# Postprint on Discovering Indirect Innovation Collaboration Opportunities Between Two Countries Based on Patent Citation Span Measurement

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## Abstract

[Purpose/Significance] Innovation cooperation opportunities between two countries can be either explicit and direct or potential and indirect. This study aims to construct a methodological framework for quantifying and analyzing patent citation relationships to identify potential indirect innovation cooperation opportunities between nations. [Method/Process] Citation relationships among patents at different stages of the global value chain embody indirect cooperative relationships that are interconnected and complementary. Since patents at different stages typically serve distinct functions, there exists a certain span in their International Patent Classification (IPC) codes. Accordingly, we devise a "patent citation span" metric and algorithm to quantify and filter patent citation relationships within the patent citation network where the citation span exceeds a predetermined threshold, thereby establishing foundational data for identifying indirect innovation cooperation opportunities. Employing invention patents granted to Singapore in China as a sample, this study identifies a series of indirect innovation cooperation opportunities between China and Singapore through patent citation span measurement combined with manual interpretation and verification. [Results/Conclusion] The proposed method for discovering indirect innovation cooperation opportunities between countries based on patent citation span measurement has been empirically validated as effective.

## Full Text

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**Discovering Indirect Innovation Cooperation Opportunities Between Two Countries Based on Patent Citation Crossing Degree Measurement**

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**Abstract:** [Purpose/Significance] Innovation cooperation opportunities between two countries can be either explicit and direct, or potential and indirect. This paper attempts to construct a method for measuring and analyzing patent citation relationships to discover potential indirect innovation cooperation opportunities between two countries. [Method/Process] Citation relationships between patents at different stages of the global value chain contain indirect cooperation relationships of mutual connection and matching. Patents at different stages typically have different functions, meaning their IPC classifications exhibit a certain degree of crossing. Therefore, a "patent citation crossing degree" indicator and algorithm were designed to measure and screen patent citation relationships in the patent citation network where the "citation crossing degree" reaches a preset threshold, serving as foundational data for discovering indirect innovation cooperation opportunities. Using Singaporean invention patents granted in China as a sample, and based on patent citation crossing degree measurement combined with manual interpretation and identification, a series of indirect innovation cooperation opportunities between China and Singapore were discovered. [Result/Conclusion] The method for discovering indirect innovation cooperation opportunities between two countries based on patent citation crossing degree measurement has been proven effective through experimental testing.

**Keywords:** global value chain; complementary technology; patent citation; innovation cooperation
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The Special Plan for Promoting Scientific and Technological Innovation Cooperation in the Construction of the Belt and Road, jointly issued by four ministries including the National Development and Reform Commission, has proposed new requirements for Belt and Road construction. Consequently, around which technological fields should scientific and technological innovation cooperation between China and countries along the Belt and Road be centered? Through which institutions (enterprises, research institutes, universities) should it be realized? These have become urgent research questions for scientific and technical intelligence workers. Patents are important carriers of scientific and technological innovation information. This study attempts to construct a new method for discovering innovation cooperation opportunities between two countries by analyzing patent citation relationships within the bibliometric approach.

Innovation cooperation opportunities between two countries (hereinafter referred to as "innovation cooperation opportunities") refer to cooperation that has not yet been implemented but could be implemented in the future, not cooperation that has already been completed. Therefore, "patent co-invention," as an explicit completed cooperation, is not the potential target to be "discovered" and is excluded from the research scope of this paper.

In addition to direct forms such as "patent co-invention," international innovation cooperation also includes indirect forms such as "patent licensing" and "patent transfer." "Indirect innovation cooperation" between two countries refers to 衔接式、匹配式、组合式 production cooperation of complementary products and intermediate product technologies on the global value chain. The logical premise is the knowledge association between technologies, and its manifestation can be patent licensing or patent transfer. However, "knowledge association" is embedded and potential, making it difficult to observe directly. Therefore, the task of this research is to construct a patent measurement method to excavate and discover objective scientific and technological knowledge associations between two countries, thereby providing a basis for proposing future potential indirect innovation cooperation fields and institutions, and explaining the feasibility of implementing cooperation. The above work constitutes "indirect innovation cooperation opportunity discovery."

