World Patent Information 51 (2017) 31–42

Contents lists available at ScienceDirect

World Patent Information

journal homepage: www.elsevier.com/locate/worpatin

Patent citation: A technique for measuring the knowledge flow of information and innovation

P. Sharma [a, *], R.C. Tripathi [b]

[a] GB University-Noida, India
[b] Nehru Gram Bharti University, India

ARTICLE INFO

Article history:
Received 2 March 2017
Received in revised form
11 October 2017
Accepted 2 November 2017
Available online 10 November 2017

Keywords:
Patents
Citation
Diffusion
Information
Innovation
Analysis

ABSTRACT

Knowledge cannot be bound, restricted or categorized. Knowledge is precisely an intangible strength that has a definite economic importance if well utilized and commercialized. Knowledge spillover is an occurrence, which is imaginable but difficult to have an effective measurement of it. Patents citation is a developing concept and has gained momentum in recent past. Patents citation contains valuable data and if analyzed well, may sometimes reveal concealed mysteries of the information flow between countries, laboratories, companies, and universities. Profuse technical research has been conducted on this topic by many scientists. Through these experiments, scientists have tried to show that the innovative information hidden in patents crosses every barrier and is taken by the research labs for its further expansion. Patents citation reveals the diffusion of information and its applicability into many other technical fields which give birth to a new technology. This paper presents a comprehensive survey of patents citation analysis covering and promoting the landmark research done in the field of patents citation, informing readers to consider this important segment of patent document as a field for analysis. Also, this paper presents an innovative methodology for generating patent citation network with the help of techniques of Information Retrievals.

Contents

1. Introduction

Since 1990, theorist and economist have started diverting their attention towards the technical data. Perhaps the world understood the importance of technology and its increasing involvement in

* Corresponding author.
E-mail address: psh.3005@gmail.com (P. Sharma).

https://doi.org/10.1016/j.wpi.2017.11.002
0172-2190/

human life. This was one of the main reasons behind blooming and constant use of patent data for the research work. Moreover, the digitalization of patent data increased its value and usability in the research. Economist, corporate-managers and policy makers were moved by the realization that technology is a major crucial determinant which is required to be studied properly for national competitiveness, endogenous growth of macroeconomics and its acceptability in terms of micro impacts. An important and less noticed section of a patent document is the reference or citation segment. Patents citation reflects the relationship between existing and current patent and previous patents. It is similar to a research paper reference later on and has emerged as a newer tool to identify the strong link existing between the technologies. Patents citation study gained momentum after the heroic effort of National Bureau of Economic Research (NBER) scientists involvement in providing the citation information of US patents from 1963 to 2006 (in different volumes). With the improved quality citation information, it became easier for researchers to utilize the patents citation information in identifying the linkage and changing trends in technologies. Patents application goes through a very rigorous prior art search, with least possibilities of infringing any other patent. These patents citation provided by the inventor prove the originality of inventions. For this reason patents citation information is considered as a reliable proxy to measure activities like technology transfer, technology life cycle, base patents and technology diffusion [1,2]. Patents with high number of citations are of higher quality and are considered as a base patent for any technology, *ceteris paribus* [3]. Though being a very important aspect, the research in terms of patents citation has been very limited. Most of the concrete research in patents citation has been performed only after the availability of NBER data and has gained momentum after year 2006–2007. Models related with patents citation relationship are scarce and the earlier research has been only at aggregate level [4].

Patents citation research has eradicated the traditional method of simple patents citation count. Poisson regression model or negative binomial model, deals simply with citation count data. Being too generic in analysis, it cannot identify the complexity in relationship between the technologies. Patents citation holds enough of data to be utilized in research practices. If assessed and analyzed properly with computational models it can reveal various aspects of technology growth and consequential developments. It can provide information like base patents, technology life cycle, technology convergence, technology mergers with other technology, scientific research converting into real time technology, etc. For all this, we need to first understand, *what is a patent citation*?

Patents citation is nothing but prior work for any invention. Citations are of two types –

Citations provided by the applicant are termed as 'prior art' and are known as 'applicant citation'. Citations which are left over and are found by the patent examiner of the country patent office during patent search are known as 'examiner citation' [5]. The cited material has some bearing to the idea(s) being patented and its claims [6]. Patent holds large amount of valuable data which cannot be perceived by the first look of patent. A vigilant analysis is required to find out this indirect linkage of information with the patent. Inventors generally see the claims and inventive part of the patent with no inquisitions towards the most valuable part of harness patent-the citation. This un-surfed citation data can be utilized in number of ways to the value of patents. Not only the citing patent but also the cited patents have enough relevancies for performing a proper analysis of the technology growth. Patent citations count usually has a direct relationship with the market value of the product [7]. The more citation a patent receives the more commercial value it holds. Patents citation is also considered as tool for assessing the commercial value of any patent. However, they are not the only parameter of assessing the value. Other factors also play considerable role. Narin et al. [8] also conducted a research and concluded that more citation a patent receives the more value it has. But they did not mention any thing about self-citation. Companies may cite their own patent for increasing number of citations of their patents.

Patent citations study is a developing concept in use since past two decades. The literature review of the patents citation theory reveals the fact that the study has been targeted mostly to understand the various technical dimensions of many popping up technologies. It depicts the importance which has been established in the field of research opening various new dimensions and scopes. Delving the research work of several inventors, one may find numerous uses of patents citation in various areas of researches. Majority have been used to understand the technology trajectories *i.e.* the road mapping of technologies and knowledge flow. For instance, Xuan Ting Ye et al. have used patents citation network for measurement of International knowledge flow [9]. Park Y et al. have applied patents citation analysis to find the innovation across industries and other domains for various prospects [10]. Patents are technical data considered as a main indicator for mapping the technical progress in real terms. They provide possible explanation for the birth of technical research problems. Here we have discussed some significant works of researchers which have been cited considerably by other authors. Also it fulfills the need for understanding in brief the pioneer works done in the field of Patent Citation Network (PCN).

2. Patents, citations & innovations: NBER research

United States, National Bureau of Economic Research[1] (NBER) researchers [11] built a comparable framework which neo theorist have widely applied in their research models for obtaining desired results. Kuznets [12] Foster [13] took initiative to introduce the idea of utilizing patents citation information. Their work was further carried away by Griliches [14] to identify those intangible valuables which push forward the economic growth. To achieve the task they utilized the massive US patent data filed at USPTO into a channelized way. They identified the generality and originality in patents, identified parameters, validated these parameters for understanding the technological changes along with the subtle economic issues emerged during the research. Their reckoned research is considered as pioneering in the field of patents citation and has been quoted by more than hundred researchers in their work related with patents citation. Their work is a well comprehended description of US patent database. The aim of their research was to make it widely available for public research use. It contains data of patents filed and granted by USPTO during 1963–2006 in various segments. These indicators show the various changing trends registered in past 44 years of technology. These patents exhibit a range of changes the technology has faced across the diverse categories. The complete dataset which consists of 3 million patents and their citations, totaling to approximately 16 million is open for public research use and is freely downloadable from the official website of NBER.

Their research also discussed some crucial issues which researchers may encounter during the use of these citation data, and suggested measures to handle them efficiently. Two alternate approaches have been used in their methodology –

[1] http://www.nber.org/

(i) *Fixed Effect* approach which involves scaling of citations and averaging them for different categories of patents
(ii) *Quasi Structural* approach which uses econometric estimation to study the multiple effects on citation rates

NBER citation data is a quantum jump and opened new possibilities for researchers to work on innovative studies. Since the data is limited till year 2006, the use of data in new researches work after year 2009 can be rarely seen.

3. Patents citation and the japanese research

It will be important here to discuss the citation work implemented by Japanese researchers in this context. Japanese researcher Jun Suzuki, Schumpeter Tamada, Yusuke Naito, Kazuyuki Motohashi, and Akira Goto in 2000 [15]conducted research on Japanese Patent documents for citation relationship between science and technology. Following NBER research example, a database was created based on patents applications filed in the Japanese Patent Office (JPO) and was named as "IIP Patent Database" to improve resources for research infrastructure in Japan. They developed a patent citation database which consists of citation from examiner as well as applicants. They extracted citation from each patent document published by JPO based on information retrieval technique and using Support Vector Machine (SVM) model. They compared the citation pattern of their data with that of US and Europe patents and found the cumulative nature of innovations. They also analyzed the backward as well as forward citation trend in patents citation tendency and citation relation among the technologies. However, the trend they tested was for a period of only 5 years over the period 1995–1999.

