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Research of the Synergetic Effects of the Impact of Innovative and Related Macroeconomic Factors on Economic Growth

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ABSTRACT

This article examines the main mechanisms and tools for implementing innovation policy in countries with fast-growing economies such as China and India. The study **aims** to explore the causal relationship between innovation, key macroeconomic variables and economic growth. The author applies the entropy **method** and adapts the Gray model to build a system of indices for assessing the coordination of the interaction of technological innovation, financial development and economic growth. The **results** show that the degree of integration of the financial system into innovation processes has a significant positive impact on the success of innovation, which is measured by patent activity. Our research proves that innovation indirectly affects economic growth through quality of life, infrastructure efficiency, employment, and trade openness. The findings of the research reveal that both economic growth and innovation tend to depend on a number of conjugate variables in the long run: capital, labor, etc. The author **concludes** that a comprehensive analysis of technological innovation, financial development and economic growth shows that the three-factor relationship has great potential for coordinated development, as a result of which, according to the calculated forecasts, economic growth in fast-growing economies will significantly accelerate its pace in the next five years. The subject of further research may be an analysis of whether the degree of conjugation of connectivity and coordination between the three systems will maintain stable growth at high values and whether they will be able to reach the stage of transformation.

Keywords: economic growth; macroeconomic factors; technological innovation; R&D; financial system; national innovation system

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INTRODUCTION

In recent years, as the study of innovation policy has advanced, most researchers have concluded that an extensive system of financing innovation is required to implement strategies for disruptive technological innovation since such a system allows the economy to quickly respond to new technological innovation challenges [1, 2]. Thus, technological innovation and financial development are integral parts of the same chain of economic growth. However, as noted by a number of researchers who conducted a comparative analysis of the national innovation systems of different countries [3], at present, the uneven development of regional economies can not only cause innovation dissonance and social instability but also impede long-term economic development.

Coordinated regional economic development will help reduce these regional differences. Banks foster technological innovation and provide finance to companies that stand a chance of success. Technological innovation contributes to financial development by expanding market demand, increasing profits and reducing transaction costs. Therefore, when studying the impact of financial development on economic growth, it is necessary to consider the impact of technological innovation on both of these factors. It should be noted that most of the existing research usually considers financial development and technological innovation as exogenous factors. However, from the point of view of our study, these factors mutually influence each other and should be considered as endogenous variables. This article attempts to combine these variables into a single system of interrelationships and comprehensively analyze the characteristics of coordinated development. At the same time, we will try to adapt our model for individual countries to identify cross-country differences in the relationship between these variables, which will contribute to the balanced development of the economy.

The main contribution of our research consists of the following results. First, we built a system of indices for assessing the coordinated interaction of technological innovation, financial development and economic growth. To do this, we used the entropy weight method combined with expert advice to determine the weight of the score index. Second, we used a relationship degree model to assess the relationship and coordination of our factors. Third, we have adapted gray model to forecast the dynamics of the relationship and coordination of our factors. Finally, based on empirical analysis, we put forward a number of assumptions and proposals to strengthen the interconnection of our factors and ensure sustainable economic growth.

REVIEW AND CRITICAL ANALYSIS OF THE MAIN THEORETICAL AND METHODOLOGICAL APPROACHES

First of all, we note that K. E. Maskus, R. Neumann, T. Seide [4] found that increasing the level of financial development can reduce the differences between technologically backward and developed countries, reduce financing costs, increase the efficiency of financing, and thus facilitate the introduction of innovations. At the same time, their research has shown that there are various methods of activating domestic financial markets, which at the same time have a positive effect on the intensity of industrial R&D. However, among the indicators of the financial market, only foreign direct investment has a positive effect on the intensity of R&D. In turn, R.H. Chowdhurya, M. Maung [5], using the example of the Indian economy, found that financial markets remove the problem of information asymmetry in R&D financing, which can significantly facilitate investment in R&D.

