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Telecommunications Policy: An evaluation of 40 years' research history

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Telecommunications Policy: An evaluation of 40 years' research history

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Abstract

Telecommunications Policy (TP) marked its 40-year milestone in 2016. At this juncture of 40-year milestone, this paper implements a text analysis with keyword frequency data derived from the abstracts of papers published for the past 40 years to take a look at the big picture of key concepts that constitute research subjects of the journal. With keywords and bibliographic data, this paper calculates key research indexes to overview dynamically changes in research focuses in the journal. This paper found that the difference in research performance across research subjects within three continents has declined over time, even though still there exist wide differences in research performance across subjects within nations, and the mid-1990s marked a watershed dividing the 40-year history into two parts.

Keywords: Telecommunications policy; Key research area; Key research index; Theil index; Text analysis; Bibliographic analysis

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1. Introduction

Telecommunications Policy (TP) marked its 40-year milestone in 2016. According to Thomson Reuters' Web of Science database, as of the end of 2016, the aggregated number of papers published in TP for the past forty years is 2,532.¹ Today, it publishes about 90 papers per year, about one thousand reviewers participate voluntarily in review processes, and rejection rate is about 70 percent. As passing the 40-year milestone, TP is entering its prime of life.

Since its inception, TP has been a key platform to share research ideas and outcomes, propose scientific and practical policy alternatives, and eventually contribute to the advancement of, narrowly speaking, the telecommunications industry worldwide and, broadly speaking, our daily lives. At this juncture of 40-year milestone, we believe that knowing TP's history will help authors of published papers build a sense of pride and give the readership a glimpse into the future research direction which is still changing incessantly in the telecommunications industry. With this intention, this paper tries to overview TP's 40-year research history that has evolved together with the telecommunications industry worldwide. Gómez-Barroso, Feijóo, Quiles-Casas & Bohlin (2017), published together with this paper, pursues the same objective but this paper is different from it in that this paper uses different methods of analyses and utilizes publication and citation data for top 20 nations in order to investigate changes in research trends on a bit deeper level.

This paper firstly implements a text analysis to create a word cloud that graphically summarizes 374 keywords derived from the abstracts of papers published in TP for the last forty years. This is a way to take a look at the big picture of key concepts that constitute research

¹ For annual distribution of published papers in TP, refer to Exhibit 1 of Gómez-Barroso, Feijóo, Quiles-Casas & Bohlin (2017).

subjects of TP. Then this paper examines relative changes in key concepts over time by calculating annual key research indexes for core five keywords. The top ten keywords identified from the text analysis are telecommunications, service, policy, market, network, mobile, competition, development and technology which, we think, remarkably well represents the journal. Secondly, by calculating the Theil indexes with publication and citation data of research subject areas (clusters) across regions and over time, this paper explores whether there has been a convergence in the distribution of research performance across regions and over time. In addition, this paper also calculates key research indexes with publication data of research subject areas and presents the observed evolution of research subjects by regions and time over the past forty years.

The structure of this paper is as follows. The next section explains the data and the research methods of the paper, and Section 3 presents the outcomes of text analysis using the abstracts of the papers published in TP for the last forty years. This section illustrates a word cloud, summarizing the forty years' of TP research history, and presents dynamic transition in key research concepts of TP. Section 4 reports the results of the Theil index analyses and discusses whether research performance across regions (continents) has converged. In addition, this section calculates key research indexes with publication data of research clusters to shed light on the evolution of research subject areas in TP over the past forty years. Section 5 concludes the paper with a succinct summary of major findings of this research.

2. Data and research methods

2.1. Data

Analyses of this paper utilize word frequency data and paper publication and citation data classified by subjects, nations and regions (continents). Abstracts and titles of the papers

published in TP for the past forty years were crawled with R from the Elsevier homepage, and paper publication and citation data for top twenty nations were extracted from Thomson Reuters' Web of Science database. According to the Web of Science, TP published 2,532 documents for the past forty years from 1977 to 2016. Out of the total documents, this research uses only 1773 research papers, excluding other types of documents such as editorial material (385), book review (285), proceedings paper (211), and note (35). This paper also uses subject classifications of paper published in TP offered by the authors of Gómez-Barroso et al. (2017).

2.2. Research methods

This paper applies a basic text analysis, word counting, to the abstracts of all papers published up to the end of 2016. The abstracts and titles of papers were crawled from TP Elsevier homepage, stop words—such as a, the, is, and which—were cleaned, and words with the same root are counted as the same word (Duke University Library, 2017). Text analysis with paper titles was not satisfactory because words are not diverse enough to present forty years' rich research subjects and word counts were small, as many as fifteen or so. Therefore, this paper used the abstracts of papers. This paper went one step further in creating word frequency table using the abstracts of papers by removing such words as country, sector, effect, level, model, impact, case, context, and factors that do not have much meaning in overviewing research trends in TP. This is not a way used in usual text analyses but this paper used this rather subjective approach in order to emphasize keywords that describes well changes in research trends. In addition, pricing is an important topic so rate or rates counts were added to price word count.

We derived 50 keywords for each year from the abstracts of papers based on the rankings of word counts and then merged them into an aggregated word table. If 50 keywords of each year were all different, then the word table would have had 2,000 distinct words. However,

many words are duplicate and duplicate word counts were added. Finally, we obtained 374 words with a total of 28,530 word counts. With 374 words, a word cloud was created with R and it is presented in Fig. 2 in Section 3. The word cloud summarizes key subject words that appeared in the abstracts of papers published in TP for forty years.

The word cloud does not show dynamic changes in research keywords for the past forty years. Changes in word frequencies and shares per year also do not present well the transition of research subjects because word frequency distribution is skewed heavily as shown in Fig. 1 and changes in word shares are usually small, making comparison difficult. Furthermore, annual word frequencies and shares do not reveal how much a word is concentrated in a specific year or in a time interval. To show a dynamic transition of research subjects over time, this paper calculates annual key research index (*KRI*), Eq. (1) where i ($= 1, \dots, n$) is an index for words and t is an index for year, for forty years with the frequency data of top 50 keywords (*FKW*) obtained from the abstracts of papers. As stated above, n is 374. The numerator of Eq. (1) is a share of a word i 's frequency in year t , and the denominator is the average share of the word i 's count in total counts, 28,530.

$$KRI_{it} = \frac{FKW_{it} / \sum_{i=1}^n FKW_{it}}{\sum_{t=1}^{40} FKW_{it} / \sum_{t=1}^{40} \sum_{i=1}^n FKW_{it}} \quad (1)$$

The key research index is calculated similarly with the trade specialization index (Fink, Kwon, Rho & So, 2014; Kwon & Cho, 2015). The key research index, however, is different from the trade specialization index in that it compares the share of a keyword frequency at time t with respect to the average share of the same keyword for the whole time period, whereas the trade specialization index compares the share of an item in a country's trade with respect to the global share of the item in world trade at time t . The KRI_{it} of unity at time t means that the share of a keyword frequency at time t is just the same as its share for the overall period, say, forty years.

The more concentrated is a word's frequency in a short time periods, the greater its KRI_{it} is because the denominator is an average word frequency spread over forty years. This is the core benefit of using KRI rather than word counts or shares. If it declines over time from a number greater than unity to a number less than unity, it implies that the concentration (importance or popularity) of the keyword has declined in research.