Tamada. S et al. [15] compiled a patent database and formed patents citation network to find out "science linkages" based on text of published Japanese Patents Gazette. Japanese patents are similar to Indian patents in aspect that they do not contain the citation information in the document. In such a case, it became tough to find the relationship between science and technology. Japanese researchers constructed a patent database of patents filed and granted in Japan covering 600 categories totaling to 880,000 patents data having patent references as well as non-patent references for each patent. From this data they created a 'science linkage index'. This science linkage index gave them astonishing results and suggested that the process of new development in technology depends on the nature of technology. Because of patents citation specification not being mandatory to file in Japanese patents, they created an automated program to tackle this problem and generated citation for each patents. A program with very high precession rate approximately 98% was created, extracting automated citation for each patent based on the abstract of the relevant patents. They performed the task on patents filed during 1995–1999 and identified the science and technology linkage between 600 categories. This research work inspired us for our present research work since Indian patent document lack the citation information similar to Japanese patent documents. We applied techniques of information retrieval (IR) to generate the citation network for Indian patents and performed the citation analysis.

Nanba. H et al. [16] created a framework for patent retrieval for patent search on the basis of techniques of IR. It not only retrieves related patents but also the published research papers and scientific literature related with the patents. They applied the IR techniques and obtained relevant cited papers for patents in two steps:-

i) Identifying the key terms from patent documents, and
ii) Extracting the bibliographic information from the extracted keywords.

They conducted several experiments which can be divided into 2 major steps:-

In first step they extracted 42,073 words from the patent document and extracted citations from them through computational approaches. In second step they extracted manually 3000 terms from patent documents containing bibliographic information. Precision rate of step one was higher than step two and the recall rate was comparatively lower in the first step. For an efficient IR model, a higher precision rate with lower recall rate is vital. They constructed an IR model which extracted citation information for patents along with the relevant scientific literature based on the technical key terms present in the patent documents.

In general patent citation analysis can efficiently contribute in finding new knowledge, and in managing and using the surviving knowledge wealth. Patent citations study can be categorized into three major research works on the basis of its applicability with network science study:-

i) Patents Citation study for assessing Technological Trajectory *i.e.* technology diffusion and its further extension for technology road mapping.
ii) Patents Citation study for measuring the Knowledge flow
iii) Patents Citation for analytical studies

All these application of citation analysis rely on the consensus among a large number of citing authors regarding the influence of and relationship between scholars and scholarly works. Three categories are explained below along with the research done in the specific areas.

3.1. Patents citation and Technological Trajectory: economic value of patents

Technological trajectories can be defined as the path by which innovations in a given field occur. The growth and development of technological trajectories can be well explained with the help of interplay between scientific advances, institutional variables and economic factors [17]. In this section we have clubbed and summarized various research works of patents citation to see how it fits well in explaining the technology trajectories.

Hu, A. G. Z., & Jaffe, A. B. [18] explains the technology diffusion from developed countries like USA and Japan to less developed countries like Korea and Taiwan with the help of patent citations. They suggested a framework based on patents filed and granted by USPTO to inventors living in these specific four countries. They found that knowledge diffusion from Japan and USA, to Taiwan and Korea has diversified forms which clearly demonstrate the roles of technology, knowledge degeneration & knowledge diffusion over time. Korean patents cited more Japanese patents as compared to US patents, whereas Taiwanese patents have citations equally from Japan as well as from US patents. Korean patents cites more Japanese patents (almost two times higher) than that of Taiwan patents citing Japanese patents. Also they found that technologically patents are cited from their own technical fields rather than any other technical area. Intra-citation diversity for patents was found to be very high. *Bulat Sanditov* in his research applied technical trajectories for explaining the concept of patent values [19]. He proposed a model based on statistical model of *Polya urn* and showed that it fits equally well with the patents citation distribution. He further argued taking into consideration the technical change theory that innovation value depends on the change of technical directions and patents citation leads to the path of dependency concept in the growth of technology. Innovations well fitted and placed in the current technical scenario have a higher value and plays a role of leader in giving new shape to innovative growth. The higher the

value an innovation has, it becomes a starting point for future innovative technology which further increases the value of the base technology. He proposed a model based on statistical model named *Polya urn* with linear and non-linear distribution. His model fits well in the patents citation theory with linear distribution of citation were in confirmation of his hypothesis and non-linear distribution of citation fits well for the whole range of citation distribution. *Park. Y* et al. observed the changing trend of technology in industries and observed dynamic behavior in their changing pattern [20]. They also examined the technical relationship existing between these industries and their respective position in the relationship. He utilized patent data of US patents filed in USPTO and applied patent citation analysis using few algorithms to identify the relationship. He recognized the major characteristics difference between the industries focusing on conventional industries as well as science based industries. He applied patent citation analysis on taxonomy of industries and investigated the difference in structural and dynamic form of innovations. For measuring the stock flow of technical knowledge, operational indices were defined in his research. With this kind of analysis he was successful in identifying the sector based characteristics of various industries. *Fontana R.* et al. [21] used patents citation network to study the dynamic change in the field of Ethernet. They first considered the evolution of local area network (LAN) and then focused on the important inventions within the area of Ethernet. Thereafter, they focused on the patent connectivity structure to build the technology trajectories of Ethernets.

Lin. Y et al. used the patents citation network analysis to study the key influential patents of automobile industry and technology which could be considered as a base for these automobile industries [22]. He used patents citation data and applied the concept of network analysis to reveal the backbone technical invention and technology diffusion which later became part of the new modern technology of automobile sector. He used Social Path Network Analysis (SPNA) algorithm to identify the evolution path of technology through patents citation data. The important technical invention granted as patent, work as a hub in the evolution path and become the base foundation for further development. They used figures, graphs, charts and interpretation of each graph to reveal the technology trajectories segmenting from base patents showing technical divergence and convergence over the time which became part of the modern world automobile industry. *Erdi. P* et al. presented a methodology to identify patent clustering *i.e.,* technological divisions and subdivisions, and forecasts about the progressive variations and changes in the structure and shape of the clusters [23]. An indicator, named as citation vector, is created for describing technical and scientific progress to reveal the fact, that a patent cited by other patent may have relevancy as well as non-relevancy from the same technical field. By implementing the clustering model, they were able to perceive the innovative combination of technology and convergence, and forecasts initial new technical clusters. His predictive analytics tool is a strong recommendation for supporting decision making policy procedures in science and technology, and can support in gaining recommendations for action. *Martinelli A* et al. [24] investigated the tele-communication switch industry with the help of patents citation network analysis. He applied a new theory stimulated by genetics known as 'genetic approach'. His research has successfully outlined the origin and evolution of modern knowledge. This genetic approach is processed by computing the patent's persistence index, *i.e.*, disintegrating patent's information by relating the *Mendelian Law of Genetic Inheritance*. It pulls the knowledge that more a patent is related to descending patents, more it moves upcoming technical growth and therefore its involvement persists in the technology. Result demonstrate that the technique projected is effective in decreasing the number of both 'nodes' and 'links' measured. Furthermore, their system is indeed fruitful in classifying technical gaps where previous knowledge is not relevant for current technological development.

3.2. Measuring the knowledge flow & spillover

Knowledge is something which cannot be bound, restricted or categorized. Knowledge is precisely that intangible strength that has a definite economic importance if well utilized and commercialized. Knowledge spillover is an occurrence, which is imaginable but difficult to have an effective measurement of it. According to the definition propounded by *De Bondt* et al. [25], 'knowledge spillover' concept can be considered as a leakage or involuntary nature or voluntary exchange of technological knowledge spread across time. *Nieuwenhuijsen* et al. [26] offered an alternate definition for knowledge spillover, and labels it as the situation, in which one entity benefits from R&D of another entity without paying any fees or compensation. The knowledge spillover is shown with the help of patents citation network. The network uses critical node, topological investigation and core network analysis for explanation. The objective is to perceive the transmission of knowledge growth between the countries, institution and companies. The objective is achieved by recognizing key players of technology, the pattern of knowledge transfer and the competence of knowledge transmission. *Bernstein and Nadiri* [27] categorize knowledge spillovers as horizontal knowledge and vertical knowledge. Horizontal spillovers occur between opponents, and vertical spillovers take place between firms in various industries. There already subsists a wide literature about the significance of knowledge spillovers as a feature defining the optimum R&D policies of firms. *Scherer* [28]; *Duguet. et. al.* [29]; *Kaiser* [30] directed a series of studies integrating patents citation with survey data and R&D and came to conclude that patent citation analysis can clear the picture showing the dissemination of knowledge from one source to another. Literature review of contemporary years shows that patents citation analysis was deemed to be a study involved with statistical investigation and quantitative features of technology innovation. Many researchers used citation data analysis for measuring the knowledge flow from one domain to another. *Hall* et al. [31] explored the statistics from analysis of inventors to prove the fact that patents citation work as a proxy for knowledge flow and are correlated with each other.