## 1. Problems with Existing Methods for Discovering Innovation Cooperation Opportunities

Patent co-invention between two countries (where institutions from both countries jointly hold invention patent rights) is often intuitively understood as innovation cooperation between the two countries. However, patent co-invention represents completed cooperation in terms of temporal status, which is not the "potential cooperation not yet implemented but feasible in the future" that this study aims to discover. Therefore, "patent co-invention" as an explicit completed cooperation is not the potential target to be "discovered" and is excluded from the research scope of this paper.

Many papers in the information science community use "patents" to represent scientific and technological innovation and attempt to discover innovation cooperation opportunities by finding patents with identical or similar technical content. For example, references [1-3] identify patents with identical or similar technical content as potential cooperative technology objects based on co-word analysis. References [4-6] determine groups of similar patents through keyword clustering to identify cooperative technology groups. References [7-11] identify cooperation possibilities between patents by calculating patent document similarity.

All of the above studies share a common default premise: that identical or similar patented technologies can engage in innovation cooperation. However, the authors argue that the relationship between identical or similar patents should be "competition" rather than "cooperation." Patents are technological private rights that pursue monopoly interests. In the sense of innovation economics, identical or similar technologies are mutually substitutable; the higher the similarity between patented technologies, the stronger the competitors rather than partners the patent holders become.

## 2. Theoretical Foundation for Discovering Indirect Innovation Cooperation Opportunities

If finding identical or similar patented technologies can only identify competitors rather than partners, how then should innovation cooperation opportunities be discovered? The authors attempt to explore a "innovation cooperation opportunity discovery" method within the bibliometric domain, guided by global value chain theory and through analyzing "citation relationships" between patents.

The concept of value chain was first proposed by Harvard Business School professor M. Porter [12]: "Companies create value through a series of activities that are independent yet interrelated." Duke University sociology professor G. Gereffi [13] applied Porter's value chain concept to analyze cooperative relationships between enterprises on a global scale, proposing the concept of Global Commodity Chain: "In the context of economic globalization, the production process of goods is decomposed into different stages, forming a transnational production system around the production of a certain commodity that organizes enterprises and institutions (universities, research institutes) of different scales distributed around the world into an integrated production network." British economist R. Kaplinsky [14], in his edited *A Handbook for Value Chain Research*, stated: "Different enterprises engage in production activities at different stages of the same value chain." From the perspective of the global value chain, enterprises in all countries must connect and match technologies and products with enterprises at other stages of the global value chain to create living space for their own technologies and find connection objects for their intermediate products. In other words, patents of enterprises from various countries will become part of the global value chain, surviving and developing in the global technology ecosystem by adapting to the surrounding technical environment and matching symbiotic technologies.

Previous studies have proposed ideas and methods for finding technology cooperation opportunities based on patent citation relationships and citation networks from different perspectives. Building upon these studies, the authors further focus on the correlation and covariation between "cross-domain citation relationships between patents" and "the connection and matching relationships between upstream and downstream stages in the global value chain." The authors attempt to use "cross-domain citation relationships between patents" as basic material, and through a series of measurement, screening, and identification processes, excavate the "specific patent citation relationships" that can map the "matching and connection relationships between upstream and downstream patents," and then further interpret and discover indirect innovation cooperation opportunities from these "specific patent citation relationships."

## 3. Patent Citation Crossing Degree and Indirect Innovation Cooperation Opportunities

Patents are classified according to function. The International Patent Classification (IPC) number describes a patent's function. Identical or highly similar IPC numbers indicate identical or highly similar patent functions. Patent citation differs from paper citation. The act of patent "citation" is essentially a technical comparison behavior; all cited references are comparison documents. The motivation for citing comparison documents can be to assess the novelty and inventiveness of a patent application, or to explain the status and background of the technology (including how it connects and matches with other technologies).

If a patent cites comparison documents that are patents with identical or highly similar IPC numbers, the citation motivation should be to compare the similarity between the patent application and existing patents to determine whether the patent application possesses novelty and inventiveness. As described in Section 1, the relationship between such patents should be competitive rather than cooperative. Empirical studies by C. Paola et al. [19] and R. Kapoor et al. [20] demonstrate that when the IPC numbers of citing and cited patents are identical or highly similar (X-type citations, Y-type citations), the citation relationship reflects competition between patents, with subsequent citation effects constituting infringement or obstruction of the cited patent's original market.

