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Article

Evaluation of China's innovative potential and its temporal and spatial evolution and convergence analysis

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Abstract: In this study, the entropy weight method, the α convergence model, the absolute β convergence model and the conditional β convergence model are used to evaluate the 31 provinces' innovative potential in China from 2011 to 2022. It is found that the innovative potential in nationwide China and in various regions are all increasing year by year, and the innovative potential in the eastern region is obviously better than that in the central region and western region. No matter considering the influence of external factors or not, the gap of innovative potential among provinces in different regions will gradually expand over time, with the largest gap among provinces in the eastern region, followed by the central region and the smallest in the western region. The conclusion of this study is instructive to enhance the innovative potential of China and promote the balanced development of regional innovative potential in China.

Keywords: innovative potential; temporal and spatial evolution; regional differences; convergence analysis; entropy weighting method

1. Introduction

A new round of scientific and technological revolution and industrial transformation is reshaping the global economic structure. Governments all over the world are increasingly aware of the important role of scientific and technological innovation in promoting economic and social development. Studies have shown that scientific and technological investment can bring about a significant increase in total factor productivity and economic aggregate. Every 1% increase in the stock of scientific and technological capital will bring about a 0.05%–0.1% increase in economic aggregate, with a social return rate of about 20%–50% (Song, 2020). The concept of "innovation" was first put forward by Schumpeter, an economist, at the beginning of the 20th century. He believed that innovation was a new production function and a recombination of various production factors (Xu and Jiang, 2021). That is, a never-before-seen production factor and production condition are recombined and introduced into the production system, thus forming a new production capacity to obtain profits. With the deepening and development of innovation theory, modern innovation theory holds that innovation is not only a process of invention and discovery, but also a process of re-creation, renewal or improvement (Deutschmann, 2011; Heiskala, 2007). Innovation activities include not only scientific and technological activities, but also organizational, financial and commercial activities. Innovation runs through the whole stage of research and development, marketization and technology diffusion (Qiu et al., 2020; Zhen, 2000).

Since the reform and opening-up, China has made great achievements in development. However, due to the limitation of the carrying capacity of resources and environment and the increase of human capital, the inherent production mode can no longer be maintained, making the traditional economic development mode unsustainable (Lu, 2022). According to the development experience of developed countries and some emerging economies in the world, with the continuous maturity of the development stage, the development dividends such as "comparative advantage" and "late-comer advantage" on which the previous development depended are gradually attenuated (Hou et al., 2016). While the weak innovative potential will seriously restrict the economic and social development and fall into the "middle income trap". In this regard, the Communist Party of China (CPC)'s 17th, 18th, 19th and 20th reports all highly emphasized the core position of innovation in the overall modernization of China. From the process of innovation and development in China, we can find that scientific and technological innovation plays an increasingly prominent role in the economic and social development of China. Especially with China's economic development entering the "new normal" (Chen and Groenewold, 2019; Zhang and Chen, 2017), it is of great significance to build a scientific and reasonable innovative potential indicator system and objectively evaluate China's innovative potential level for China's rapid economic development and improving the core competitiveness in the future. On this basis, the α convergence model and absolute β model are constructed to test whether the regional innovative potential of China can achieve balanced development.

To this end, this study tentatively uses the entropy weighting method to select 21 indicators based on five dimensions of innovative fund projects, innovative personnel organizations, innovative external environment, innovative government support and innovative technology output to comprehensively and objectively evaluate innovative potential in China from 2011 to 2022. The reason for choosing the entropy weighting method is that it not only eliminates the need to subjectively set the data distribution shape and maintains the relative objectivity of the evaluation results, but also avoids the one-sided evaluation defects of the single indicator method. On this basis, this study also constructs the α convergence model and the absolute β convergence model to examine the convergence of regional innovative potential gap in China. The results show: First, nationwide innovative potential in China has shown a rapid growth trend from 2011 to 2022. Its comprehensive score has increased from 0.0793 in 2011 to 0.2197 in 2022, an increase of 177.05%, and an average annual growth rate of 9.71%. But there are obvious regional differences. The innovative potential in the eastern region is the highest, followed by the central region, and the western region is the lowest. Second, there is no absolute β convergence property in the innovative potential of nationwide China and in various regions, indicating that the innovative potential in nationwide China and in various regions are all in a divergent status. The α coefficient value of nationwide innovative potential in China has shown a steady growth trend from 2011 to 2022, indicating that the innovative potential gap among provinces in China is constantly widening, and the gap among provinces in the eastern region is the largest, followed by the central region, and the western region is the smallest.

