Measurement and Improvement Path of Cross-region Technology Transfer Efficiency Based on a Clear-set QCA Approach

Yuhan Hu, Sida Kang, Weijun Yan, Libing Wu

Abstract—**Cross-regional technology transfer is an important driving force for achieving the coordinated development of technology resources and breaking down China's provincial technical barriers. Due to the imbalance in China's technology development level, it is difficult to achieve comprehensive revitalization policies. Therefore, improving the efficiency of technology transfer is an effective way to solve this problem. This paper selects the relevant data of 31 provinces and regions in China in 2019 for analysis, uses factor analysis to measure the efficiency of technology transfer, and then proposes a technology transfer improvement path through QCA clear set configuration analysis. The study found that the development of technology transfer efficiency in 31 provinces and regions in China is extremely unbalanced. The improvement paths that effectively break this unbalanced development status can be summarized into 4 types, namely, the "intermediary-environment" leading path, weak "intermediary-R&D-environment" leading path, strong "intermediary-R&D-environment" leading path and "intermediary-economic" leading path.**

Index Terms—**technology transfer efficiency, factor analysis, QCA analysis, configuration analysis.**

I. Introduction

WITH economic globalization and the subdivision of the industrial value chain, technological resources have become the main driving force for the coordinated development of various industries. At the same time, they have formed their own unique characteristics and technical barriers in space. Looking at the current competitive situation at home and abroad, tremendous changes have taken place. The competition among countries around the world has gradually shifted from the competition of comparative advantages dominated by resources to the competition with technological elements as the main advantage. Regardless of whether it is competition between countries or between different regions within a country, the goal is for the region to occupy a major position in the global value chain. As an important bridge to break this kind of space barrier, technology transfer not only promotes the in-depth integration of industries in different regions but also accelerates the coordinated development of cutting-edge technologies. It is an important means to enhance China's overall technological competitiveness.

For the first time since 2007, the Chinese government has written technology transfer as a major national strategy in a document. To implement the "Outline of the Eleventh Five-Year Plan for National Economic and Social Development" and the "National Medium and Long-term Scientific and Technological Development", the "Planning Outline (2006-2020)" specifically proposed the "National Technology Transfer Promotion Action Plan." The plan points out that technology transfer is an important part of China's implementation of an independent innovation strategy, a key link for enterprises to achieve technological innovation and enhance core competitiveness, and an important way for innovation to be transformed into productivity. At the same time, it emphasizes the full implementation of the scientific development concept to create independent innovation. Focusing on creating an environment for independent innovation, accelerating knowledge flow and technology transfer is the main line, and building a technology transfer system is the support.

Subsequently, in 2016 and 2017, the General Office of the State Council issued the Action Plan for Promoting the Transfer and Transformation of Scientific and Technological Achievements and the National Technology Transfer System Construction Plan, which more clearly stated that technology transfer is an important means for the innovation-driven development strategy and for improving the regions. The main driver of competitiveness can promote sound economic and social development and enhance regional technological innovation capabilities. With the unfolding of the Sino-U.S. trade war in 2018, the U.S. Trade Representative Office issued the "Results of the 301 Survey on China's Technology Transfer, Intellectual Property and Innovation Behaviors and Policies", which confirmed the importance of technology transfer for national development and social progress from the international level.

This paper takes 31 provinces and regions in China as the research object, selects the relevant data in 2019, and carries out factor analysis and clear set configuration analysis on the selected data through SPSS 23.0 and fsqca 3.0 software to measure the technology transfer efficiency and improvement path of the selected regions. The results have guiding significance for the coordinated development of technology resources and the improvement of technology transfer in China.

The organization of this paper is as follows: Section III describes the general steps of the factor analysis method and

Manuscript received April 28, 2022; revised April 26, 2023. This work was supported by the Social Science Planning Fund of Liaoning Province China (No.L22AGL015), the Natural Science Foundation of Liaoning Science and Technology Agency of China (No.2022-MS-356).

Yuhan Hu is a professor of School of Science, University of Science and Technology Liaoning, 114051, P. R. CHINA (Corresponding author, phone: 86-0412-5929421; email: anshanhyh@163.com).

Sida Kang is a doctoral candidate of School of Electronic and Information Engineering, University of Science and Technology Liaoning, 114051, P. R. CHINA (e-mail: kangsida@ustl.edu.cn).

Weijun Yan is a professor of School of General Education, Dalian Neusoft University of Information, 116023, P. R. CHINA (email: yanweijun@neusoft.edu.cn).

Libing Wu is a professor of School of Science, University of Science and Technology Liaoning, 114051, P. R. CHINA (email: beyondwlb@163.com).

QCA method. Section IV uses factor analysis to measure the technology transfer efficiency of China's 31 regions and ranks the measurement results. Section V uses the QCA method to put forward the technology transfer and promotion path of the regions studied. Finally, the conclusion of this paper is given.

II. Literature Review

The concept of technology transfer was first proposed in the 1960s. At the first United Nations Conference on Trade and Development held in 1964, the conference emphasized that developed countries should transfer technology to developing countries to promote their technological development. China's technology transfer model mainly draws on the experience of Western developed countries, and its origin is relatively late. The beginning is marked by the "Industry-University-Research Joint Development Project" implemented in the 1990s. At present, the concept of technology transfer generally recognized in China refers to the behavior of technology owners to transfer technology to others in a variety of ways for profit, and it is also the main way for science to be transformed into production [1].

Technology transfer is affected by many factors. From the perspective of research objects, scholars have conducted much research on the influencing factors of technology transfer in colleges and universities and enterprises. The influencing factors of university technology transfer have been found to include reward systems, office staff salaries and cultural barriers, establishing a research paradigm for the influencing factors of university technology transfer. Jiménez-Sáez et al. found that the process of technology transfer between universities and enterprises is not only affected by the technology transfer office (TTO), but policy factors such as intellectual property protection also have a significant impact on technology transfer [2]. This study expands the research methods of technology transfer between different subjects. Lin and Berg studied the influencing factors of technology transfer of manufacturing enterprises in Taiwan from the perspective of enterprises. They also found that technology transfer is affected by cultural differences [3]. At the same time, they further found that cultural differences also have a significant impact on the nature of technology.

Cross-regional technology transfer is different from technology transfer between universities and enterprises. It is both more difficult and more complex. Professional technicians and sufficient resources are needed to ensure technology transfer between regions [4]. Li et al. [5] found that entrepreneurial orientation can overcome the difficulty of transfer to a certain extent. Kafouros and Wang revealed that the geographic diffusion and concentration of organizations in the alliance changed the organization's ability and willingness to transfer technology to other organizations (or receive technology from other organizations), resulting in different levels of performance [6]. Hu et al. took developing countries as the research object and found that the impact of corporate efficiency is affected by technology transfer at home and abroad, which depends on the interaction of R&D [7].

