ISSN: 2688-8653

Green Innovation Promoting High-quality Economic Development: An Empirical Research based on Data from Henan Province in China

Meng Du[1, 2]

[1]Graduate School, Lyceum of the Philippines University (Intramuros, Manila), The Philippines

[2]Jiaozuo Normal College, Henan, China

Abstract

The global economic growth has been sluggish in recent years. Many countries have shifted from paying attention to the speed of economic growth to paying attention to the quality of economic growth, and exploring the fundamental driving force and effective way to achieve high-quality economic development. Based on the data of Henan Province, this paper selects the Li Keqiang Index as a high-quality development variable, and uses the VAR model to analyze the promotion of green innovation to high-quality development with high energy consumption, environmental pollution and technological innovation as the key factors. The results show that the main influencing factors of high-level development of green innovation are energy consumption and environmental pollution. The driving force of energy consumption on high-quality development shows an inverted N-type. The hindrance of environmental pollution to high-quality development is lagging and cumulative. Innovation is the long-term driving force for promoting high-quality development, but the effect is small. Finally, based on the research results, policy recommendations were made from the aspects of improving energy efficiency, reducing environmental pollution, and promoting the transformation of innovation results.

Keywords

Green Innovation; High Quality Development; Li Keqiang Index.

1. Introduction

Three industrial revolutions in human history have not only brought great-leap-forward development to human civilization and economy, but also excessive consumption of resources and imbalance of ecological environment (Allen et al., 2009[1]). Since the beginning of the 21st century, global environmental degradation and climate warming have become increasingly severe. Facing the double pressure of environmental protection and economic development, countries and all walks of life are actively exploring the ways of harmonious development between human economy and natural environment. In 2008, the United Nations Environment Programme (UNEP) launched a global green economy initiative, and defined the green economy as an economic model with low carbon emission, high resource utilization and social inclusion, whose purpose was to pursue high-quality economic development under the premise of environmental protection, relief of resource pressure and ecosystem maintenance. UNEP's "Green Economy Report" in 2011 pointed out the positive effect of green economy and green innovation in preserving the ecological environment, increasing employment rate and promoting economic growth, which provided ways for countries to deal with the financial crisis and improve the quality of economic development. In recent years, several countries, including the United States, the European Union and China, have made strategic plans for green economy and green innovation. For example, before 2011, the United States had passed bills focusing on

ISSN: 2688-8653

the development of green energy, manufacturing green products and guiding enterprises to take the path of green and sustainable development; Under the entire allocation of the EU 2020 strategy, the European commission had launched the "European Eco-Innovation Action Plan" to propel the healthy development of green economy in European countries; Comrade Xi Jinping pointed out that "lucid waters and lush mountains are invaluable assets." The report of the 19th National Congress of the Communist Party of China vigorously promoted green development, and the development concept of "innovation, coordination, green, openness, sharing" was put forward. Thus, green innovation and green high-quality development are effective means to realize the harmonious coexistence of human economy and natural environment, and green innovation plays a certain role in promoting high-quality development. It is of theoretical and practical significance to study the path of the driving effect for the realization of the high-quality economy and human sustainable development.

2. Literature Review

Green innovation is a gradual evolutionary concept, which is the integration of green development, green economic thought, technological innovation and institutional innovation thought. In the 1860s, American scholar Rachel Carson described the destruction to natural environment by human economic behavior in his book "Silent Spring", which was the awakening of human environmental awareness. In 1989, British scholar Pearce put forward the concept of green economy in "Blue Book: Green Economy", holding that green economy was a sustainable economic model that coordinates and motivates the joint development of resources, environment, economy and society. Brawn & Wield (1994)[2] argued that green technologies were no longer confined to conventional technologies, but focused on the systematic integration of ecological environment correlation technologies and emphasized the significance of green technology innovation for sustainable economic and social development. Subsequently, other scholars further expanded the theory and technology research interrelated with ecological technology innovation.