Tijssen et al. [32] provided empirical facts showing that patents citation analysis provides systematic linkage of quantitative data which provides contextual information concerning nation and technology specific features in national and international frame showing technology linkages and knowledge flows. *Verspagen* [33] evidenced the knowledge flow as showed by patent citations between various regions of Europe. *Alcácer* and *Gittelman* [34] specified the implications of using pooled citations may suffer from biasness significance level. *Bacchiocchi* et al. [35] showed in his research, the cross border diffusion of technical knowledge using patent citations data. *Pinheiro* et al. used patent citations data of USPTO to study the patenting activities of Brazilian and American activities to understand the involvement of Universities in patenting activities. Using patents and patents citation statics he found that in spite the fact that Brazilian Universities are filing more patents than American Universities they lack in certain aspects. He has wisely utilized the patents and patents citation data in his work. *Sampat B.* [36] conducted experiments to identify the economic value of patents. He used patents citation network analysis to find out whether University research is converted into patents and licensed, and if so then what economic value they add to the society and research practices. He used data of two US research

Universities to find the same. He found that the University patents are licensed and the same is affirmed by the number of citations, University patents were receiving, but it could not provide any information on the economic value contribution of these patents. *Von Wartburg* et al. [37] explicated about utilization of patents citation data at various levels and worked to measure the progress of invention. He believed single stage analysis of citation is more proactive than multi stage application of patents citation data, which can reveal technology path or lineage and had used indirect citations and bibliographical coupling. He made use of network analysis and bibliometric techniques with patents citation data and developed an algorithm which helps in clustering technical subfields. He further added patent analysis through value adding and tracking technologies change through multi-stage analysis of patents citation rather than one step citation.

Lee Yong-Gil et. al. [38] in his experiment worked on patents citation data to identify the technical importance and contribution in terms of patents of Korea Institute of Science and Technology. They filtered out patent data from USPTO granted to KIST and used zero inflated model to handle excess zero data. They used two main characteristics, one geographical characteristic and second invention related characteristics and found that Korean patents have more influence from Japan. The Korean inventions have more dependency on Japanese technology than any other country. *Criscuolo* et al. [39] evidenced the fact that the patents citation differs across the borders. He tested the information with his research conducted on US patents and European patents applying various economic models to find the probability of citations by examiner and inventor. He found that geographical distance play an important role in patents citation and it reduces the probability of knowledge flow. Not only geographical distance but also time and cognitive distance plays important role in citations. His identified parameters of patents citation were missing from the previous theories on patents citation. He found great variation in citing patterns of US patents and Europe patents and further propounded that inventor citation should be given more weightage than examiner citation because inventor citation is more close to real citation of the invented work and therefore the inventor citation should be only considered for measuring the knowledge flow and knowledge spillover rather than discovered by the examiner citations. *Hung* et al. [40] showed the power law distribution through his patent citation network study of Radio Frequency Identification. The obtained results suggested that patents citation network can be considered as a small world in itself where the innovations are closely related to each other which can be termed as 'preferential connectivity distribution' behavior of patents. The power law distribution suggests that a few patents have more connecting patents compared to majority of the other patent connections. Their research identified high between-ness centrality of patents and found that 81% of the patents citation bears a relation with the patents having high number of between-ness centrality. This helped in identifying the key patents, for managers and maps their patent activity to bring them in picture with the patent landscape of the technology. *Kihoon Sung* et al. [41] concluded from his research that innovative technologies are the outcome of technology union in industries. They adopted a refined approach for the measurement, changes and level of technology convergence using patents citation information. Technology convergence is a phenomenon where technologies find place with each other and lead to a new area. They developed an indicator based on forward and backward citation details of patents and measured the degree of convergence as an association of a technology with other and assessed the originality maintained in the association.

Chen et al. [42] used Pareto principle to identify the difference between the original patent network and the comprehensive patents citation network. He illustrated the difference with help of LED as an example. He applied Freeman vertex between-ness centrality model and Johnson Clustering for hierarchy to find the difference between the two patent citation networks. Freeman vertex between-ness centrality model showed distinct results for patent with more new links to other patents. These links have a different kind of clustering compared to the other model. *Ou Yang. K* et al. [43] research presented a new model known as New Comprehensive Patent Analysis (NCPA) model. It integrates technology with management parameters and builds a patent family dependent on basic technical patents, identifying the key patents from the patent family, utilizing patents citation information to collect basic understanding of patented technology, giving new dimensions for the under developed technologies, and combining TRIZ method to identify the technology value and its performance. This model has been tested and now applied in most of the real time products. *Chang. S. B* [44] in his research used patents citation information to establish an effective model for the technology development. He proposed a framework, using matrix to know the technology strategy of any firm and its support to the business objective. If the firms belong to same category in matrix their technology capabilities is identified to be similar and are more interdependent in relation. However, if they do not fall in same category their technology capabilities are highly of different nature and have less or no interdependency. *Xuan Ting Ye* et al. [45] through his tested model showed reuse of scientific and technical information. Knowledge flow of technology is important for continuous growth and extension of science and patent data has facilitated this. The available patent data information crosses the border, corresponds and interacts with new inventions to give new strength and dimension to the technology. Thus patent citation information works as a key carrier of knowledge flow. *Ribeiro L. C. et al.* [46] presented a methodology which can show a global innovation network. They used patent data from USPTO for year 2009 including 167,315 patent information's from the entire field. They showed the citation linkage between scientific and non-patent references. The methodology shows how the technologies cross national boundaries and interact with multinational companies and industries. Their data and graphical features of model show the flow of technology and insight to evidence taxonomy of global network of innovations.

Luan C. et al. [47] conducted a study with the help of patents citation data from Derwent Innovation Index to find out whether important inventions are more technically diversified. Through his experimental results, he proved his hypothesis, that significant inventions have diverse nature in terms of individual inventions. Focusing on core technology areas could be a great step in creating significant invention considering the R&D activities. *Yoshikane. F.* et al. [48] through his experimental result focused on the patent classification variation for backward citations. He proposed that a patent which is a mixture of various technologies deems the status of an important patent and receives more citations. He clarified the diversity of classification in backward citation and forward citation for patents belonging to Japanese patent. He propagated that backward citation diversity can be utilized for grouping often cited patents and less cited patents.

3.3. Patents citation for analytical studies

With the influx of better-quality patent data and its easy accessibility, patents citation analysis has received much attention and importance in recent years. Simple citation count has become an obsolete technique and is considered as a weak measure in evaluating the importance of any innovation. Patents citation analysis provides a comparative study such as identification of base

patents and key technologies, investigation of the relationship between science and technology. Citation analysis has helped not only a patent analyst's researcher but also to non-patent specialized person, be it an economist or statistician to understand the hidden secrets of technology and its exponential growth [49]. A detailed and intense knowledge about the cited patents provides a better understanding of patents as well as facilitates and strengthen the argument in support of analysis results. Patent analysis incorporates all the patent data like patent number, application number, inventor, assignee, country, classification code, title, etc. [50]. Analysis of patent requires an advance merging of a patent database with a scientific literature database. Analysis can be worked on from two different standpoints. Either taking a patent and finding out the scientific literature it has cited from the scientific literature database or taking a publication and finding out whether it has been cited in patents or not.

Narin et al. [51] identified certain techniques which can be utilized for study and analysis of bibliometric data of patents. He came to conclusion that patents citation analysis is one of the most effective methods for analyzing the data compared to other methods. He defined patents citation as number of citations a subsequent patent holds and even shows a linkage between them. Citation per patent show the value patent holds. Patents citation creates a link between patents, not surely of same class of same nature, but which has contributed in forming the basis for the subsequent technology. The linkage between the patents is same as citation/reference connectivity between scientific papers. But patent citations contain more citation of patents as well as few of research papers.