QX. Zhang and L. Feng [6] used empirical data from the listed companies to analyze the influence of financial impact on firms' technological innovation. They viewed financial development and technological innovation as two subsystems and studied the spatial characteristics of communication and coordination, as well as the temporal differentiation between them. QX. Zhang and L. Feng found that the degree of coordination and interrelation of these factors in countries differs significantly. In other words, the technological innovation potential of individual countries lags behind the level of financial development. They used a systemic communication model to empirically analyze the evolution of convergence and coordinated development between technological innovation, industrial sectoral structure and financial development and concluded that, in general, the level of convergence of the three systems is steadily increasing, and the level of development tends to be optimized.

C. Bravo-Ortega and A.G. Marin [7] found that with a 0.1% increase in R&D, labor productivity grows by 1.6%.

F.R. Lichtenberg [8] indicated that the private sector's contribution to R&D to increase productivity growth is 7 times higher than investment in fixed assets.

P. Howitt and D. Mayer-Foulkes [9] put forward the theory of vertical technological innovation, believing that an increase in enterprise investment in R&D can increase opportunities for successful technological innovation and contribute to further economic development.

A.B. Atkinson and J.E. Stiglitz [10] presented the concept of a learning-by-doing model and believed that with its help countries would disseminate the accumulated experience of technological innovation through trade, thereby contributing to economic development between regions. Later, they conducted an empirical study of the impact of technological innovation on the quality of economic growth and found that, in general, technological innovation can significantly improve the quality of all-around economic growth and significantly increase efficiency, optimize the sectoral structure of the industry. In doing so, however, they found that technological innovation exacerbated income inequality.

Nevertheless, in his studies, J. Xiao [11] argues that technological innovation can be developed to form a pole of economic growth and contribute to regional economic development. Technological innovation can create new resources or production methods and contribute to the modernization of the sectoral structure of the industry, and the interactive promotion of technological and institutional innovations can stimulate new knowledge and technologies. Innovation and transformation of factors of production make the status of knowledge elements more visible.

L. L. Li and L. B. Zhou [12] conducted a factor analysis of the Chinese economy in 2017, reducing 23 estimates to three factors. They found a positive relationship between economic growth and the complex potential of technological innovation, consisting of three main factors, namely: the effectiveness of the contribution of talent, the basic potential of regional innovation development and regional economic growth.

F. Y. Wang and J. Zheng [13] used data from the 40 largest steel companies in China from 2011 to 2018 to find a positive relationship between the integrated potential of technological innovation and economic growth, and found an increase in the degree of relationship in two of them.

P.L. Rousseau and P. Wachtel [14], using the methods of dynamic panel data, showed that the activity of the stock market and the banking sector has a positive effect on the development of the economy.

A. Ilyina and R. Samaniego [15] selected 28 manufacturing industries in the United States and used their data to study the impact of financial development on economic development from 1970 to 1999. Research has shown that developed financial markets directly stimulate industrial growth through R&D.

Also R. G. Rajan and L. Zingales [16], N. Cetorelli and M. Gambera [17] conducted similar studies and found the relationship between financial development and industrial development in India.

In turn, F. Y. Wang and J. Zheng [13], based on data from 1999 to 2016, found that the real economy has a positive side effect, and there is a positive impact of technological innovation on the local real economy, but a negative impact on neighboring provinces and cities in China.

S. Yang and T. T. Huang [18], using differential regression methods such as the generalized method of moments (GMM) and least squares dummy variable (LSDVC), based on the theory of least squares (OLS), investigated the relationship between financial development and economic growth, and found a lagging non-linear effect between the two, which means lagging inverted U-shaped relashinship.

Meanwhile, in his studies, X. B. He [19] found that there is a long-term, stable equilibrium relationship between financial development, technological innovation and economic growth. He stresses that financial development is the direct cause of economic growth.

