Study on the Technology Cooperation between China and Countries Alongside One Belt and One Road Area Based on Gravity Model

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Abstract To research the affective factors between China and countries alongside One Belt and One Road Area technology cooperation, it is helpful to guide the patent layout, foreign cooperation, and investment of Chinese enterprises in the region. Using patent data of cooperation between China and the countries along the Belt and Road for the period of 2001 and 2020, this paper examines the determinants of China's international research collaboration. Our empirical results, based on a gravity model, show that the scientific research strength of China and cooperative countries will have a positive impact on the output of technical cooperation. In addition, the population size of cooperative countries is conducive to the output of bilateral technical cooperation. The influence of economic proximity and technological proximity on technological cooperation between China and countries along the belt and road is not obvious. This conclusion has strong policy implications for promoting China's international scientific research cooperation.

Keywords : gravity Model; One Belt and One Road; International Patent Cooperation; Patent Analysis

1 INTRODUCTION

Science is a practical activity that represents the process of human exploration of the nature and laws of nature[1].With the development of society, scientific problems have become more complex, researchers have become more specialized, and the behavior of individual solo scientific research has changed to collaborative team research. In addition, with the rapid development of network and information technology, the influence of geographical location on scientific cooperation has gradually become less and more cross-institutional, cross-regional and even transnational scientific cooperation has emerged.

Scholar Katz's study of scientific research cooperation between universities in Europe and the United States found that geographical distance can affect such cooperation, with the number of scientific research collaborations decreasing exponentially as the distance between universities increases. However, factors such as economics, language, and socio-political issues do not significantly impact the number of scientific research collaborations[2].Similarly, Zitt et al. studied the scientific cooperation between five developed countries from 1985 to 1995 and found that language, culture, and history were the primary factors influencing international scientific research cooperation[3].Matthiessen et al. studied the scientific research cooperation relationships

ICEKIM 2023, May 26-28, Nanjing, People's Republic of China

DOI 10.4108/eai.26-5-2023.2337273

between major cities and found that the primary factors influencing scientific research cooperation were the country, geographical distance, and language similarity[4].Finally, Hoekman et al. analyzed scientific research co-authorship documents from European countries and concluded that an increase in geographical distance weakens the production of scientific research co-authorship documents among European countries[5].

In this paper, we study the main influencing factors of international research cooperation in China based on the gravity model approach. The structure is organized as follows: Section 2 describes the data collected from the European Patent Office database. Section 3 presents the econometric model from the gravity equation used in our study, and the empirical results. Finally, Section 4 draws conclusions.

2 DATA SOURCE

Cross-border patent cooperation can be divided into three forms: cooperation patents between inventors from different countries, cooperation patents between applicants from different countries, and cross-border patent authorizations [6].Since knowledge is more easily disseminated in collaborative R&D networks, innovation entities in collaborative R&D networks are more innovative[7].Therefore, this article chooses cooperation patents between inventors from different countries to represent cross-border cooperative patents.

Based on the global patent database of the European Patent Office database, this paper collected cooperation patent record data between China and countries along the Belt and Road from 2001 to 2020, which includes patent information from multiple patent organizations, and the data is updated daily. A total of 31,692 patent record data were retrieved.

Geographic distance data and language data for capital cities around the world were downloaded from the CEPII database, and economic and population data for countries along the Belt and Road were downloaded from the World Bank database. Due to the lack of data for Bosnia and Herzegovina and Palestine in the World Bank database, basic data for only 64 countries along the Belt and Road were collected.

Table 1 shows the example of patent data.

Table 1. Example of patent data

Title	Publication number	inventors	IPC	Application number
NATURAL KILLER CELLS AND USES THEROF	KR20150063374 (A)	LAW ERIC[US]; KANG LIN[CN]; JANKOVIC VLADIMIR[RS];	C12N5/0783; A61K35/17; C12N5/00	KR20157006395

3 ANALYSIS OF TECHNICAL COOPERATION INFLUENCE FACTORS

3.1 Influencing Factors Assumptions

Technological proximity refers to the degree of overlap in the various fields that both parties are involved in, reflecting the similarity of the two parties in terms of their technological development level and direction[8]. Technological proximity means that technology, as a carrier, integrates innovative entities into a system, and to a certain extent, knowledge overlap is necessary to drive the technological subjects to identify and utilize each other's technologies, thereby conducting cooperation[9]. In similar technological fields, the cooperating parties embed their innovative capabilities, and the cross-domain integration of technology is also conducive to incubating new technologies. Extensive research has shown that the emergence of new technologies is largely influenced by the combination of existing technologies in a certain area, and technological proximity is one of the potential factors for regional technological cooperation. Based on this, the following hypothesis is proposed in this article:

H1: Technological proximity has a positive impact on the output of cross-border technological cooperation.