If a patent cites comparison documents that are cross-domain patents with significantly different IPC numbers, the citation motivation is often to explain the technical status and background related to the patent application, including how it connects and matches with other technologies. The connection and matching relationship between technologies is essentially a relationship of mutual adaptation and symbiosis between different stages of the global value chain. Patents at different stages of the global value chain typically have IPC numbers with certain differences. Therefore, we can start from cross-domain citation relationships between patents of two countries to further discover indirect innovation cooperation opportunities between them. Studies by Lin Deming et al. [21], S.C. Yu et al. [22], J.H. Chen et al. [23], and K. Angue et al. [24] all support the above viewpoints to a certain extent.

In summary, cross-domain citation relationships between patents (where IPC numbers have certain differences) are citation relationships that may contain indirect innovation cooperation opportunities. The principle is illustrated in Figure 1 [Figure 1: see original paper]. However, not all cross-domain patent citation relationships can reflect indirect innovation cooperation opportunities. Further measurement, screening, and manual identification are required to ultimately discover the indirect innovation cooperation opportunities embedded within them.

The foundation and core element of the above "principle" is constructing a measurement indicator for "patent citation crossing degree." The definition of “patent citation crossing degree” is: the degree of difference in functional categories between the main IPC numbers of the citing patent and the cited patent. The specific measurement algorithm is as follows:

**Patent Citation Crossing Degree =**

## 5. When the first digit of the citing IPC number differs from that of the cited IPC number, i.e., they belong to different sections

The workflow for “discovering indirect innovation cooperation opportunities based on patent citation crossing degree measurement” is shown in Figure 2 [Figure 2: see original paper]. The core steps are:

## 4. Discovering Indirect Innovation Cooperation Opportunities Based on Patent Citation Crossing Degree Measurement

### 4.1 Experimental Sample Selection

Among the 65 countries along the Belt and Road, 46 have been granted Chinese invention patents, with Singapore ranking first in terms of the number of invention patents granted in China. Therefore, the authors selected Singaporean invention patents granted in China as the research sample to attempt to discover potential indirect innovation cooperation opportunities between China and Singapore based on patent citation crossing degree measurement.

### 4.2 Data Acquisition

The authors collected valid invention patents applied for by Singapore in China and granted. Regarding citation information, based on citation data collected from the “Patsnap Global Patent Database” and combined with data from the China National Intellectual Property Administration, the final citation relationship sample dataset was compiled. After data deduplication and cleaning, 323 groups of valid Singaporean invention patents granted in China were obtained, among which 141 groups of patents cited 263 groups of Chinese patents, and 48 groups of patents were cited by 111 groups of Chinese patents.

### 4.3 Overview of Singapore’s Patent Layout in China

Among Singapore’s valid invention patents granted in China, patents in the “semiconductor” field are the most numerous, accounting for 13.31% of Singapore’s patents in China, with “methods or apparatus specially adapted for manufacturing or processing semiconductor or solid-state devices or their components” being the main category, accounting for 65.12% of patents in the “semiconductor” field. The number of patents in semiconductor, digital communication, computer technology, electrical machinery, energy, and audio-visual technology fields all exceed 20 groups, collectively accounting for 43.03%. Patents in measurement, medical technology, civil engineering, biotechnology, chemical engineering, transportation, and other specialized machinery fields number between 10-20 groups, collectively accounting for 25.39%. Patents in telecommunications, control, and 17 other technical fields number fewer than 10 groups, collectively accounting for 26.93%.

### 4.4 Measurement and Analysis of Patent Citation Relationships Between China and Singapore

The "Singaporean patents" mentioned in the text refer to valid invention patents granted in China whose patentees are Singaporean individuals or enterprises. The "Chinese patents" mentioned refer to patents whose holders are Chinese individuals or domestic Chinese enterprises, excluding patents of foreign-funded enterprises or subsidiaries established in China by foreign enterprises.

**(1) Data analysis of Singaporean patents citing Chinese patents.** Among the 323 groups of Singaporean patents, 141 groups (distributed across 110 technology fields) cited Chinese patents, accounting for 43.65% and totaling 263 groups of Chinese patents (distributed across 148 technology fields). A 110$×$148 citation relationship matrix was constructed with technology fields as nodes. Using SNA two-mode network analysis methods and UCINET software, a two-mode network diagram was drawn (as shown in Figure 3 [Figure 3: see original paper]), where rectangular nodes represent Chinese patent technology fields and circular nodes represent Singaporean patent technology fields.

