Measurement and Evalution of the Correlation between Innovation and Economic Growth: Empirical Analysis Based on Innovation Index and GDP Growth Rate

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Abstract: The correlation between innovation and economic growth has always been the focus of academic research. By using EViews, SPSS, and SPSSPRO software to conduct correlation analysis, cointegration test, Granger causality test, and coupling relationship evaluation on the innovation index and GDP growth rate. It shows that the two are significantly correlated. In the long run, they maintain a degree of interaction, and innovation drives GDP growth, and GDP growth supports innovation. As long as the innovation-driven strategy is continuously promoted and thoroughly implemented, the coupling coordination between economic growth and innovation will become better and better. China's GDP and GDP growth rate will show a stable and coordinated growth trend. Therefore, we should continue to promote innovation, reasonable economic growth expectations, and actively strengthen macro-control to ensure stability and promote development.

Keywords: Innovation Index; GDP Growth Rate; Cointegration Test; Granger Causality Test; Coupling Relationship Evaluation

1. Introduction

Whether in academia or industry, "innovation" has always been a hot word. The source of economic and social development is innovation. The revised National Science and Technology Progress Law will come into effect on January 1, 2022.This law highlights the core position of scientific and technological innovation in the overall development of the country, makes it clear that the strategic support for national development lies in self-reliance in science and technology, adhere to the strategy of rejuvenating the country through science and technology and the strategy of innovation-driven development, and build an innovative country based on the path of independent innovation.

In recent years, one of the hot spots of academic research is the correlation between economic growth and innovation. Sort out the academic literature included in the CSSCI database of China National Knowledge Infrastructure (CNKI) from 2013 to 2022, and the top three keywords in terms of frequency are "technological innovation", "economic growth", and "economic development" [1]. With China's transition towards high-quality development, it is increasingly relying on independent innovation. In the short term, the driving effect of new technologies mainly relying on independent innovation on regional economic growth is relatively limited, but in the long run, the driving effect is showing a continuous strengthening trend [2]. Worldwide, innovation-driven does not have the characteristics of inertial development, and there is no Granger causality between innovation-driven and economic growth, but there is a short-term interaction effect between them [3]. Through empirical analysis, it is found that the role of labor and capital in boosting economic growth is getting smaller and smaller, and the role of technological progress in boosting economic growth is getting bigger and bigger [4]. There is a two-way granger causality between invention patents and economic growth in Zhejiang and Shanghai, while Jiangsu province has a unidirectional causality relationship between invention patent authorization and economic growth, while Anhui province does not have causality between them [5]. In the above studies, due to the different variables selected and the different data sources, the conclusions

drawn from the research are also different. In order to accurately reflect the correlation between economic growth and innovation, it is more important to reasonably select variables and data that can comprehensively reflect economic growth and innovation. Based on this, empirical research is conducted to measure and evaluate the correlation between the two, providing guidance for innovation and macroeconomic regulation decisions.

2. Selection of Variables and Data Sources For Innovation and Economic Growth

The innovation referred to here refers to comprehensive innovation ability, which for a country is its national innovation ability. How to evaluate the national innovation ability, many scholars and institutions have carried out related research, such as difference analysis on global national innovation ability evaluation - position of China's innovation [6]. Estimate and prospect of China's national Innovation ability: A study based on the National Innovation Index Report [7]. Evaluation of national innovation ability [8]. Comparative analysis of national innovation ability evaluation indicators [9] etc. The aim of these studies is to evaluate the national innovation ability through the comprehensive evaluation index system.

At present, the Global Innovation Index Report published by the World Intellectual Property Organization, the National Innovation Index Report published by the China Academy of Science and Technology Development Strategy, and the China Innovation Index published by the National Bureau of Statistics are relatively influential results in the evaluation and research of national innovation ability.

Innovation index is an important indicator that reflects the comprehensive innovation ability. The China Innovation Index (CII) Research group of the National Bureau of Statistics has designed an index system and index compilation method to evaluate China's innovation ability. This index system involves 21 indicators in four innovation sub-fields: innovation environment, innovation input, innovation output and innovation effect. The research group has published the China Innovation Index every year since 2006 (the index value was 100 in 2005).

Both innovation and economic growth studied in this paper are selected as data variables of China Innovation Index, GDP and GDP growth rate released annually by the National Bureau of Statistics. Data from 2006-2020 are collected, and the resulting time series of China Innovation Index, GDP and GDP growth rate are shown in Table 1.