In terms of the evaluation method of technology transfer efficiency and the characteristics of China's technology transfer, Gao et al. [8] found that China's technology transfer shows centrality. The general technology transfer area was concentrated in Beijing, while the technology transfer area was more concentrated in the Yangtze River Delta region. Kim studied the technology transfer efficiency of American colleges and universities in the past 10 years [9] and found that the technology transfer efficiency of American colleges and universities exhibited a gradual and significant increase. The main explanation for this development is the increase in the frequency of commercial activities. Trappey et al. took several specific technical fields as research objects and measured the potential value of patents in specific fields by using the BP neural network method [10]. Hsu and Lee examined the military technology of 67 countries, measuring the efficiency of military technology transfer in the past five years and exploring the impact of military technology transfer on the economy [11]. The research found that military technology transfer has played a great positive role in regional economic development. Ercan and Kayakutlu conducted an in-depth exploration of patent application evaluation, programmed the pass and reject in patent evaluation by using a support vector machine algorithm, and scientifically established a scientific patent evaluation method [12]. Curi et al. studied the French TTO organization to explore the efficiency of technology transfer offices during daily operations [13] and found that nearly half of the efficiency improvements of technology transfer in France depend on the operations of the technology transfer office. Cerqueti and Ventura introduced the evaluation method of real options to conduct scientific evaluations of patent values, filling a gap in the scientific methods of patent evaluation [14]. Gumpert found that technology transfer has been affected by both local demand and local development [15]. Technology transfer is generally caused by the relationship between supply and demand in both regions. The value of patents is also assessed by Kabore and Park, but the difference is that this study correlated the market size with the number of patent families [16]. Chung and Sohn took the semiconductor industry as the research object and a convolutional neural network as the research method to evaluate patent value, using patent semantic information in the evaluation process [17]. Deng [18] found that sci tech finance (STF) and sci tech innovation (STI) promote scientific and technological progress and development. Then, take Guangdong Province as an example to measure the weight of STF and STI. On the choice of methods, the DEA evaluation method and factor analysis method are often used for evaluation of technology transfer [19].

The existing research is a reference for the construction of the index system and the application of the method of technology transfer efficiency evaluation. Needed improvements in the existing research include the expansion of the coverage of the evaluation index system and additional research through the QCA method based on the measurement results of technology transfer efficiency.

III. Research Design

A. Factor Analysis

Factor analysis was first developed by L. Thurstone in 1931. In the process of evolution, it was gradually applied to the field of statistics and then developed to the data statistics of other disciplines. The core of factor analysis is the dimensionality reduction method, which eliminates the overlap of information from multiple factors. By analyzing the correlation coefficient matrix of the variables, we find the common factors that contain most of the information to reduce the number of variables and represent most of the information. To make the variables within the common factor more correlated, factor analysis conducts the following steps:

1) Data Standardization Processing: Due to the difference in data statistical standards and dimensions and because the order of magnitude of each index is different, it is necessary to quantify the original dimensionless index. To maintain the robustness of the original index, the commonly used standardization methods are $0 \sim 1$ standardization and Z standardization. Because Z standardization will cause the measurement result to be negative, which is inconsistent with the facts, this paper selects $0 \sim 1$ standardization to process the data, and its transformation function is as follows:

$$x_i^* = \frac{x_i - x_{\min}}{x_{\max} - x_{\min}}, \tag{1}$$

where Eq. (1) is the data in the original index.

2) The Carrier Number Matrix Is Solved: After obtaining the standardized data, calculate the load number r_{ij} and list the load number matrix $R = (r_{ij})_{m*m}$, whose expressions are as follows:

$$r_{ij} = \frac{1}{n}\sum_{k=1}^{n} z_{kk} z_{kj} = \frac{\sqrt{\sum_{k=1}^{n}\left(x_{ki} - \overline{x_i}\right)\left(x_{ki} - \overline{x_j}\right)}}{\sqrt{\sum_{k=1}^{n}\left(x_{ki} - \overline{x_j}\right)^2\left(x_{ki} - \overline{x_j}\right)^2}} \quad (i, j = 1, 2, \ldots, m), \tag{2}$$

$$R = \begin{pmatrix} F_{11} & F_{12} & \cdots & F_{1n} \\ F_{21} & F_{22} & \cdots & F_{2n} \\ \vdots & \vdots & \cdots & \vdots \\ r_{n1} & r_{n2} & \cdots & r_{nn} \end{pmatrix}. \tag{3}$$

3) Calculate the Eigenvalue and Eigenvector: Calculate the characteristic equation $|R - \lambda I| = 0$, find all characteristic roots $\lambda_1 > \lambda_2 > ...... > \lambda_i > 0$ and the corresponding eigenvector $t_j = (t_{1j}, t_{2j}, ..., t_{mj})$.

4) Eigenvectors and Their Weights: According to the principal component eigenvalues and the factor-carrying number matrix, the eigenvectors and their weights are obtained, and the expression is:

$$Q_{ij} = \frac{\eta_{ij}}{\lambda_i} \tag{4}$$

5) Linear Combination Coefficients and Weights: According to the calculation results of eigenvector and its weight, the expressions of linear combination coefficient and weight can be obtained, which are respectively:

$$L_i = \frac{\sum_{i,j=1}^{n} Q_{ij}/W_i}{\sum_{i=1}^{n} W_i} \tag{5}$$

$$P_i = \frac{L_i}{\sum_{i=1}^{n} L_i} \tag{6}$$

Eq. (5) and Eq. (6) are linear combination coefficients and weights, respectively. n is the number of principal components and is the variance of the $i - th$ principal component.