This paper calculates the Theil indexes for nations and regions (continents) with the distribution of papers by research areas and the distribution of paper citations by the same research areas in order to show the inequality in research performance across nations and regions and to check if the inequality have declined among continents over time. Paper publication distribution over subjects represents supply side of research in TP and paper citation distribution over subjects shows consumption of research offered by TP. Thus, the Theil index, measured by paper number and citation distributions, can be thought of as a way to look into the discrepancy between research production and consumption. The Theil index for a country or a continent j at time t is shown in Eq. (2), where c_{kt} is the citation share of a subject in total citations of all subjects at time t (k is an index for m subject clusters) and p_{kt} is the share of papers published across research subjects at time t (Bellu & Liberati, 2006; Conceição & Ferreira, 2000).

$$T_{jt} = \sum_{k=1}^m c_{kt} \ln \left(\frac{c_{kt}}{p_{kt}} \right) \quad (3)$$

The Theil index in this paper is used for measuring the discrepancy between two distributions because the Theil index conceptually measures the gap between two distributions, even though it was traditionally used for measuring the gap between income distribution and population distribution (Bellu & Liberati, 2006; Conceição & Ferreira, 2000; Kwon, Park & Rhee, 2017). The Theil index ranges between zero, implying the exact match between two distributions, and unity, implying a wide gap between two distributions. It is also decomposable

into the between-group Theil index and the within-group Theil index. In other words, after calculating a global level Theil index, we can decompose it into the between-group (nations or subjects) Theil index and the within-group Theil index in order to find the sources of the discrepancy between any two distributions.

3. Changes in forty years' research keywords in TP

3.1 A word cloud representing the papers published for forty years

As explained in the previous section, 50 keywords with highest frequency are extracted from the abstracts of papers published every year and then all of them are merged again to obtain a distribution for unique words that represent TP's past forty year research papers. A total of 374 words are finally identified and Fig. 1 illustrates the frequency table of top 50 keywords out of 374 words. Those 50 keywords match with those shown in Exhibit 2 of Gómez-Barroso et al. (2017) even though the rankings of some words are different. The ranking difference is likely to stem from the difference in the papers included in analyses.²

² Gómez-Barroso et al. (2017) used papers published up to June 2016 and this paper used all papers published in 2016.