In turn, L. L. Li and L. B. Zhou [12] also found that economic growth promotes financial development and technological innovation. For example, in China, financial development and technological innovation contribute to economic growth more than in India. In their research L. L. Li and L. B. Zhou [12] proposed a three-sector dynamic game model, and the results of this model show that financial innovation itself inhibits economic growth, while co-financing of technological innovation has a significant impact on economic growth.

In general, summing up the results of the theoretical and methodological analysis, it can be noted that the existing research creates a reliable prerequisite for further research, but still have a number of shortcomings.

First, previous studies have mainly looked at current nodal problems, or have focused on analyzing the relationship between two or three factors, but in pairwise correlation.

Second, these studies did not reveal long-term dynamic effects, especially those that have not yet been observed. There are studies analyzing the possible interdependence of these three factors, and to identify the relationship, the structure of the analysis in these studies is based on an ideal research platform and methodology, more precisely, on the application of a systemic communication approach built on the "three-module vector" model and analysis of their interaction.

Based on this methodology, in our study, we use the degree of convergence and coordination of the three systems, as well as the gray model to forecast their future dynamics.

IMPROVEMENT OF FUNCTIONALITY AND ADAPTATION OF NEW TOOLS IN RESEARCH METHODOLOGY

One of the methods that has generated wide interest in the research environment in recent years is the entropy method. It is based on the distance between a finite number of valuable objects and positive and negative ideal solutions to determine the relative pros and cons of each evaluated object and is widely used in systems engineering. The distance principle is a popular mathematical model for solving multipurpose decision analysis problems that use the entropy weight method to determine the weighting index. For assigning weights to indices, the method of entropy weights is more often used, since it allows you to overcome subjective factors and more objectively, comprehensively and accurately reflect the information and laws inherent in the data of the index. The entropy weight method can significantly improve the contrast and spacing between index data and effectively avoid a number of errors due to too small a difference in the index data. This method is distinguished by high objectivity, high accuracy and scientific validity. It can comprehensively and systematically reflect the usefulness of the indicative information.

The entropy method is an objective way to determine the weight of an index. This is mainly determined by the size of the observation value information. If there are m system and n indices, then the data matrix can be expressed as $X=\left(x_{ij}\right)_{m*n}$. If the difference between the values of the X_{ij} index is greater, then the effect of complex assessment is better. If the index values are the same, then the complex assessment is invalid.

When determining the weight of an index, the data must first be standardized. This reduces bias in the results due to subjective factors.

The data standardization process includes two stages. At the first stage, the entropy method can ignore the standardization process without any impact on the dimension. The principle is to find the proportion of a certain indicator in different schemes of the same indicator. The data must be non-negative for processing. It also makes sense to translate the data to ensure that the entropy logarithm makes sense for the following structural elements:

For large indicators:

$$X'_{ij}=\frac{X_{ij}-\min\left(X_{1j},X_{2j},\ldots X_{nj}\right)}{\max\left(X_{1j},X_{2j},\ldots X_{nj}\right)-\min\left(X_{1j},X_{2j},\ldots X_{nj}\right)},i==1,2,\ldots,n;\ j=1,2,\ldots m. \quad (1)$$

For small indicators:

$$X'_{ij}=\frac{max\left(X_{1j},X_{2j},\ldots X_{nj}\right)-X_{ij}}{\max\left(X_{1j},X_{2j},\ldots X_{nj}\right)-\min\left(X_{1j},X_{2j},\ldots X_{nj}\right)}++1,i=1,2,\ldots,n;\ j=1,2,\ldots m. \quad (2)$$

At the second stage, the weight indicator is determined. This stage is intended for quantitative assessment and complex processing of all information about the evaluated object. Weighing each factor avoids the complexity of the assessment process. The entropy method is used to determine the weights of the indices. First, based on the selected estimates, our $n\times m$ input matrix can be obtained as follows:

$$X=\begin{bmatrix} x_{11} & x_{12}\dots & x_{1n} \\ x_{21} & x_{22}\dots & x_{2n} \\ x_{n1} & x_{n2}\cdots & x_{nm} \end{bmatrix}_{n\times m}, \quad (3)$$

where the system number is expressed in terms of n, and the index score is expressed in terms of m.

