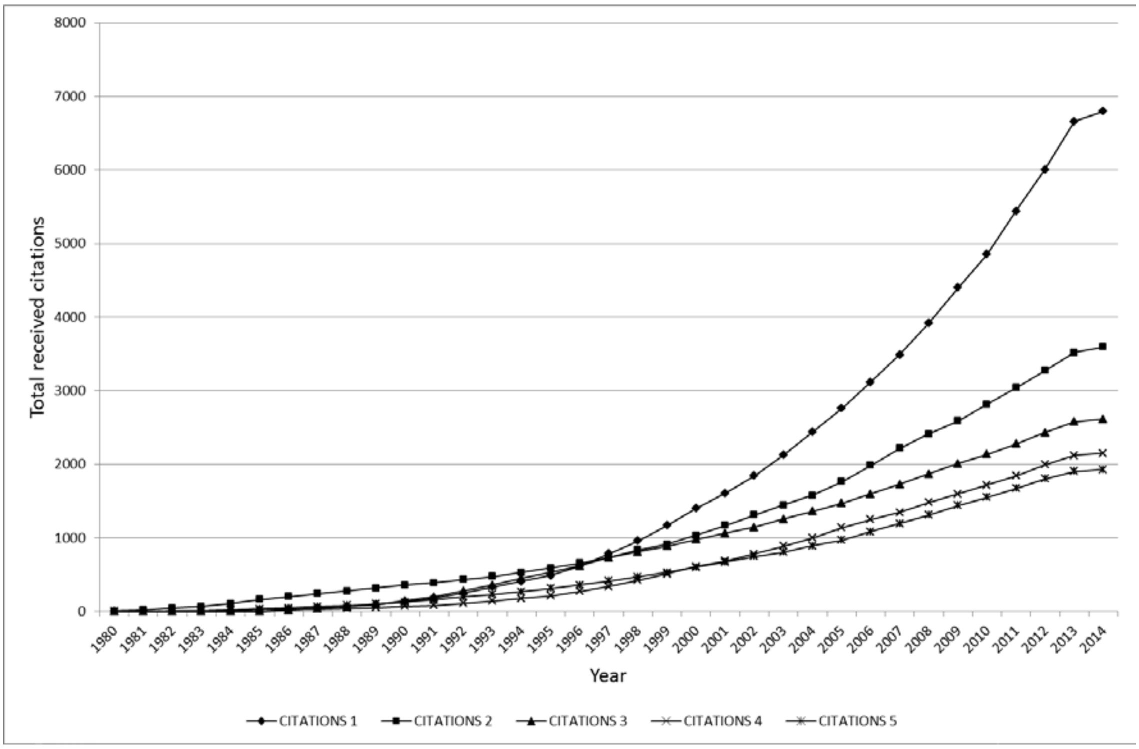
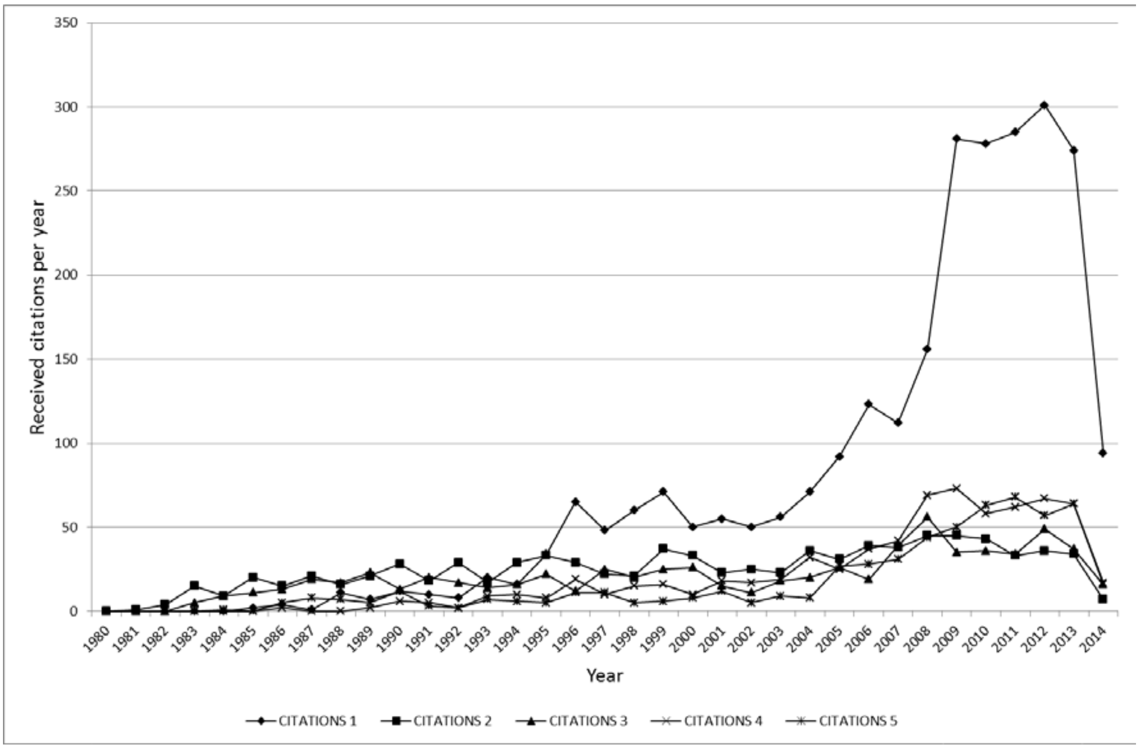