Park Yoon et al. [52] identified limitations related with patents citation and proposed his own approach for dealing with citation analysis. He identified that it is very difficult to understand the complete relationship between patents because citation links exist between two patents and the citation analysis only show this link. He further mentioned that scope analysis is very much restricted because patent citation takes into consideration citing and cited patents information only. Also citation analysis considers only frequency of patent citations and hence have nothing to do with the internal relation between patent *i.e*. linkage relationship on the basis of technology. This may sometimes produce superfluous results which could be misleading. It is a time consuming task because of the exhaustiveness involved into it. Recognizing the shortcomings of patents citation, he proposed a network based patents citation analysis as an alternative approach for analyzing the citation relation of patents. Patents citation has developed certain indicators over the time for analysis as told by *Hirschey & Richardson* [53]. These indicators are related to the intrinsic value of patents and are used as a tool for the evaluation of patents during licensing, estimating the market value of the patents during negotiation of patent infringement. To name a few are central impact index, citation per patent, current impact index, technical impact index, technology life cycle and growth, and so on. They also worked to identify the growing technologies across borders and find a way to merge with them [54].

Meyer, [55] propagated his view through his experimental results which explained the direct patent counting related with basic research. It could be one of the possible gauge scales to measure the development of basic research in science and its applicability in industries. Research supporting agencies and their linkage with industry patented technology was observed on a high note. The linkage between science related technology convey an idea that the knowledge flow is directly taking place from academic research towards industry in form of citation relations which exhibits between science research papers citation in patents. *Michel J.* et al. [56] through his research gave an important message that patents citation analysis can be performed only with the help of strong understandings of patent search reports. He showed through his research that though patents citation has a common objective behind them, still they vary to a great extent regarding the reports. This difference in search report may have some effect on the patents citation analysis. *Huang M. H.* et al. [57] worked to explore the use of citation coupling exploration to plot a patents citation map. They explored the relationship between companies and industries in Taiwan and ongoing research and development in the technologies used in the country. They used a multidimensional scaling for plotting patents citation map, which showed association of various groups of invention. The result reveals greater similarity in companies of semiconductor domain. A patents citation map was constructed from cluster analysis and multi-dimensional scaling results. Map revealed interesting results. It was found from the map, that companies dealing with peripheral equipment's like monitor, scanner, printer, image processor were placed near to midpoint, in the main section of information technology industry. Semiconductor industries were positioned far from the other companies. Studying the relationship between the companies from the citation analysis it was concluded that, semiconductor industries were more closely connected to other industries. Citations coupling showed that IT industries can be subdivided into sub clusters of peripheral hardware's like scanner, image processor, etc. The citation map showed that semiconductor industries have a high correlation coefficient which evidences the bonding between them. The division between IT, electronic and communication industry is very thin and show their strong linkage and overlapping in few cases. This shows that there is no division between these industries and they are totally dependent on each other. Citations coupling can be a good research tool in exploring the relation between various sectors and periodical articles. It can also be used to sketch the patents citation map to visualize the association between various sectors, industries and companies.

Huang Z. et al. [58] performed test on patent data filed in USPTO office to study the development of Nanoscale Science and Engineering (NSE). He utilized the patent data filed in USPTO irrespective of their origination but related it with NSE. He used keywords related with Nano Science to identify patents related with the said technology. The objective was to find the contribution which was made in the field of NSE by companies, research laboratories, Universities, institutions and individuals. They used visualization techniques along with statistical experimental models integrating both. They found that though the technology is growing but with very slow pace. The top technology which has grown considerable in comparison to NSE was chemical, pharmaceuticals and semiconductor technology. They took the research data of the period 1976–2002 and their citations from NBER citation data. They showed the potential of information based search and visualization technologies to study the transfer of knowledge between countries, trends of development and incremental changes which happened across the time. *Tijssen* et al. [59] research objective was to find out the Dutch contribution to science and technology. They used USPTO data to find out patents filed by Dutch inventors or their involvement as a researcher in foreign patents. His results provided new experimental indication showing that patents citation analysis produces measureable data which further provides information flowing across nations as well as sectoral knowledge factors in domestic and international arena. *Chang* et al. [60] proposed a model for retrieving relevant patents from USPTO database. His model focused on business method technology. Objective of his research was to identify indicators which can be used to find out the basic patents of this technology. These indicators will help to understand the relation of basic patents and the technology diffusion. He applied linear citation relationship for creating indicators

for finding basic patents. They not only considered direct citations but also gave weightage to indirect citations. They conducted study on 10,386 patents granted under the category of business method from USPTO. 157 patents were identified as base patent under the category. Through lineal linkage equation a matrix of 157 by 157 was generated. This matrix was used for cluster analysis. This study found that business method patents are splitting into two specializations one streaming towards marketing technology and the other focusing on data security. *Meyer M.* [61] research work is related with patents filed in the field of Nano Science. He explored the citation impact of Nano Science patents. He found in his study that patent which cites more technology and scientific papers have a better performance compared to those which cites other patents. Their citation of scientific literature brings them more closely to the definition of originality. Also it was observed that these scientific literature are further cited by the subsequent patents. These pioneer patents become base patent for the further technologies and have more value than other patents. His analysis additionally determined the incidence and the significance of the bandwagon effects motivating the expansion of science and technology. *Wang X.* et al. [62] provided a view of technology progress through PCN. Patents citation analysis, social network analysis and visualization method were used to study the patents relation of fortune 500 countries. They utilized the Derwent Innovation index related with Patent data of fortune 500 countries. Based on this, information technology was categorized in different set and their relation was studied. It was found that the technology is separated with very minute lines and has no thick divisions between them. He proposed a method of constructing long patent citations network and also used co-citation network for the analysis. Technologies in industries are coming closer and forming new methods of doing work. *Cho T S.* et al. [63] conducted experimental research with the help of patents citation to identify core emerging sectors of Taiwan during 1997–2008. They utilized USPTO patent database and filtered out all the patents of Taiwan along with their citation information. They also wanted to measure the citation which Taiwanese patents have received during the said duration. They performed analysis of the main indicators of important holes and degree of centrality. The linkage between patent classes to identify the structure of connected systems were measured. They collected 42,650 patents related with Taiwan and 282,714 citations of these identified patents which included cited as well as citing patents. The objective behind this experiment was to suggest government, industries, and research institutions to pick up which technology for investment can lead to high growth as well as strengthen the Taiwan technology global competence. Each patent class can be recognized by its input in the central technology as an outgoing technology or an incoming technology flow. Network analysis display the growing and developing technologies of IPC categories. His study showed that with the help of centrality measure and holes pointers of PCN analysis of IPC categories, one can identify the core and upcoming technologies.

Gerken J. et al. [64] used example of automotive industry to identify the novelty in technology. He used semantic patent analysis technique, a new model to identify inventions carrying high level of novelty. Following the conception of patent novelty, the semantic patent analysis model was altered to match with the novelty factors. He emphasized that semantic patent analysis can remove the drawbacks of existing methods for identifying the inventions carrying good level of novelty. Semantic information has the capability to enrich technology monitoring while decreasing costs and ambiguity in the identification of inventions of extraordinary novelty. *Mahdabi P.* et al. [65] in his research checked whether the idea in the patent application is novel and does not include patents citation. They proposed a method for query modeling estimation which utilizes the citation links for a virtual significance feedback set and constructed a topic dependent citation graph, starting from the initially retrieved set of feedback documents and utilizing citation links of feedback documents to expand the set. Further they have identified the important documents in the theme reliant citation graph using a citation analysis measure. Thereafter, citation graph is used for the term dissemination of the documents in to estimate a query model by identifying the distinguishing terms and their respective weights. They then use these terms to expand the original query. They investigated the effect of several parameters on the result of the proposed method to check the efficiency of model. The experimental results demonstrate that the proposed approach significantly improves the recall over a state-of-the-art baseline which uses the link structure of the citation graph.

Erdi et al. [66] presented a model and an algorithm to study the evolution of a technology. His model made predictions about the technologies by going through a patents citation data network analysis. A citation vector is created which work as a predictor, for each patent. Vectors Coordinate is proportional to the frequency of their being cited by other patents of same technology. Changes in this value of citation vector coordinates reflect the changing value of citation. Showing that a particular technology is gaining more importance. Thus, they merged vectors analysis with citation network to predict future technologies. *Yoshikane F.* [67] focused on the classification pattern of patent and examined the diversity involved in the classification and their citation by other patents. From the citation pattern, it was found that the citing pattern according to the classification had been constant throughout *i.e.*, a class of patent citing only a specific class of patent. They examined the diversity of citing patents from two different perspective (1) strength of connection between patents is constant and (2) increase in number of citations over time for growth in citation fields. From the results they derived the conclusion that patents citation is not a fixed pattern and changes with the time.