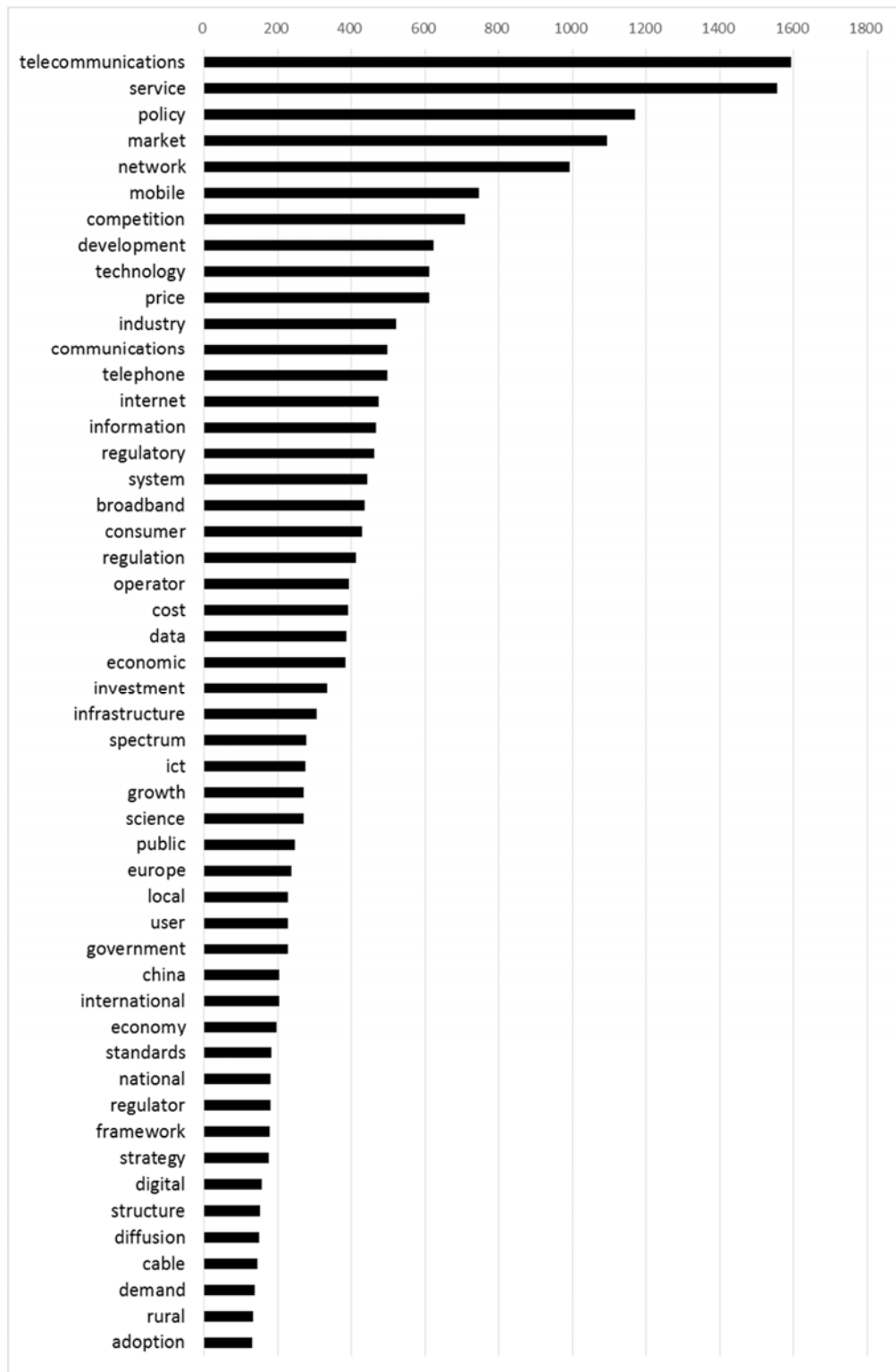


Fig. 1 Top 50 keyword frequency chart

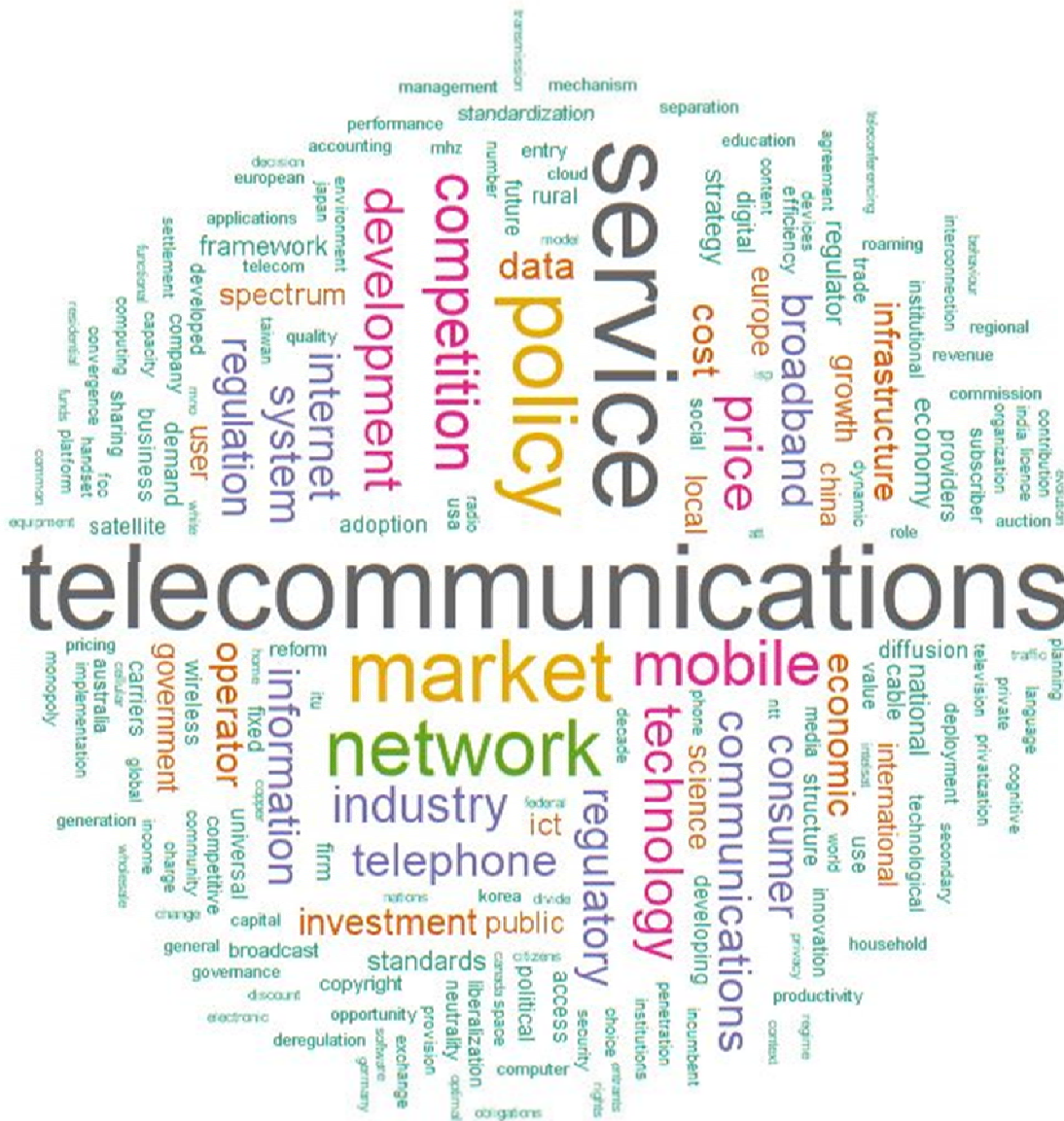


Fig. 2 A word cloud from the abstracts of the published papers for the past forty years

Top twenty keywords are telecommunications, service, policy, market, network, mobile, competition, development, technology, price, industry, communications, telephone, Internet, information, regulatory, system, broadband, consumer, and regulation. From the 50 keywords, an expert of the telecommunications industry can immediately notice that these keywords and the

word cloud, Fig. 2, describe well the history of the telecommunications industry, having been providing to consumers fixed and mobile telephone and broadband services through networks. Since the early 1980s when the telecommunications industry was privatized and liberalized, competition has been promoted in the telecommunications market, and innovations in the telecommunications industry have contributed to economic growth and development in developed and developing countries. Telecommunications services have been changed from services for the rich into universal services affordable for everyone as their prices declined, and global economies and societies have become smaller, not physically but emotionally and in communication time. For the past forty years, the landscape of the telecommunications market has been drastically changed from fixed (wired) voice communications services to mobile (wireless) voice and broadband Internet services. Technologies in the telecommunications industry also have made rapid progresses, enabling us to live in a ubiquitous society and to envision a new world where all things are connected (Internet of Things).

3.2 Changes in forty years' research keywords

Among 374 words that consist of 50 words most frequently mentioned in the abstracts published for the past 40 years in TP, only five words—telecommunications, service, policy, market, and network—gained more than 3% of the total word frequency (28,530). Only two words, telecommunications and service, took up more than 5% of the total frequency and ranked within top ten in most years, implying that TP has been an academic journal about telecommunications services. A bit broadly saying, it has been an academic journal about telecommunications network, service, market, and policy.

As explained in the previous section, we calculated KRI_{it} in order to shed light on the transition in research keywords of TP over the forty years. As explained the previous section, the

more concentrated is a word's frequency in a few years, the greater its KRI_{it} is because the denominator is an average word frequency of that word. In other words, if a word was popular during a few years, its KRI would be very high. For example, WiFi and neutrality ranked the 45th and the first only once in 2008 and in 2014 and their KRI was 27.3 and 19.28, respectively, whereas the KRI values of telecommunications, included in top ten ranking almost all the time, have never been greater than 2.

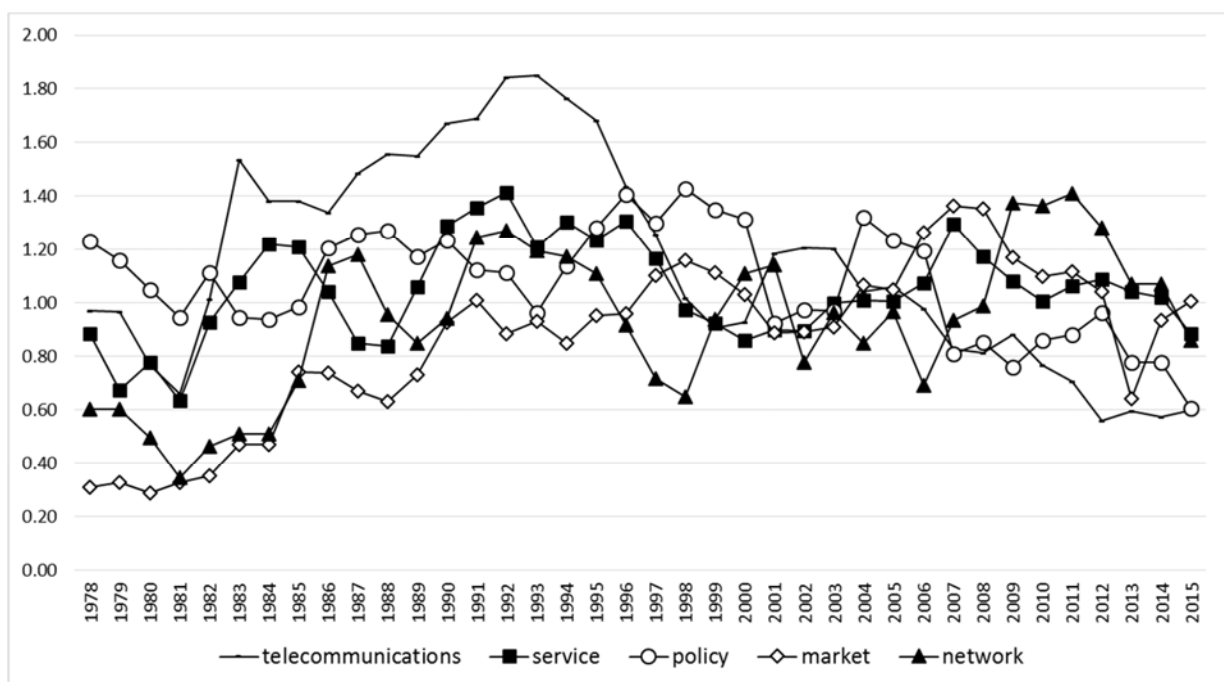


Fig. 3 Changes in key research indexes of top 5 keywords

Fig. 3 presents three-year moving average value of top five keywords.³ The KRI values of telecommunications were greater than unity up to year 1997 except early several years from 1977 to 1982 and have been less than unity since 1998 except only a few years. This transition of KRI values of telecommunications from greater than unity to less than unity implies that the

³ Three-year moving average of the KRI values of the five keywords are used in presenting their trends in Fig. 1 in order to remove empty years without losing annual variations too much.

relative importance of the word has declined over time in research. The transition period coincided with rapid expansion of 2G services and Internet in advanced countries. The word, mobile, the 6th ranked word in Fig. 1 began to appear in annual top 50 words from 1993 and the word, Internet, the 14th ranked word, from 1996. This implies that the word, telecommunications, is likely to be a word representing old telecommunications paradigm.