Figure 4. Operations Research & Management Science



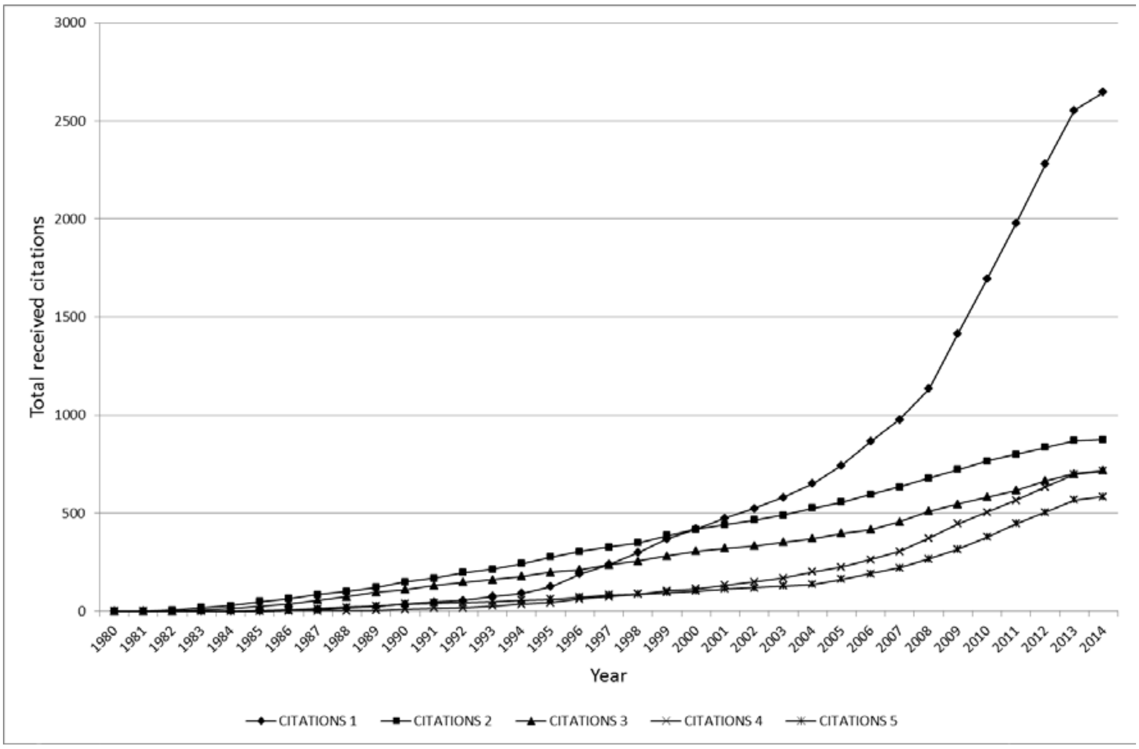
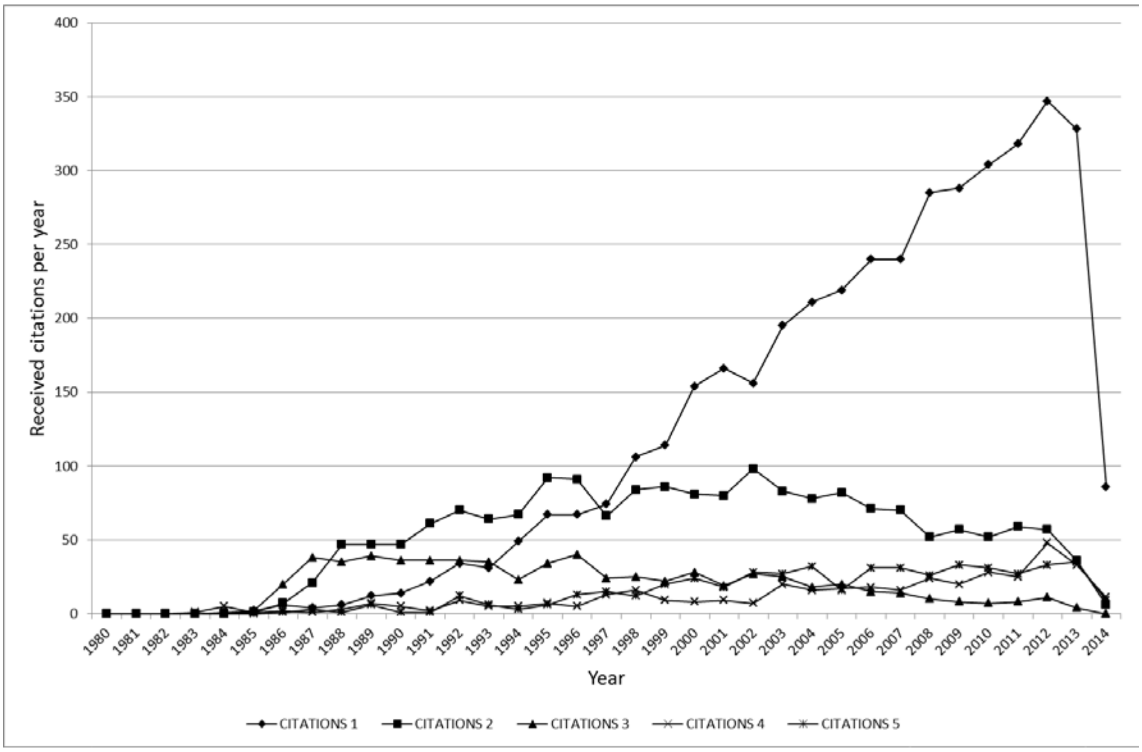