Geographical proximity reflects the most basic connotation of proximity, which is the degree of proximity of the space where the subject is located. This article uses the degree of distance between national nodes in geographical space to characterize geographical proximity.

Geographical proximity facilitates better communication and learning, and therefore, network members typically choose partners who are geographically close for collaboration. Additionally, literature suggests[10] that cooperation between geographically close partners may have similar political systems and cultural customs, which can lower communication costs and increase cooperation efficiency, thereby facilitating the spillover of implicit knowledge. Under similar conditions, to avoid negative effects caused by geographical distance, cooperation partners seek partners who are relatively closer in location for cross-border technological research collaboration. Therefore, parties with smaller geographical proximity are more likely to form cross-border technological cooperation relationships, which result in higher cooperation frequency and patent outputs between the two countries. Additionally, individuals who are geographically close enhance mutual understanding through frequent interactions, which helps align their technological development towards the same direction. In the process of technological exchange and cooperation, the breadth and depth of technological cooperation are strengthened. Therefore, geographical proximity helps promote technological cooperation between countries. Based on this, the following hypothesis is proposed in this article:

H2: Geographical proximity has a negative impact on the output of cross-border technological cooperation.

Few studies have considered the impact of economic proximity on international scientific and technological cooperation. When the technical levels of the two cooperating parties are similar, the material resources and related technologies provided by the partners to each other may be comparable, and the resulting cooperative relationship may be more stable, thereby forming a long-term, fair, and mutually beneficial cooperative relationship. At the same time, in countries with similar levels of development, the difference in technological development levels may also be relatively small, making it easier to find common research topics between the two sides and forming a cooperative relationship. In addition, once both parties have reached long-term cooperation in a certain field, the development status and research direction of both parties in this field may be similar, and the possibility of future cooperation will also increase. This article uses GDP data in constant 2010 US dollars to characterize the economic situation of each country, and uses the absolute value of the GDP difference between two countries to represent the economic proximity between the two countries. Based on this, this article proposes the following hypothesis:

H3: Economic proximity has a negative impact on the output of cross-border technology cooperation.

3.2 model specification and variable description

The basic idea of the empirical application of the gravity model in this paper is as follows: the amount of technological cooperation output between two countries is usually related to the strength of their scientific research capabilities and the distance between them. Generally speaking, the stronger the scientific research capabilities of the two countries, the greater the possibility of cooperation between them. However, geographic distance may hinder technological cooperation between the two countries. In addition, other explanatory variables are also included in the gravity model, which can to some extent explain the amount of technological cooperation output between the two parties. For example, variables such as whether the research areas of the two parties are similar, whether the languages of the two parties are similar, the economic gap between the two parties, and the population size of the two parties will all be introduced into the model.

This paper uses the gravity model to study the determinants of China's international scientific research cooperation. The gravity model originated from Newton's law of universal gravitation. The gravity model that is suitable for this paper is expressed as:

$$C_{ijt}=\alpha_0+P01_{it}^{\alpha_1}P02_{jt}^{\alpha_2}+\exp\left[\sum_{k=1}^{K}\beta_k d_{(k)}^{ij}\right]+\varepsilon_{ijt} \tag{1}$$

In this model, i represents the partner countries along the Belt and Road, and j represents China. C_{ijt} represents the number of patents resulting from technological cooperation between China and partner countries, $P01_{it}$ represents the number of patents from China, indicating China's scientific research strength, and $P02_{jt}$ represents the number of patents from the partner country, indicating the partner country's scientific research strength. a_1 and a_2 are the influence weights or coefficients that are expected to be positive. $d_{ij(k)}$ includes geographical proximity $Geography_{ij}$, technological proximity $Technology_{ijt}$, economic proximity $Economy_{ijt}$, and language $Language_{ij}$, and b_k represents the weight or coefficient of the k-th impact. ε_{ijt} represents the error term. Therefore, the gravity model in natural logarithmic form is:

$$C_{ij}=\alpha_0+\alpha_1 Ln01_{it}+\alpha_2 Ln02_{jt}+\alpha_3 LnGeography_{ij}+\alpha_4 Technology_{ijt}+\alpha_5 Economy_{ijt}+\alpha_6 Population_{ijt} \tag{2}$$

The various variables used in this paper are defined as follows:

C_{ijt}: The dependent variable of this paper, representing the number of collaborative patents between China and Belt and Road countries in period t.

$P01_{it}$: China's scientific research strength, representing the number of patent applications filed by China in period t. The data source is the global patent database of the European Patent Office.

$P02_{jt}$: Scientific research strength of the country collaborating with China, representing the number of patent applications filed by that country in period t. The data source is the global patent database of the European Patent Office.