Second, the same trend is used to process the target index and a positive matrix is obtained. After evaluating, for all indicators to be of good quality, the low-quality indicator should be processed in reverse order, as the above indicators have their advantages and disadvantages. We get the corresponding matrix:

$$Y=\begin{bmatrix} y_{11} & y_{12}\dots & y_{1n} \\ y_{21} & y_{22}\dots & y_{2n} \\ y_{n1} & y_{n2}\cdots & y_{nm} \end{bmatrix}_{n\times m}. \quad (4)$$

Now that we have a normal matrix, we can get the following calculation formula:

$$z_{ij}=\frac{y_{ij}}{\sum_{i=1}^{n} Y_{ij}},(j=1,2,\dots,m), \quad (5)$$

where z_{ij} — an element in a normal matrix.

When we get an estimate of the weight index, the calculation formula will be as follows:

$$H(x_j)=-k\sum_{i=1}^{n} z_{ij} ln z_{ij}, j=1,2,\dots,m. \quad (6)$$

Here k — the correcting factor, and z_{ij} — j-th index of the -th estimated index.

Then the entropy value of the estimated index will be converted into a weight value as follows:

$$d_j=\frac{1-H(x_j)}{m-\sum_{j-1}^{m} H(x_j)}, j=1,2,\dots m, \quad (7)$$

where $0\le d_j\le 1, \sum_{j=1}^{m} d_j=1$.

Systems of technological innovation, financial development, and economic growth are particularly complex and involve technical, social, and economic factors. Economic growth needs financial support. In addition, technological innovation requires sufficient financial support and must be supported by economic growth. Together they form a system of interaction. The degree of connection chosen in our work represents the degree of correlation and influence between different indicators in the three systems. It is defined as the degree of coordinated development of the three subsystems. In particular, to understand the degree of coordination, the degree of influence, and the level of these three factors, a system of assessment indicators should be built that determines the degree of connection and coordination of these three factors.

The next method is the gray forecasting model GM (1.1), which is a time series forecasting model that includes a group of differential equations adapted to parameter variance as well as a first-order differential equation.

These three systems are quite large and very complex. They are linked dynamically and in stages, the entire link trend cannot be predicted using conventional linear or nonlinear models and is highly uncertain. Gray model is a method of forecasting the development of the characteristic value of the behavior of a system containing both known and uncertain information, i.e. predicting changes in a certain range.

We take a look at the data processing methodology. First, the time series being processed is called the generated column. Suppose that $X^{(0)}=\{X^{0}(1),X^{(0)}(2),X^{(0)}(3),\dots,X^{(0)}(n)\}$ — initial data of the indicator that we need to predict. This can be done by calculating the ratio of the levels of the series

$$\lambda(t)=\frac{X^{(0)}(t-1)}{X^{(0)}(t)}, t=1,2,3,\dots,n.$$

Gray forecasting model is valid when most levels are added to the interval $\left(\frac{-2}{e^{n+1}},\frac{2}{e^{n+2}}\right)$. Otherwise, it is needed to reprocess the data to make it logarithmic and smoothed. The preprocessed data is smoothed to three-point smoothing as follows:

$$X^{(0)}(t)=\left[X^{(0)}(t-1)+2X^{(0)}(t)+X^{(0)}(t+1)\right]/4, \quad (8)$$

$$X^{(0)}(1)=\left[3X^{(0)}(1)+X^{(0)}(2)\right]/4, \quad (9)$$

$$X^{(0)}(n)=\left[X^{(0)}(n-1)+3X^{(0)}(n)\right]/4. \quad (10)$$

The final preprocessing step also accumulates the generated processing data. The secondary data is then continuously looped to get the fully generated column.