As can be seen from Figure 3, since more than half of the Singaporean patents cited only one group of Chinese patents, they appear as numerous isolated "two-point-one-line" relationships in the diagram. However, some Singaporean patents form multi-node connected subgraphs through citation coupling, as shown in Figure 4 [Figure 4: see original paper]. These citation relationships enable Singapore and China to form multiple technology chains (local branches of the global value chain) bridged across multiple technology fields.

**(2) Data analysis of Chinese patents citing Singaporean patents.** Chinese patents comprise 111 groups (distributed across 80 technology fields) that cited 48 groups of Singaporean patents in China (distributed across 36 technology fields), accounting for 64.53% of total citations of Singaporean patents in China. A 36$×$80 citation relationship matrix was constructed with technology fields as nodes, and an overall network diagram of Chinese patents citing Singaporean patents was drawn (as shown in Figure 5 [Figure 5: see original paper]), where rectangular nodes represent Chinese patent technology fields and circular nodes represent Singaporean patent technology fields.

Overall, the overall network of Chinese patents citing Singaporean patents exhibits characteristics of "large dispersion, small concentration." Most Singaporean patents are cited by only one group of Chinese patents, and the network component number is only 2, so most nodes in the network have very low betweenness. However, a few Singaporean patents are significantly focused on being cited by multiple groups of Chinese patents, showing high node degrees in the network. For example, 15 Chinese patents cited Singaporean patents in the H01L21 technology field, 13 Chinese patents cited Singaporean patents in the B01D63 technology field, 11 Chinese patents cited Singaporean patents in the H04L9 technology field, and 11 Chinese patents cited Singaporean patents in the A47G29 technology field.

From the perspective of connected subgraphs, the technology fields of Chinese patents citing Singaporean patents are highly concentrated, mainly forming some radial connected subgraphs around Singapore's H01L21, H04L9, A47G29, B01D63, and other technology fields, as shown in Figure 6 [Figure 6: see original paper]. The largest connected subgraph has 15 nodes, formed by 17 Chinese patents citing 2 Singaporean patents, with Singapore's H01L21 technology field being the core of this connected subgraph.

### 4.5 Association Strength Calculation and Threshold Setting

Based on the citation relationship network of Singaporean patents citing Chinese patents and the network of Chinese patents citing Singaporean patents, the association strength between citing and cited node pairs was statistically analyzed, with results shown in Table 1 .

As can be seen from Table 1, 76.5% of the association strength values between citing and cited node pairs are 1, while the remaining 23.5% have association strength of 2 or above. Citation relationships with association strength of only 1 have occurred only once, and such single-occurrence citation relationships are too accidental to confirm the existence of knowledge association. Using the "quartile method," the association strength threshold r was set as the TOP 25% boundary value, i.e., r = 2. Node pairs with association strength $\geq$ 2 were selected as "candidate samples for discovering cooperation opportunities."

### 4.6 Patent Citation Crossing Degree Calculation and Threshold Setting

Patent citation relationships between Chinese and Singaporean patent node pairs may originate from competitive relationships motivated by technology substitution, or from cooperative relationships motivated by technology connection or matching. For example, Singaporean patent CN101853797B cited Chinese patent CN1845305A, both having the same main IPC number H01L21/66 (testing or measuring during manufacturing or processing), with both concerning "wafer inspection systems or methods." This Singaporean patent used the citation to attack the technical defects of the Chinese patent—"cannot simultaneously use bright-field and dark-field imaging to inspect wafers during movement"—and explained its own invented wafer inspection system and method that could solve these problems. As a result, five months after the Singaporean patent was successfully granted, the Chinese patent ceased maintenance due to failure to pay annual fees. This is a typical case of competitive citation.

Another example is Singaporean Creative Technology Ltd.'s invention patent CN101326574B (IPC number G11B7/00), which cited Chinese Lenovo Company's invention patent CN1484162A (IPC number H02J7/00). Creative Technology's invention concerns "portable digital media devices with force sensors," while Lenovo's invention concerns "notebook computers capable of charging portable electronic devices," clearly showing a matching relationship between intermediate products. This is a typical case of cooperative citation.