In Fig. 3, service KRI values move similarly with telecommunications' with less variations. Service is a word whose KRI values have been most stable among the five words in Fig. 3, suggesting that the identity of the telecommunications industry as a service industry has not been changed even though technologies and services have been drastically transformed over the forty years. For the past forty years, a noticeable reversal occurred between the two words, policy and market. On average, the KRI values of policy have declined over time, while those of market have risen. This reversal is likely to be caused by the paradigm changes from fixed voice services oriented industry to mobile voice and broadband services industry. Policy is a keyword representing old telecommunications paradigm based on the monopolistic industry structure, whereas market is a keyword closely associated with deregulation and competition which have been fostered since the 1980s and enhanced after digital mobile communications services became a popular service in the latter part of the 1990s. The KRI values of network on average have risen over time and it is no surprise considering the facts that network technologies have been continuously improving and telecommunication networks continuously upgraded.

Top five keywords in Fig. 1 can be used to make two-word phrases, especially telecommunications being the first word, from which we can guess the reason why telecommunications is the most frequently observed word in abstracts. When calculated pairwise correlation coefficients between top five keywords with annual KRI values, we can confirm that

the conjecture is partly correct. As shown in Table 1, it turned out that the word, telecommunications, had moderate positive correlation with service and policy and little correlation with market and networks, implying that concentration of telecommunications is not so much associated with that of the latter two words. Policy had a moderate correlation only with telecommunications among the five words, supporting the previous conjecture that the two words are representing the old paradigm of the telecommunications industry, whereas service had moderate correlations with other words except policy. The correlation of service with market and network is likely to stem from the facts that the telecommunications market is a service market where service is delivered through networks and its quality depends on the quality of networks.

Table 1. Pairwise correlation coefficients between top five keywords' KRI values

	telecommunications	service	policy	market		network
telecommunications	1.00	0.52	0.44	-0.10		0.11
service	0.52	1.00	0.003	0.46		0.39
policy	0.44	0.003	1.00	-0.045		0.17
market	-0.10	0.46	-0.045	1.00		0.57
network	0.11	0.39	-0.17	0.57		1.00

3.3 Other observations of noticeable changes in the KRI values

While calculating KRI values, we were able to notice several interesting changes in keyword trends that can represent paradigm changes that occurred in the forty-year history of the telecommunications industry. First, satellite (56th) and television (90th) recorded KRI values greater than unity until the mid-1990s and once the KRI value of television reached as high as 16.4 in 1985. However, after the 1997, they disappeared from the annual top 50 keyword list. Cable (47th) appeared consistently between 1984 and 1997 with four sporadic appearances

thereafter. Second, once spectrum appeared in the annual top 50 keyword list in 1991, it was not in top 50 annual keyword list until 2001, when spectrum became a key research subject in TP.

Auction (122nd), a way of assigning spectrum to mobile network operators (Kwon & Kim, 2012; Kwon, Lee & Oh, 2010), appeared twice in annual top 50 word list in 2001 and 2003, around the time when auction was globally used for the first time in assigning spectrum for 3G services.

Third, Internet (15th) became a steady keywords from 1996 and broadband (19th) from 2004.

Considering that the early Internet was narrowband communication services, the time lag between Internet and broadband is understandable. Forth, universal that usually used with service had appeared mainly between 1993 and 2004 in TP. Today, as mobile subscription rates often exceed 100 percent in many advanced countries (Jung & Kwon, 2015), universal service policy does not seem to gain political attention any longer.

Fifth, among 374 keywords, eight country names and one regional name appeared with more than ten frequencies in abstracts in different times: Europe (32th), China (36th), USA (67th), Australia (84th), Japan (97th), Korea (98th), Taiwan (125th), Canada (182th) and Germany (197th). Taiwan, Canada, and Germany appeared only two or three times, so they are not shown in Fig. 4 to improve readability by reducing complexity. From Fig. 4, two meaningful points can be observed. First, Europe is the only one area name that appeared in abstracts evenly for the last forty years of TP history, implying that a large share of TP papers were about Europe cases and probably TP has been a journal led by European scholars. Australia is a country that appeared through the forty year TP history, even though its appearance was much less frequent than Europe. Second, as found in the previous subsection, the mid-1990s marked a watershed, dividing the forty years in two sub-periods. As shown in Fig. 4, four economically advanced country names such as the USA, Japan, Canada and Germany dominated until 1997, and from

1995 China, Korea and Taiwan (not shown in figure) began to appear more frequently in published papers. This transition seems to reflect Asia-Pacific countries' prominent performance in new telecommunications services such as cellphone services and fixed and mobile broadband Internet services.