Table 1. China Innovation Index, GDP, and GDP Growth Rate from 2006 to 2020

Year	China Innovation Index (CII)	GDP	GDP growth rate
2006	105.7	209407	10.7%
2007	110.8	246619	11.4%
2008	116.5	300670	9.0%
2009	125.5	335353	8.7%
2010	131.8	397983	10.3%
2011	139.6	471564	9.2%
2012	148.2	519322	7.8%
2013	152.8	568845	7.7%
2014	158.2	636463	7.4%
2015	171.5	676708	6.9%
2016	181.2	744127	6.7%
2017	196.3	827122	6.9%
2018	212.0	900309	6.6%
2019	228.3	990865	6.1%
2020	242.6	1015986	2.3%

Data source: China Innovation Index is based on annual estimates released by the National Bureau of Statistics. The GDP and GDP growth rate come from the statistical bulletin of National Economic and Social Development issued by the National Bureau of Statistics every year.

3. Empirical Results and Analysis

3.1 The Correlation between Innovation and Economic Growth

Use EViews software to plot scatter plots of China Innovation Index series and GDP series, as well as China Innovation Index series and GDP growth rate series, as shown in Figure 1 and 2.

Figure 1 shows that there is an obvious positive interaction between China Innovation Index and GDP, and with the growth of China Innovation Index, GDP is also growing steadily. Figure 2 shows that there is an obvious negative interaction between China Innovation Index and GDP growth rate. With the growth of China Innovation Index, GDP growth rate shows a downward trend. The gradual slowdown of GDP growth is firstly inseparable from major changes in the global pattern, the world is becoming more unstable,

and China's economy is facing a variety of complex environmental impacts; Secondly, the impact of the global novel coronavirus epidemic that has lasted for many years, the global economic downturn, and the downward pressure on China's economy has increased; Again, it is related to China's promotion of supply-side structural reform, the implementation of industrial transformation and upgrading, and the transformation of economic growth mode, from the original pursuit of quantitative high-speed growth, gradually shifted to moderate and stable growth under high-quality development. From an economic point of view, the negative correlation between the two variables reflects the diminishing marginal effect.

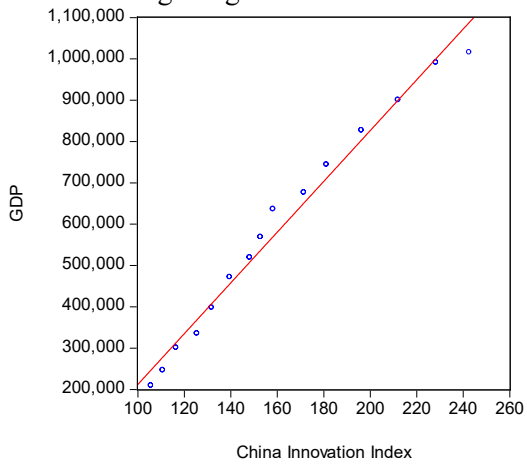

Figure 1. Scatter Plot of China Innovation Index Series and GDP Series

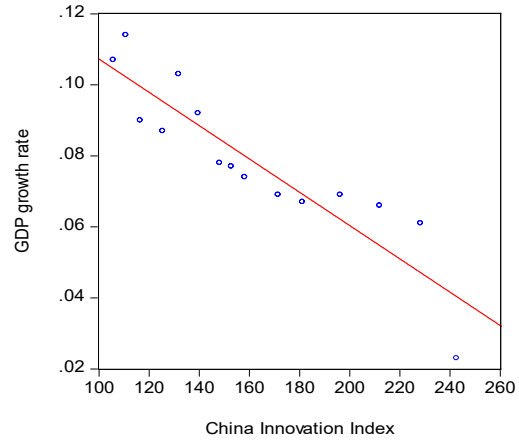

Figure 2. Scatter Plot of China Innovation Index Series and GDP Growth Rate Series

SPSS software is used to measure the correlation between China Innovation Index and GDP, and between China Innovation Index and GDP growth rate, and the results are shown in Table 2 and Table 3.

Table 2 shows that the P-value of Sig. significance test is equal to 0, indicating that there is a strong and significant correlation between China Innovation Index and GDP, and the Pearson correlation coefficient r between them is equal to 0.991, indicating that the two variables are highly positively correlated, and there is a "**" after the correlation coefficient, indicating that the two variables are significantly positively correlated at the 1% level (double tailed).

