

Research of Scientific and Technological Cooperation between Heilongjiang Province and Russia Based on SCI Co-Authorship Analysis

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Abstract:

In recent years, China-Russia cooperation has made great strides in many fields. Science and technology cooperation is not only the key strategy of Heilongjiang Province, but also the focus of the Chinese and Russian governments. In order to find the breakthrough of the further development of China-Russian science and technology cooperation, the coauthored scientific literature has become our main research object. We use the composite index to measure the coauthor strength, and describe the cooperation density using the co-existing network analysis method. In this way, we can clearly see the problems in the cooperation and find the right solutions. They can help provide scientific and effective basis for bilateral scientific and technological cooperation.

Keywords:

China-Russia Cooperation, Science and Technology, Heilongjiang Province and Russia

1. Introduction

In recent years, the relationship between China and Russia has made tremendous progress. The development of cooperation in various fields between China and Russia, especially the strategic cooperation in science and technology, is one of the most potential ways for cooperation between the two countries [1]. As the largest developing country in the world, China is also an advanced country of science and technology. To expand cooperation with Russia on the science and technology level is of great significance to the scientific and technological and economic development of both countries. In the mid-1990s, China and Russia have established a strategic cooperative partnership, and the scientific and technological cooperation between them has been gradually deepened. In recent years, China and Russia have gradually marched toward technological innovation and industrialization [2]. Heilongjiang

Province has the geographical advantage for its proximity to Russia and a long history of exchanges and cooperation with Russia so that it has always been the front line for China's cooperation with Russia [3]. China urgently needs the R&D and introduction of technologies so that focusing on the leading-edge core technology during science and technology exchanges and cooperation is of vital importance.

Heilongjiang Province has the advantage of convenient geographical location to actively carrying out cooperation in science and technology with Russia. It plays an important role in promoting provincial technological development, economic progress and strengthening the advantages of technological innovation to utilize the advantage. Besides, Heilongjiang Province is one of the provinces with the largest number of bilateral cooperation projects with Russia [4]. And it has established an innovative cooperation platform and a diversified cooperation path for China's cooperation with Russia. With the continuous development of international cooperation, Heilongjiang has made significant progress in technology industrialization and the talents introduction. However, the current level of cooperation in science and technology with Russia can't catch up with that in geographic location due to being trapped in the slow economic development [5]. Therefore, we urgently need to find out the source of these problems and put forward countermeasures. International co-authored papers and cooperation patents reflect international cooperation relationship in science and technology [6]. To analyze the SCI Co-Authored papers of Heilongjiang Province in scientific and technological cooperation with Russia can help Heilongjiang Province reach new heights in the level of bilateral scientific and technological cooperation [7].

2. Literature Review

Regarding international cooperation in science and technology, Wang M. G. [8] analyzed existing problems about the technological cooperation between China and the United States. The study found that bilateral relations or total diplomatic relations have a significant effect on the cooperation between the two countries in all fields. The development of China-US expo and scientific and technological year will have a strong driving force on the desire of the two sides to cooperate in science and technology. Wu J.N. and Yang R.Y. [9] took the articles co-authored by both the Belt and Road countries and China as the analysis objects, according to the contents of the documents contained in the Web of Science. They sorted out the characteristics of the co-authored documents and concluded that the depth and breadth of the cooperation among China and the other countries have yet to be developed. In recent years, some scholars have started to study the related topics about regional technology exchange between China and Russia, the development of Russia's Far East and the rejuvenation of the Northeast. The Far East of Russia is linked to Heilongjiang Province. However, these areas have poor economic development and natural environment, which urgently need to input the production factors of production such as capital, technology, labor, etc. to start economic development. Xiang Y. J. and Zhang J. P. [10] studied the obstacles and conflicts in the docking of China-Russia regional trade and technological cooperation policies and concluded that the Eurasian Economic Community and "the Belt and Road Initiative" strategy are mutually beneficial and complementary. Feng C.P. [11] pointed out that the forms of scientific and technological cooperation existing in China and Russia now include the bilateral or multilateral cooperation, enterprises or the government as the main body, natural persons as the main body and the legal person as the main body.