2. Literature review

In recent years, with the increasing emphasis on innovation in China, the evaluation of regional innovative potential, as one of the hot issues, has been widely discussed by Chinese scholars. The existing research on regional innovative potential mainly focuses on the following two aspects:

Based on different understandings of innovative potential, scholars have constructed the diversified evaluation indicator system. Ivanová and Masárová (2016) constructed the evaluation indicator system of innovative potential in Slovakia based on ten dimensions: publications, citations, patents, creation or substantial improvement of new materials, products, equipment, processes, technological procedures, systems and services. Dong and Cai (2018) constructed the evaluation indicator system of innovative potential in China based on five dimensions: innovation input, innovation talents, innovation output, innovation subject and innovation environment. Ni and Wu (2019) measured and evaluated the innovative potential of 10 major metropolitan areas in China in 2017 from four dimensions: innovation input potential, innovation output potential, innovation structure composition and innovation supporting environment, and other 14 secondary indicators. Wang et al. (2020) constructed an indicator system including three first-level indicators and twelve second-level indicators of innovation investment, innovation environment and innovation achievement, measured the innovative potential of 289 cities in China with the data of 2015. Li et al. (2020) constructed four first-level indicators, including knowledge innovative potential, technological innovative potential, government support and services, and innovation basic environment, and other 19 second-level indicators to evaluate and visually analyze the innovative potential and spatial-temporal pattern evolution of 35 large and medium-sized cities in China from 2007 to 2016. Lin and Wang (2022) evaluated the innovative potential of 27 central cities in the Yangtze River Delta from 2000 to 2019 from five dimensions: innovation basic conditions, innovation technology potential, innovation education investment, industrial agglomeration and innovation openness. Han et al. (2023) constructed 3 first-class indicators and 16 second-class indicators including policy innovation, scientific and technological innovation and industrial innovation ability to evaluate and rank the innovative potential of six provinces in central China in 2021.

Based on different preferences, scholars have used a variety of different empirical methods to evaluate regional innovative potential. Pan et al. (2010) used DEA method to measure the innovative potential of 33 Asian and European countries and regions and conduct comparative analysis. Crescenzi and Rodríguez-Pose (2013) used SFA method to measure innovative potential in USA from 1994 to 2007. Wei and Dai (2015) used AHP and Delphi method to evaluate the innovative potential of Jilin Province from 2006 to 2015. Hu (2016) used Delphi method, entropy method, factor analysis method and grey correlation method to empirically analyze the innovative potential of Henan Province in 2013. Li et al. (2018) used principal component analysis to evaluate and analyze the innovative potential of 21 cities in Guangdong Province in 2016. Jiang and Zhang (2019) applied min-max standardized analysis method to evaluate the innovative potential of Pearl River Delta region in 2010–2015. Zemtsov and Kotsemir (2019) used DEA-KPF method to measure innovative potential in Russia from 1998 to 2012. Song (2020) used factor analysis to evaluate the innovative potential of China and other provincial regions from 2006 to 2017. Shao et al. (2020) used factor analysis and cluster analysis to measure the innovative potential of China in 2010–2016 and make a classification judgment. Shan (2020) took Shanxi Province as an example and uses entropy method to evaluate the innovative potential of resource-based cities. Ali (2024) used OLS model to analyze the influencing factors of innovative potential in Egypt in 2018.

By combing the literature, we can find that Chinese scholars have made a lot of rich achievements in the research of regional innovative potential evaluation system and evaluation methods. But there are still the following shortcomings: Due to the different perspectives of researchers, there is no consensus on the selection principle of regional innovative potential evaluation indicators. The existing research on the construction of innovative potential indicators often ignores the selection of related indicators of the Internet and private enterprises, and the development level of the Internet and private enterprises is also an important factor affecting regional innovative potential. For example, Qiu and Zhu (2022) found that the Internet can effectively improve the matching efficiency of innovation resources, reduce the cost of innovation, and broaden the breadth and depth of innovation. Li and Xu (2015) found that private enterprises are profit-oriented, self-financing, self-management and self-financing, with strong development momentum and tenacious vitality, and high innovative potential. Therefore, on the basis of referring to the existing research, this study not only takes the traditional indicators such as capital, talents and technology into account, but also adds the indicators at the level of the Internet and private enterprises, and adopts the entropy weighting method to make a more objective and comprehensive evaluation of China's regional innovative potential from 2011 to 2022. On this basis, the α convergence model and absolute β model are constructed to test whether the regional innovative potential of China can achieve balanced development.

3. Research methodology

3.1. Construction of innovative potential evaluation system

3.1.1. Model construction

In order to evaluate the innovative potential of China relatively comprehensively and objectively, referring to the existing research (Ma and Dena, 2020; Wei and Li, 2018), this study uses entropy weighting method to make a comprehensive evaluation of China's innovative potential. The specific model is constructed as follows.

The first step is to standardize the original indicators for evaluating the innovative potential by using the deviation standardization method:

$$SX_{i,j} = \frac{X_{i,j} - \text{MIN}\ (X_{i,j})}{\text{MAX}(X_{i,j}) - \text{MIN}\ (X_{i,j})} \times 0.99 + 0.01 \tag{1}$$

In Equation (1), $SX_{i,j}$ and $X_{i,j}$ respectively represent the *j*-th original indicator of province *i* after standardization and without standardization, $\text{MAX}(X_{i,j})$ and $\text{MIN}\ (X_{i,j})$ respectively represent the maximum value and minimum value of the *j*-th original indicator of province *i* without standardization.