Table 2. Correlation between China Innovation Index and GDP

		China Innovation Index	GDP
China Innovation Index	Pearson Correlation	1	.991**
	Sig.(2-tailed)		.000
GDP	Pearson Correlation	.991**	1
	Sig.(2-tailed)	.000	

**.Correlation is significant at the 0.01 level (2-tailed).

Table 3. Correlation between China Innovation Index and GDP growth rate

		China Innovation Index	GDP growth rate
China Innovation Index	Pearson Correlation	1	-.907**
	Sig.(2-tailed)		.000
GDP growth rate	Pearson Correlation	-.907**	1
	Sig.(2-tailed)	.000	

**.Correlation is significant at the 0.01 level (2-tailed).

Table 3 shows that the P-value of Sig. significance test is equal to 0, indicating that there is a strong and significant correlation between China Innovation Index and GDP growth rate, and the Pearson correlation coefficient r between them is equal to -0.907, indicating that the two variables are highly negatively correlated, and there is a "**" after the correlation coefficient, indicating that the two variables are significantly negatively correlated at the 1% level (double tailed).

3.2 Cointegration Test of Innovation and Economic Growth

EViews software is used to conduct unit root test on China Innovation Index series, GDP series and GDP growth rate series to determine whether they have stationarity. Table 4, Table 5 and Table 6 show the unit root test results for each series.

Table 4. ADF Unit Root Test of China Innovation Index Series

Variable	T-test	Critical value			Prob. value	With or without unit roots	Stablity
		1% level	5% level	10% level			
X	4.967415	-4.004425	-3.098896	-2.690439	1.0000	With	Unstable
D(X)	-1.469592	-4.057901	-3.119910	-2.701103	0.5164	With	Unstable
D(X,2)	-5.119583	-4.121990	-3.144920	-2.713751	0.0021	Without	Stable

Table 5. ADF Unit Root Test of GDP Series

Variable	T-test	Critical value			Prob. value	With or without unit roots	Stablity
		1% level	5% level	10% level			
Y1	1.014761	-4.004425	-3.098896	-2.690439	0.9938	With	Unstable
D(Y1)	-3.342545	-4.057910	-3.119910	-2.701103	0.0343	Without	Stable

Table 6. ADF Unit Root Test of GDP Growth Rate Series

Variable	T-test	Critical value			Prob. value	With or without unit roots	Stablity
		1% level	5% level	10% level			
Y2	0.121802	-4.004425	-3.098896	-2.690439	0.9553	With	Unstable
D(Y2)	-3.050051	-4.057901	-3.119910	-2.701103	0.0562	With	Unstable
D(Y2,2)	-4.013350	-4.121990	-3.144920	-2.713751	0.0119	Without	Stable

Table 4 and Table 5 show that the P-value of T-test after second-order difference of China Innovation Index series is less than 0.05, indicating that this variable is a second-order monointeger. The P-value of T-test after first-order difference of GDP series is less than 0.05, indicating that this variable is a first-order monointeger. Because the two series are not homogeneous, the cointegration test cannot be performed.

Table 4 and Table 6 show that the P-value of T-test after second-order difference of China Innovation Index series and GDP growth rate series are both less than 0.05, indicating that these two variables are all second-order monointeger, so the cointegration test can be conducted. The cointegration test of China Innovation Index (explanatory variable) and GDP growth rate (dependent variable) is conducted by using EViews software. Table 7 shows the test results.

Table 7. Cointegration Test between China Innovation Index (Explanatory Variable) and GDP Growth Rate (Dependent Variable)

Variable	Coefficient	Std.Error	t-Statistic	Prob.
C	0.154163	0.010097	15.26807	0.0000
X	-0.000469	6.06E-05	-7.741480	0.0000
R-squared	0.821748	Mean dependent var		0.078467
Adjusted R-squared	0.808036	S.D. dependent var		0.022261
Prob(F-statistic)	0.000003			

Table 7 shows that the regression equation estimated by the cointegration test is: Y=0.154163- 0.000469*X. The P-value of the T-test of the regression coefficient of this model is 0, which is less than 0.05, indicating that the regression coefficient is significant. The R^2 of this model is equal to 0.821748, greater than 0.8, and the P-value of F-test is equal to 0.000003, less than 0.05, indicating that the model is significant as a whole. The economic explanation of this model is that for every 1 increase in China Innovation Index, the GDP growth rate will decrease by 0.0469%, which is consistent with the negative correlation between the two reflected in Figure 2.

Then, extract the residual series from the GDP growth rate series, and its time series diagram is shown in Figure 3.