Using the expression $X^{(1)}(k)=\sum_{n=1}^{k}X^{(0)}(n)$, we can get the following series:

$$X^{(1)}=\left\{X^{(1)}(1),X^{(1)}(2),X^{(1)}(3),\ldots,X^{(1)}(n)\right\}. \quad (11)$$

The degree of randomness weakens, and stationarity increases significantly, which can be described by the following series:

$$\frac{dX^{(1)}}{dt}+aX^{(1)}=u. \quad (12)$$

Finally, the index system consists of a number of indexes that reflect the relationship between them (*Table 1* and *2*). *Table 1* and *2* show the generalized values of the estimates of the indicators of the system of economies of India and China.

The choice of indices should clarify the logical correlation, scientific validity and representativeness of the indices, and reflect the correlation of different systems. Our research is based on the above principles. The indicators in the tables are divided into three main systems: technological innovation, financial development, and economic growth.

The system of technological innovation includes a system of R&D costs and the results of implemented innovations, and the system of financial development is subdivided into financial depth, financial range and a system of financial efficiency. The economic growth system includes systems of quality and quantity of economic growth. To prevent the influence of subjective factors on the results of the weighting coefficients of the indices and to ensure the reliability of the assessment, the weighting coefficients of all indices are considered.

In general, the results of the calculations show that the degree of convergence of the three key systems in these countries does not differ much, except that India as a whole is in a position to "catch up" with the Chinese innovation system and gradually increase in R&D spending.

Meanwhile, returning to our methodology, it can be noted that over the past two decades, technological innovation, financial development, and economic growth in India and China have demonstrated different values of the degree of mutual coordination throughout the entire cycle (*Tables 3* and *4*).

According to the above classification of the degrees of coordination, we see that during 2006–2018 the degree of coordination of the three systems of the Chinese economy is gradually increasing, but at the same time, we observe that the level of coordination is below the average level (0.4204) in general for 2006–2010.

The degree of conjugacy increased from 0.2478 to 0.4817, i.e. indicators were relatively stable, and in general, the situation tended to grow. From 2006 to 2008, it was at a low level, mainly due to a slowdown in economic growth. Lagging economic growth lacked funds to invest in technological innovation, so financial development was relatively slow, resulting in a low degree of conjugacy coordination. In addition, the structure of the economy has been relatively unified over the years, and the structure of the industry has been somewhat backward. 2009–2018 saw strong economic growth, a negative phase, and the overall degree of conjugacy was still relatively low but had a long-term uptrend. The conjugacy level in 2018 was 0.4817, which is close to the transformation stage.

We consider similar indicators of India (*Table. 4*).

Table 1

Index system for assessing the relationship between technological innovation, financial development and economic growth in India

System	Subsystem	Rating index	Type of relationship	Index weights
Technological innovation	Innovation costs Innovation system launch	R&D spending (per Rs 1 billion) R&D investment intensity, % Number of permits for the issuance of patent applications, ea. Patent applications, ea.	+ + + +	0.0717 0.0564 0.0943 0.0751
Financial development	Depth of financial involvement Range of financial involvement Financial involvement efficiency	Cumulative assets of financial institutions/ GDP, % The total output of shares in the stock market (per Rs 1 billion) Premium income/GDP, % Per capita insurance (Rs/person) The volume of cumulative trade bonds (per Rs 1 billion) The number of retail offices offering financial services (per 10 thousand people) The number of retail offices offering financial services per 100 square meters Number of personnel working in retail offices (thousand people) Value added of the financial industry/total population of the region (Rs/person) General balance sheet/ deposits of financial institutions, % Investments in financial assets (Rs million)	+ + + + + + + + + + +	0.0653 0.0337 0.0516 0.0527 0.0315 0.00998 0.0112 0.0311 0.0531 0.0593 0.0157
Economic growth	Quality of economic growth Economic growth rate	Aggregate retail consumer goods (per Rs 1 billion) Consumer price index, % Average monthly wages of employees (per 100 thousand rupees) Per capita consumption expenditure (Rs) Number of participants serving personnel insurance (people) GDP per capita (Rs 100 thousand/person) City population density (people/sq. km) Urbanization rate, %	+ – + + + + + +	0.0108 0.0378 0.0542 0.0237 0.0082 0.0116 0.0385 0.0395