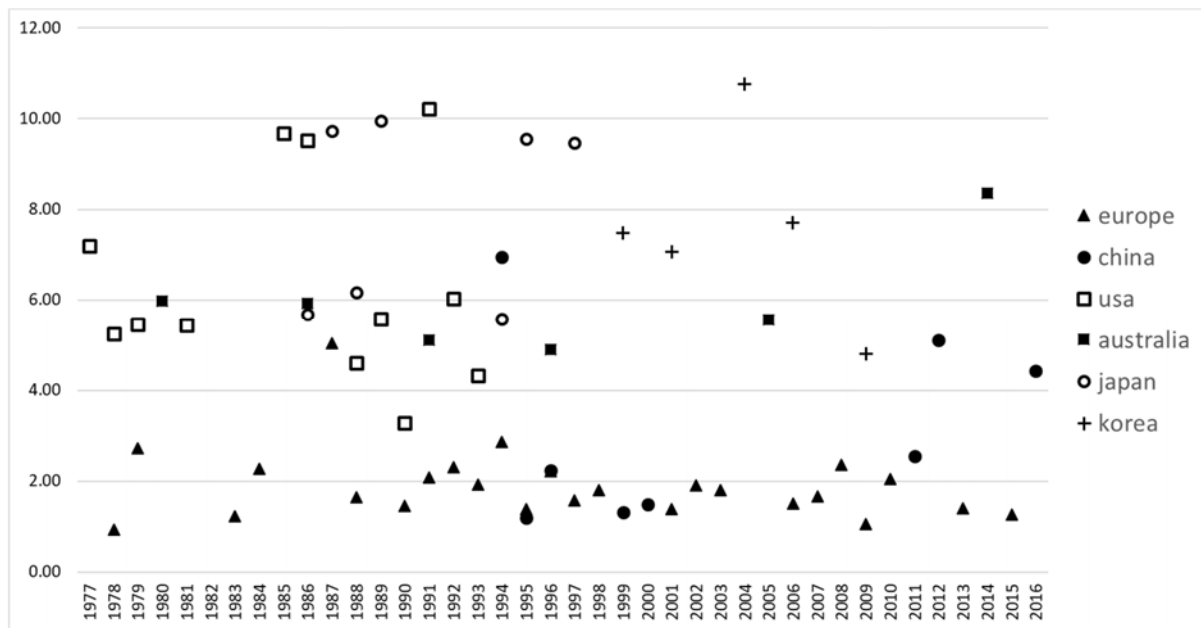


Fig. 4 KRI values of country names appeared in TP abstracts

4. Changes in research impacts and subjects

This section compares the distributions of papers published across nations and subjects with those of paper citations in order to show the inequality in research performance across nations, continents and subjects. This paper uses document classification by nation offered by the WoS, which classifies papers into nation categories based on authors' affiliation information, and utilizes a subject classification of TP papers, developed and shared generously by the authors of Gómez-Barroso et al. (2017). In the previous sections, this paper used 1,773 research papers for analyses, this subsection utilizes only the papers of top 20 nations, ranked by the number of papers published in TP. The number of papers of top 20 nations is 1,683 which is smaller than

2,121, which is the number of papers, used in the analyses of Gómez-Barroso et al. (2017).⁴ The reason of focusing on top 20 nations' papers is for simplicity's sake in presentation and we thought that top 20 nations, which published about 80 percent of all papers in TP, can be considered to have led research in TP. In addition, Gómez-Barroso et al. (2017) used papers published up to mid-2016, so did our analyses in this section because paper classification information was taken from their paper. The top 20 nations listed in Table 4 of Gómez-Barroso et al. (2017) is slightly different from those listed by the WoS. In Table 4 of Gómez-Barroso et al. (2017), Ireland is included in top 20 but not in the WoS because the WoS separately treats Taiwan as a nation. In addition, the number of papers and that of citations are also slightly different between the two datasets because the population of TP papers used for analyses is different.

4.1. Comparison of publication and citation distributions using the Theil index

This subsection calculates Theil indexes using two distributions: the distribution of paper number and the distribution of citations over thirteen clusters (subjects). If citation per paper across subjects and over time is stable, there would be no much difference between the two distributions across time. Gómez-Barroso et al. (2017) presented the evolution of paper ratios across 13 subjects (clusters) in its Exhibit 5 and reported the counts of papers and citations aggregated over forty years and their shares across nations in its Table 4. Exhibit 11 in Gómez-Barroso et al. (2017) also presented changes in the shares of citations across subjects and over time. This subsection complements Gómez-Barroso et al. (2017) by finding the discrepancy with the Theil index between the distribution of paper production measured by the number of papers

⁴ The number of papers used in this subsection includes some level of duplication because some papers with multiple authors of different nations could be listed in as many nations as the number of authors.

published and that of paper consumption measured by citation.

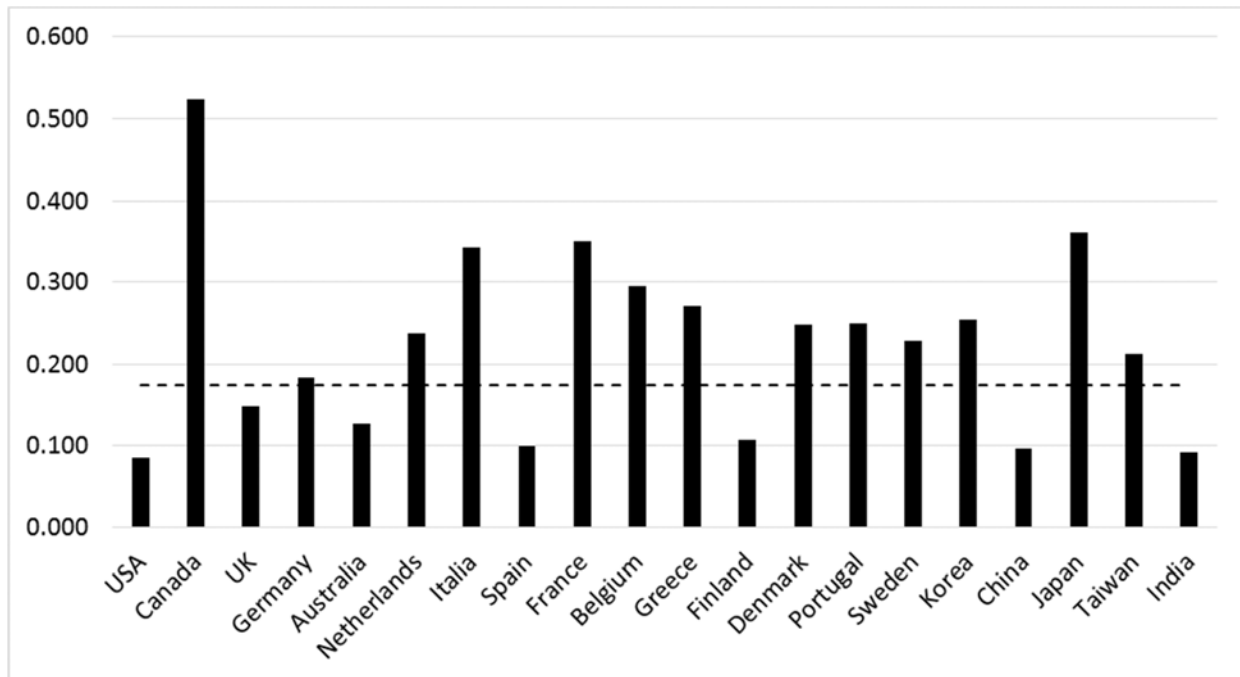


Fig. 5 Theil indexes for top 20 nations

The Theil indexes of 20 nations is presented in Fig. 5, where the dotted horizontal line shows the Theil index calculated with 20 countries' aggregated paper and citation data across subjects (clusters). The Theil index ranges between zero and unity, and zero Theil index means that no difference between any two distributions (Conceição & Ferreira, 2000; Kwon et al., 2017). The higher the Theil index, the greater the difference between the distribution of paper production across subjects and that of citation. Canada recorded the highest Theil index, implying that a small number of papers in a few clusters (Mobile and Standards) gained a large share of citations. Specifically, it is found that Canadian authors wrote a few impactful papers in Mobile and Standards clusters. The USA records the lowest Theil index, meaning that citation per paper across subject categories (clusters) is most evenly distributed.