Domestic and overseas scholars have done a lot of work on the definition of green innovation, but there is not yet a common definition in academia. Some scholars believe that green is a narrow sense of green technology innovation, but in recent years, an increasing number of scholars believe that green innovation is a broader concept beyond the technology level. Blättel-Mink (1998)[3] emphasized that the ecological dimension should be added to the business strategy. Meanwhile, it is also very important to develop and introduce new products, technologies, markets and systems. Huber (2004)[4] believed that green innovation was to make the production of new products cleaner and more efficient and reduce resource consumption by making use of new technologies. Beise & Reennings (2005)[5] argued from the perspective of environmental protection that green innovation was the behavior that could avoid and bring down environmental damage, and enterprises could realize green innovation by reconstructing or adopting new processes, technologies, practices, products and systems. Chen et al. (2006)[6] further extended green innovation to relevant technologies including antipollution, energy conservation, waste recycling utilization, design of green products and management of enterprise environment, covering innovation of green production process and software and hardware in final products. Lin &Tseng (2012)[7] expressed similar viewpoints as well, and divided green innovation into four categories: green product, process, management and technology. Lampikoski (2015)[8] held that green innovation was an innovation, which achieves environmental performance and promotes competitiveness by reforming products and markets, technologies and production processes, organizational ways, management implementation and social institution structure, etc.

The Industrial Science Technology Policy Committee (ISTPC) of the Japanese government defined green innovation as a new territory in technological and social innovation, which focused more on environmental protection and human development rather than production capacity. The Organization for Economic cooperation and Development (OECD) defined green innovation as the innovation or improvement to products, processes, marketing methods, organizational structure and institutional arrangements by enterprises consciously or unconsciously, resulting in a more improved environment compared with relevant peers (OECD [9], 2008). The definition of OECD shows that green innovation is not limited to innovation under the motivation of environmental improvement, but also includes unconscious environmental innovation. From the development of the definition of green innovation, in terms of its connotation, Schiederig et al. (2012) retrieved and analyzed more than 8,500 literature associated with the research on green innovation from 1990 to 2012, and concluded that the essence of green innovation was as follows: First, the motivation of green innovation was to reduce the impact of economic activities on ecology and environment; Second, green innovation was the innovation of the full life cycle; Third, the level of green innovation was generally the innovation standard or green standard specified at the enterprise level; Fourth, the objects of green innovation were products, services, courses and methods; Fifth, the effect generated by green innovation was to minimize negative effects or even eliminate them completely; Finally, green innovation should meet the demands of enterprise market competition.

The following is the study of the impact of green innovation on enterprise economic activities. In the evaluation of green innovation performance of enterprises, Kemp & Arundel (2002) [10] believed that the key point of evaluation in green innovation performance focused on whether green innovation can give companies the upper hand in sustainable competition. Ghisetti & Rennings (2014) [11], from the view of decreasing environmental pollution, constructed the green innovation performance measurement index of enterprises by adopting reduction amount of environmental pollution such as CO_2 emission, water pollution, air pollution, soil pollution, noise pollution and other environmental protection indexes such as replacement of dangerous goods and utilization recovery. Claver et al. (2007) [12] discovered that green innovation in the prevention stage could bring stronger environmental performance than end treatment, and on the other hand, the pressure from stakeholders would oblige enterprises to consider more environmental factors in management. The research of Eiadat et al. (2008) [13] showed that if green innovation could be implemented in operation, enterprises could not only enhance economic performance, but also acquire favorable environmental performance. In the research on the influence of green innovation on enterprise economic performance, scholars have some differences. Wally (1994) [14] argued that green innovation was in conflict with enterprise competitiveness, because the pursuit of environmental performance would generate extra costs so that negative influence would be produced on productivity, reducing profits. While Porter & Linde (1995) [15] believed that green innovation could enhance environmental performance, improve productivity and operating efficiency, save costs and finally boost the competitive advantage of enterprises. This point of view has been recognized and proved by many scholars (Cherrafi et al [16], 2018). In the study on the mechanism of green innovation accelerating enterprise economic performance, Hart (1995) [17] proposed that under strict emission standards, enterprises' implementation of green innovation strategy could reduce the cost of regulatory compliance and form competitive cost advantage. Porter & Linde (1995) also believed that the improvement of resource productivity, optimization flow and innovative products could form competitive cost advantage or product differential advantage, and through the implementation of green innovation strategy, enterprises could transform polluted wastes into marketable products to create extraneous income. Eiadat et al. (2008) [18] pointed out that enterprises could gain word of mouth and honor in environmental protection through