4. Francis narin contribution from patents citation to scientific literature

Literature review remains incomplete without mentioning the contribution of Narin, F. et al. 1997 [51] in the area of patent citation network. He gave a new concept through which basic science can be mapped with government and industries. Narin published over 50 articles on the linkage of science, observing citations connections between elementary research and intellectual property in various subject areas, such as Agriculture, Eye care Technology, Biotechnology and Human Genome Mapping. Working together with researchers from all domains around the globe, Narin devoted his career to the study of the networks between citations and patents, and gauging the economic power of countries and companies through their scientific and intellectual property competences. Narin and his colleagues were competent to corroborate that basic science supports not only a country's educational and scientific capability, but also has a straight effect on its economic affluence through the conversion of science into products and services.

One of the illustrations given by Narin in his article was used by Google in its page ranking algorithm. The association between his own citation influence methodology and the development of Google page ranking algorithm is something which adds to the credit of Narin's innovative research. The “citation influence methodology”, given by Narin in 1970s, shows the citation links which exist between research journals, citation linkage between specific journals and special journal publishing papers on any extraordinary focused technology. This linkage of journal form a

network among them shows how a technology links itself with another technology. This methodology was later used as page ranking algorithm for internet search on Google. Page ranking algorithm of Google is a unique creation which distinguishes it from other search engines and leads it to top. Patent citation studies gained momentum after the pioneering work of Narin. *Leeuwen* [68] developed a research program to find the relation between science and technology by performing patent analysis on the same line of thought applied by Narin.

Lewison [69] evaluated the effect of funding on gastroenterology research using patent analysis in U.K. Patents citation information can be used as a proxy tool for measurement of high level knowledge flow on the basis of patent citations. *Chakrabarti* et al. [70] tested the interlinking defense related patents and their effect on civil sector. *Chen and Hicks* [71] studied the tissue engineering growth to analyze the relations between industry and academic research. *Verbeek* et al. [72] identified the effect of patents citation on research in the area of Bioinformatics and Information Technology. Citation pattern model shows the knowledge dispersion. The development of knowledge in citation network augmented their study and understanding of knowledge flow and analysis and interpretation through patent citation.

The page ranking centrality measure was further used by *Bruck* et al. [73] to study the chronological development of the USPTO database. They revealed that by accepting a citation-based recursive ranking technique for patents the advancement of new fields of technology can be outlined. Specifically, they demonstrated that the laser/inkjet printer technology emerged from the recombination of two existing technologies: sequential printing and static image production. The dynamics of the citations coming from the different classes illuminates the mechanism of the emergence of new arenas and give the opportunity to make forecasts about future technological development. They developed a PL/SQL program to compute the PageRank significance of each node using the innovative iterative algorithm.

5. Study of patents citation evolution with network science

The general objective of the patents citation study is to gain a better understanding of the advancement and organization of technical relationship between patents, and to examine current patenting performance so as to gain perception into innovation policies Finding the way patents are connected is the easiest way to create an image on a large scale pattern and processes associated with the collective dynamics of innovation as it evolves. Thus, patents are used with each other patent through a network of federation's patent. You can put on a large scale to this dialogue invention many interesting questions: What is the global organization of interactions between innovations? Is this a repeatable pattern? How do they relate to similar types of innovations? Do you respond to these pattern dependent rules for the history or are writable by simple models? Network science seeks to measure from the beginning and describe several relational structures found between the nodes. Network approach can well be utilized to answer these questions. In network science structure patent is used as a node, research publication and other patents as links that can be cited. Network science is capable to work with situations where limited relationships are significant and mixed. There are ways to illuminate the complex relationship between patterns and arrangement.

Network science has three broad, continuous and permanent objectives [74]:

(A) to measure the structure of the network and the pattern of links between nodes of the network.
(B) to understand the development and growth of the network and its relation to the structure of the network
(C) to recognize how the joint behavior of entities that are associated in a network, bring variation to the structure.

It highlights the potential importance of heterogeneity and local relations patterns in determining collective behavior. Network-based patent citation analysis can provide detailed information on the innovative process. The analysis performed [74] shows the likelihood that a patent is cited more number of times when it is new. It also has a slow long decay process, the power law concept, suggesting that some patents retain their influence over very long periods. The continued strength of some older patents indicates that few common patents have a potential to recover after a long period of time. This dependency on patent age is an evidence to the very non-linear nature of innovation. From it we can make out that innovation can be classified into two kinds;

- Incremental innovations which follow a standard patent models and move ahead on a fixed set of path.
- Unpredictable innovations that may be radical in behavior and may cite any patent contributing in their growth.

Probability that a patent is cited again and again, depends on the age of the patent and citation extinguishes with age a patent. The science of networks also reflects that “dormant” patents are being quoted sometimes after a long gap, perhaps meaning that innovation is not only through the progressive development of progress, but also by recycling to the technology so far neglected in innovation.

The analysis of patent citation networks shows that the number of patent applications has increased rapidly in recent years. Also the citation pattern have changed. The average citability of a patent increases rapidly with the number of times it has already cited, showing the preferred system, or “richer rich” phenomenon. The concept of network science can be a fruitful way to explore the connections between different technical areas. A measure of the “technological distance” network could be used to classify the patent alternatively and quantitatively, classify patents and to evaluate the state of the art. The application is a good source to find patches of patents and patents thickets. Network-based measures of local structure may be able to distinguish between the average thickness of patents and patent areas of competing technologies. This approach helps distinguish between groups of socially valuable patents and cross-licenses that are anti-competitive.

Valverde et. al. [75] in his research, showed the importance of network analysis used by applying the concept of network science. He took CT commonly known as computer tomography that uses x-rays for producing pictures of internal organs of human body opening as a test set. They have been characterized as community modularity of standard detection procedures, a tentatively network, which has several limitations. Researching this functionality suggests a good relationship between topological components and things defined in patent documents. The occurrence of correlations is a natural consequence between the patents specialized in similar functions. It could also reveal the arrangement precise innovation landscape. The new patents can be understood as comprehensive solutions that discover the neighborhood of the above creations. This vision provides a measureable image of the topology of technical backgrounds.

6. Patents citation network

In the previous section, we presented a review on the patents citation and its several network applications. This part of the paper

presents an innovative method of creating patents citation network for a query patent. For generating patents citation, java libraries and techniques of information retrieval were applied. With these libraries we were successful in mapping the cited patents on time scale. This helped in finding the base/route patent of any patent. Fig. 1 shows a simple patents citation generation. We started with a patent '*A*' and generated its citation through the methodology of information retrieval and keywords matching. A threshold of 85% similarity was set. Patents below the threshold limit are dissimilar in nature and were not recognized as a cited patent. The date of application determines it as a forward citation or backward citation. Similarly identified patents (above the threshold in the first process) are used further in citation graph generation. In the next step, citation for these identified cited patent of first process are generated using the similar methodology. Citation for these identified cited patents of previous step were found through the same step. This loop process chain of citation generation continues till all the patents have received citation and the database is exhausted from search. The patents are arranged on the graph according to chronology. Fig. 2 shows a citation map of the first query patent *i.e.* patent '*A*' arranged chronologically. The blue dots represent nodes and the connecting lines represent vertices.

In Fig. 1 above we can see that the patents which hold a similarity beyond 85% on the basis of keywords used in the abstract, description and claims of patents are traced and a roadmap of development is created. Patents were filtered from the database on the basis of International Patent Classification (IPC). This reduce the search time and optimized the result. Patents belonging to a particular IPC class were used for finding similarities between patents. Fig. 2 reflects individual patents citations graph of a particular patent with all the identified patents in first step. Each patent inline identify their own citation with the method of information retrieval used for finding citations for the main patent.

For creating the network graphs shown in figures Java Universal Network Graph Framework (JUNG) version 2.0.1 was applied. It is an open source library which provides language for the analysis, modeling, and representation of data as a network graph. It is developed on java platform, which enhance its performance with built in capacity of Java API and other libraries. It provides a method for graph annotations and relation with other entities and metadata. These feature helps in analysis of complex data. It is widely used in implementing number of algorithm for graph theory, social network analysis, data mining through visual representation, clustering, measuring centrality, network distance between nodes *etc*. Using its filtering mechanism, unwanted data can be removed from the graph and analysis can be performed on the core data. A combined network graph is created in Fig. 3 showing the patents citation network for a particular query patent. All the individual roadmaps are merged together in relevancy with the timeline to bring forward a combined network citation map. The extent to which a patent cites another patent is a measure of similarity between the citing and cited patent. It provides a linkage between patents on the basis of reference similarity.

7. Discussion

Patents citation study evolved since 1980 and the literature available for research work of Narin and Noma can be considered as pioneering work. With the availability of patent citation data the study gained momentum and now there is huge number of published articles and research papers available on this subject. We can divide this section on patent citation into four phases of growth. The classification has been done on the basis of usage and the complexity answered by the researchers.