The second step is to calculate the entropy value of each standardized indicator for evaluating the innovative potential:

$$E_j = -\frac{1}{\ln(n)}\sum_{i=1}^{n} P_{i,j}\ln P_{i,j} \quad (2)$$

In Equation (2), $P_{i,j} = SX_{i,j}/\sum_{i=1}^{n} SX_{i,j}$, when $P_{i,j} = 0$, commanding $P_{i,j}\ln P_{i,j} = 0$, so as to ensure that $0 \leq E_j \leq 1$.

The third step is to calculate the weight of each standardized indicator to evaluate the innovative potential:

$$W_j = \frac{1 - E_j}{\sum_{j=1}^{m}(1 - E_j)} = \frac{1 - E_j}{m - \sum_{j=1}^{m} E_j} \quad (3)$$

In Equation (3), $0 \leq W_j \leq 1$, $\sum_{j=1}^{m} W_j = 1$.

The fourth step is to calculate the comprehensive score of the innovative potential of each province in China:

$$IP_i = \sum_{j=1}^{m} W_j SX_{i,j} \quad (4)$$

In Equation (4), the greater the value of IP_i, the higher the innovative potential of province i.

3.1.2. Indicator selection

Referring to the existing research (Chen and Xie, 2023; Sheng and Zhang, 2021; Yang and Fang, 2022; Zhang et al., 2022), in order to reflect innovative potential of China more comprehensively, this study evaluates China's innovative potential from five dimensions: innovative fund projects, innovative personnel organizations, innovative external environment, innovative government support and innovative technology output (see **Table 1**). Compared with the existing indicator system, this study not only fully considers various traditional innovation resources and outputs when designing the indicator system, but also incorporated Internet resources with the characteristics of the times and strong innovation power into the indicator system. Among them, this study selects R&D funds, number of new product projects and new product funds as proxy indicators of innovative fund projects, selects R&D personnel, number of colleges and universities, number of students enrolled in colleges and universities, and number of full-time teachers in colleges and universities as proxy indicators of innovative personnel organizations, selects optical cable line length, mobile phone penetration rate, number of domain names, number of web pages, Internet broadband access ports and Internet broadband access users and information transmission, software and information technology services, employed persons in urban units as proxy indicators of innovative external environment, selects number of social organizations, local fiscal expenditure on science and technology and local financial education expenditure as proxy indicators of innovative government support, selects number of patent applications accepted, number of patent applications granted, technology market turnover and sales revenue of new products proxy as indicators of innovative technology output.

Table 1. Evaluation indicator system of China's innovative potential.

Dimension	Indicator name (Influence direction)	Mean (SD)	Measuring unit	Indicator weight
Innovative fund projects	R&D funds (+)	3,839,029.1830 (5,258,489.1424)	Ten thousand CNY	0.0576
	Number of new product projects (+)	17,717.1022 (30,363.4955)	One project	0.0683
	New product funds (+)	4,530,614.6100 (7,122,402.1880)	Ten thousand CNY	0.0631
Innovative personnel organizations	R&D personnel (+)	94,173.6855 (135,554.6580)	One people	0.0619
	Number of colleges and universities (+)	84.0403 (41.1622)	One college or university	0.0164
	Number of students enrolled in colleges and universities (+)	91.6499 (58.5582)	Ten thousand	0.0224
	Number of full-time teachers in colleges and universities (+)	5.3079 (3.1773)	Ten thousand	0.0209
Innovative external environment	Optical cable line length (+)	1,114,851.2500 (922,731.5925)	Kilometer	0.0333
	Mobile phone penetration rate (+)	102.2605 (24.9798)	One mobile phone/ one people	0.0123
	Number of domain names (+)	95.1344 (139.1173)	Ten thousand	0.0637
	Number of web pages (+)	765,236.5425 (1,751,089.6216)	Ten thousand	0.0914
	Internet broadband access ports (+)	2204.9715 (1874.3283)	Ten thousand	0.0312
	Internet broadband access users (+)	1098.2339 (959.0280)	Ten thousand	0.0330
	Information transmission, software and information technology services, employed persons in urban units (+)	12.4272 (16.6203)	Ten thousand	0.0523
Innovative government support	Number of social organizations (+)	23,077.5000 (18,281.0205)	One organization	0.0270
	Local fiscal expenditure on science and technology (+)	138.8895 (176.3730)	One hundred million CNY	0.0522
	Local financial education expenditure (+)	887.7775 (596.3707)	One hundred million CNY	0.0229
Innovative technology output	Number of patent application accepted (+)	109,324.5833 (158,247.5322)	One application	0.0601
	Number of patent applications granted (+)	70,494.3387 (114,909.0887)	One application	0.0645
	Technology market turnover (+)	564.5260 (1057.4655)	One hundred million CNY	0.0813
	Sales revenue of new products (+)	61,192,534.2700 (89,709,683.3587)	Ten thousand CNY	0.0642

3.1.3. Data source and description

In terms of data sources, the data for evaluating the innovative potential of China in this study all come from China Statistical Yearbook and China Statistical Yearbook of Science and Technology, covering all the relevant data for evaluating the innovative potential of 31 provinces in Chinese mainland from 2011 to 2022. In terms of regional division, according to the classification standard of China National Bureau of Statistics, this study divided 31 provinces in Chinese mainland into eastern region, central region and western region. The eastern region includes Beijing, Tianjin, Hebei, Liaoning, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong and Hainan, with a total of 11 provinces (municipalities and autonomous regions). The central region includes Shanxi, Jilin, Heilongjiang, Anhui, Jiangxi, Henan, Hubei and Hunan, with a total of 8 provinces (municipalities and autonomous regions). The western region includes Sichuan, Guizhou, Yunnan, Tibet, Shaanxi, Gansu, Qinghai, Ningxia, Xinjiang, Inner Mongolia, Guangxi and Chongqing, with a total of 12 provinces (municipalities and autonomous regions).