3. Research Method

According to equation (1) and (2), we calculated the coauthors of scientific literature. Cooperation Index (CI) refers to the average number of authors in an article published by unit or individual [12]. k is the maximum number of co-authors. N is the total number of papers. DC indicates the proportion of co-authored documents in all the literatures [13].

$$CI = \sum_{j=1}^k \frac{jf_j}{N} \quad (1)$$

$$DC = \left(1 - \frac{f_1}{N}\right) \times 100\% \quad (2)$$

Cooperation intensity is an indicator used to measure the closeness of cooperation, and the strength of cooperation can be calculated by Salton index (S_{ij}) and Jaccard index (J_{ij}), as equation (3) and (4). n_{ij} is the number of papers co-authored by i and j , n_i and n_j is the number of papers published by i and j respectively.

$$S_{ij} = \frac{n_{ij}}{\sqrt{n_i n_j}} \quad (3)$$

$$J_{ij} = \frac{n_{ij}}{n_i + n_j - n_{ij}} \quad (4)$$

4. Data Analysis

4.1 Time distribution of SCI papers co-authored by Heilongjiang and Russia

To analyze the distribution of the total number of articles in chronological sequence can reflect the overall situation and trend in a particular field [14]. In this paper, we choose the science and technology literatures on the SCI database from 2006 to 2015 to analyze the trends from a macro perspective.

By analyzing the data in Table 1, the total number of scientific and technological documents co-authored by the two countries showed a steady growth in the past 10 years. However, according to the DC index, the proportion of the number of co-authored articles is still very small, fluctuating in the range of 0.32%~0.48%, which reflects that the R&D cooperation between the two countries is relatively weak to some extent. During these 10 years, the Jaccard index of Russia and China co-authored dissertations was only between 0.0026 and 0.0042, reflecting the low level of cooperation between China and Russia. Additionally, the Salton index shows a clear upward trend, rising from 0.0081 in 2006 to 0.0125 in 2015. It can be seen that the cooperation between China and Russia is rapidly increasing. In recent years, Russia's desire for cooperation between China and Russia has become increasingly stronger. Both sides need to continue to increase the intensity and depth of cooperation.

Table 2 shows the distribution of SCI scientific papers in Heilongjiang Province and Russia. It can be seen that the number of SCI papers co-authored with Russia and Heilongjiang Province increased slowly. As the number of SCI published by Heilongjiang Province accounts for a small proportion of SCI in China, the DC of SCI papers between Russia and Heilongjiang Province has been relatively low.

Table 1. Total Distribution of Sino-Russian Co-Authored Science and Technology Literatures Indexed by SCI from 2006 to 2015

Year	China	Russia	Co-authored Number of Sino-Russian	DC of Sino-Russian	Jaccard Index	Salton Index
2015	297032	37191	1313	0.44%	0.0039	0.0125
2014	267015	33555	1112	0.42%	0.0037	0.0117
2013	233256	32655	949	0.41%	0.0036	0.0109
2012	195439	30176	940	0.48%	0.0042	0.0122
2011	170031	31048	683	0.40%	0.0034	0.0094
2010	146776	29439	556	0.38%	0.0032	0.0085
2009	132216	30114	429	0.32%	0.0026	0.0068
2008	115116	29664	431	0.37%	0.0030	0.0074
2007	99612	27527	386	0.39%	0.0030	0.0074
2006	91539	26083	398	0.43%	0.0034	0.0081

(Data sources: Web of Science)

Table 2. The Total Amount of Scientific and Technological Documents Indexed by SCI and Co-Authored by Heilongjiang Province (HP) and Russia from 2006 to 2015

Year	α^*	Co-authored Number of HP & Russia	α^*/β^*	DC of HP and Russia
2015	1768	36	0.60%	0.0204
2014	1402	29	0.53%	0.0207
2013	1119	27	0.48%	0.0241
2012	895	24	0.46%	0.0268
2011	748	16	0.44%	0.0214
2010	655	19	0.45%	0.0290
2009	543	20	0.41%	0.0368
2008	340	14	0.30%	0.0412
2007	179	12	0.18%	0.0670
2006	164	8	0.18%	0.0488