Source: Handbook of Statistics on Indian Economy. URL: https://www.india.gov.in/handbook-statistics-indian-economy; IMF Statistics — International Financial Statistics. URL: https://data.imf.org/?sk=388dfa60–1d26–4ade-b505-a05a558d9a42 (accessed on 21.06.2021); author's calculations.

India's conjugacy coordination increased from 0.2355 in 2006 to 0.5106 in 2018 — more than doubled. The overall level of coordination has improved, but there is still a large gap with China.

We have divided the research into two phases. The first phase was from 2006 to 2008, when the degree of alignment of the pairing was low, and economic growth during this period lagged behind. This was due to the long-term formation of a resource-dependent model of economic growth in both countries, which could not effectively respond to the urgent need to adjust the development regime; therefore, the coordinated development of the system

Table 2

Index system for assessing the relationship between technological innovation, financial development and economic growth in China

System	Subsystem	Rating index	Type of relationship	Index weights
Technological innovation	Innovation costs Innovation system launch	R&D spending (per Rs 1 billion) R&D investment intensity, % Number of permits for the issuance of patent applications, ea. Patent applications, ea.	+ + + +	0.0621 0.0453 0.0921 0.0744
Financial development	Depth of financial involvement Range of financial involvement Financial involvement efficiency	Cumulative assets of financial institutions/ GDP,% The total output of shares in the stock market (per Rs 1 billion) Premium income/GDP, % Per capita insurance (Rs/person) The volume of cumulative trade bonds (per Rs 1 billion) The number of retail offices offering financial services (per 10 thousand people) The number of retail offices offering financial services per 100 square meters Number of personnel working in retail offices (thousand people) Value added of the financial industry/total population of the region (Rs/person) General balance sheet/ deposits of financial institutions, % Investments in financial assets (Rs million)	+ + + + + + + + + + +	0.0632 0.0225 0.0421 0.0431 0.0262 0.0111 0.0233 0.0411 0.0652 0.0681 0.0215
Economic growth	Quality of economic growth Economic growth rate	Aggregate retail consumer goods (per Rs 1 billion) Consumer price index, % Average monthly wages of employees (per 100 thousand rupees) Per capita consumption expenditure (Rs) Number of participants serving personnel insurance (people) GDP per capita (Rs 100 thousand /person) City population density (people/sq. km) Urbanization rate, %	+ – + + + + + +	0.0209 0.0477 0.0655 0.0352 0.0200 0.0127 0.0491 0.0477

Source: National Bureau of Statistics of China. URL: http://www.stats.gov.cn/english/; IMF Statistics — International Financial Statistics. URL: https://data.imf.org/?sk=388dfa60–1d26–4ade-b505-a05a558d9a42 (accessed on 21.06.2021); author’s calculations.

was severely limited. The second phase was characterized by moderate coordination of interaction from 2008 to 2018. At this phase, countries continued to pursue a policy of openness, and financial development proceeded at a rapid pace. The first years showed a lag in economic growth and financial development, and in subsequent years — in technological innovation. The lag in technological innovation results in an inability to effectively stimulate economic growth, and the overall degree of connectivity and coordination is low.