The horizontal dotted line in Fig. 5 presents 0.1744, which is the Theil's T index calculated 20 nations' total paper numbers and citation statistics across subjects, which is

decomposable into the between-group Theil index and the within-group Theil index in order to figure out which one is contributing more to the Theil's T index. This subsection focuses on Top 20 nations, so there are only three continents: America, Europe, and Asia. America includes the USA and Canada, Asia is composed of South Korea, China, Japan, Taiwan and India, and Europe has 12 European countries and Australia.⁵

Table 2. Theil indexes for top 20 nations

	Theil's T	Within	Between
Top 20's	0.174		
Continent		0.173	0.001
Nation		0.156	0.018
Cluster		0.091	0.083
America	0.111		
Nation		0.105	0.006
Cluster		0.022	0.089
Europe	0.216		
Nation		0.194	0.022
Cluster		0.127	0.089
Asia	0.251		
Nation		0.211	0.040
Cluster		0.087	0.164

As shown in Table 2, continent-wise discrepancy between the distributions of paper counts and citations across clusters is almost zero, implying that most discrepancy in the continent level stems from the within-group difference. The within-group Theil index at continent level is the weighted sum of three continents' Theil's T index shown in the second column of Table 2. Among three continents, Asia reveals the widest gap between paper counts

⁵ Twelve European countries are U.K., Germany, Netherlands, Italy, Spain, France, Belgium, Greece, Finland, Sweden, Portugal, and Denmark.

and citations, whereas America the smallest. These results imply that between the continents, the difference in relative research performance is almost zero and most inequality in research impacts comes from the differences among nations in each continent.

When the Theil's T index is decomposed at nation level, the within-group difference is also dominating factor (within-group Theil index = 0.156), while the between-group difference takes up about ten percent of the Theil's T index, suggesting that each country's subject-wise difference in research impact is far greater than the between-nation difference. When the Theil's T is decomposed at cluster (subject) level, the between-group (cluster) difference (0.083) is comparable to the within-group difference (0.091), meaning that given a cluster (subject), the distribution of paper number across nations is quite different from the distribution of paper citations across nations.⁶ Put differently, countries are different in research impacts across clusters (subjects) given the paper production distribution. The relatively large value of the between-group Theil index implies that clusters are also quite different from each other in research impact (performance).

America has only two countries in this analysis: the USA and Canada. According to the Theil indexes shown in Table 2, a large share of the Theil's T, 0.111, is due to the within-group difference and the between-group gap is just 0.006. A small between-group Theil index again suggests that mean differences of two nations across clusters are small, but the differences between the paper numbers and citations are large in each nation. However, when America's Theil's T is decomposed at cluster-level, it turned out that the between-group (cluster) difference is about four times greater than the within-group difference. This means that differences in

⁶ The within-group Theil index measures the difference between paper counts and citations distributions across nations, given a subject category.

research impact among clusters are far greater than differences between nation in each cluster.

When Europe's Theil's T is decomposed at nation level, we can notice that a similar pattern that is found in America with a bit larger difference among nations. One interesting finding is that when it is decomposed at cluster level, the within-group difference is greater than the between-group difference, telling that cluster-wise, the difference in research impact between European countries is larger than the between-group (cluster) mean difference. Asia recorded Theil's T, 0.251, the highest value among three continents, and when the value is decomposed at nation level, it is found that the inequality in research impact (performance) across subject areas in each nation is the main source of total inequality.

To sum up, at continent- and nation-level, mean-ratio difference between regions or nations, measured by the between-group Theil indexes, is not large, implying that the inequality in mean research impact across regions and countries is small. It is noted that most differences in research impacts, measured by Theil's T, stem from the within-continent or within-nation differences. In research impact, America attained the most balanced performance across research subjects (clusters) and Asia showed the most unbalanced performance.

4.2. Convergence in research performance across subjects

Using publication and citation data, we calculated the Theil indexes for three continents for ten-year periods in order to see whether there has been convergence in citation performance. The reason why this paper uses data aggregated at continent-level, rather than nation-level, is that at nation-level there are too many zeros in publication and citation across clusters. In addition, before 1994, scholars in Asia published only one to three papers per year in TP, so we used 20-year data for Asia only for the first 20 years. Therefore, in Fig. 6, Theil index of Asia begins to appear from the second decade. From Fig. 6, it can be easily noticed that relative

research performance across continents over 13 clusters (research areas) has shown a convergence trend. This result is consistent with the very small between-group Theil index at continent level in Table 2. If we use a simile to make the convergence easier understood, the difference in income inequality across continents has declined and converged over time. Between 1996 and 2005, in Asia, the Theil index was 0.425, which implying that there was a large difference between the publication distribution and the citation distribution, i.e., papers in a few clusters gained a lion's share of citations. The reason that Asia revealed the largest inequality in research performance consistently is likely to be that Asia is composed of more heterogeneous nations in economic development stages than the other two continents.

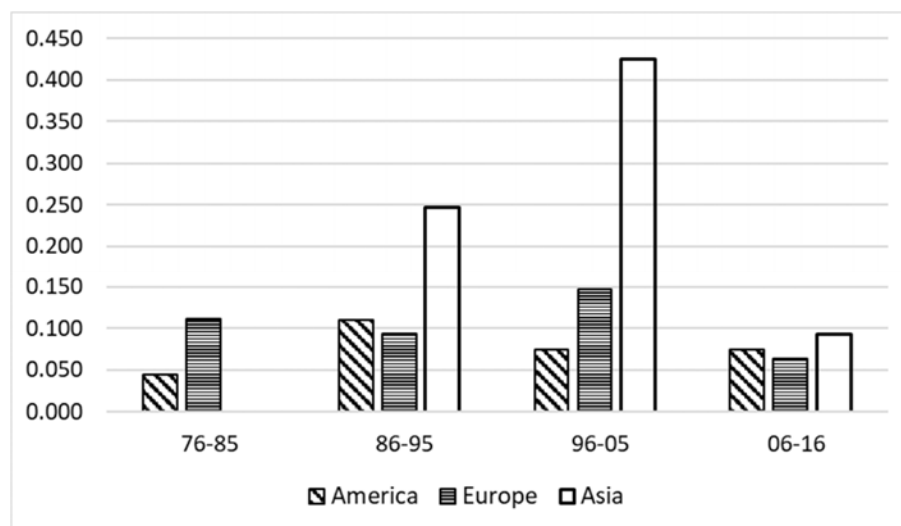


Fig. 6 Changes in the Theil indexes over time in three continents

4.3. Changes in research focuses in TP over time in three continents

Changes in the Theil index reveal only the changes in the degree of performance concentration across research subjects (13 clusters) and allow us to compare them across continents. In order to look further into changes in the intensity of specific research subjects over time, it is necessary to calculate the key research index (KRI), Eq. (1) for 13 clusters. This

subsection uses paper production data, not citation data, measured at continent-level because publications data do not change after publication but citation counts vary with time. In other words, publication data is likely to better reflect research concerns of the scholars and policy makers of each continent than citation data at a specific point of time. The denominator is each cluster's share in total publication number aggregated over the forty years and the numerator is the same cluster's share in specific years' total publication number. The KRI of a specific cluster, greater than unity at a year, means that the cluster's share of papers published in the year is greater than the same cluster's average share in the total number of papers published in a continent. The higher an annual KRI is, the more concentrated is the publication on a specific cluster in the year.

Out of 13 clusters, eight clusters are chosen based on the ranking of publication shares and used to illustrate changes in research focuses of three continents.⁷ Figs. 7, 8 and 9 illustrate changes in KRI values over time in three continents. In case of Asia, KRI values only from 1994 are used in Fig. 9 because there are only several KRI values before 1994, which are very large in value and make KRI values from 1994 cluttered in small space.

⁷ For 13 clusters, refer to Tables 2 and 3 of Gómez-Barroso et al. (2017), and Asia cluster is dropped in illustration because it is an area specific subject even though its ranking is the fifth in publication number. Cluster rankings from the highest are ordered: Policy/Regulation/Development, Information/Internet, Fixed Telephony, Mobile, Asia, Regulation/Competition, Broadband, Spectrum, Regional/Rural, Television, Standards, Satellite, International ITU.