6) Comprehensive Evaluation Score Calculation: According to the weight of the linear combination coefficient and the original data, the comprehensive evaluation score can be obtained, and the expression is:

$$F_i = \sum_{i=1}^{n} P_i X_I^* \tag{7}$$

B. QCA Clarity Set Configuration Analysis Method

As a new method beyond qualitative research and quantitative research, the QCA method is not only a research method but also a set of research tools. It takes into account "configuration comparison" and "set theory". At the same time, based on computer algorithms, it has the ability to deal with a large number of cases and systematically analyze their differences and similarities. Its principal orientation is "result-driven"; that is, the method can evaluate "multiple concurrent causality" through the causal path of the same result identified in different situations. QCA methods include clear set qualitative comparative analysis (csQCA), multivalue set qualitative comparative analysis (mvQCA), fuzzy set qualitative comparative analysis (fsQCA) and MSDO/MDSO (maximum similarity, different results, and maximum difference, same results). The QCA method mainly includes five types of applications: summarizing data, checking the consistency of data, testing hypotheses or existing theories, quickly testing conjectures, and developing new theoretical conclusions.

csQCA is a widely used QCA analysis method. This method can determine the dichotomous threshold table and the "truth table" according to the numerical relationship of the variables. Since the variables selected in this paper are all statistical values, this paper adopts csQCA as the research method. Among them, the basis of csQCA is Boolean algebra. In Boolean algebra, logical "AND" is represented by "$*$", logical "OR" is represented by "$+$", logical "not" is represented by "$\sim$", and the connection between conditions and results is represented by "$\rightarrow$", which is usually used to explain causality. Boolean minimization is a method to reduce complex expressions. The expression is created as:

$$A * B * C \rightarrow X. \tag{8}$$

In Eq. (8), when three Conditions A, B and C exist at the same time, it can lead to the result X.

$$A * B * \sim C \rightarrow X. \tag{9}$$

$$A * B * c \rightarrow X. \tag{10}$$

In Eq. (9) and Eq. (10), when A and B exist at the same time, but C does not exist, it also leads to the result X.

Therefore, Equations Eq. (8), Eq. (9) and Eq. (10) can be expressed by Eq. (11).

$$A * B * C + A * B * c \rightarrow X. \tag{11}$$

Eq. (11) shows that when Eq. (8) to Eq. (10) are used as two conditions, at least one condition can lead to X. Furthermore, the Boolean logic minimization operation simplification Eq. (11) can be expressed as:

$$A * B \rightarrow X. \tag{12}$$

In Equation Eq. (12), when both Conditions A and B exist at the same time, it leads to the result X, regardless of whether Condition C exists.

Of these, the basic idea of QCA is to calibrate the cause conditions and results into sets and determine the sufficiency and necessity of each condition and its combination to the results by calculating the subset relationship between sets. Consistency and coverage are two important indicators to evaluate the strength of the relationship between subsets.

Therefore, the consistency of sufficient conditions can be expressed as:

$$Consistency(X_i \leq Y_i) = \sum[\min(X_i, Y_i)] / \sum(X_i). \tag{13}$$

The coverage of sufficient conditions can be expressed as:

$$Consistency(X_i \leq Y_i) = \sum[\min(X_i, Y_i)] / \sum(Y_i). \tag{14}$$

In Eq. (13) and Eq. (14), X is the membership set of result variables, y is the membership set of conditional variables, and the consistency of X as a subset of Y is the proportion of their intersection to X.

In addition, the consistency of the necessary conditions can be expressed as:

$$Consistency(Y_i \leq X_i) = \sum[\min(X_i, Y_i)] / \sum(Y_i). \tag{15}$$

The coverage of the necessary conditions can be expressed as:

$$Consistency(Y_i \leq X_i) = \sum[\min(X_i, Y_i)] / \sum(X_i). \tag{16}$$

In Eq. (15) and Eq. (16), the consistency of result y as A subset of Condition X is the proportion of their intersection to Y.

The main operation steps of csQCA include the following: (1) Construct a dichotomous threshold table, which is based on the original data and constructs a dichotomous data table with relevant definitions; (2) Construct a “truth table”, which is a configuration table that integrates the dichotomous data table into a ”truth table” through the fsQCA software to obtain the relevant condition combination of the given result; and (3) Conduct Boolean minimization, which is to perform Boolean minimization of configuration 1 and configuration 0 twice and simplify the result formula to obtain the condition combination of the path method that leads to the most streamlined result to obtain the conclusion. The operation flow of fsQCA software is shown in Figure 1.

C. Variable Selection and Data Sources

The purpose of this paper is to measure the efficiency and improvement path of technology transfer among 31 provinces selected in China. Therefore, the selected variables can reflect the characteristics of technology transfer across regions. At present, the indicators of technology transfer research in China are mainly selected from two perspectives: patent transfer and technology production. Patent transfer is divided into two dimensions: patent input and patent output. Technology production is divided into the two dimensions of technology input and technology output, and few scholars combine the two perspectives to carry out research. This article selects the patent transfer records in the patent search and analysis platform of the State Intellectual Property Office of China in 2019 and the 2020 China Statistics Yearbook of Science and Technology as the data sources. The four dimensions of technical output construct an evaluation index system, as shown in Table I.

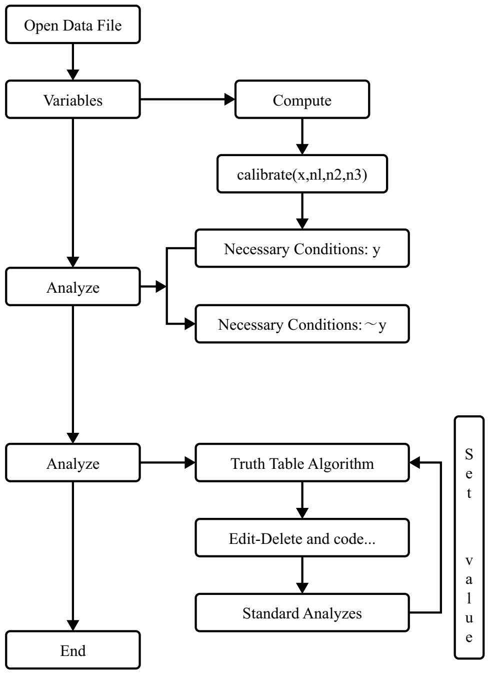

Fig. 1: fsQCA Software Operation Process

IV. EFFICIENCY MEASUREMENT OF CROSS-REGIONAL TECHNOLOGY TRANSFER

A. Variable Selection and Data Sources

1) Test of Applicability of Factor Score: To test whether this set of data is suitable for factor analysis, KMO and Bartlett’s sphericity tests were first performed. It can be seen from Table II that KMO is $0.718 > 0.7$, indicating that this group of data is applicable to factor analysis, in which the significance of the Bartlett sphericity test is $0.000 < 0.00$, indicating that the assumption of independence of variables is not tenable, so the applicability test is passed.

2) Determine the Common Factor and Factor Loading: First, the standardized data of 31 provincial and regional indicators are extracted to obtain the characteristic root and factor contribution rate of cross-regional technology transfer. A characteristic root greater than 1 is taken as the extraction standard of the common factor. As shown in Table III, a total of 3 common factors are extracted, among which the characteristic root of common Factor 1 is 9.564, and the variance contribution rate is 63.76%. The characteristic root of common Factor 2 was 1.794, and the contribution rate of variance was 11.963%. The characteristic root of common Factor 3 was 1.329, and the contribution rate of variance was 8.86%. The cumulative variance contribution rate of the

TABLE I: Evaluation System of Cross Regional Technology Transfer Efficiency.