First Phase: The initial phase of patents citation consisted of researcher's proposal. These proposed elements highlighted the concept of patents citation and its usages. Perhaps with the non-availability of digital patent data much could not be done in this area.

Second phase: In this phase, researchers focused on the science and its linkage to the technology with the help of available patent data. Digitalization and availability of USPTO patent data led the things gain momentum. *Narin* et al., introduced linkage between science and technology through patents citation of scientific papers.

Third phase: Availability of patent data and NBER citation data for research purpose, motivated researchers from different fields to use the data and to identify the various trends followed in innovation and the changing trend of technology. This phase also found new concepts like measurement of technology spillover, technology diffusions, originality and generality in patents. Various parameters were introduced which formed the basis of further research in patents citation. This phase used patent references for apprehending the various relationships and course between

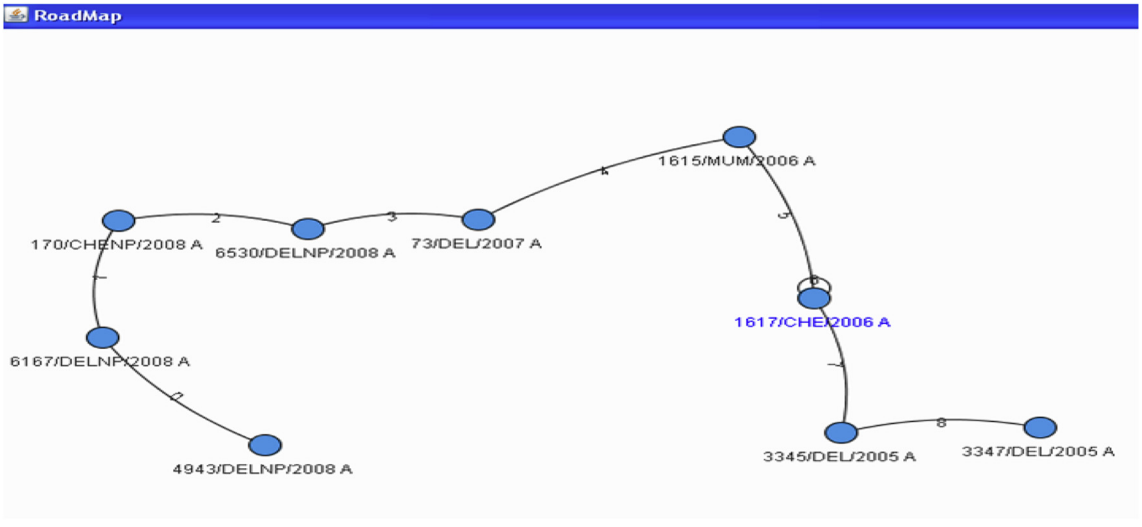

Fig. 1. Identified patent similar in nature found through similarity in keywords used in drafting abstract, description and claims of a patent.

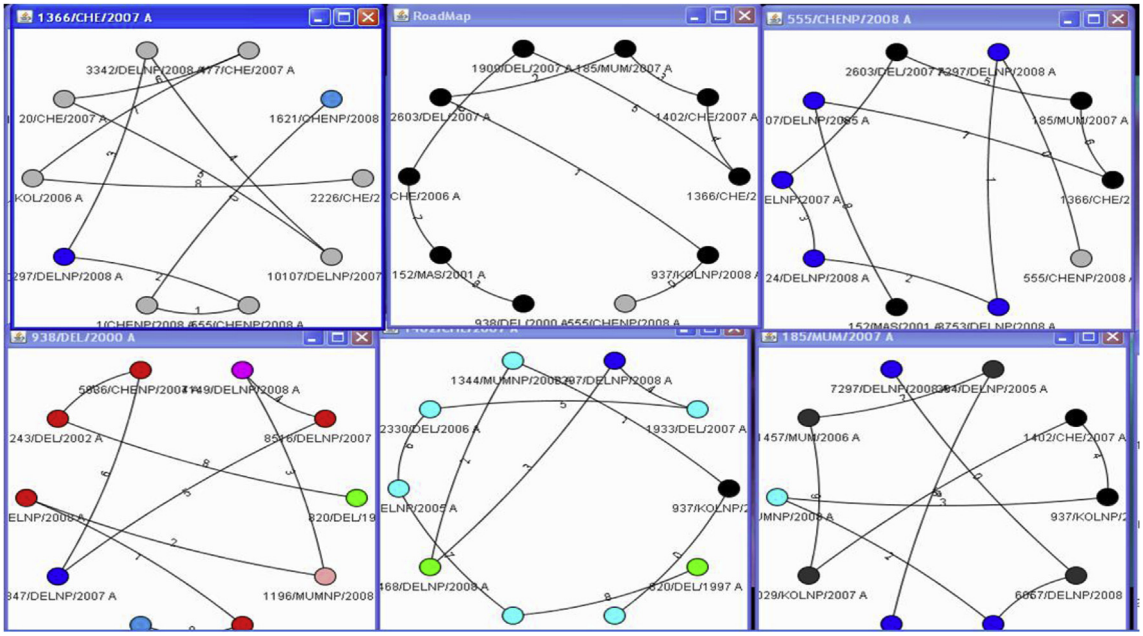

Fig. 2. Figure shows identified cited patents for a particular query patent. Each patent inline has identified their own citation and a roadmap for each is created in different windows.

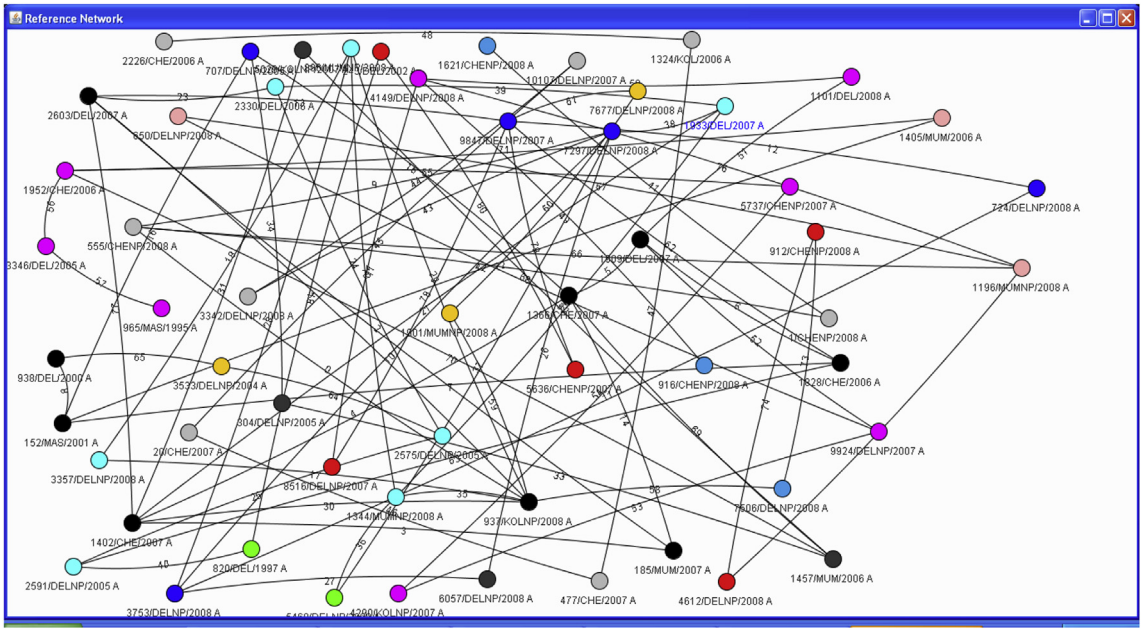

Fig. 3. Figure shows a combined graph of all the cited patents for any query patent. The graph is a combined roadmap of all the patents identified as cited on the basis of keyword matching.

technology and science. This phase also contains research papers focusing on countries innovation measurement on industrial sectors for thin films, on flow of knowledge geographically, signifying the prospective use of patents citation for a broad range of applicability in different domains of knowledge.

Fourth phase; this is still in its developmental stage and has seen more acceptability and adaptability of patent data for various studies. This stage has switched from simple patents citation count data to patents citation network analysis using tools like TRIZ, etc. Patent citation network analysis is used now to study and identify parameters like base patents, technology life cycle through citations, etc.

The development of the studies using patent citations delivers significant background for our methodological proposal. We may not only realize importance of these statistics, but also their limitations and basis. Through the process of literature survey we found 243 research papers published in various reputed international journals and proceeding of International conferences. Also we found 23 software patents filed in USPTO which deals in valuing a patent economically through citation analysis. The graph in Fig. 4 shows variation in publication related with patent citation analysis.