ISSN: 2688-8653

green innovation strategy, which could be translated into a competitive advantage. The driving effect of green innovation on enterprise economic performance is influenced by various factors. Rezende et al. (2019) believed that the driving effect of green innovation on enterprise economic performance was a long-term effect rather than a short-term effect. The study of Lin et al. (2019) [19] showed that small enterprises had higher green innovation reports than large ones. In addition to the time and the firm size, the drive of green innovation to economic performance is affected by the government, finance, management, and other factors. Therefore, the identification and solution of barriers to enterprise green innovation performance is one of the research hotspots in recent years. For example, Gupta & Barua (2018) [20] confirmed 7 major barriers of SMEs in green innovation and 20 solutions from the subjective perspective of managers, and verified the effectiveness of the solutions through the application in 4 companies.

The following is the research on the impact of green innovation on (regional) economic development. Whether green innovation drives economic development is one of the research hotspots in this field, which has been verified by scholars in a variety of ways. Li & Lin (2016) [22] incorporated innovation into the assessment indicator system of China's economic performance and green productivity growth. By analyzing the evaluation results of 275 Chinese cities, the following conclusions are drawn: Innovation is the major impetus of China's green economy; Most Chinese cities have poor performance in the green economy; The increasing speed of green productivity is slower than that of real GDP. Chen & Lei (2018) [22] used data from China, the EU and the US to confirm the prominent effect of R&D on CO2 emission reduction, and proposed that R&D expenditure could not only serve as an economic growth engine of any economy, but also a driving factor of sustainable development. Chen et al. (2019) [23] used Chinese panel data and Spatial Durbin Model to discuss the influence of environmental regulation, degree of openness, urbanization, industrial structure and technological innovation on regional green environmental efficiency. The results showed that the degree of openness, urbanization level, industrial structure and technological innovation level had positive role on promoting regional green and sustainable development, while economic growth, enterprise ownership structure, fiscal policy, foreign investment dependence degree and other factors have a hindrance effect to some extent. On this basis, some scholars directly take green innovation as the evaluation index of economic development to evaluate all aspects of economic development. Fankhauser et al. (2012) [24] constructed an evaluation index system of green competition by taking green innovation, competitive advantage and output as indicators, and evaluated the manufacturing sectors of 8 countries. The results showed that green competition would change the existing economic competition situation. Jo et al. (2015) constructed an ecological innovation index by taking ecological innovation capacity, environmental supportability, activities and performance as indicators to appraise the support degree of eco-innovation to sustainable development. The results showed that there was a great upside potential for the eco-innovation index in Asian countries. Cao et al. (2019) [26] discussed the impact of innovation on green development by taking SO2, waste water and soot emissions per unit of GDP as green development indicators, and the results showed that innovation-driven could effectively promote green development.