Table 3

The value and degree of conjugacy coordination of the three systems (technological, financial and economic growth) of China in 2006–2018

Год	Index of financial development, I_1	Index of technological development, I_2	Index of economic growth, I_3	Complex coordination index, *K*	Degree of conjugacy, *F*	Degree of conjugacy coordination, φ	Level of conjugacy	Level of conjugacy coordination	A system that is lagging in conjugacy coordination
2006	0.1821	0.1912	0.1647	0.1797	0.2478	0.2421	Low	Low	Economic growth
2007	0.1842	0.2033	0.1749	0.1886	0.2476	0.2566	Low	Low	Economic growth
2008	0.1923	0.2112	0.3192	0.2443	0.3133	0.3199	Negative	Moderate	Financial development
2009	0.2032	0.2132	0.2722	0.2314	0.3279	0.3494	Negative	Moderate	Financial development
2010	0.2109	0.2234	0.2601	0.2331	0.3744	0.4112	Negative	Moderate	Financial development
2011	0.2117	0.2242	0.3036	0.2489	0.4626	0.4346	Negative	Moderate	Financial development
2012	0.2284	0.2372	0.2993	0.2567	0.4897	0.4438	Negative	Moderate	Financial development
2013	0.2331	0.2387	0.3581	0.2791	0.4997	0.4722	Negative	Moderate	Financial development
2014	0.2423	0.2503	0.3686	0.2897	0.4998	0.4728	Negative	Moderate	Financial development
2015	0.2679	0.2512	0.3769	0.2994	0.4939	0.5008	Negative	Moderate	Technological innovations
2016	0.2701	0.2526	0.3885	0.3045	0.4840	0.5023	Negative	Moderate	Technological innovation
2017	0.2923	0.2555	0.4166	0.3211	0.4814	0.5080	Negative	Moderate	Technological innovation
2018	0.2956	0.2634	0.2953	0.2826	0.4817	0.5193	Negative	Moderate	Technological innovation
Average value	0.2369	0.2350	0.3002	0.2583	0.4204	0.4266	Negative	Moderate	Technological innovation

Source: National Bureau of Statistics of China. URL: http://www.stats.gov.cn/english/; IMF Statistics — International Financial Statistics. URL: https://data.imf.org/?sk=388dfa60–1d26–4ade-b505-a05a558d9a42 (accessed on 21.06.2021); author's calculations.

Thus, the degree of conjugacy and coordination of these three systems as a whole demonstrates an upward trend, which to some extent correlates with their economic policies. The question of whether the degree of conjugacy and coordination between them will support stable growth at the level of high values and whether they will be able to reach the stage of transformation is the subject of a separate study.

Finally, we will try to adapt gray model to forecast the conjugacy and conjugacy coordination of the three systems over the next

Table 4

The value and degree of conjugacy coordination of the three systems (technological, financial and economic growth) of India in 2006–2018

Год	Index of financial development, I_1	Index of technological development, I_2	Index of economic growth, I_3	Complex coordination index, K	Degree of conjugacy, F	Degree of conjugacy coordination, φ	Level of conjugacy	Level of conjugacy coordination	A system that is lagging in conjugacy coordination
2006	0.1821	0.1912	0.1647	0.1797	0.2478	0.2421	Low	Low	Economic growth
2007	0.1842	0.2033	0.1749	0.1886	0.2476	0.2566	Low	Low	Economic growth
2008	0.1923	0.2112	0.3192	0.2443	0.3133	0.3199	Negative	Moderate	Financial development
2009	0.2032	0.2132	0.2722	0.2314	0.3279	0.3494	Negative	Moderate	Financial development
2010	0.2109	0.2234	0.2601	0.2331	0.3744	0.4112	Negative	Moderate	Financial development
2011	0.2117	0.2242	0.3036	0.2489	0.4626	0.4346	Negative	Moderate	Financial development
2012	0.2284	0.2372	0.2993	0.2567	0.4897	0.4438	Negative	Moderate	Financial development
2013	0.2331	0.2387	0.3581	0.2791	0.4997	0.4722	Negative	Moderate	Financial development
2014	0.2423	0.2503	0.3686	0.2897	0.4998	0.4728	Negative	Moderate	Financial development
2015	0.2679	0.2512	0.3769	0.2994	0.4939	0.5008	Negative	Moderate	Technological innovations
2016	0.2701	0.2526	0.3885	0.3045	0.4840	0.5023	Negative	Moderate	Technological innovation
2017	0.2923	0.2555	0.4166	0.3211	0.4814	0.5080	Negative	Moderate	Technological innovation
2018	0.2956	0.2634	0.2953	0.2826	0.4817	0.5193	Negative	Moderate	Technological innovation
Average value	0.2369	0.2350	0.3002	0.2583	0.4204	0.4266	Negative	Moderate	Technological innovation