We also identified that 98% of the published research papers

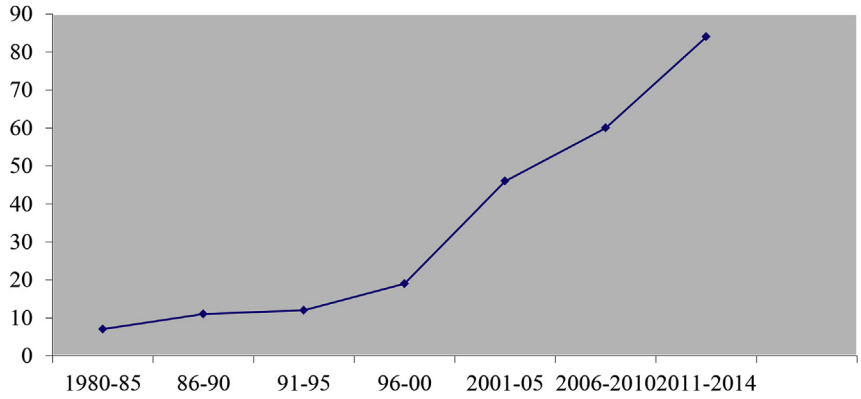

Fig. 4. Research papers related to patent citation published in various International Journals and proceedings of International Conferences.

related to patents citation and associated topics have utilized USPTO patent database for their research work. Patents citation research related to China, Taiwan, and Korea have also used USPTO patent data. This clearly reflect that the citation information provided by the USPTO can act as a reliable source for research purposes in this area. Thus we see how patent citation data has been utilized to understand the knowledge flow of information by researchers and economists.

8. Summary and conclusion of the findings

On the basis of the survey performed we can derive following conclusions for patent citation:

- Radical patents connect to other patent irrespective of their IPC class.
- A very small percentage of patent represent technology break through.
- Citation gap in terms of years is irrelevant in patents. A patent may be cited even after a gap of 15–20 years.
- Time series analysis plays an important role in patent analysis.
- Patent citation analysis enables in identifying the knowledge flow between countries as well as between university and research labs.
- Newer patents have more scientific literature citations.
- A cited patent confirms about its novelty and quality, if cited numerous times.
- Patent citation is effected by the economic value it holds. The more the value the more number of times it get cited.
- Patent citation helps to find out the base patents on the basis of which current technology stands.
- Citation analysis can be performed on the basis of co-citation analysis, IPC, similar keywords analysis.
- It identifies the patent and publication which plays a vital role in the growth of technology.

References

[1] M. Meyer, Does science push technology? Patents citing scientific literature, Res. Policy 29 (2000) 409–434.
[2] J. Michel, B. Bettels, Patent citation analysis: a close look at the basic input data from patent research reports, Scientometrics 51 (2001) 185–201.
[3] S. Breschi, G. Tarasconi, C. Catalini, L. Novella, P. Guatta, H. Johnson, Highly cited patents, highly cited publications, and research networks, CESPRI-BOCCONI UNIVERSITY, http://ec.europa.eu/invest-in-research/pdf/download_en/final_report_hcp.Pdf, 2006 (Accessed 17 october 2016).
[4] A.B. Jaffe, M.S. Fogarty, B.A. Banks, Evidence from patents and patent citations on the impact of NASA and other federal labs on commercial innovation, J. Industrial Econ. 46 (2) (1998) 183–205.
[5] M.M.S. Karki, Patent citation analysis: a policy analysis tool, World Pat. Inf. 19 (1997) 269–272.
[6] B.H. Hall, A.B. Jaffe, M. Trajtenberg, The NBER Patent Citation Data File: Lessons, Insights and Methodological Tools (No. W8498), National Bureau of Economic Research, 2001.
[7] D. Harhoff, F. Narin, F.M. Scherer, K. Vopel, Citation frequency and the value of patented inventions, Rev. Econ. Statistics 81 (1999) 511–515.
[8] F. Narin, K.S. Hamilton, D. Olivastro, The increasing linkage between U.S. technology and public science, Res. Policy 26 (1997) 317–330.
[9] J. Liu, X.-T. Ye, Y. Liu, Study on the effect of international knowledge flows on the industry innovation performance in China, J. Appl. Sci. 13 (2013), https://doi.org/10.3923/jas.2013.1669.1676.
[10] Y. Park, B. Yoon, S. Lee, The idiosyncrasy and dynamism of technological innovation across industries: patent citation analysis, Technol. Soc. 27 (2005) 471–485.
[11] S. Kuznet, Economic growth and income inequality, Am. Econ. Rev. 45 (1955) 1–28.
[12] J. Foster, Joseph Schumpeter, Simon Kuznets, Comparing their evolutionary economic approaches to business cycles and economic growth, J. Evol. Econ. 25 (1) (2015) 163–172.
[13] Z. Griliches, Patent statistics as economic indicator: a survey, J. Econ. Literature 28 (1990) 1324–1330.
[14] S. Tamada, Y. Naito, F. Kodama, K. Gemba, J. Suzuki, Significant difference of dependence upon scientific knowledge among different technologies, Scientometrics 68 (2006) 289–302.
[15] H. Nanba, N. Anzen, M. Okumura, Automatic extraction of citation information in Japanese patent applications, Int. J. Digital Libr. 9 (2008) 151–161.
[16] W.J. Abernathy, et al., Technological paradigms and technological trajectories, Res. Policy 22 (1993) 107–108.
[17] A.G.Z. Hu, A.B. Jaffe, Patent citations and international knowledge flow: the cases of Korea and Taiwan, Int. J. Industrial Organ. 21 (2003) 849–880.
[18] B. Sanditov, Patent Citations, the Value of Innovations and Technological Trajectories, 2005.
[19] Y. Park, B. Yoon, S. Lee, The idiosyncrasy and dynamism of technological innovation across industries: patent citation analysis, Technol. Soc. 27 (2005) 471–485.
[20] R. Fontana, A. Nuvolari, B. Verspagen, Mapping technological trajectories as patent citation networks. An application to data communication standards, Econ. Innovation New Technol. 18 (2009) 311–336.
[21] Y. Lin, J. Chen, Y. Chen, Backbone of technology evolution in the modern era automobile industry: an analysis by the patents citation network, J. Syst. Sci. Syst. Eng. 20 (2011) 416–442.
[22] P. Erdi, K. Makovi, Z. Somogyvri, K. Strandburg, J. Tobochnik, P. Volf, L. Zalnyi, Prediction of emerging technologies based on analysis of the US patent citation network, Scientometrics 95 (2013) 225–242.
[23] A. Martinelli, Ö. Nomaler, Measuring knowledge persistence: a genetic approach to patent citation networks, J. Evol. Econ. 24 (2014) 623–652.
[24] R. De Bondt, P. Slaets, B. Cassiman, The degree of spillovers and the number of rivals for maximum effective R &D, Int. J. Industrial Organ. 10 (1992) 35–54.
[25] A.J. Van Stel, H.R. Nieuwenhuijsen, Knowledge spillovers and economic growth: an analysis using data of Dutch regions in the period 1987–1995, Reg. Stud. 38 (2004) 393–407.
[26] J. Bernstein, M.I. Nadiri, Interindustry R&D spillovers, rates of return and production in high-tech industries, Am. Econ. Rev. 78 (1988) 429–434.
[27] F.M. Scherer, The propensity to patent, Int. J. Industrial Organ. 1 (1983) 107–128.
[28] E. Duguet, M. MacGarvie, How well do patent citations measure flows of technology? Evidence from French innovation surveys, Econ. Innovation New Technol. 14 (2005) 375–393.
[29] U. Kaiser, The Value of Danish Patents—evidence from a Survey of Inventors, 2006. Centre for Economic and Business Research Discussion Paper 1.
[30] B.H. Hall, A.B. Jaffe, M. Trajtenberg, The nber patent citation data file: lessons, insights and methodological tools, NBER Work. Pap. 8498 (2000).