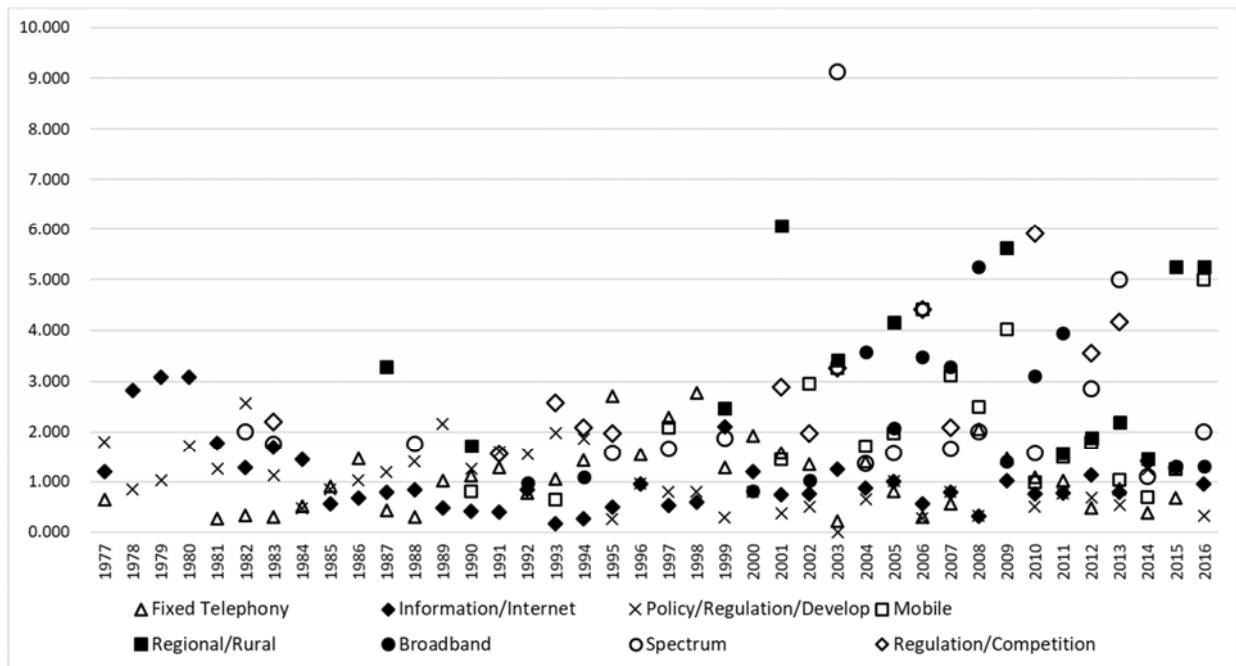


Fig. 7 Changes in key research areas in America

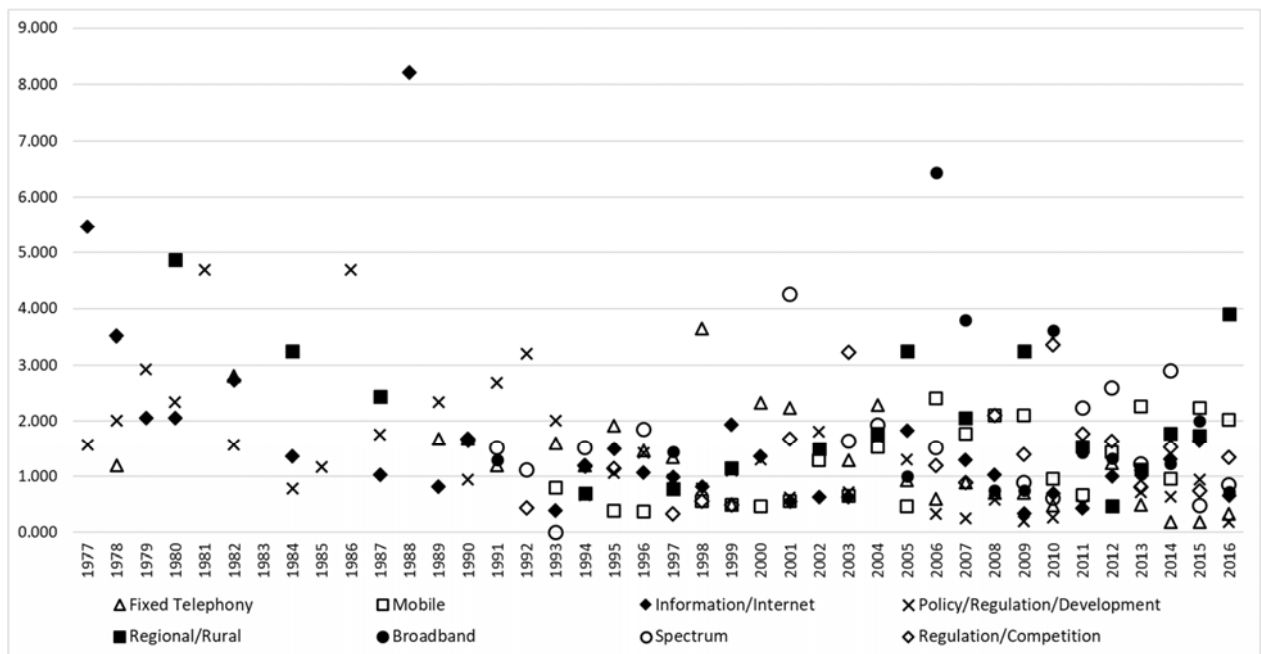


Fig. 8 Changes in key research areas in Europe

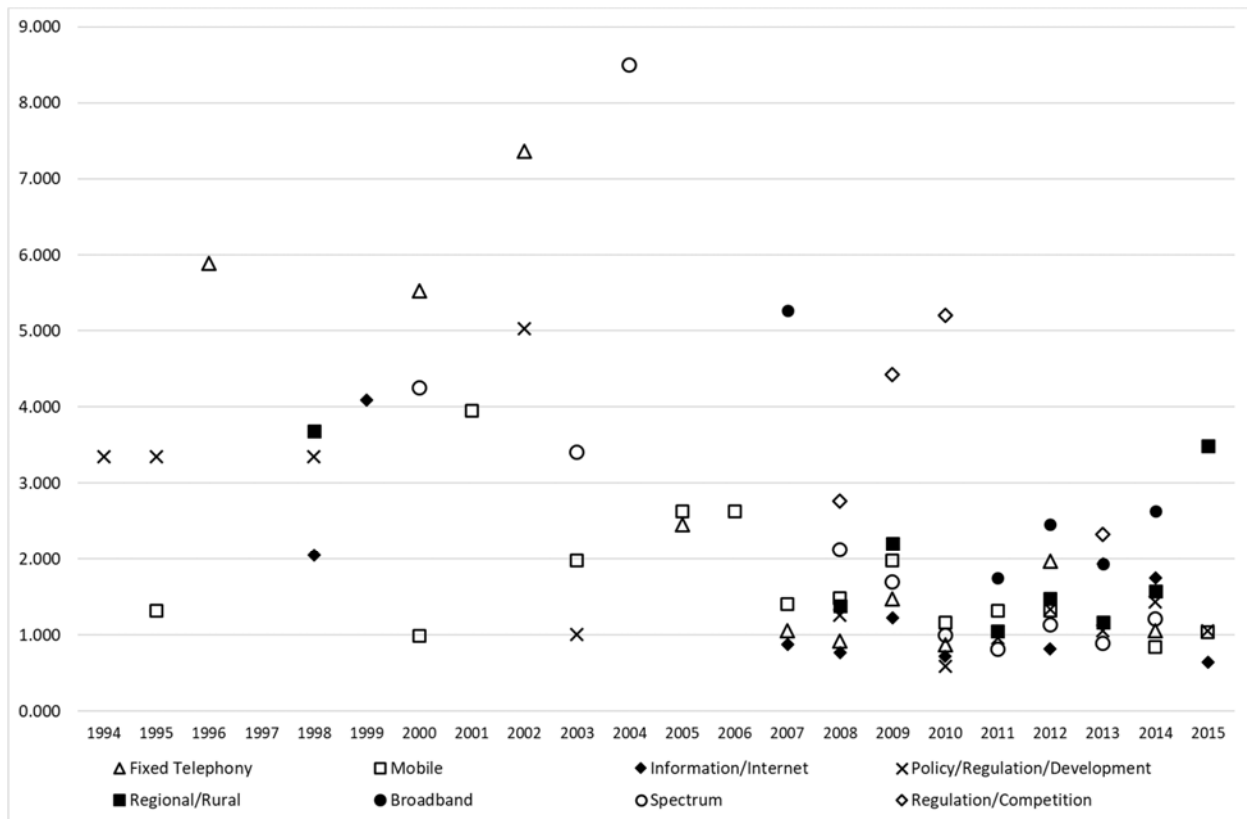


Fig. 9 Changes in key research areas in Asia

From the three figures, common features and idiosyncratic ones are identifiable. First, in all three Figures, the KRI values of Policy/Regulation/Development cluster (denoted by crosses) are spread over the whole periods, implying that regulation and development policies in the telecommunications industry has been a steady research topics in the three continents.

Historically, the communications and telecommunications industries have been regulated globally because competition has often been intrinsically constrained in these industries by the economies of scale effects and limited amount of spectrum (Kwon et al., 2010; Nam, Kwon, Kim & Lee, 2009). In order to provide media and telecommunications services, broadcasting and telecommunications service firms need to roll out their networks and acquire spectrum for transmitting radio signals. In addition, economic development capitalizing on information and communication technologies in both developed and developing countries has been a key

economic policy concern. Therefore, it is no wonder that Policy/Regulation/Development becomes a steady research subject in TP.

Second, another common feature, identifiable from KRI values of Policy/Regulation/Development cluster, is that KRI values of the cluster has declined over time. KRI values of the cluster had been greater than unity up until the mid-1990s in America, until 2005 in Europe, and until recently in Asia. It is interesting to observe that around the mid-1990s when KRI values of the cluster declined to unity, KRI values of the Regulation/Competition (denoted by empty diamonds) began to grow above unity and remained above unity up to now in both America and Europe. This transition reveals that policy focuses moved from regulation and development to market-oriented competition in both continents for the past forty years. In Asia, empty diamonds in Fig. 9 began to appear after 2009, implying that competition policy gained more attention in research from the latter part of the 2000s. In Asia, empty diamonds and crosses coexist with values greater than unity, which is also likely to be caused by wide heterogeneity in the level of economic development among member countries.

Third, as noted in Section 3, in Figs. 7 and 8, the mid-1990s works as a watershed dividing the forty years into two sub-periods. In the first sub-period, crosses and black diamonds (Information/Internet cluster) are frequently observed with values above unity, and in the second sub-period, empty diamonds, empty circles (Spectrum), empty squares (Mobile), and black circles (Broadband) are frequently found with values above unity. Information/Internet cluster, characterizing the first sub-period with Policy/Regulation/Development cluster, seems to represent research topic of early information society, especially considering that key concept words such as information, Internet, technology, computer, and media were frequently observed in the first sub-period. The second sub-period can be defined as a period of mobile

communication and broadband Internet.

Fourth, fixed telephony is an old telecommunications services, so fixed telephony cluster (triangles) is supposed to dominate the first sub-period and fade away in the second sub-period, similarly with crosses. However, in both America and Europe, in the 1990s and early 2000s, triangles have values over unity, which is a counterintuitive feature. It is our guess that in that period, fixed-mobile convergence was an important business and policy issue in the telecommunications industry, resulting in a surge in research concerns on fixed telephony services, networks, market and policy.