Dimension layer	Index level	Symbol	Index description
Technical input	Number of transferred patents	A1	The total number of patents transferred to the region. The more patents transferred, the greater the demand for technological innovation in the region
	Proportion of transferred patents in the number of patents	A2	The number of patents transferred to the region accounts for the proportion of the total number of patents in the region. The higher the ratio, the stronger the absorption of technological innovation in the region
	Number of technology categories transferred into patents	A3	The greater the number of technology categories transferred to the region, the more abundant the types of technologies in the region, and the more complete the region's technological innovation system is constructed.
Technical output	Number of transferred out patents	B1	The total number of patents transferred out to other regions, the greater the number of transferred out patents and the stronger the technological innovation capability of the region.
	Proportion of transferred out patents in the number of patents	B2	The number of patents transferred to other regions accounts for the proportion of the total number of patents in the region. The higher the proportion, the greater the loss of technological innovation in the region.
	Number of technology categories transferred out	B3	The greater the number of technology categories transferred to other regions, the more abundant the types of technologies in the region, and the more complete the region's technological innovation system is constructed.
Technology investment	R&D personnel full time equivalent	C1	The number of R&D personnel and the time spent on R&D. The higher the value, the greater the intensity of the research personnel in the region.
	R&D funds internal	C2	The total amount of funds invested in R&D in the region. The larger the amount, the higher the importance the region attaches to R&D.
	R&D expenditure intensity (%)	C3	The greater the intensity of investment in research funding in the region, the higher the importance the region attaches to R&D
	Expenditure for new product development	C4	The special funds invested in new product research and development, the greater the amount of funds, the higher the importance the region attaches to the research and development of new products
Technical output	Turnover of export technology contract	D1	The transaction amount of technology contracts for transferring technological achievements to other regions in this region. The higher the amount, the stronger the region's technological research and development capabilities.
	New product sales revenue	D2	The higher the sales revenue of new products developed in the region, the higher the R&D direction of the region is in line with the market, and the stronger technological R&D capabilities.
	Number of R&D projects (Topics)	D3	The more R&D projects or topics generated in the area, the better the scientific research atmosphere in the area
	Regional Gross Domestic Product (GDP)	D4	The economic strength of the region, the stronger the experience, the greater the impact of the region's R&D output on the economy.
	Number of patents authorized	D5	The level of scientific research achievements in the region, the more patents granted, the stronger the scientific research capabilities and achievements of the region

TABLE II: KMO and Bartlett sphericity test

KMO		0.718
Bartlett sphericity test	Approximate chi-square	842.477
	Degree of freedom	105
	Significance	0.000

three common factors reached 84.583%, indicating that the three common factors express most of the information in the index.

The indicators contained in the common factor can be expressed through the factor load matrix, as shown in Table IV.

3) Calculate Linear Combination Coefficients and Weights: First, the eigenvector and its weight are obtained through the factor load matrix, as shown in Table V. Then, the obtained eigenvector weights are used to calculate the linear combination coefficients and their weights, as shown in Table VI. Through the linear combination coefficient weight, the factor comprehensive evaluation score expression is listed, and finally, the comprehensive score and each dimension score are calculated.

B. Measurement Results

According to the weights obtained by the linear combination coefficients, a comprehensive evaluation equation of cross-regional technology transfer efficiency can be obtained. Through the calculation results, the technology transfer efficiency of the 31 Chinese provinces and regions studied are ranked, as shown in Table VII and Table VIII, where F is the comprehensive score and $F1 \sim F4$ are the scores of the 4 dimensions.

$F = 0.05878063D^{*}3 + 0.016268229C^{*}1 + 0.077226117C^{*}2 - 0.006793369D^{*}5 - 0.071320217D^{*}4 - 0.024426446D^{*}2 - 0.034555645C^{*}4 + 0.086379582A^{*}1 + 0.080329486B * 1 - 0.077614757A^{*}3 + 0.25993089D^{*}1 + 0.307629016A^{*}2 - 0.173016227B^{*}3 + 0.315145276B^{*}2 + 0.186037434C^{*}3$

As shown in Table VII and Table VIII, among the 31 selected provinces and regions, Jiangsu Province ranks first with a technology transfer efficiency score of 4.32676445, and Yunnan Province ranks last with a technology transfer efficiency score of 0.39374943. Their comprehensive efficiency scores are very poor, indicating that there are great differences in technology transfer efficiency among provinces and regions in China, and the development of the technology transfer level is extremely uneven. Regions with weak technology transfer need to take certain measures to strengthen their own technology transfer efficiency to improve their comprehensive technological strength. The regions with high

TABLE III: Factor Characteristic Roots and Cumulative Variance Contribution Rate

Element	Initial characteristic root			Extract the sum of squares of the load			Rotating load sum of squares		
	total	variance%	accumulation%	total	variance%	accumulation%	total	variance%	accumulation%
1	9.564	63.76	63.76	9.564	63.76	63.76	7.841	52.273	52.273
2	1.794	11.963	75.723	1.794	11.963	75.723	2.837	18.913	71.186
3	1.329	8.86	84.583	1.329	8.86	84.583	2.01	13.397	84.583
4	0.909	6.058	90.641						
5	0.711	4.737	95.378						
6	0.239	1.596	96.974						
7	0.154	1.029	98.003						
8	0.113	0.75	98.754						
9	0.106	0.71	99.463						
10	0.043	0.284	99.747						
11	0.019	0.127	99.874						
12	0.011	0.072	99.945						
13	0.005	0.033	99.978						
14	0.002	0.012	99.991						
15	0.001	0.009	100						

TABLE IV: Factor Loading Matrix

	Element		
	1	2	3
D*3	0.98	-0.006	0.094
C*1	0.98	0.14	-0.101
C*2	0.975	0.023	0.12
D*5	0.949	0.175	-0.177
D*4	0.935	0.015	-0.229
D*2	0.934	0.215	-0.244
C*4	0.92	0.2	-0.258
A*1	0.917	0.23	0.013
B*1	0.858	0.234	-0.001
A*3	0.668	-0.478	0.084
D*1	0.666	-0.071	0.634
A*2	-0.276	0.665	0.328
B*3	0.569	-0.628	-0.044
B*2	-0.023	0.588	0.382
C*3	0.574	-0.365	0.649