$Geography_{ij}$: Geographic proximity, representing the distance between the capitals of China and the collaborating country. The data source is the CEPII database.

$Technology_{ijt}$: Technological proximity, representing the angle between the technology vectors of China and the collaborating country in year t. The technological similarity is calculated using the formula for technological specialization similarity between different metropolitan areas in the United States, as computed by Peri (2005):

$$Technology_{ijt} = \frac{\sum_{k=1}^{6}(X_{ikt} * X_{jkt})}{\sqrt{\sum_{k=1}^{6}(X_{ikt})^2 * \sum_{k=1}^{6}(X_{jkt})^2}} \quad (3)$$

Where X_{ikt} represents the number of patents in the scientific research of country i along the route at time t (P01it), and X_{jkt} represents the number of patents in the scientific research of China j at time t ($P02_{jt}$); K represents the technology field, which is divided into 6 major fields according to the International Patent Classification (IPC). The technology similarity index Technology takes a value in the range of 0 to 1, with a higher value indicating a higher level of technological specialization similarity between the two countries.

$Economy_{ijt}$: Economic proximity represents the GDP difference between China and country i during time t. Data comes from the World Bank WDI database and is calculated in constant 2010 US dollars.

$Language_{ij}$: Common language represents the percentage of people using the same language in the cooperation between the two countries. Generally speaking, the more people using the same language between two countries, the closer their regional culture will be, which will make it easier to generate cooperation and communication.

$Population_j$: Population size represents the population of the cooperating country.

Table 2 presents the summary statistics for all variables.

Table 2. Summary statistics

Variable	Mean	Std	Min	Max
C_{ijt}	34.9303	135.6353	0	861
$P01_{it}$	95666.6	28116.62	40426	133612
$P02_{jt}$	2957.994	8474.867	0	46419
$Geography_{ij}$	5972.273	1953.424	945	7722.639
$Technology_{ijt}$	0.841	0.117	0.279	0.986
GDP_{ijt}	7711.729	6567.239	7.553879	26900.26

3.3 Empirical results

This paper conducted regression analysis on the technological cooperation output of China and the Belt and Road countries and its related influencing factors. This paper conducted fixed effects regression. The regression results are shown in Table 3 STATA software was used for regression analysis. The numbers outside the brackets in the table are coefficients, and the numbers inside the brackets are t-values. ***, **, and * represent the significance of the results passing the 1%, 5%, and 10% levels of significance testing, respectively.

Table 3 presents the individual fixed effect regression results. The adjusted R-squared value of the individual fixed effect model is 0.4920, indicating a good fit of the model and a good explanation of the variables in the model. Among the many explanatory variables, the variables that passed the test at the 1% significance level are China's scientific research strength, the scientific research strength of the cooperating countries, and the population size of the cooperating countries. The variables that passed the test at the 10% significance level are technological proximity. The regression results show that China's scientific research strength and the scientific research strength of cooperating countries have a positive impact on the output of technical cooperation, while technological proximity has a negative impact on output, which is consistent with the assumed direction. In addition, the significant positive coefficient of the population size of cooperating countries indicates that it contributes to the output of technical cooperation between the two sides.

Table 3. Determinants of Transnational Research Collaboration in China(FE)

Variable	(1)	(2)	(3)	(4)
$LN(Patent01_{it})$	64.5974^{***}(5.53)	102.1554^{***}(6.07)	110.4923^{***}(6.13)	65.2554^{***}(4.48)
$LN(Patent02_{jt})$	13.0443^{**}(3.39)	20.0594^{***}(3.88)	21.74784^{***}(4.08)	7.34693^{*}(1.70)
$Technology_{ijt}$		-22.4489(-0.24)	-21.7075(-0.23)	-125.7409^{*}(-1.72)
$LN(GDP_{ijt})$			-13.8115(-1.29)	-2.2777(-0.27)
$Geography_{ij}$				——
$Language_{ij}$				——
$Population_{ijt}$				11.9897^{***}(11.64)
Constant	-764.77^{***}(-5.26)	-1207.77^{***}(-5.49)	1189.84^{***}(-5.40)	-1189.84(-5.40)

4 Conclusions

Research collaboration has always been influenced by a dynamic interplay of economic, scientific, cultural and geographical factors. Using data on all collaboration patents between China and other countries along the one belt and one road for the period 2001–2020, this paper examines the determinants of China’s international research collaboration.

This paper draws the following conclusions through analyzing the influencing factors of technical cooperation between China and the countries along the "Belt and Road", the following conclusions are drawn: Improvements in both the research capabilities of the cooperating countries and those of China are conducive to enhancing the cross-border technology cooperation output of China, and the population size of the cooperating countries has a positive impact on cross-border patent cooperation activities. In addition, geographical distance has a hindering effect on China's cross-border technology cooperation output activities.

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