3.2. Convergence model construction

3.2.1. *α* convergence model

With the passage of time, if the standard deviation of the innovative potential of a certain region from the mean value decreases gradually, it is considered that the innovative potential of this region has the α convergence property (Liu and Gao, 2024). The specific model is set as follows:

$$\alpha_t = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(IP_{i,t} - \frac{1}{N}\sum\nolimits_{1}^{N} IP_{i,t})^2} \tag{5}$$

In Equation (5), $IP_{i,t}$ represents the natural logarithm of the innovative potential of province *i* in the *t* year. If $\alpha_t < \alpha_{t+1}$, it shows that with the passage of time, the gap of innovative potential in this region gradually narrows, and there is α convergence property.

3.2.2. *β* convergence model

Without considering any other factors, if the region with low innovative potential is gradually converging to the region with high innovative potential at a faster growth rate, it is considered that the innovative potential of this region has absolute β convergence. On this basis, if the convergence speed is further improved after introducing other influencing factors, it is considered that the innovative potential in this region has conditional β convergence property. Referring to the practice of Liu et al. (2021), the specific model of this study is set as follows:

$$\left(\ln IP_{i,0+T} - \ln IP_{i,0}\right)/T = C + \beta_1 \times \ln IP_{i,0} + \varepsilon_{i,t} \tag{6}$$

$$\left(\ln IP_{i,0+T} - \ln IP_{i,0}\right)/T = C + \beta_2 \times \ln IP_{i,0} + factors_{i,t} + \varepsilon_{i,t} \tag{7}$$

In Equation (6), $\ln IP_{i,0}$ represents the natural logarithmic value of the innovative potential of province *i* in 2011, $factors_{i,t}$ represents a series of control variables that affect innovative potential in the *t* year of province *i*, including fiscal revenue decentralization, fiscal expenditure decentralization, public transportation, trade openness and social consumption demand (Chen et al., 2021; Feng, 2023; Liu et al., 2022; Wang and Zhang, 2022; Zhang, 2010), T represents the length of time, C represents the constant term, β_1 represents the absolute β coefficient value to be measured, and $\varepsilon_{i,t}$ represents the random error term. If $\beta_1 < 0$ is significant, it shows that the innovative potential of this region has the absolute β convergence property. Even if other factors are not considered, the gap of innovative potential of this region will narrow with time, and the convergence rate is $v_1 = \frac{-\ln(1+\beta_1)}{T}$. If $\beta_2 < 0$ is significant, and the value is $<\beta_1$, it shows that the innovative potential in this region has the property of conditional β convergence, and the variables of fiscal revenue decentralization, fiscal expenditure decentralization, public transportation, trade openness and social consumption demand can promote the regional innovative potential gap to converge at a faster speed, and the convergence rate is $v_2 = \frac{-\ln(1+\beta_2)}{T}$.

4. Empirical analysis

4.1. Evaluation results

Based on the entropy weighting method, this study calculates the comprehensive scores of innovative potential of 31 provinces in Chinese mainland during 2011–2022 (see **Table 2**).

Table 2. Evaluation results of China's innovative potential.