TABLE V: Feature Vectors and Their Weights

	Element		
	T1	T2	T3
D*3	0.316888364	-0.0044796	0.081539
C*1	0.316888364	0.10452419	-0.087611
C*2	0.315271586	0.01717183	0.10409234
D*5	0.306864344	0.13065524	-0.1535362
D*4	0.302337367	0.01119902	-0.1986429
D*2	0.302014012	0.16051929	-0.2116544
C*4	0.297487035	0.14932027	-0.2237985
A*1	0.296516969	0.17171831	0.01127667
B*1	0.277438996	0.17470472	-0.0008674
A*3	0.216001456	-0.3568755	0.07286464
D*1	0.215354745	-0.0530087	0.54995451
A*2	-0.089246111	0.49648991	0.28451905
B*3	0.183989264	-0.4688657	-0.0381672
B*2	-0.007437176	0.4390016	0.3313606
C*3	0.185606042	-0.2725095	0.56296605

TABLE VI: Linear Combination Coefficients and Their Weights

	Linear combination coefficient	Weights
D*3	0.00016314	0.05878063
C*1	0.00004515	0.016268229
C*2	0.00021433	0.077226117
D*5	-0.00001885	-0.006793369
D*4	-0.00019794	-0.071320217
D*2	-0.00006779	-0.024426446
C*4	-0.00009590	-0.034555645
A*1	0.00023973	0.086379582
B*1	0.00022294	0.080329486
A*3	-0.00021541	-0.077614757
D*1	0.00072140	0.25993089
A*2	0.00085378	0.307629016
B*3	-0.00048018	-0.173016227
B*2	0.00087464	0.315145276
C*3	0.00051632	0.186037434

technology transfer efficiency should increase the technical support for the relatively weaker regions in policy, narrow the gap, and then achieve balanced development. The technology transfer efficiency of Tibet, Guangxi and Hainan ranked 9, 10 and 14, respectively, in the middle and upper reaches, but the technology production capacity of the three regions ranked at the bottom, while the technology input or output ranked at the top, indicating that the three regions' own technology R&D capacity is weak, and most of their technologies depend on the support of other regions. At the same time, the technology R&D achievements in this region have not been effectively applied, so such regions should focus on the effective utilization of technology.

V. TRANS-REGIONAL TECHNOLOGY TRANSFER EFFICIENCY IMPROVEMENT PATH

A. Analysis of the Dimensional Layer Configuration Effect

1) Construction of the Binary Data Table and Truth Table: In QCA technology, the variables to be explained are usually called results, that is, the "cross regional technology transfer efficiency" in this paper. At the same time, the four explanatory variables are called conditions, that is, "technology input", "technology output", "technology input" and "technology output" in this paper.

For further csQCA operations, a binary data table based on Boolean algebra needs to be constructed on the basis of the original data, that is, the above multidimensional comprehensive score of cross-regional technology transfer efficiency. In the process of building the binary threshold table, a critical value is usually found first. The data greater than the critical value are recorded as [1], and the data less than the critical value are recorded as [0]. The usual methods are "qualitative comparison" and "mean anchor point method". In this stage, the "mean anchor point method" is adopted, meaning the average value of each group of data is taken as the critical point. If it is greater than the average value, it is recorded as [1]; otherwise, it is recorded as [0]. The first synthesis result of the binary table is called the "truth table", which is also a configuration

TABLE VII: Evaluation Results of Cross-Regional Technology Transfer Efficiency

Area	Technical input(F1)	Technical output(F2)	Technology investment(F3)	Technical output(F4)	Overall ratings(F)
Jiangsu	1.14866086	0.45363975	1.26032706	1.46413678	4.32676445
Guangdong	0.54592468	0.46348175	1.44816984	1.668281	4.12585727
Beijing	0.63208715	0.49328206	1.28701879	1.44799064	3.86037864
Zhejiang	0.69332386	1.04847122	0.90111566	0.99431571	3.63722645
Shanghai	0.66040732	0.49146897	0.81438371	0.72665448	2.69291449
Anhui	0.9423318	0.82570896	0.43065975	0.45124373	2.64994423
Shandong	0.57511796	0.33045075	0.75111425	0.68447001	2.34115297
Fujian	0.25597419	0.93036529	0.39914682	0.37342685	1.95891315
Tibet	0.67061209	1.00167311	0	0.00034086	1.67262606
Guangxi	0.73036014	0.54948024	0.14344078	0.14247483	1.56575599
Sichuan	0.32138578	0.41796651	0.42235957	0.39264882	1.55436068
Hebei	0.69381052	0.23527089	0.29553135	0.2784157	1.50302846
Hubei	0.37143415	0.18655668	0.49399022	0.44587917	1.49786023
Hainan	1.12269216	0.22386349	0.04200303	0.0277625	1.41632118
Hunan	0.48262899	0.18085348	0.4055835	0.34400648	1.41307245
Tianjin	0.30079116	0.22147707	0.65005413	0.2146771	1.38699946
Jiangxi	0.68338016	0.21215209	0.23445445	0.25248629	1.382473
Liaoning	0.37206738	0.20180348	0.42317747	0.31126651	1.30831483
Shanxi	0.8538023	0.15190944	0.18450544	0.10946725	1.29968443
Henan	0.24897907	0.21057801	0.37225543	0.37519332	1.20700584
Chongqing	0.32457265	0.23645046	0.30378711	0.31899268	1.1838029
Heilongjiang	0.45053727	0.40825334	0.19759304	0.10653103	1.16291468
Ningxia	0.62852865	0.3461646	0.09877426	0.02826433	1.10173184
Shaanxi	0.2196654	0.12932525	0.41571331	0.25886286	1.02356682
Xinjiang	0.39429664	0.27663077	0.05777737	0.10326532	0.8319701
Jilin	0.24090394	0.24580922	0.19616027	0.11996751	0.80284095
Qinghai	0.57685094	0.06581531	0.08880194	0.00647772	0.7379459
Inner Mongolia	0.39630198	0.04954881	0.14060279	0.08376814	0.67022172
Guizhou	0.26131827	0.11293435	0.09757362	0.10250408	0.57433031
Gansu	0.08666457	0.16755655	0.15246062	0.06195788	0.46863962
Yunnan	0.13742791	0.00552854	0.12226108	0.1285319	0.39374943