Note: α^* refers to the number of papers indexed by SCI of Heilongjiang Province

β^* refers to the number of papers indexed by SCI of Russia

(Data sources: Web of Science)

4.2 Disciplinary distribution of co-authored papers by Heilongjiang and Russia

From 2007 to 2016, a total of 240 SCI papers were co-authored between Heilongjiang Province and Russia, involving 45 research directions, which means that the areas of cooperation between Heilongjiang and Russia are wide and involve a large number of disciplines. Figure 1 shows the distribution of SCI co-authored papers between China and Russia in 2007-2016. According to the ranking of papers, the representative top ten research directions are selected for analysis. It can be seen from Figure 1 that the top 10 disciplines are Physics, Materials Science, Chemistry, Zoology, Metallurgical Engineering, Engineering, Mathematics, Biochemistry Molecular Biology, optics. Physics and Mathematics, account for more than 20%, respectively, showing that Heilongjiang and Russia are active in these two fields and should conduct deeper exploration to promote more in-depth cooperation. Furthermore, it shows that both parties cooperate more in strong disciplines [15]. It is noteworthy that the proportion of Metallurgical Engineering and Engineering add up

to nearly 20%, indicating that Heilongjiang and Russia have more cooperation in the field of engineering.

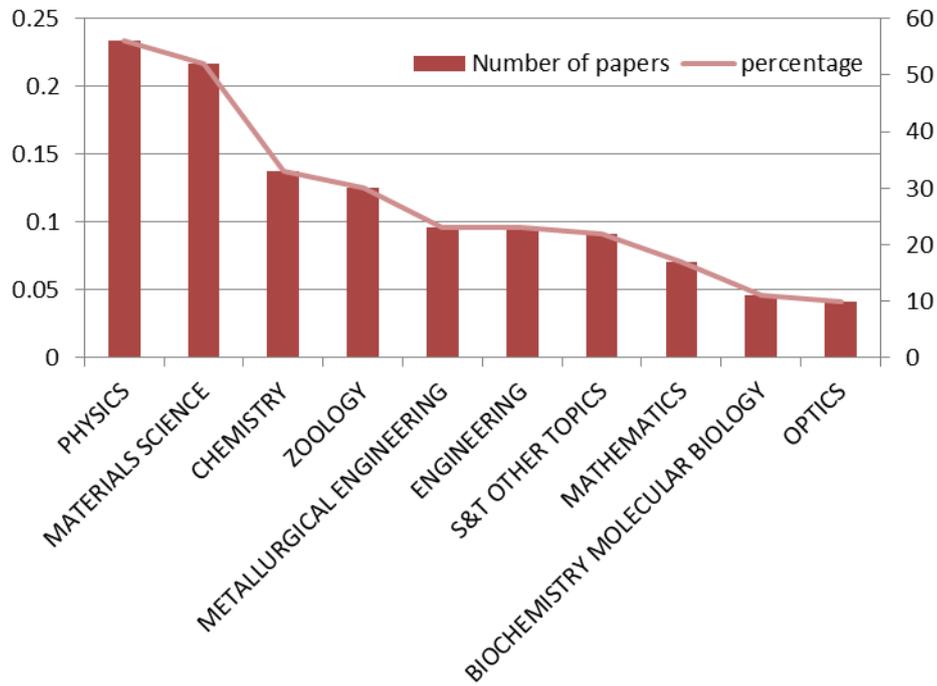


Figure 1. Disciplinary distribution of SCI papers co-authored by Heilongjiang and Russia

4.3 Frequency analysis of keywords in co-authored SCI papers by Heilongjiang and Russia

Table3. Partial Co-occurrence matrix of high-frequency keywords in SCI papers co-authored by Heilongjiang and Russia