[31] R.J.W. Tijssen, Global and domestic utilization of industrial relevant science: patent citation analysis of science-technology interactions and knowledge flows, Res. Policy 30 (2001) 35–54.
[32] C. Chen, Patents, citations & innovations: a window on the knowledge economy, 54, 2003. http://doi.wiley.com/10.1002/asi.10248.
[33] J. Alcácer, M. Gittelman, Patent citations as a measure of knowledge flows: the influence of examiner citations, Rev. Econ. Statistics 88 (2006) 774–779.
[34] http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.472.7742&rep=rep1&type=pdf.
[35] E. Bacchiocchi, F. Montobbio, International knowledge diffusion and home-bias effect: do USPTO and EPO patent citations tell the same story? Scand. J. Econ. 112 (2010) 441–470.
[36] B.N. Sampat, A. Ziedonis, in: H.F. Moed, W. Glänzel, U. Schmoch (Eds.), Handbook of Quantitative Science and Technology Research, Kluwer Academic Publisher, Dordrecht, 2005, pp. 277–298. https://doi.org/10.1007/1-4020-2755-9_13.
[37] I. Von Wartburg, T. Teichert, K. Rost, Inventive progress measured by multi-stage patent citation analysis, Res. Policy 34 (2005) 1591–1607.
[38] Y.G. Lee, J.D. Lee, Y.I. Song, S.J. Lee, An in-depth empirical analysis of patent citation counts using zero-inflated count data model: the case of KIST, Scientometrics 70 (2007) 27–39.
[39] P. Criscuolo, B. Verspagen, Does it matter where patent citations come from? Inventor vs. examiner citations in European patents, Res. Policy 37 (2008) 1892–1908.
[40] S.W. Hung, A.P. Wang, Examining the small world phenomenon in the patent citation network: a case study of the radio frequency identification (RFID) network, Scientometrics 82 (2010) 121–134.
[41] K. Sung, K. Taehan, K. Hee-Kyung, Microscopic Approach to Evaluating Technological Convergence Using Patent Citation Analysis. In International Conference on U-and E-service, Science and Technology, Springer Berlin Heidelberg, 2010, pp. 188–194.
[42] D.Z. Chen, M.H. Huang, H.C. Hsieh, C.P. Lin, Identifying missing relevant patent citation links by using bibliographic coupling in LED illuminating technology, J. Inf. 5 (2011) 400–412.
[43] O. Kuang, C.S. Weng, A new comprehensive patent analysis approach for new product design in mechanical engineering, Technol. Forecast. Soc. Change 78 (2011) 1183–1199.
[44] S.B. Chang, Using patent analysis to establish technological position: two different strategic approaches, Technol. Forecast. Soc. Change 79 (2012) 3–15.
[45] J. Liu, X.-T. Ye, Y. Liu, Study on the effect of international knowledge flows on the industry innovation performance in China, J. Appl. Sci. 13 (2013), https://doi.org/10.3923/jas.2013.1669.1676.
[46] L.C. Ribeiro, K. Glenda, B. Gustavo, M.R. Ricardo, B.T. Américo, A. Eduardo da Motta, Unveiling Global Innovation Networks. No. 463, Universidade Federal de Minas Gerais, Cedeplar, 2012.
[47] C. Luan, H. Hou, Y. Wang, X. Wang, Are significant inventions more diversified? Scientometrics 100 (2014) 459–470.
[48] F. Yoshikane, T. Suzuki, Diversity of fields in patent citations: synchronic and diachronic changes, Scientometrics 98 (2014) 1879–1897.
[49] W. Dolfsma, L. Leydesdorff, Innovation systems as patent networks: The Netherlands, India and Nanotech, Innovation Manag. Policy Pract. 13 (2011), https://doi.org/10.5172/impp.2011.13.3.311.
[50] V.K. Gupta, N.B. Pangannaya, Carbon nanotubes: bibliometric analysis of patents, World Pat. Inf. 22 (2000) 185–189.
[51] F. Narin, K.S. Hamilton, D. Olivastro, The increasing linkage between U.S. technology and public science, Res. Policy 26 (1997) 317–330.
[52] Y. Park, B. Yoon, S. Lee, The idiosyncrasy and dynamism of technological innovation across industries: patent citation analysis, Technol. Soc. 27 (4) (2005) 471–485.
[53] M. Hirschey, V.J. Richardson, S. Scholz, Value relevance of nonfinancial information: the case of patent data, Rev. Quantitative Finance Account. 17 (2001) 223–235.
[54] R.J.W. Tijssen, Global and domestic utilization of industrial relevant science: patent citation analysis of science-technology interactions and knowledge flows, Res. Policy 30 (1) (2001) 35–54.
[55] M. Meyer, Does science push technology? Patents citing scientific literature, Res. Policy 29 (3) (2001) 409–434. Retrieved from: http://www.sciencedirect.com/science/article/pii/S0048733399000402.
[56] J. Michel, B. Bettels, Patent citation analysis: a close look at the basic input data from patent research reports, Scientometrics 51 (1) (2001) 185–201.
[57] M.H. Huang, L.Y. Chiang, D.Z. Chen, Constructing a patent citation map using bibliographic coupling: a study of Taiwan's high-tech companies, Scientometrics 58 (2003) 489–506.
[58] Z. Huang, H. Chen, A. Yip, G. Ng, F. Guo, Z.K. Chen, M.C. Roco, Longitudinal patent analysis for nanoscale science and engineering: country, institution and technology field, J. Nanoparticle Res. 5 (2003) 333–363.
[59] R.J.W. Tijssen, T.N. Van Leeuwen, Measuring impacts of academic science on industrial research: a citation-based approach, Scientometrics 66 (2005) 55–69.
[60] S.B. Chang, K.K. Lai, S.M. Chang, Exploring technology diffusion and classification of business methods: using the patent citation network, Technol. Forecast. Soc. Change 76 (2009) 107–117.
[61] M. Meyer, K. Debackere, W. Glänzel, Can applied science be "good science"? Exploring the relationship between patent citations and citation impact in nanoscience, Scientometrics 85 (2010) 527–539.
[62] X. Wang, X. Zhang, S. Xu, Patent co-citation networks of Fortune 500 companies, Scientometrics 88 (2011) 761–770.
[63] T.S. Cho, H.Y. Shih, Patent citation network analysis of core and emerging technologies in Taiwan: 1997-2008, Scientometrics 89 (2011) 795–811.
[64] J.M. Gerken, M.G. Moehrle, A new instrument for technology monitoring: novelty in patents measured by semantic patent analysis, Scientometrics 91 (2012) 645–670.
[65] P. Mahdabi, F. Crestani, Patent query formulation by synthesizing multiple sources of relevance evidence, ACM Trans. Inf. Syst. 32 (2014) 1–30.
[66] P. Erdi, K. Makovi, Z. Somogyvri, K. Strandburg, J. Tobochnik, P. Volf, L. Zalnyi, Prediction of emerging technologies based on analysis of the US patent citation network, Scientometrics 95 (1) (2013) 225–242.
[67] F. Yoshikane, T. Suzuki, Diversity of fields in patent citations: synchronic and diachronic changes, Scientometrics 98 (3) (2014) 1879–1897. Kluwer Academic Publishers.
[68] R.J.W. Tijssen, T.N. Van Leeuwen, Measuring impacts of academic science on industrial research: a citation-based approach, Scientometrics 66 (2005) 55–69.
[69] G. Lewison, Gastroenterology research in the United Kingdom: funding sources and impact, Gut 43 (1998) 288–293.
[70] A.K. Chakrabarti, I. Dror, N. Eakabuse, Interorganizational transfer of knowledge: an analysis of patent citations of a defense firm, IEEE Trans. Eng. Manag. 40 (1993) 91–94.
[71] C. Chen, D. Hicks, Tracing knowledge diffusion, Scientometrics 59 (2004) 199–211.
[72] A. Verbeek, et al., Linking science to technology: using bibliographic references in patents to build linkage schemes, Scientometrics 54 (2002) 399–420.
[73] P. Bruck, I.R.J. Szente, J. Tobochnik, P. Erdi, Recognition of emerging technology trends: class-selective study of citations in the U.S. Patent Citation Network, Scientometrics 107 (2016) 1465–1475.
[74] K.J. Strandburg, Law and the science of networks: an overview and an application to the "patent explosion", SSRN Electron. J. (2006) https://doi.org/10.2139/ssrn.926354.
[75] S. Valverde, R.V. Solé, M.A. Bedau, N. Packard, Topology and evolution of technology innovation networks, Phys. Rev. E - Stat. Nonlinear, Soft Matter Phys. 76 (2007), https://doi.org/10.1103/PhysRevE.76.056118.

P. Sharma, is working as Assistant Professor. He has completed his Ph.D. in field of Software Patents (IPR). He is author of a book titled "Software Patents in India". He has to his credit more than a dozen research paper published in various international journals and conference proceedings.

Prof. R.C.Tripathi has worked as Professor in India. He is an expert in area of software patents and has served more than 30 years as director of Innovations in Indian Ministry.