TABLE VIII: Ranking of Cross-Regional Technology Transfer Efficiency Evaluation

Area	Technical input(F1)	Technical output(F2)	Technology investment(F3)	Technical output(F4)	Overall ratings(F)
Jiangsu	1	9	3	2	1
Guangdong	15	8	1	1	2
Beijing	11	6	2	3	3
Zhejiang	7	1	4	4	4
Shanghai	10	7	5	5	5
Anhui	3	4	9	7	6
Shandong	14	13	6	6	7
Fujian	26	3	14	11	8
Tibet	9	2	31	31	9
Guangxi	5	5	23	19	10
Sichuan	23	10	11	9	11
Hebei	6	17	17	15	12
Hubei	21	23	8	8	13
Hainan	2	18	30	29	14
Hunan	16	24	13	12	15
Tianjin	24	19	7	18	16
Jiangxi	8	20	18	17	17
Liaoning	20	22	10	14	18
Shanxi	4	26	21	22	19
Henan	27	21	15	10	20
Chongqing	22	16	16	13	21
Heilongjiang	17	11	19	23	22
Ningxia	12	12	26	28	23
Shaanxi	29	27	12	16	24
Xinjiang	19	14	29	24	25
Jilin	28	15	20	21	26
Qinghai	13	29	28	30	27
Inner Mongolia	18	30	24	26	28
Guizhou	25	28	27	25	29
Gansu	31	25	22	27	30
Yunnan	30	31	25	20	31

table, that is, the combination of given conditions related to the given result, including 1 configuration, 0 configuration, irrelevant configuration and C contradiction configuration. With the help of fsqca3.0 software, this paper takes the binary table as a sample to obtain a set of "truth tables" without contradictory configurations.

2) Intermediate Solution Analysis: The conditional combination consistency and coverage analysis results of the intermediate solutions are obtained through calculation, as shown in Table IX.

It can be seen from Table 9 that when the result variable is "1", the consistency and solution consistency of the two combinations included in the result are both 1.0, and the overall coverage of the two combinations (solution coverage) is 1.0, which is greater than the theoretical value of 0.8. At the same time, the unique coverage values of the two combinations 1 and 2 are both 0.777778, indicating that both combinations have the ability to explain the results.

3) Parsimonious Analysis: Through further calculation, the conditional combination consistency and coverage analysis results of the reduced solution are obtained, as shown in Table X.

The simplified solution is a core condition in the evaluation of the QCA scheme. This is the same as the above intermediate solution result. When the result variable is "1", the consistency and overall consistency of the two combinations included in the result are both 1.0, and the overall solution coverage of the two combinations is 1.0, both of which are greater than the theoretical value of 0.8. At the same time, the unique coverage value of configuration is 0.777778, indicating that both combinations can explain the results.

From the results of the intermediate solution and the reduced solution, it can be seen that the α_1 and α_2 configurations show that the regional technology transfer efficiency can be effectively improved through the combination of $F1*F3$ and $F1*F4$, and the β_1 configuration shows that the regional technology transfer efficiency can be significantly enhanced under the joint action of $F1*F3*F4$. Therefore, in the next stage of research, we will consider the technology input, technology input and technology output from the perspective of calculating the improvement path of technology transfer efficiency from the index level.

B. Analysis of Configuration Effect of Index Level

1) Construction of the Binary Data Table and Truth Table: Using the QCA method to analyze the promotion path of the four dimensions above, combined with the configuration results of α_1 and α_2 above, the indicators included in the dimensions of technology input, technology input and technology output in the two paths are further used as samples. We also set the "efficiency of cross-regional technology transfer" as the result. In addition, for the calculation of csQCA, it is necessary to construct a Boolean algebraic dichotomous data table of cross-regional technology transfer efficiency index items. Affected by the amount of data and complexity, the "qualitative comparison" method is used in this stage to divide the critical value. The index data are divided into three equal parts: the 22nd ranked data are regarded as the critical value, the data above the critical value are recorded as [1], and the data less than the critical value are recorded as [0]. Furthermore, with the help of fsQCA3.0 software for calculation, two sets of "truth tables" with no contradictory configurations are obtained based on the bipartite data table of the α_1 and α_2 configurations.

2) Conditional Combination Consistency and Coverage Analysis: According to the truth table obtained above, the conditional combination consistency and coverage analysis table is constructed. Before that, it is necessary to conduct univariate necessity analysis, eliminate the variables that do not meet the requirements, repeat the univariate necessity of the eliminated "truth table", and conduct conditional combination consistency and coverage analysis.

Table XI shows that when Outcome=1 and Outcome=0, the univariate analysis all passed the necessity analysis test. According to the univariate analysis results, the consistency and coverage of the condition combination are further analyzed by fsQCA3.0 software. The Boolean algebra minimization operation will obtain simplified solutions, intermediate solutions and complex solutions. Finally, based on the combination of intermediate solutions and simplified solutions, a path to improve the efficiency of cross-regional technology transfer will be explored.

3) Analysis of Intermediate Solutions: Through operations, the conditional combination consistency and coverage analysis results of the intermediate solution are obtained, as shown in Table XII.

Table XII shows that when the result variable is "1", the consistency and solution consistency in the result are 1.0, and the overall solution coverage is 0.842105, which is greater than the theoretical value of 0.8. At the same time, the values of unique coverage in the results are greater than 0, indicating that the results in the combination have interpretation ability.

4) Reduced Solution Analysis: Through further calculation, the conditional combination consistency and coverage analysis results of the reduced solution are obtained, as shown in Table XIII.

The simplified solution is a core condition in the evaluation of the QCA program. This is the same as the above intermediate solution result. When the result variable is "1", the consistency and solution consistency of the 4 combinations included in the result are all 1.0, and the overall solution coverage of the 4 combinations is 0.842105, which are all greater than the theoretical value of 0.8. At the same time, the unique coverage values of the four combinations are all greater than 0, indicating that the four combinations have the ability to explain the results.

5) Conditional Combination Analysis: The results are analyzed and summarized by conditional combination, and the paths expressed by the intermediate solution are grouped by conditional combination according to the core conditions expressed by the reduced solution to obtain the conditional combination of cross-regional technology transfer efficiency improvement paths. All paths of this combination are cross-regional technology transfer efficiency improvement paths, as shown in Table XIV, where ● or • means the condition exists, ⨂ or⊗ means the condition does not exist, ● or ⨂ indicates the core condition, • or ⊗ indicates the auxiliary condition, "blank" means that the condition in the combination does not affect whether the condition exists or not, CS indicates consistency, CV stands for solution coverage, and NCV stands for net coverage.