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
A	0	0	3	0	0	2	1	0	1	0	0	0	0	2	0	2	0	4	4
B	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0
C	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0
E	0	0	0	0	0	3	4	3	16	6	13	8	0	1	0	3	3	6	4
F	2	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	1	0
G	1	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	2	1
H	0	0	0	0	3	0	0	0	2	0	0	0	0	1	0	0	0	1	0
I	1	0	0	0	16	0	0	2	0	6	0	0	0	2	0	3	0	6	4
J	0	0	0	0	6	0	0	0	6	0	0	0	0	0	1	0	0	3	2
K	0	0	0	0	13	0	0	0	0	0	0	8	0	2	0	2	3	5	3
L	0	0	0	0	8	0	0	0	0	0	8	0	0	0	0	2	3	6	4
M	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
N	2	0	0	0	1	0	0	1	2	0	2	0	0	0	0	0	0	0	0
O	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
P	2	0	0	0	3	0	0	0	3	1	2	2	0	0	0	0	0	1	1
Q	0	0	0	0	3	0	0	0	0	0	3	3	0	0	0	0	0	3	3
R	4	0	0	0	6	1	2	1	6	3	5	6	0	0	0	1	3	0	2
S	4	0	0	0	4	0	1	0	4	2	3	4	0	0	0	1	3	2	0

A. China B. defects C. Indonesia D. Lectin E. Lepidoptera F. Myanmar G. new combination H. newgenus I. newspecies J. newsynonymy K. Noctuidae L. Pantheine M. proton irradiation N. Russian Far East O. Saccharomyces cerevisiae P. Taiwan Q. taxonomic revision R. Thailand S. Vietnam

The matrix is an undirected symmetric relation matrix. The rows and columns correspond to 19 high-frequency keywords. When the two appear in the same article at the same time, it indicates the existence of relations between the two keywords [16]. The matrix is an undirected symmetric relation matrix. The rows and columns correspond to 19 high-frequency keywords. When the two keywords appear in the same article at the same time, it indicates that they have connections. The high-frequency keyword co-occurrence matrix is imported into the social network analysis software UCINET to obtain the co-occurrence network diagram of the high frequency keywords of co-authored documents.

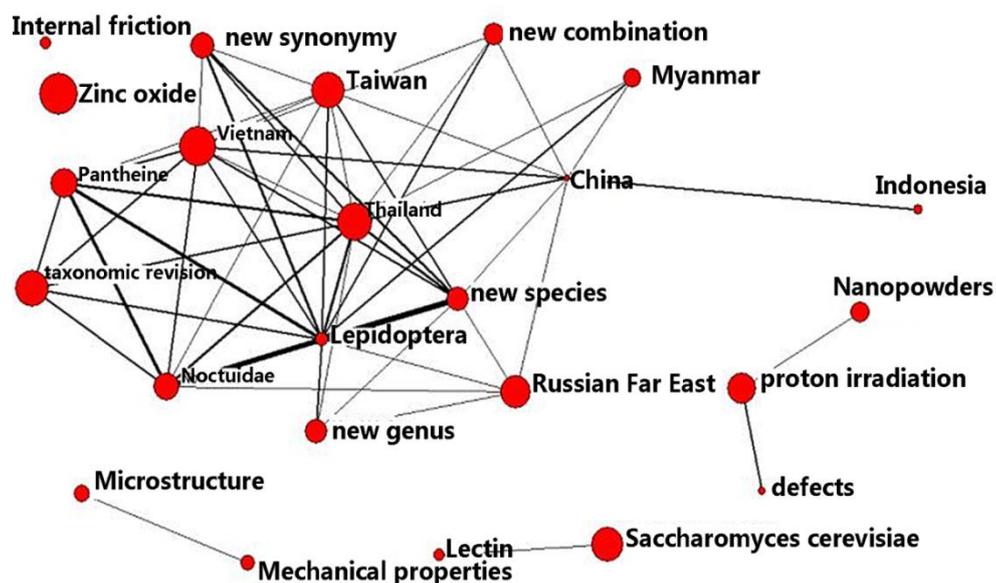


Figure 2. Co-occurrence network diagram of SCI high-frequency keywords co-authored by Heilongjiang and Russia