Region	**Province**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**
Eastern region	Beijing	0.1536	0.1765	0.1962	0.2264	0.2726	0.2933	0.3087	0.3272	0.3496	0.3569	0.3999	0.4317
	Tianjin	0.0605	0.0675	0.0763	0.0820	0.0844	0.0894	0.0832	0.0879	0.0927	0.1014	0.1074	0.1089
	Hebei	0.0827	0.0938	0.1032	0.1102	0.1206	0.1357	0.1489	0.1656	0.1855	0.2011	0.2202	0.2355
	Liaoning	0.0897	0.0988	0.1072	0.1102	0.1088	0.1153	0.1196	0.1286	0.1372	0.1453	0.1502	0.1564
	Shanghai	0.1115	0.1240	0.1330	0.1430	0.1519	0.1721	0.1827	0.1930	0.2044	0.2187	0.2450	0.2640
	Jiangsu	0.2367	0.2869	0.3243	0.3407	0.3684	0.4006	0.4228	0.4641	0.5002	0.5523	0.5982	0.6267
	Zhejiang	0.1679	0.2148	0.2262	0.2446	0.2852	0.3166	0.3313	0.3670	0.4105	0.4479	0.5006	0.5436
	Fujian	0.0812	0.0951	0.0993	0.1069	0.1268	0.1596	0.1987	0.2068	0.2107	0.1987	0.2222	0.2287
	Shandong	0.1673	0.1876	0.2387	0.2416	0.2517	0.2712	0.2873	0.2982	0.3090	0.3560	0.4213	0.4650
	Guangdong	0.2348	0.2835	0.3301	0.3485	0.3945	0.4645	0.5173	0.6130	0.6821	0.7313	0.7986	0.8327
	Hainan	0.0192	0.0214	0.0244	0.0262	0.0277	0.0288	0.0316	0.0336	0.0390	0.0396	0.0418	0.0445
	Means	**0.1277**	**0.1500**	**0.1690**	**0.1800**	**0.1993**	**0.2225**	**0.2393**	**0.2623**	**0.2837**	**0.3045**	**0.3369**	**0.3580**
Central Region	Shanxi	0.0538	0.0590	0.0666	0.0684	0.0686	0.0731	0.0792	0.0920	0.0944	0.1005	0.1046	0.1093
	Jilin	0.0466	0.0501	0.0530	0.0558	0.0590	0.0648	0.0687	0.0726	0.0791	0.0812	0.0784	0.0776
	Heilongjiang	0.0571	0.0616	0.0691	0.0715	0.0726	0.0737	0.0789	0.0799	0.0874	0.0928	0.0920	0.0968
	Anhui	0.0823	0.0965	0.1062	0.1155	0.1308	0.1513	0.1650	0.1860	0.2026	0.2231	0.2553	0.2863
	Jiangxi	0.0543	0.0605	0.0676	0.0744	0.0852	0.0945	0.1121	0.1310	0.1517	0.1639	0.1743	0.1856
	Henan	0.0999	0.1117	0.1284	0.1398	0.1586	0.1770	0.1937	0.2196	0.2429	0.2640	0.2783	0.3010
	Hubei	0.0933	0.1050	0.1158	0.1280	0.1468	0.1588	0.1676	0.1861	0.2122	0.2227	0.2444	0.2694
	Hunan	0.0818	0.0941	0.1016	0.1096	0.1218	0.1369	0.1515	0.1656	0.1913	0.2059	0.2252	0.2573
	Means	**0.0711**	**0.0798**	**0.0885**	**0.0954**	**0.1054**	**0.1163**	**0.1271**	**0.1416**	**0.1577**	**0.1693**	**0.1816**	**0.1979**

Table 2. (*Continued*).

Region	Province	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Western region	Sichuan	0.0876	0.1027	0.1173	0.1299	0.1499	0.1638	0.1822	0.2072	0.2284	0.2472	0.2618	0.2776
	Guizhou	0.0340	0.0379	0.0435	0.0472	0.0538	0.0604	0.0685	0.0787	0.0915	0.0953	0.1083	0.1126
	Yunnan	0.0426	0.0491	0.0560	0.0585	0.0644	0.0726	0.0794	0.0904	0.1026	0.1083	0.1112	0.1175
	Xizang	0.0111	0.0127	0.0137	0.0148	0.0145	0.0152	0.0163	0.0172	0.0180	0.0184	0.0192	0.0200
	Shaanxi	0.0688	0.0775	0.0872	0.0924	0.1000	0.1091	0.1169	0.1264	0.1419	0.1524	0.1676	0.1810
	Gansu	0.0323	0.0365	0.0406	0.0429	0.0482	0.0523	0.0581	0.0627	0.0669	0.0703	0.0725	0.0761
	Qinghai	0.0157	0.0178	0.0178	0.0188	0.0193	0.0206	0.0229	0.0255	0.0254	0.0264	0.0272	0.0285
	Ningxia	0.0180	0.0198	0.0208	0.0225	0.0231	0.0254	0.0285	0.0317	0.0317	0.0328	0.0348	0.0367
	Xinjiang	0.0323	0.0369	0.0399	0.0418	0.0456	0.0493	0.0515	0.0594	0.0612	0.0660	0.0724	0.0770
	Inner Mongolia	0.0407	0.0452	0.0483	0.0491	0.0518	0.0551	0.0605	0.0618	0.0681	0.0725	0.0767	0.0831
	Guangxi	0.0494	0.0552	0.0607	0.0664	0.0717	0.0808	0.0879	0.0962	0.1116	0.1239	0.1399	0.1402
	Chongqing	0.0524	0.0585	0.0654	0.0736	0.0836	0.0916	0.0973	0.1053	0.1114	0.1223	0.1323	0.1404
	Means	**0.0404**	**0.0458**	**0.0509**	**0.0548**	**0.0605**	**0.0664**	**0.0725**	**0.0802**	**0.0882**	**0.0947**	**0.1020**	**0.1076**
Nationwide	**Means**	**0.0793**	**0.0916**	**0.1025**	**0.1097**	**0.1214**	**0.1346**	**0.1458**	**0.1607**	**0.1755**	**0.1884**	**0.2059**	**0.2197**