TABLE IX: Consistency and Coverage Analysis of Conditional Combination of Intermediate Solutions

Combination	Variable combination of intermediate solutions	Raw coverage	Unique coverage	Consistency	Solution coverage	Solution consistency
α_1	F1*F3	0.777778	0.777778	1.0	1.0	1.0
α_2	F1*F4	0.777778	0.777778	1.0		

TABLE X: Consistency and Coverage Analysis of Reduced Solution Condition Combination

Combination	Variable combination of intermediate solutions	Raw coverage	Unique coverage	Consistency	Solution coverage	Solution consistency
β_1	F1*F3*F4	0.777778	0.777778	1.0	1.0	1.0

TABLE XI: Univariate Analysis Results

Condition variable	Outcome=1		Outcome=0	
	Consistency	Coverage	Consistency	Coverage
A1	0.894737	0.894737	0.166667	0.105263
∼A1	0.105263	0.166667	0.833333	0.833333
A2	0.736842	0.736842	0.416667	0.263158
∼A2	0.263158	0.416667	0.583333	0.583333
A3	0.789474	0.833333	0.250000	0.166667
∼A3	0.210526	0.307692	0.750000	0.692308
C1	0.789474	0.789474	0.333333	0.210526
∼C1	0.210526	0.333333	0.666667	0.666667
C2	0.789474	0.789474	0.333333	0.210526
∼C2	0.210526	0.333333	0.666667	0.666667
C3	0.736842	0.736842	0.416667	0.263158
∼C3	0.263158	0.416667	0.583333	0.583333
C4	0.789474	0.789474	0.333333	0.210526
∼C4	0.210526	0.333333	0.666667	0.666667
D1	0.789474	0.789474	0.333333	0.210526
∼D1	0.210526	0.333333	0.666667	0.666667
D2	0.789474	0.789474	0.333333	0.210526
∼D2	0.210526	0.333333	0.666667	0.666667
D3	0.842105	0.842105	0.250000	0.157895
∼D3	0.157895	0.250000	0.750000	0.750000
D4	0.789474	0.789474	0.333333	0.210526
∼D4	0.210526	0.333333	0.666667	0.666667
D5	0.789474	0.789474	0.333333	0.210526
∼D5	0.210526	0.333333	0.666667	0.666667

TABLE XII: Consistency and Coverage Analysis of Intermediate Solution Condition Combination

Combination	Variable combination of intermediate solutions	Raw coverage	Unique coverage	Consistency	Solution coverage	Solution consistency
Z1	$A1* \sim A2*A3*C1*C2*C3*C4*D1*D2*D3*D5$	0.210526	0.210526	1.0	0.842105	1.0
Z2	$A1*A2*A3*C1*C2*C4*D1*D2*D3*D4*D5$	0.473684	0.105263	1.0		
Z3	$A1*A2*C1*C2*C3*C4*D1*D2*D3*D4*D5$	0.421053	0.526316	1.0		
Z4	$A1*A2*A3* \sim C1* \sim C2*C3* \sim C4* \sim D1* \sim D2* \sim D3* \sim D4* \sim D5$	0.526316	0.526316	1.0		
Z5	$A1*A2*A3* \sim C1* \sim C2* \sim C3* \sim C4* \sim D1* \sim D2*D3*D4* \sim D5$	0.526316	0.526316	1.0		

TABLE XIII: Consistency and Coverage Analysis of Reduced Solution Condition Combination

Combination	Variable combination of intermediate solutions	Raw coverage	Unique coverage	Consistency	Solution coverage	Solution consistency
Y1	A1*A3*C3	0.631579	0.210526	1.0	0.842105	1.0
Y2	A1*A2	0.631579	0.210526	1.0		
Y3	A2*D3	0.578947	0.142857	1.0		
Y4	A2*D4	0.578947	0.142857	1.0		

TABLE XIV: Cross-Regional Technology Transfer Efficiency Improvement Path Configuration

Variable	Z1	Z2	Z3	Z4	Z5
A1	●	●	●	●	●
A2	⊗	●	●	●	●
A3	●	•		●	•
C1	•	•	•	⊗	⊗
C2	•	•	•	⊗	⊗
C3	●		•	●	⊗
C4	•	•	•	⊗	⊗
D1	•	•	•	⊗	⊗
D2	•	•	•	⊗	⊗
D3	•	●	●	⊗	●
D4		●	●	⊗	●
D5	•	•	•	⊗	⊗
CS	1.0	1.0	1.0	1.0	1.0
CV	0.210526	0.473684	0.421053	0.526316	0.526316
NCV	0.210526	0.105263	0.526316	0.526316	0.526316

Table XIV shows that most CS, CV and NCV values gradually increase to 0.5, indicating that the results have strong interpretation ability.

C. Cross-Regional Technology Transfer Efficiency Improvement Path

According to the results of the conditional combination analysis, five paths to improve the efficiency of cross-regional technology transfer and their key improvement methods can be obtained:

1) Path One $(A1* \sim A2*A3*C1*C2*C3*C4*D1*D2*D3*D5)$*:* Taking the number and category of transferred patents and the investment intensity of R&D funds as the main factors to improve, expanding the diversification of transferred patents and increasing the investment intensity of science, technology and R&D funds are the characteristics of the "intermediary environment" leading path. This path applies to Jiangsu, Guangdong, Beijing, Shanghai and Shandong, where the efficiency of comprehensive technology transfer is high, but the efficiency of technology input is low. Although it has strong economic strength and can increase the intensity of technology investment, to ensure the diversity of technology in the province, it is necessary to focus on improving the technology input capacity.

2) Path Two $(A1*A2*A3*C1*C2*C4*D1*D2*D3*D4*D5), (A1*A2*C1*C2*C3*C4*D1*D2*D3*D4*D5)$*:* Taking the number and proportion of transferred patents, the number of R&D projects (topics), and regional GDP as the main improvement factors, expanding the diversification of transferred patents, encouraging the active research and development of R&D projects (topics), and improving regional economic strength, as external supports, represent the weak "intermediary-R&D-environment" leading path. This path needs to be developed at multiple points and promoted by multiple factors. It is applicable to Tibet, Guangxi, Hainan, Shanxi and Ningxia. These regions generally have a relatively poor economic environment, but thanks to the high intensity of technological input, the comprehensive capacity ranks above the output.

3) Path Three $(A1*A2*A3*C1*C2*C4*D1*D2*D3*D4*D5), (A1*A2*C1*C2*C3*C4*D1*D2*D3*D4*D5)$*:* Taking the number of transferred patents and their proportion and categories as well as the R&D investment intensity as the promotion factors, strengthening the introduction of external patents, and increasing the R&D investment intensity internally are the characteristics of the "intermediary economy" leading path. This path applies to Hunan, Tianjin, Jiangxi, Liaoning, Henan, Chongqing, Heilongjiang, Shaanxi, Xinjiang and Jilin. These regions rank moderately in terms of technology input efficiency and economic environment. Similarly, comprehensive technology transfer efficiency ranks in the middle, so it is necessary to improve technology transfer efficiency from the perspective of technology input and economic level.