The following is the research on the impact of green innovation on high-quality development. In conducting research on path to promote high-quality development, the first thing is to understand the meaning of "high-quality development". In 2018, general Secretary Xi Jinping said in the inspection in Hubei Province that "high-quality development" is to reflect the development of new concepts, and to transform economic development from "have or not" to "good or bad". This point of view has also been supported and developed in academia. Barro (2002) [26] discussed the quality of economic growth from the angles of environmental conditions, life expectancy, fertility rate, political system and religious belief. Mlachila et al. (2014) [27] held that for developing countries, the socially-friendly growth with higher and

ISSN: 2688-8653

more lasting growth rate was high-quality growth, and such growth was beneficial to developing countries. China is a typical developing country. In the report of the 19th National Congress of the Communist Party, high-quality development was set as the mission and goal of China's economic development, which is enough to prove the correctness of taking the path of high-quality development. The exploration of how to achieve high-quality development based on its connotation is one of the primary research goals in this field. The report also pointed out that innovation is the first driving force guiding development, and scholars reached similar conclusions by means of theoretical and empirical analysis: Through carding quality development achievement, from four aspects of industry, innovation, opening to the outside world and the people's life, Yu & Hu (2018) put forward the dilemma of China's high-quality development, and the elementary path of China's high-quality development: taking innovation-driven as the first driving force, market-oriented reform as the pointcut, reform and opening up as the important means, and the improvement of people's living quality as the main goal; Hua & Hu (2018) proposed the path of promoting scientific and technological innovation to lead regional high-quality development through the appraisal of coupled system degree between scientific and technological innovation system and high-quality economic development system in 30 provinces of China. High-quality development is green development, so in addition to innovation, environmental issue is also one of the concerning elements of high-quality development path research. The study of Wu & Yu (2018) showed that environmental taxes and government subsidies for technology research and development affect high-quality economic development by stimulating technological innovation in enterprises. Wang & Lu (2018) proved that environmental regulation had threshold effect on the quality of economic development with Chinese panel data. When the environmental regulation intensity is lower than the threshold value, it has a significant positive impact on the quality of economic growth; After the threshold value is crossed, its effect is not significant.

In conclusion, scholars' research results on the concept of green innovation and the relationship between innovation and economy are very abundant, providing sufficient theoretical and methodological foundation for the research of this paper. However, the following deficiencies remain: First, there is no widely accepted definition of green innovation; Second, the research on the impact of green innovation on the economy focuses more on the economic activities of enterprises, while the research from the perspective of national or regional economy is less and less comprehensive than that of the former. Furthermore, in the study of green innovation influence on regional economic development, most scholars place emphasis on the empirical research of the green innovation-driven economic development currently, but there is little research on its driving path, let alone direct research, especially in today's call for high quality development; Finally, most of the existing researches value on the influence of green and innovation on high-quality development respectively, lacking of research that considers green and innovation as a system. High-quality development is the national orientation of development. It is of both theoretical and practical significance to the realization of national development goals to study whether green innovation drives high-quality development and its driving path. Compared with existing literature, this paper tries to make contributions in the following aspects: in terms of theory, by defining the concept of green innovation and high-quality development on the basis of literature review and theoretical research, the influence of various factors of green innovation on high-quality development is analyzed to enrich the theoretical research on green innovation driving high-quality development; In practical terms, based on the above research findings, the path of green innovation to promote high-quality economic development is explored to provide reference for improving the high-quality development of regional economy.

3. Methodology and Data Source

3.1. Index and Data Source

Combined with what has been mentioned previously, the evaluation of high-quality development level should not be based solely on GDP. After repeated comparison and consideration, this paper chooses an important and classic index -- Li Keqiang Index, which can better reflect the truth and development quality of China's economic development than GDP, as the indicator of high-quality economic development variable. The Li Keqiang Index was proposed by Li Keqiang, the Secretary of the Party Committee of Liaoning Province. When evaluating the economic operation of Liaoning Province, he selected three indexes of industrial electricity consumption, railway freight volume and amount of bank loans issued for analysis. The index is scientific in China and applicable in other provinces. In 2010, "The Economist", a well-known British political and economic magazine, launched the " Li Keqiang Index", which is composed by the weighting to the growth rate of railway freight volume, medium and long-term bank loans and industrial electricity consumption. In this paper, the calculation method of the Li Keqiang index refers to the authoritative weight allocation of Citibank and other institutions -- railway freight volume growth rate of 20%, medium and long-term loan growth rate of bank of 35%, industrial electricity consumption growth rate of 40%.