Drawing **Figure 1** according to the above measurement results shows that the comprehensive score of China's innovative potential is increasing year by year from 2011 to 2022, and the development momentum is strong. The comprehensive score of China's innovative potential increases from 0.0793 in 2011 to 0.2197 in 2022, an increase of about 177.05%, with an average annual increase of 9.71%. Regionally, the spatial distribution of regional innovative potential in China presents a pattern of eastern region > central region > western region. From 2011 to 2022, the comprehensive score of innovative potential in the eastern region increases from 0.1277 to 0.3580, an increase of about 180.34%, with an average annual growth rate of 9.82%, which is faster than that in the whole country, the central region and the western region. However, there is a big gap in the innovative potential among the provinces. 60% of the provinces in the eastern region have not yet reached the average innovative potential level of the eastern region, and the difference between Guangdong with the highest comprehensive score of innovative potential and Hainan with the lowest score is about 16 times. From 2011 to 2022, the comprehensive score of innovative potential in central region of China increases from 0.0711 to 0.1979, an increase of about 178.34%, with an average annual increase of 9.75%. There is a big gap in the development of innovative potential between the central region and the eastern region. Henan (0.1929), which scores the highest in the central region, has not yet reached the average comprehensive score of innovative potential in the eastern region (0.2361). From 2011 to 2022, the comprehensive score of innovative potential in the western region increases from 0.0404 to 0.1076, an increase of about 166.34%, with an average annual increase of 9.31%. The comprehensive score of innovative potential in the western region is generally low, and four of the last five comprehensive scores of innovative potential in China are from the western region. In addition, the gap between the eastern region and the central region and the gap between the eastern region and the western region are both getting bigger and bigger. In 2011, the gap between the eastern region and the central region and the gap between the eastern region and the western region is 79.61% and 216.09% respectively, while in 2022, it is 80.9% and 232.71% respectively.

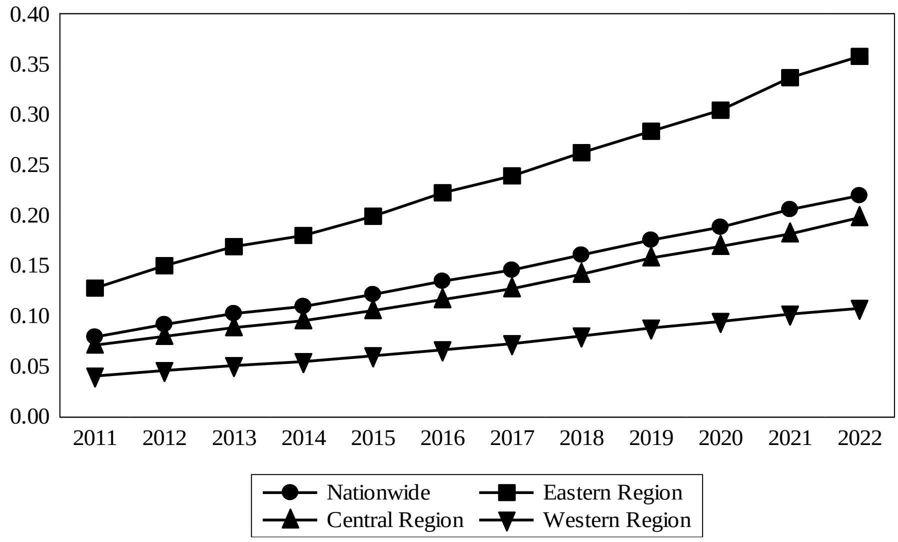

Figure 1. The changing trend of China's innovative potential.

According to the comprehensive score, the innovative potential of China provinces can be roughly divided into five echelons. The first echelon is Guangdong (0.5192), Jiangsu (0.4268) and Zhejiang (0.3380). The comprehensive scores of innovative potential of the above three provinces rank among the top three in China for 12 consecutive years, and their comprehensive scores of innovative potential have reached 0.8327, 0.6267 and 0.5436 respectively in 2022. Guangdong is the forefront of China's reform and opening-up. High-quality talents and active innovation consciousness are the key to Guangdong's innovative potential in the leading position in the country for 12 consecutive years. Jiangsu and Zhejiang are located in the Yangtze River Delta region where China's economy is highly developed. Jiangsu has always adhered to the innovation-driven strategy and is the first pilot province for the construction of innovative provinces in China. Outstanding enterprise innovation ability has become the key to Zhejiang's high innovative potential. At present, Zhejiang has initially formed an open regional innovation system framework with enterprises as the main body and Industry-University-Research closely integrated.

The second echelon is Shandong (0.2912) and Beijing (0.2911). Shandong has a strong innovative potential in the past two years. Since 2021, the comprehensive score of innovative potential has surpassed Beijing, ranking fourth in the whole country. Shandong government attaches great importance to innovation and development, and strives to build Shandong into an important regional innovation highland in China, constantly optimizing the innovation environment, and increasing R&D expenditure by more than 10%. Beijing is the region with the most intensive innovation resources in China, which has gathered a large number of top-notch scientific research institutions, universities and innovative enterprises in China, attracting a large number of talents. It should be noted that all the provinces in the first echelon and the second echelon of China's innovative potential are from the eastern region.