Figure 5. International Relations



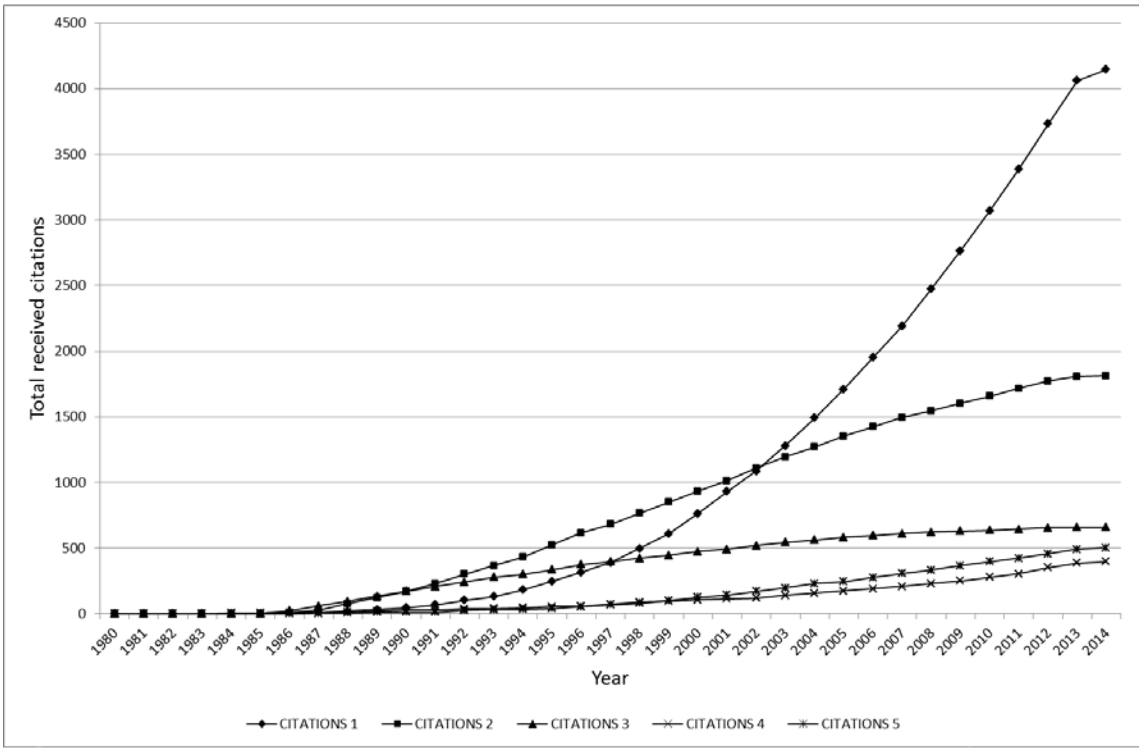


Figure 6. Business Economics