According to the carding on the concept of green innovation in literature review, green innovation is an organic whole composed of many factors with green and innovative characteristics, among which green refers to reducing environmental pollution and preserving ecological environment, and innovation refers to various conscious or unconscious innovation activities. Besides, considering the great influence of energy on the environment, this paper also included energy into the green innovation system. Therefore, everything about green innovation that can promote the coordinated development behavior of "energy-environment-innovation-economy" system were included, whether the behavior is consciously aimed at environmental performance or not. As a consequence, this paper adopts three variables of the energy, environment and innovation to measure green innovation. In view of the the systematic and operational principle of index selection,it finally chooses the total energy consumption, industrial tailpipe emission and patent granted to represent energy, environment and innovation respectively.

Table 1. Variable name and indicator selection table

Variable	Variable Code	Indicator Selection
High-quality economic development	QE	Li Keqiang Index
Energy	EC	Total energy consumption
Economy	EN	Industrial tailpipe emission
Innovation	IN	Patent granted

3.2. Data Source

The original data of this paper are the annual data from 2002 to 2017, and the research space scope is Henan Province. In order to ensure the validity and reliability of the data, the data required for the research are all from the official website of the National Bureau of Statistics of China, "Henan Statistical Yearbook", "China Statistical Yearbook" and "Statistical Bulletin of Henan Province on National Economy and Social Development". The original data are shown in table 2. Due to the small number of raw data periods, the annual data from 2002 to 2017 is converted into quarterly data to improve the quality of data, and the methods of Quadratic-mathc Average in Eviews are adopted. In order to eliminate the influence of variable heteroscedasticity and different dimensions of different variables, the three variables of energy

(EC), environment (EN) and innovation (IN) are logarithmic treated to get LNEN, LNEN and LNIN.

Table 2. Raw Data

Year	Medium and long-term bank loans (100 million yuan)	Railway freight volume (10,000 tons)	Annual electricity consumption (100 million kWh)	Li Keqiang index(%)	Energy consumption (10,000 tons of standard coal)	Industrial exhaust emissions (100 million cubic meters)	Number of patents granted (pieces)
2002	985.9	90334.0	916.3		9005	10644.0	2590
2003	1278.9	81323.0	1041.9	13.4	10595	11991.6	2961
2004	1552.2	91013.0	1191.0	16.2	13074	13103.0	3318
2005	2057.0	98099.0	1352.7	18.8	14625	15498.0	3748
2006	2524.8	108059.7	1523.5	15.5	16234	16770.0	5242
2007	2972.7	122557.5	1808.0	17.0	17838	18890.4	6998
2008	3321.8	134863.0	1970.8	10.2	18976	20264.1	9133
2009	4852.7	144666.0	2081.4	20.2	19751	22185.6	11425
2010	7726.4	167804.0	2354.0	30.0	18964	22709.0	16539
2011	8563.9	193882.0	2659.1	12.9	20462	40791.1	19259
2012	9462.7	208094.0	2747.8	6.8	20920	35001.9	26833
2013	10844.7	181655.0	2899.2	4.1	21909	37665.3	29482
2014	13523.7	141780.0	2919.6	3.4	22890	39628.7	33366
2015	16309.1	136439.0	2879.6	5.7	23161	36285.6	47766
2016	20420.9	122342.0	2989.2	7.8	23117	29810.2	49145
2017	25524.2	116574.0	3166.0	9.9	22944	29448.2	55407

Data source: Statistical Yearbook of Henan Province from 2002 to 2018, the Li Keqiang index is calculated by the author.