The third echelon is Jiangxi (0.1129), Shaanxi (0.1184), Liaoning (0.1223), Hebei (0.1503), Hunan (0.1536), Fujian (0.1612), Anhui (0.1667), Hubei (0.1708), Shanghai (0.1786), Sichuan (0.1796) and Henan (0.1929). The comprehensive score of innovative potential of the third echelon is between 0.1 and 0.2. Although its comprehensive score of innovative potential is still far from that of the first and second echelons, its innovative potential is developing very fast. Except Shaanxi, Liaoning and Shanghai, other provinces in the third echelon far exceed the average innovative potential development speed of their regions, and the development momentum is not weaker than that of the first and second echelons.

The fourth echelon is Xinjiang (0.0528), Gansu (0.0550), Inner Mongolia (0.0594), Jilin (0.0656), Guizhou (0.0693), Heilongjiang (0.0778), Yunnan (0.0794), Shanxi (0.0808), Tianjin (0.0868), Guangxi (0.0903) and Chongqing (0.0945). The fifth echelon is Tibet (0.0159), Qinghai (0.0222), Ningxia (0.0272) and Hainan (0.0315). The innovation scores of the provinces in the fourth echelon and the fifth echelon are all less than 0.1, and most of them come from the western region. The innovative potential of the western region has been low because of the talent, technology and economic development level. Especially the four provinces from the fifth echelon are also in a weak position in other indicators of China.

4.2. Convergence test

4.2.1. *α* convergence result

Based on the *α* convergence model, this study measures the *α* coefficient of China's innovative potential from 2011 to 2022 (see **Table 3**).

Table 3. *α* coefficient measurement results of China's innovative potential.

Year	Nationwide	Eastern Region	Central Region	Western Region
2011	0.0584	0.0703	0.0205	0.0222
2012	0.0709	0.0870	0.0244	0.0257
2013	0.0816	0.1014	0.0277	0.0297
2014	0.0866	0.1068	0.0315	0.0329
2015	0.0977	0.1211	0.0386	0.0381
2016	0.1101	0.1369	0.0446	0.0418
2017	0.1189	0.1488	0.0483	0.0460
2018	0.1346	0.1726	0.0557	0.0519
2019	0.1477	0.1912	0.0638	0.0584
2020	0.1603	0.2087	0.0701	0.0637
2021	0.1779	0.2300	0.0804	0.0685
2022	0.1891	0.2430	0.0924	0.0726

Drawing **Figure 2** according to the above measurement results shows that, as far as the development trend of the *α* coefficient values is concerned, the *α* coefficient values of innovative potential in the whole country, eastern region, central region and western region of China are all increasing year by year with the passage of time from 2011 to 2022, which shows that the innovative potential in the whole country, eastern region, central region and western region of China do not have the *α* convergence property, and the gaps of innovative potential among provinces in the whole country, eastern region, central region and western region of China are all widening with the passage of time. Among them, the gap of innovative potential among provinces in the eastern region is the largest, followed by the central region and the western region is the smallest.

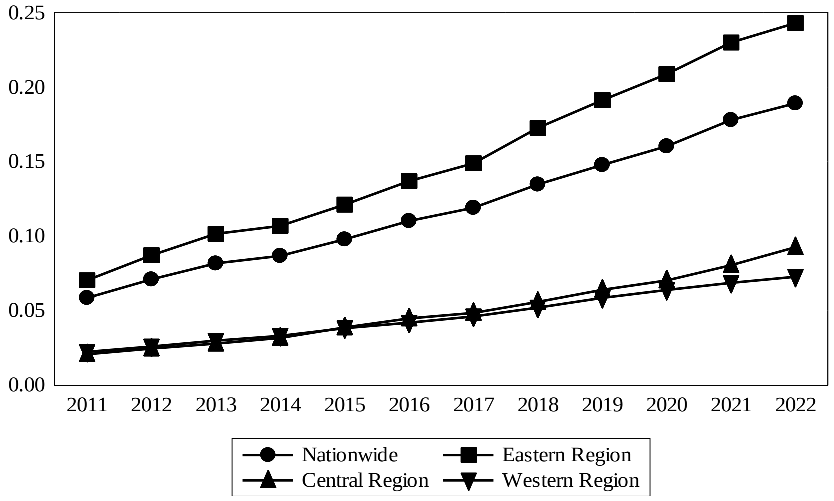

Figure 2. The changing trend of the α coefficient of innovative potential in China.

4.2.2. *β* convergence result

Table 4 reports the results of absolute β and conditional β convergence of innovative potential in China. The results show that the absolute β and conditional β coefficient values of innovative potential in China as a whole, the eastern region, the central region and the western region are all significantly greater than 0, indicating that there is no absolute β and conditional β convergence property of innovative potential in the whole country or in different regions. This means that, regardless of other factors, the gaps of innovative potential among provinces in China as a whole, eastern region, central region and western region are all gradually widening with time. This is mutually confirmed by the α convergence test results. It is worth noting that the conditional β coefficient values of innovative potential have been improved in different degrees compared with the absolute β coefficient values after introducing fiscal revenue decentralization, fiscal expenditure decentralization, public transport,

Table 4. β convergence results of innovative potential in China.