4) Path Four $(A1*A2*A3* \sim C1* \sim C2* \sim C3* \sim C4* \sim D1* \sim D2*D3*D4* \sim D5)$*:* Taking the number and proportion of transferred patents, the number of R&D projects (Topics) and regional GDP as the promotion factors, increasing the introduction of external patents, and encouraging R&D projects (Topics) to actively develop and improve regional economic strength belong to a strong "intermediary R&D environment" leading path. This path applies to Zhejiang, Anhui, Fujian, Sichuan, Hebei, Hubei, Qinghai, Inner Mongolia, Guizhou, Gansu and Yunnan.

VI. CONCLUSION

Using factor analysis and QCA clear set qualitative comparative analysis, this paper takes 31 provinces and regions in China as the research sample, constructs a cross regional technology transfer efficiency research system from the perspective of technology input, technology output, and technology input and technology input, measures and ranks the technology transfer efficiency of the 31 provinces and regions, and summarizes four types of technology transfer efficiency improvement paths through configuration analysis. According to the characteristics of each path, the 31 regions are matched. The results show that the data passed the KMO and Bartlett sphericity tests. Three common factors were extracted according to the cumulative variance contribution rate of the factor characteristic root machine. The linear combination coefficient and its weight were calculated through the characteristic vector and its weight. Finally, the measurement results of cross-regional technology transfer efficiency were obtained. In addition, through the QCA clear set qualitative comparative analysis method, based on the construction of a binary data table and truth table, the consistency and coverage results of the condition combination are obtained. Through the analysis of the intermediate solution and reduced solution, the path configuration is obtained. Finally, according to the path configuration, the technology transfer efficiency of the 31 regions are assigned to the "intermediary environment" dominant path, the weak "intermediary R&D environment" dominant path strengthening the "intermediary R&D environment" leading path and the "intermediary economy" leading path.

The result of factor analysis shows that the technology transfer capacities of the 31 selected regions vary greatly. Among them, Jiangsu, Guangdong, Beijing and other regions with good economic environment have strong technology transfer capacity. However, Yunnan, Gansu, Guizhou and other regions with poor economic environment and remote geographical location have poor technology transfer capacity. It can be seen that the level of technology investment is positively correlated with regional technology transfer capacity. Further, we obtained the technology transfer and improvement path of 31 regions through QCA analysis. It is found that the technology transfer and upgrading path of the 31 regions can be divided into four configurations. However, technology transfer capability has little influence on configuration division. Regions with more comprehensive differences in technology transfer capabilities may also be in the same configuration. Finally, the technology transfer capability of each region can be effectively improved by using different configurations of upgrade paths.

REFERENCES

[1] G. Buenstorf and M. Geissler, "Not invented here: Technology licensing, knowledge transfer and innovation based on public research," *Journal of Evolutionary Economics*, vol. 22, no. 3, pp. 481–511, 2012.

[2] F. Jiménez-Sáez, J. M. Zabala-Iturriagagoitia, J. L. Zofío, and E. Castro-Martínez, "Evaluating research efficiency within national r&d programmes," *Research Policy*, vol. 40, no. 2, pp. 230–241, 2011.

[3] B.-W. Lin and D. Berg, "Effects of cultural difference on technology transfer projects: an empirical study of taiwanese manufacturing companies," *International Journal of Project Management*, vol. 19, no. 5, pp. 287–293, 2001.

[4] E. M. Rogers, S. Takegami, and J. Yin, "Lessons learned about technology transfer," *Technovation*, vol. 21, no. 4, pp. 253–261, 2001.

[5] Y. Li, H. Guo, Y. Liu, and M. Li, "Incentive mechanisms, entrepreneurial orientation, and technology commercialization: Evidence from china's transitional economy*," *Journal of Product Innovation Management*, vol. 25, no. 1, pp. 63–78, 2008.

[6] M. Kafouros and E. Y. Wang, "Technology transfer within china and the role of location choices," *International Business Review*, vol. 24, no. 3, pp. 353–366, 2015.

[7] A. G. Z. Hu, G. H. Jefferson, and Q. Jinchang, "R&d and technology transfer: Firm-level evidence from chinese industry," *The Review of Economics and Statistics*, vol. 87, no. 4, pp. 780–786, 2005.

[8] X. Gao, J. Guan, and R. Rousseau, "Mapping collaborative knowledge production in china using patent co-inventorships," *Scientometrics*, vol. 88, no. 2, pp. 343–362, 2011.

[9] Y. Kim, "The ivory tower approach to entrepreneurial linkage: productivity changes in university technology transfer," *Journal of Technology Transfer*, vol. 38, no. 2, pp. 180–197, 2013.

[10] A. J. C. Trappey, C. V. Trappey, C.-Y. Wu, and C.-W. Lin, "A patent quality analysis for innovative technology and product development," *Advanced Engineering Informatics*, vol. 26, no. 1, pp. 26–34, 2012.

[11] Y.-C. Hsu and C.-C. Lee, "The impact of military technology transfer on economic growth: international evidence," *Applied Economics*, vol. 44, no. 19, pp. 2437–2449, 2012.

[12] S. Ercan and G. Kayakutlu, "Patent value analysis using support vector machines," *Soft Computing*, vol. 18, no. 2, pp. 313–328, 2014.

[13] C. Curi, C. Daraio, and P. Llerena, "The productivity of french technology transfer offices after government reforms," *Applied Economics*, vol. 47, no. 28, pp. 3008–3019, 2015.

[14] R. Cerqueti and M. Ventura, "Patent valuation under spatial point processes with delayed and decreasing jump intensity," *The B.E. Journal of Theoretical Economics*, vol. 15, no. 2, pp. 433–456, 2015.

[15] M. Gumpert, "Rational underdevelopment: regional economic disparities under the heckscher-ohlin theorem," *International Review of Applied Economics*, vol. 30, no. 1, pp. 89–111, 2016.

[16] F. P. Kabore and W. G. Park, "Can patent family size and composition signal patent value?" *Applied Economics*, vol. 51, no. 60, pp. 6476–6496, 2019.

[17] P. Chung and S. Y. Sohn, "Early detection of valuable patents using a deep learning model: Case of semiconductor industry," *Technological Forecasting and Social Change*, vol. 158, p. 120146, 2020.

[18] X. Deng, Y. Liang, J. Li, and C. Chen, "Synergy degree model between sci-tech finance and sci-tech innovation based on correlation matrix weight in guangdong." *IAENG International Journal of Applied Mathematics*, vol. 51, no. 1, pp. 192–198, 2021.

[19] X. Deng, C. Huang, and Y. Liu, "Research on mean-variance-efficiency portfolio of fuzzy dea based on possibility theory." *IAENG International Journal of Computer Science*, vol. 48, no. 3, pp. 592–598, 2021.