The next problem to be solved is how to exclude "competitive citations" and identify and screen "cooperative citations" from the citation relationship network. The specific approach in this paper is: calculate the patent citation crossing degree and set an appropriate threshold to screen "candidate samples that may contain indirect innovation cooperation opportunities." The calculation process and threshold setting process for patent citation crossing degree are shown in Table 2 and Table 3 .

Table 2 shows the calculation of patent citation crossing degree for various technology fields.

As shown in Table 3, the distribution of "patent citation crossing degree" values exhibits a "large at both ends, small in the middle" pattern. Competitive citations within the same field with crossing degree of 0 account for approximately 37%, complementary cooperative citations with crossing degree reaching a certain level (4-5) account for approximately 37%, with very few in the middle range that can be temporarily ignored. The "large at both ends, small in the middle" distribution pattern of "patent citation crossing degree" aligns with the two types of patent citation motivations hypothesized in Section 3: "substitution" and "complementation." The patent citation crossing degree threshold was set at a = 4, using the condition that the patent citation crossing degree value is not less than 4 to exclude competitive citation relationships within the same field and screen out candidate samples that may contain indirect innovation cooperation opportunities.

### 4.7 Experimental Results

Through the above steps, candidate sample patent node pairs that may contain indirect innovation cooperation opportunities were screened out, as shown in Table 4 .

The authors conducted technical content analysis on the patent node pairs in Table 4 and identified the following 10 groups of "indirect innovation cooperation opportunities":

(1) Singaporean H04S1 (stereo system dual-channel system) patent products can be embedded as basic components into Chinese G10K15 (acoustic

devices not included in other categories) patent products to improve sound effects, achieving connection-type cooperation.

(2) Chinese B63C5 (facilities usable both on shipways and in dry docks) patent products (e.g., ship scaffolding platforms) can be combined with Singaporean B24C9 (accessories for abrasive jet machines or apparatus, such as work chambers, used abrasive treatment devices) patent products (e.g., abrasive jet machine work chambers) for combined application, achieving connection-type cooperation.

(3) Singaporean A47C7 (chair or stool components, parts, or accessories) patent products can be applied as supporting components to Chinese B60N3 (arrangement or configuration of passenger articles not included in other categories) patent products, achieving complementary matching cooperation between products.

(4) Singaporean B63J4 (equipment configuration for wastewater or sewage treatment) patent products can be applied as technical means and equipment devices in Chinese C02F1 (treatment of water, wastewater, or sewage) and C02F9 (multistage treatment of water, wastewater, or sewage) patent technologies, achieving connection-type cooperation.

(5) Chinese F16K11 (multi-way valves, such as mixing valves; pipe fittings with such valves; flow pipe configurations specially adapted for mixing fluids) patent products (e.g., automatic thermostatic mixing valves) can be embedded as basic components into Singaporean G05D23 (temperature control in non-electric variable control or regulation systems) patent technology (e.g., water temperature management systems), achieving connection-type cooperation.

(6) Chinese C22C37 (treatment of aluminum or silicon containing in alloys in metallurgy) patent technology can be applied in the production process of Singaporean B01D63 (general equipment for semi-permeable membrane separation processes in separation technology) patent products (e.g., ceramic membranes), achieving connection-type cooperation.

(7) Singaporean H01L21 (methods or apparatus specially adapted for manufacturing or processing semiconductor or solid-state devices or their components) patent technology can be applied as upstream basic material technology in Chinese G01R1 (components of various instruments or devices included in groups for "converting individual currents or voltages into mechanical displacement") patent products, achieving connection-type cooperation.

(8) Singaporean F28G1 (non-rotating appliances, such as reciprocating appliances) patent products can be applied in Chinese B08B9 (cleaning hollow articles by specialized methods or apparatus) patent technology, achieving complementary matching cooperation between products.

(9) Singaporean E05C1 (fastening devices with linear moving bolts) patent

products can be applied as basic components in Chinese F24F11 (control systems or apparatus; safety systems or apparatus) patent products, achieving connection-type cooperation.