Convergence coefficient	Nationwide		Eastern Region		Central Region		Western Region	
	Absolute convergence	**Conditional convergence**	**Absolute convergence**	**Conditional convergence**	**Absolute convergence**	**Conditional convergence**	**Absolute convergence**	**Conditional convergence**
β	0.2598*** (0.0044)	0.2945*** (0.0174)	0.2593*** (0.0083)	0.2677*** (0.0186)	0.3038*** (0.0126)	0.5903*** (0.0479)	0.2695*** (0.0069)	0.2865*** (0.0409)
Control variables	Uncontrolled	Controlled	Uncontrolled	Controlled	Uncontrolled	Controlled	Uncontrolled	Controlled
Constant term	0.5697*** (0.0127)	1.0915*** (0.1757)	0.5827*** (0.0195)	2.9115*** (0.6711)	0.6868*** (0.0341)	1.6799*** (0.2593)	0.5905*** (0.0236)	0.9503** (0.3080)
Convergence state	divergent	divergent	divergent	divergent	divergent	divergent	divergent	divergent
N	341	341	121	121	88	88	132	132

Note. *** represents $p < 0.001$, ** represents $p < 0.01$, and the figures in brackets are standard errors.

trade openness and social consumption demand as the traditional influencing factors of innovative potential in China. The innovative potential gap among provinces in nationwide China and the innovative potential gap among provinces within different regions will be further widened.

5. Discussion and conclusions

In this study, the evaluation system of regional innovative potential in China is established, and the 31 provinces' innovative potential in China during 2011–2022 are measured relatively objectively and comprehensively by using the entropy weighting method. On this basis, the α convergence model and the absolute β convergence model are used to evaluate and test the convergence of innovative potential in China and various regions. It is found that during the observation period, the innovative potential in nationwide China and in different regions are increasing year by year, but there are great differences among different regions, and the spatial distribution of innovative potential presents a pattern of eastern region > central region > western region, which is consistent with the research conclusions of Song (2020) and Zhang and Zhou (2021). And without considering the influence of other external factors, with the passage of time, the gaps of innovative potential among provinces in China as a whole, eastern region, central region and western region have all been expanding with the passage of time. Among them, the gap of innovative potential among provinces in the eastern region is the largest, followed by the central region and the western region is the smallest.

Analyzing the reasons, although the eastern region has a high level of economic development, rich educational resources, a good innovation environment and a complete policy support system. There is a large number of outstanding talents and enterprises gather here, its innovative potential is high. However, there are obvious gaps in the economic development level, the distribution of educational resources, the innovation environment and policy support, and the concentration of innovative talents and enterprises among the provinces in the eastern region. There are provinces in a strong position like Guangdong, Jiangsu and Zhejiang, and provinces in a weak position like Hainan, Liaoning and Fujian, so the gap between the highest and lowest innovative potential in the eastern region can be 16 times. Compared with the eastern region, although the economic development levels of the central region and western region are relatively weak, the investment in innovation funds is relatively insufficient, high-level innovative talents are relatively scarce, the limited innovation resources are mainly concentrated in state-owned institutions, and the development of private enterprises is weak, there is no particularly wide gap between the provinces in the central region and the western region. Therefore, although the innovative potential of the central region and the western region both need to be further improved, the innovative potential gaps between the provinces in the central region and the western region is obviously lower than that of the eastern region.

To sum up, this study takes the potential positive impact of Internet and private enterprises on innovative potential into account, so it is included in the indicator system when constructing the evaluation system of innovative potential in China, and analyzes the changes of innovative potential in China as a whole and in different regions without considering other external factors. However, there are also some shortcomings in this study. Some soft innovation elements, such as financial environment and soft environment of cultural system, can also be used in the evaluation system of regional innovative potential. However, due to the availability of data, this study can only choose the most suitable indicators from the published data, so the evaluation system of innovative potential indicators may still have some defects. In the future, after the relevant data are gradually released, this study will try to build a more comprehensive and accurate evaluation system of China's regional innovative potential, with a view to making a more comprehensive evaluation of China's innovative potential.

6. Application

From a practical perspective, it is normal for there to be a certain degree of innovative potential gap between eastern region, central region and western region in China. We cannot require all regions to have the same innovative potential, especially for a country as vast as China. However, the trend of widening innovative potential gap among provinces in nationwide China and different regions deserves great attention. Combined with the empirical research results, this study puts forward the following policy recommendations.

On the one hand, talents, especially high-level talents, are the most lacking and important resources in the central region and the western region. On the basis of retaining local talents, the central region and the western region should actively introduce high-level talents to provide services to the central region and the western region. Provide necessary human resources and intellectual support for regional innovative development. At the same time, the central region and the western region should actively promote cooperation with the eastern region to build industrial parks, actively explore new models for undertaking industrial transfers, make full use of and integrate various resources, gradually form competitive regional pillar industries, and accelerate improvement Independent innovative potential.

On the other hand, regarding the growing innovative potential gap among provinces within the eastern region, provinces with higher innovative potential in the eastern region should continue to make full use of the diversity of their innovation resources and focus on developing forward-looking and original innovations research to maintain its original advantages. Provinces with low innovative potential in the eastern region should improve the efficiency of use of various innovation resources in the process of increasing investment in innovation resources, and strengthen the introduction, digestion and absorption of domestic and foreign advanced technologies to enhance their own innovative potential.

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