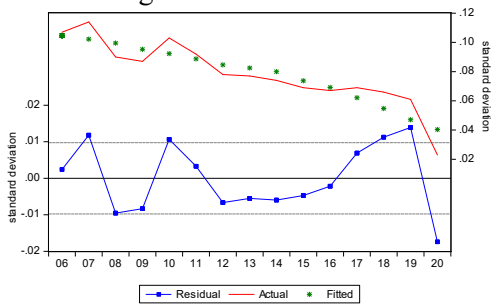

Figure 3. Time Series Diagram on the Residual Series of GDP Growth Rate Series

Figure 3 shows that the fitted value of GDP growth rate is very close to the actual value,

and the residual fluctuates around the zero axis within the range of one standard deviation. The coefficient of determination R^2 of the cointegration test model is equal to 0.821748, close to 1, indicating that the overall fitting effect of the model is good, and 82% of the change of the dependent variable "GDP growth rate" can be explained by the explanatory variable "China Innovation Index".

However, whether the residual series of GDP growth rate series has stationarity requires an ADF unit root test, and Table 8 reflects the test results. Table 8 shows that the P-value of the T-test of this residual series is equal to 0.0192, less than 0.05, rejecting the null hypothesis, that is, this residual series has no unit root and the residual series is stable, indicating that there is a cointegration relationship between China Innovation Index (explanatory variable) and GDP growth rate (dependent variable), and an equilibrium can be formed in the long run.

If GDP growth rate is taken as the explanatory variable and China Innovation Index is taken as the dependent variable, is there a cointegration relationship between them? A cointegration test is required, and Table 9 shows the results.

Table 9 shows that the regression coefficient and regression equation of the cointegration test model are significant.

Similarly, whether the residual series of China Innovation Index series has stationarity requires an ADF unit root test, and Table 10 reflects the test results.

Table 8. ADF Unit Root Test on the Residual Series of GDP Growth Rate Series

Variable	T-test	Critical value			Prob. value	With or without unit roots	Stablity
		1% level	5% level	10% level			
Residual of GDP growth rate series	-3.680036	-4.057910	-3.119910	-2.701103	0.0192	Without	Stable

Table 9. Cointegration Test between GDP Growth Rate (Explanatory Variable) and China Innovation Index (Dependent Variable)

Variable	Coefficient	Std.Error	t-Statistic	Prob.
C	298.8848	18.41447	16.23098	0.0000
Y	-1752.143	226.3318	-7.741480	0.0000
R-squared	0.821748	Mean dependent var		161.4000
Adjusted R-squared	0.808036	S.D. dependent var		43.02738
Prob(F-statistic)	0.000003			

Table 10. ADF Unit Root Test on the Residual Series of China Innovation Index Series

Variable	T-test	Critical value			Prob. value	With or without unit roots	Stablity
		1% level	5% level	10% level			
Residual of China Innovation Index Series	-2.526643	-4.004425	-3.098896	-2.690439	0.1304	With	Unstable

Table 10 shows that the P-value of the T-test of this residual series is equal to 0.1304, which is greater than 0.05. The null hypothesis is accepted, that is, this residual series has a unit root and the residual series is not stable, indicating that there is no cointegration relationship between GDP growth rate (explanatory variable) and China Innovation Index (dependent variable).

3.3 Granger Causality Test for Innovation and Economic Growth

Is there a causal relationship between China Innovation Index and GDP growth rate? EViews software is used to conduct Granger causality test for them. China Innovation Index is variable X and GDP growth rate is variable Y. Table 11 reflects the results of Granger causality test between the two.

Table 11. Granger Causality Test for China Innovation Index and GDP Growth Rate

Null Hypothesis	Obs	F-Statistic	Prob
X does not Granger Cause Y	13	11.2734	0.0047
Y does not Granger Cause X		0.02331	0.9770

Table 11 shows the original hypothesis: China Innovation Index is not the Granger cause of the change of GDP growth rate, and the P-value of the corresponding F-test is 0.0047,

less than 0.05. The original hypothesis is rejected, indicating that China Innovation Index is the Granger cause of the change of GDP growth rate. Some scholars have also concluded that scientific and technological innovation has a significant positive impact on GDP growth [10]. Original hypothesis: GDP growth rate is not the Granger cause of the change of China Innovation Index, and the P-value of the corresponding F-test is equal to 0.9770, greater than 0.05. Accepting the original hypothesis, it indicates that innovation should not be affected by the change of GDP growth rate and should always be on the road.