As shown in Figure 2, each node in the figure represents a keyword. The size of a node represents the degree of centrality of a node [17]. That is, the larger the number of co-occurrences with a certain keyword is, the higher the degree of centrality and the larger the size of nodes is. The connection between the nodes represents the relationship between the nodes. The thickness of the connection represents the degree of closeness between the keywords. The coarser the connection between two nodes is, the more co-occurrence times of two keywords are. As can be seen from Figure 2 and table 3, proton irradiation has more links with defects, and Nanopowders, which reflect that the research on S&T cooperation between Heilongjiang and Russia focuses on high frequency topics such as physics. Connections among Lepidoptera and the new species, Pantherinae, Noctuidae and other keywords in the field of biology are coarser. There are a lot of site nodes, such as Thailand, Vietnam, the Russian Far East, Taiwan, China and so on, attached to biological keywords, showing that the cooperative research on Heilongjiang and Russian biology is closely related to these areas. Overall, keywords in physics, chemistry and biology are in large scale and more frequently discussed in Heilongjiang and Russia co-authored papers.

There is less international cooperation research on other subject keywords and the cooperation network is relatively loose.

5. Analysis of Science and Technology Cooperation of Heilongjiang Province with Russia

Heilongjiang Province has the advantage of local talents. There is a number of well-known universities at home and abroad like Harbin Institute of Technology. Also, there are Welding Technology Institute, Institute of Applied Physics in Harbin Institute of Technology and many other domestic research institutes in leading positions. More than one million researchers are engaged in scientific research in these universities and institutes.

Heilongjiang Province has Geographical advantages. Heilongjiang Province is a large bordering province with Russia. In recent years, it has opened nearly 100 international and domestic routes, several of which can reach directly to Northeast Asia and all regions of Russia. Along with the economic belt of the Silk Road, China will open more ports along the border to trade with all countries and establish a complementary platform for scientific and technological cooperation with various disciplines in Russia [18].

Table 4 shows the output of patents and essays in Russia from 2009 to 2013, which helps us to correctly know about the scientific and technological strength of Russia. Russia has been ranked 5th in the world in the output of patents during the five years, and the number of documents in the world is about 15th. It can be seen that there is still a gap in scientific and technological strength between Russia and the United States and European countries, and it is similar to China's technological strength.

Table 4. The Number of Russian Documents and Patents from 2009 to 2013

Year	Number of patents	International ranking	Number of articles	International ranking
2013	31638	5	32258	15
2012	32880	5	29589	16
2011	29999	5	30118	15
2010	30322	5	29000	15
2009	34824	5	31549	15

Data Source: Compilation of Statistical Data of Chinese Science and Technology (<http://www.sts.org.cn/zlhb/index.htm>)

Russia has obvious advantages in the field of national defense and aerospace and has the ability to be the leader in bioengineering and ionization technologies [19]. In addition, Russia's scientific research organizations and teams are characterized by large numbers and scale. In the field of basic disciplines research, Russia takes the world's leading position. Therefore, the cooperation between China and Russia should focus on the complementary advanced technology of both sides.

In brief, we can find the scientific and technological needs of Heilongjiang Province by weighing and comparing the scientific and technological strength of the two countries. It is beneficial to optimize the mode of bilateral scientific and technological cooperation.

6. The Inadequacies of Heilongjiang Province in Its Cooperation with Russia

6.1 Shortage of Standard Cooperation System

China and Russia have signed a number of cooperation projects and the relations between them are getting closer. However, the cooperation between the two countries still lacks the cooperation and coordination system. There is no effective scientific management mechanism for cooperation between Heilongjiang province and Russia in Heilongjiang Province.

6.2 Deficiency of Cooperative Funds

State owned units in China are the main force of scientific and technological cooperation with Russia, and more and more private-owned enterprises are participating in the cooperation with Russia. Enterprises in Heilongjiang Province do have cooperation needs, many of which lack the sales scale and can't afford technology R&D costs simply relying on their own strength. China's R&D expenditure accounted for about 13% of the world, ranking second in the world. However, Russia's R&D expenditure in its GDP accounted for less than 2% for a long-term. The investment is difficult to match with the position of science and technology of the country. Additionally, it is hard to find a steady source of scientific research funds due to the lack of industrialization of its scientific research, which leads to insufficient funds for cooperation [20].