(10) Singaporean A47G29 (supports, brackets, or containers for domestic use not included in other categories) patent products (e.g., improved multi-compartment water tanks) can be applied as constituent components in Chinese C02F1 (treatment of water, wastewater, or sewage) patent products (e.g., household water purification reaction devices), achieving complementary matching cooperation between products.

From the perspective of institutions (patent holders) corresponding to the above 10 cooperation fields, three major categories of institutional cooperation feasibility can be summarized:

Chinese institutions such as Tongji University, Zhejiang University of Technology, and the Chinese Academy of Sciences can cooperate with Singaporean institutions such as Qianhu Fishery Group and Yeo Tiat Liong (Private) Limited to apply environmental science research and development achievements (through patent licensing or transfer) in water purification technology fields, forming industry-academia-research indirect innovation cooperation between the two countries.

Singaporean institutions such as the Agency for Science, Technology and Research (A*STAR), Creative Technology Research Company, Nanyang Polytechnic, Sembcorp Industries Ltd., and Certis Cisco Security Pte. Ltd. can cooperate with Chinese institutions such as Harbin Institute of Technology, Zhejiang University, Nanjing Golden Eagle International Group Software System Co., Ltd., Beijing University of Technology, Liaoning Technical University, South China University of Technology, and Baidu Online Network Technology (Beijing) Co., Ltd. to form industry-academia-research indirect innovation cooperation between the two countries in semiconductor, audio-visual technology, digital communication, network security, and other fields (through patent licensing or transfer).

Chinese institutions such as Fudan University, Shanghai Cancer Institute, Zhejiang University, Shanghai Bode Gene Development Co., Ltd., Shanghai Bodao Gene Technology Co., Ltd., and Shanghai Borong Gene Development Co., Ltd. can cooperate with Singaporean institutions such as the Agency for Science, Technology and Research (A*STAR) and Singapore Health Services Pte. Ltd. to transfer and apply basic research achievements in silicon materials and organic chemistry to biomaterials fields (through patent licensing or transfer), forming industry-academia-research indirect innovation cooperation between the two countries.

## 5. Research Conclusions and Outlook

The measurement of patent citation crossing degree and the corresponding threshold setting can, to a certain extent, exclude "substitutive competitive citations" between patents and screen out "complementary cooperative citations," thereby providing materials and evidence from the citation analysis path for discovering potential indirect innovation cooperation opportunities between two countries.

This study has sample limitations. Future research will expand the sample to more Belt and Road countries to further test and refine the "indirect innovation cooperation opportunity discovery method based on patent citation crossing degree measurement" proposed in this paper.

## References

[1] Ma Dandan, Guo Min, Duan Qingfeng. Visual comparative analysis of domestic and foreign graphene composite material research trends [J]. Mineral Protection and Utilization, 2018, 217(5): 20-27.

[2] Yue Junju. Technology opportunity identification based on local outlier factor analysis and multi-dimensional technology innovation mapping [J]. Technology Economics, 2017, 36(10): 1-8.

[3] Wang Jinfeng, Wu Min, Yue Junju, et al. Research on technology opportunity identification paths in the innovation process—Based on patent mining and morphological analysis [J]. Information Studies: Theory & Application, 2017, 40(8): 82-86.

[4] WANG H, CHI Y, HSIN P. Constructing patent maps using text mining to sustainably detect potential technological opportunities [J]. Sustainability, 2018, 10(10): 1-18.

[5] YOU H, LI M, JIANG J, et al. Evolution monitoring for innovation sources using patent cluster analysis [J]. Scientometrics, 2017, 111(2): 693-715.

[6] WANG M Y, FANG S C, CHANG Y H. Exploring technological opportunities by mining the gaps between science and technology: microalgal biofuels [J]. Technological Forecasting & Social Change, 2015, 92(3): 182-195.

[7] SONG K, KIM K S, LEE S. Discovering new technology opportunities based on patents: text-mining and f-term analysis [J]. Technovation, 2017, 60-61(3): 1-14.

[8] Zhai Dongsheng, Guo Cheng, Zhang Jie, Li Dengjie. Research on technology opportunity identification method using anomaly detection [J]. New Technology of Library and Information Service, 2016(10): 81-90.

[9] Wang Jingjing. Technology opportunity analysis based on papers and patents [D]. Beijing: Beijing University of Technology, 2016.