Fifth, Regional/Rural cluster (black squares) in America and Europe is a cluster that consistently appear without decay. According to Gómez-Barroso (2017), the cluster is related with research on regional or rural development using information and communications technology, which is a continuing issue for the past forty years in both developed and developing countries. This is also similarly found in Asia.

Sixth, Asia is a mix of countries in various stages of economic development and the continent except Japan began to actively participate in publishing research papers in TP from the mid-1990s. Therefore, it is natural to find a full mix of all clusters cluttered, even though it is possible to see vaguely similar trends found in America and Europe.

5. Conclusions

At the juncture of TP's 40-year milestone, this paper collected abstracts of all papers published in the journal until the end of 2016 and the bibliographic data for each paper from the Web of Science database to implement a text analysis and a bibliographic analysis. This paper extracted 374 keywords from annual top fifty keywords, again extracted from the abstracts of papers, and calculated key research indexes for the extracted keywords. In addition, publication

and citation data, tabulated into subject, nation, and region categories based on author's affiliation information, are used to calculate Theil indexes and key research indexes across research subjects (clusters) and identified several noticeable trends.

First, from the analyses of key research indexes with keywords frequency data and publication and citation data across subject areas, this paper found a common feature that the mid-1990s marked a watershed dividing the 40-year history into two parts: the first sub-period in which old telecommunications paradigm dominated the telecommunications market, industry, and policy and the second sub-period in which new telecommunications paradigm prevailed in the industry, and policy. The keywords of the first sub-period are satellite, television, cable, computer, media, deregulation, monopoly, teleconferencing, telecommunications, policy, ITU, Europe, USA, Canada, Japan, and Australia, and those of the second sub-period are mobile, broadband, wireless, competition, market, network, spectrum, auction, growth, Europe, China, Korea, Taiwan. This changes in keywords also corresponded with the changes in research areas, as illustrated in Figs 7, 8 and 9 and discussed in Section 4. The telecommunications market evolved from fixed services to mobile services, competition increased in the telecommunications industry, and Asian countries emerged as key players in the telecommunications market, industry and policy.

Second, as shown in Table 4 of Gómez-Barroso (2017), paper publication and citation statistics are not balanced across countries, implying that there are wide discrepancies among countries in absolute research performance. When top 20 countries' relative inequality in research impacts were examined in this research, it is found that Canada, Japan, France, and Italia showed high inequality across research subject areas, implying that relatively small number of papers gained a large share of citations. Overall, top ranking countries in publication numbers

such as the USA, UK, Germany, China, and Australia turned out to have even performance across subject areas. In addition, it is found that the difference in research performance across research subjects within three continents has declined over time, even though still there exist wide differences in research performance across subjects within nations.

In conclusion, Telecommunication Policy has been a leading global research platform to share research ideas and outcomes among international scholars and policy makers, and we expect that it will continue to prosper as a leading research platform in the coming new era of Internet of Things and the fourth industrial revolution.

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