6.3 Absence of Professional Talents

Heilongjiang Province does not have sufficient support for its workforce in science and technology cooperation with Russia. For the sake of seeking development, the top talents trained in the province have successively switched to economically developed areas [21].

However, Heilongjiang is still using traditional ways for personnel training. This training method can no longer produce professional talents suitable for the cooperation with Russia in science and technology. At the same time, the education policy in China increasingly emphasizes the importance of language studying. In Heilongjiang Province, the Russian-related majors that continue to be kept in universities are very deficient. Even though some Russian-related majors are retained, most of them are unpopular majors with a very small number of applicants or enrollments. The ability to communicate in Russian also affects the progress of the cooperation with Russia to some extent.

7. Countermeasures of Existing Problems in Heilongjiang Province's Scientific and Technological Cooperation with Russia

7.1 Constructing the Cooperation and Coordination System of Scientific and Technological Cooperation with Russia

Over the years, both the trade and cooperation between Heilongjiang Province and Russia have lacked a scientific and effective management mechanism, and they have been in a chaotic and disorderly situation, failing to effectively deploy various departments. Heilongjiang Province can solve the problem of normative cooperation

by establishing a coordination mechanism for cooperation with Russia in science and technology. The transformation of scientific research achievements between China and Russia should be strengthened and a coordinating and organizing system headed by the vice-provincial and deputy-city-level leaders should be established to coordinate various cooperation projects with Russia within the province. Sort out the scientific and institutional framework for all aspects in the cooperation with Russia and create an environment that is suitable for conducting international cooperation. Set up Heilongjiang Cooperation with Russia Committee which has several branches or divisions, including science and technology subcommittee, military technology sub-committee and economic and trade sub-committee. The government should actively promote sharing and releasing information on technological cooperation among enterprises, research institutes and Russia.

7.2 Looking for a Stable Source of Cooperation Funds

To deepen the cooperation in science and technology with Russia, it is necessary to obtain support from the state policies. The state attaches great importance to Russia's space technology and other key technologies when introducing technology, which inspires Heilongjiang Province to actively seek policy support from the perspective of national defense and security and aerospace. Therefore, Heilongjiang Provincial Government should establish special funds for exchanges and cooperation with Russia and particularly emphasis on supporting cutting-edge technology research and basic research. We should also set up a special fund for cooperation with Russia and adopt the method of government support, market operation and coordinated operation of the government and market so as to obtain the necessary financial support for Heilongjiang Province's cooperation in science and technology with Russia. Additionally, the government should establish a review and appraisal team for the special fund to rationally plan and differentiate the importance of all kinds of cooperation. The government makes reasonable use of the limited funds so that those enterprises or units that receive funding support will be able to repay the fund after they have obtained benefits.

7.3 Training Compound Talents to Cooperate with Russia

Although Heilongjiang has some talent advantages in its cooperation with Russia, it still lacks specialized personnel suitable for carrying out Sino-Russian cooperation. We must focus on the planning and fostering of high-level talents from the strategic development of disciplines. At the same time, the ability of Russian language is another major obstacle to their exchange and cooperation with Russia. To solve the problems above, Heilongjiang Province not only needs to attach importance to the training of science and technology personnel but also the management of personnel training. In addition to technology, cooperation in science and technology with Russia also includes various issues concerning management, economy, finance and law, all of which are necessary support for the international cooperation in science and technology. The number of Russian majors in institutions of higher learning in Heilongjiang Province has decreased year by year, and few young Russian teachers are now available. Heilongjiang Province must make up for the talent gap as soon as possible and develop some highly-skilled personnel who are excellent in management ability and good at language communication at the same time. In addition, colleges and universities in the province especially key colleges and universities that have the advantages of cooperation in science and technology with Russia should play the

main role in the cultivation of qualified personnel. For example, they can set up such specialized majors as the “trade and economic cooperation with Russia” and the “technical management to Russia”. We must also strengthen the teaching staff in higher education institutions and employ experts and scholars in related fields with generous treatment to assist cultivating compound talents for science and technology cooperation with Russia.

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this article.

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