Source: Handbook of Statistics on Indian Economy. URL: https://www.india.gov.in/handbook-statistics-indian-economy; IMF Statistics — International Financial Statistics. URL: https://data.imf.org/?sk=388dfa60–1d26–4ade-b505-a05a558d9a42 (accessed on 21.06.2021); author's calculations.

five years, and to provide a theoretical basis for policy implementation.

After passing the model verification, the correspondence of the degree of conjugacy was C = 0.2561, P = 0.9677, and the correspondence of the conjugacy coordination was C = 0.1521, P = 0.9876. According to the likelihood rank of this model, P ⩾ 0.95 and C ⩾ 0.35, which can be used for forecasting. That is, the degree of coordination of the three systems can be predicted during 2019–2024. Overall, we found that the degree of conjugacy increases steadily from 2020 to 2024 and enters the transformation phase of the degree of conjugacy in 2021, and the growth rate increases significantly. In addition, the predicted value of the degree of conjugacy coordination is also greatly improved. The final coordination phase will begin in 2023 and the synergies from the development of the three systems will improve significantly. As a result, the degree of conjugacy coordination in the interaction of technological innovation, financial development, and economic growth tends to increase in the next five years, but from the tables above, we see that the degree of conjugacy coordination is not synchronized and their evolution is not the same. Coordination of technological innovation, financial development and economic growth still takes time, and proactive economic policies are needed to promote coordinated development.

CONCLUSIONS

On the basis of the idea of system communication in this paper, a model of a "three-vector module" was built [20]. On the basis of a cross-country comparative analysis of the mechanisms of interaction of these three systems, an analysis of the conjugacy degree was carried out. In general, our conclusions are as follows.

First, from a comprehensive analysis of technological innovation, financial development and economic growth, we see that they are all on the rise. The technological innovation index has the greatest increase indicating that it has relatively great potential to facilitate coordinated development in the future. The financial development index shows an accelerated growth trend, which means that the financial reform has reached good initial results and additionally contributes to a combination of three systems.

Second, from the point of view of the change in the degree of conjugacy in China, more precisely, an increase from 0.2478 to 0.4817, the leading advantage of this country becomes more and more evident. This is due to the significant improvement in technological innovation in China and the improvement in the financial climate, which is setting a good example for other countries.

Third, the degree of coordination of conjugacy in China is growing, albeit slowly, although it showed a lag in terms of financial development. From 2013 to 2018, China entered a state of high conjugate coordination. In 2018, the degree of conjugacy coordination reached an extreme value.

Fourth, the forecast results show that the degree of conjugacy will grow steadily from 2020 to 2024 and enter the transformation stage in 2022, and the growth rate will increase significantly. In addition, the predicted value of the degree of conjugacy coordination will also be significantly improved. The highest value of the degree of coordination will be achieved in 2024, and the synergistic effect of development will improve. However, the growth of the degree of conjugacy during the transformation period is expected to be significantly lower than the degree of conjugacy coordination. Their coordination will still take a long time, therefore, to promote coordinated development, it is necessary to pursue an active economic policy.

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