3.4 Evaluation of the Coupling Relationship between Innovation and Economic Growth

What is the coupling relationship between innovation and economic growth? SPSS software is used to calculate the coupling coordination degree of China Innovation Index series, GDP series and GDP growth rate series, and Table 12 reflects their coupling coordination degree.

Table 12. The Coupling Coordination Degree of China Innovation Index and GDP, GDP Growth Rate

Index entry	Coupling degree C value	Coordination index T-value	Coupling coordination degree D value	Coordination level	Degree of coupling coordination
Item 1	0.144622044	0.311538462	0.212262407	3	Moderate imbalance
Item 2	0.375040768	0.363907094	0.369431991	4	Mild disorders
Item 3	0.630972222	0.313245217	0.444577362	5	Near Dysfunction
Item 4	0.765143302	0.337998224	0.508544076	6	Barely coordinated
Item 5	0.791318306	0.435832311	0.587266623	6	Barely coordinated
Item 6	0.892342010	0.444757760	0.629980979	7	Primary coordination
Item 7	0.962880387	0.434364530	0.646715615	7	Primary coordination
Item 8	0.976615415	0.461808116	0.671571981	7	Primary coordination
Item 9	0.987238383	0.491309675	0.696447966	7	Primary coordination
Item 10	0.996971732	0.521396351	0.720983650	8	Intermediate coordination
Item 11	0.991896985	0.564667589	0.748392998	8	Intermediate coordination
Item 12	0.986098609	0.641491441	0.795345093	8	Intermediate coordination
Item 13	0.969657351	0.697826011	0.822588671	9	Good coordination
Item 14	0.939081004	0.755447287	0.842274419	9	Good coordination
Item 15	0.322620263	0.663333333	0.462606501	5	Near Dysfunction

Table 12 shows that the coupling relationship between innovation and economic growth is steadily improving, and the coupling coordination degree is getting higher and higher [11]. This is consistent with the conclusion of the cointegration test of China Innovation Index (explanatory variable) and GDP growth rate (dependent variable). Innovation and economic development can form a long-term equilibrium, and innovation has a positive promoting effect on economic development, but the promoting effect of innovation on economic development has a lagging effect, which cannot effectively promote economic development in the short term. As time goes by, the promoting effect of innovation gradually appears.

4. Conclusions and Suggestions

With the in-depth implementation and continuous promotion of the innovation-driven strategy, the pace of industrial transformation and upgrading in China continues to accelerate, high-quality development will jump to a new level, the trend of declining GDP growth rate is expected to usher in an inflection point, GDP and GDP growth rate will continue to grow steadily. From the trend of China Innovation Index from 2006 to 2020, China's innovation development has shown a steady growth trend. In general, China's scientific and technological innovation ability and efficiency continue to improve, innovation quality steadily improve, innovation system is constantly improved, and the construction of an innovative country continues to advance. However, China still has outstanding weaknesses in forward-looking basic research and disruptive technological innovation, major original achievements are lacking, the situation that key core technologies in some fields are subject to human control has not been fundamentally changed, and the talent development and incentive mechanisms need to be further improved.

Based on the research in this paper, the following three suggestions are proposed:

Firstly, adhere to the concept of innovative

development, take innovation as the fundamental principle guiding development, strengthen the status and role of innovation as a source of driving force, and accelerate the development of new quality productive forces. Firmly and consistently implement the innovation strategy, vigorously strengthen the construction of the national innovation system, continuously improve the ecological environment for scientific and technological innovation, further optimize innovation incentive policies, strengthen the training of innovative personnel, increase investment in innovation, strengthen the application of scientific and technological achievements, and improve innovation performance.

Secondly, thoroughly implement the major decisions and arrangements of the State on scientific and technological innovation, vigorously promote the implementation of the newly revised National Law on Science and Technology Progress, attach importance to basic research, strengthen applied research, carry out targeted research and make breakthroughs in key and core technologies. Encourage innovation, stimulate the vitality of innovation, and make unremitting efforts to achieve the grand goal of being among the forefront of innovative countries and scientific and technological powers.

Thirdly, implement the spirit of the National Economic Work Conference, with the goal of stabilizing growth, prices and employment, strengthen the analysis and prediction of GDP growth trends, adjust economic growth expectations in a timely manner, increase macroeconomic policy regulation efforts, adopt scientific and flexible macroeconomic policies, improve the feasibility of macroeconomic regulation goals, enhance confidence in future macroeconomic regulation, enhance expectations for future development and stability, and create a good external environment for scientific and technological innovation.

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