[10] Zhou Lei, Li Ying, Shi Chongde. Patent information extraction for technology opportunity discovery TOD—KISTI semantic service of Korea Institute of Science and Technology Information [J]. Technology Intelligence Engineering, 2015, 1(2): 31-37.

[11] PETRUZZELLI A M. The impact of technological relatedness, prior ties, and geographical distance on university-industry collaborations: a joint-patent analysis [J]. Technovation, 2011, (7): 309-319.

[12] Porter. Competitive Advantage [M]. Sun Xiaoyue, trans. Beijing: Huaxia Publishing House, 1997: 26-.

[13] GEREFFI G. International trade and industrial upgrading in the apparel commodity chain [J]. Journal of International Economics, 1999, 48(1): 37-70.

[14] Global Value Chain Evolution - Five-star Document Library [EB/OL]. [2020-05-22]. http://www.wxphp.com/wxd_{0fyxy0om7j76vac3m050}1.html.

[15] BARAK S A, MELISSA A S. Mapping the technological landscape: measuring technology distance, technological footprints, and technology evolution [J]. Research Policy, 2016, 45(1): 81-.

[16] PARK I, YOON B. Technological opportunity discovery for technological convergence based on the prediction of technology knowledge flow in citation network [J]. Journal of Informetrics, 2018, 12(4): 1199-1222.

[17] Kang Yuhang. Technology opportunity analysis based on "coupling-co-citation" hybrid network [J]. Journal of Intelligence, 2017, 36(2): 170-179.

[18] KIM E, CHO Y, KIM W. Dynamic patterns of technological convergence in printed electronics technologies: patent citation network analysis [J]. Scientometrics, 2014, 98(2): 975-998.

[19] PAOLA C, BART V. Does it matter where patent citations come from? Inventor vs. examiner citations in European patents [J]. Research Policy, 2008, 37(10): 1892-1908.

[20] KAPOOR R, KARVONEN M, RANA E S, et al. Patent portfolios of European wind industry: new insights using citation categories [J]. World Patent Information, 2015, 41(2): 4-10.

[21] Lin Deming, Sun Jiansong, Hao Tao, et al. Applicability study of patent citation in patent value evaluation [J]. Journal of Intelligence, 2016, 35(12): 150-154.

[22] YU S C, CHEN B Y. Utilizing patent analysis to explore the cooperative competition relationship of the two LED companies: Nichia and Osram [J]. Technological Forecasting & Social Change, 2011, 78(2): 294-302.

[23] CHEN J H, LO S, JANG S, et al. Strategic partnership and its effect on external learning of technology descendants [J]. Scientometrics, 2012, 92(1): 157-179.

[24] ANGUE K, AYERBE C & MITKOVA L. A method using two dimensions of the patent classification for measuring the technological proximity: an application in identifying a potential R&D partner in biotechnology [J]. The Journal of Technology Transfer, 2014, 39(5): 716-747.

**Author Contributions:**
Li Rui: Paper topic selection, research method and technical route formulation, core viewpoint elaboration, partial content writing.
Qing Yangmei: Data processing and analysis, partial content writing.
Fan Jiujiang: Data processing and analysis, partial content writing.

**Abstract:** [Purpose/significance] Some of the innovation cooperation opportunities between the two countries are explicit and direct, while others are potentially indirect. This paper attempts to construct a method for measuring and analyzing patent citation relationships to discover potential indirect innovation cooperation opportunities between two countries. [Method/process] Citations between patents which act as various roles in the global value chain contain indirect cooperation such as mutual joint or complementary support. Patents acting as various roles have different functions and their IPC numbers are crossing different categories. Therefore, the algorithm of "citation crossing degree" was designed to measure and screen the patent citation relationship while the "citation crossing degree" reaches the preset threshold in the patent citation network. These screened relationships are used as the basic data for discovering indirect innovation cooperation opportunities. Taking Singapore's patents granted in China as samples, based on the measurement of citation crossing degree and manual interpretation, a series of indirect innovation cooperation opportunities between China and Singapore were found. [Result/conclusion] The method for discovering the indirect innovation cooperation opportunities between two countries based on the citation crossing degree measurement is proved to be effective by the experiment in this paper.

**Keywords:** global value chain; complementary technology; patent citation; innovation cooperation

*Note: Figure translations are in progress. See original paper for figures.*