3.3. Empirical Model

As can be seen from the above description, green innovation is a collaborative system where various factors are correlated and interact with each other. In order to explore the path of green innovation and push high-quality development, it is necessary to quantitatively analyze the dynamic influence of various elements in green innovation on high-quality development. Vector Autoregressive(VAR) is one of the most commonly used models for analyzing multivariable time series. Through impulse response analysis and variance decomposition, it can dynamically observe the influence relationship between various variables and the influence degree of independent variables on dependent variables in different periods. Therefore, the construction of VAR model, as shown in formula (1), is used to analyze the influence of energy, environment and innovation factors on high-quality development.

$$Y_t = \alpha + \sum_{i=1}^{p} \beta_i Y_{t-i} + \varepsilon_t \quad (1)$$

Where, Y_t is the column vector of endogenous variables, β_i is the maintenance matrix of n×n), Y_{t-i} is the lagged variable of column vector Y_t, and ε_t is the random disturbance term, which satisfies the classical hypothesis of zero mean value, identical distribution and uncorrelated independent variables.

ISSN: 2688-8653

4. Results and Discussion

4.1. Stationarity Test

The VAR model requires that all variables are stable or the same order integration. Therefore, in order to ensure the reliability of the model and the relationship between variables, it is necessary to conduct the stationary test of variables before establishing the model. In this paper, ADF method is used to proceed unit root test for variables. If there is no unit root in the time series, the null hypothesis is rejected and judged to be stationary time series. The intercept term and trend term are determined in accordance with the timing diagram of variables, and the Lag Intervals for Endogenous is determined by AIC and SC information criteria. The test results are shown in table 3. The P values corresponding to the ADF values of variables QE, LNEC, LNEN and LNIN are all greater than 0.05. Therefore, at the significance level of 5%, the null hypothesis is accepted and judged as non-stationary series. After the first order difference to the original variable, ΔQE, ΔLNEC, ΔLNEN, ΔLNIN are obtained, and the P values corresponding to the ADF test results are all less than 0.05, which is a stationary series. It can be seen that variables QE, LNEC, LNEN and LNIN are first-order integrated series, meeting the requirements of building VAR model.

Table 3. Results of Stationarity Test of Variables

Variable	ADF Statistical	P	conclusion
KQ	-1.564973	0.4928	Unstable
ΔKQ	-4.173071	0.0016	Stable
LNEC	-2.027114	0.2747	Unstable
ΔLNEC	-3.898911	0.0037	Stable
LNIE	-1.65515	0.4474	Unstable
ΔLNIE	-8.270137	0.0000	Stable
LNPA	-1.642289	0.4543	Unstable
ΔLNPA	-3.173903	0.0272	Stable

Data source: calculated by the author by operating EViews 10.0.

4.2. VAR Model Construction

Table 4. Results of Optimal Lag Order Determination

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-127.0179	NA	0.001378	4.764287	4.910274	4.820741
1	342.3303	853.3604	9.56E-11	-11.7211	-10.99116	-11.43883
2	473.8186	219.944	1.45E-12	-15.92068	-14.60679	-15.41258
3	645.4556	262.1365	5.17E-15	-21.5802	-19.68236	-20.84629
4	698.0428	72.66601*	1.43e-15*	-22.91065*	-20.42885*	-21.95092*
5	712.1249	17.41059	1.66E-15	-22.84091	-19.77516	-21.65536

Data source: calculated by the author by operating EViews 10.0.

Note: * represents the optimal selection of this statistic.

On the basis of research purposes and stationarity test results, VAR models based on variables QE, LNEC, LNEN and LNIN are constructed. LR, FRE, AIC, SC and HQ statistics are used to determine the optimal lag order. The results are shown in table 4. The optimal lag orders

ISSN: 2688-8653

determined by all the five methods are all of order 4, so the VAR (4) model with order 4 is established.

For the VAR model, it is primarily through the impulse response and variance analysis to determine the dynamic feature of the whole model, rather than paying too much attention to a specific value of the measurement result. (Zhou, 2019). Before the analysis, the stability of VAR (4) model is tested using the AR root method. The results are shown in figure 1, and all test points fall within the unit circle, indicating that the model constructed is stable.

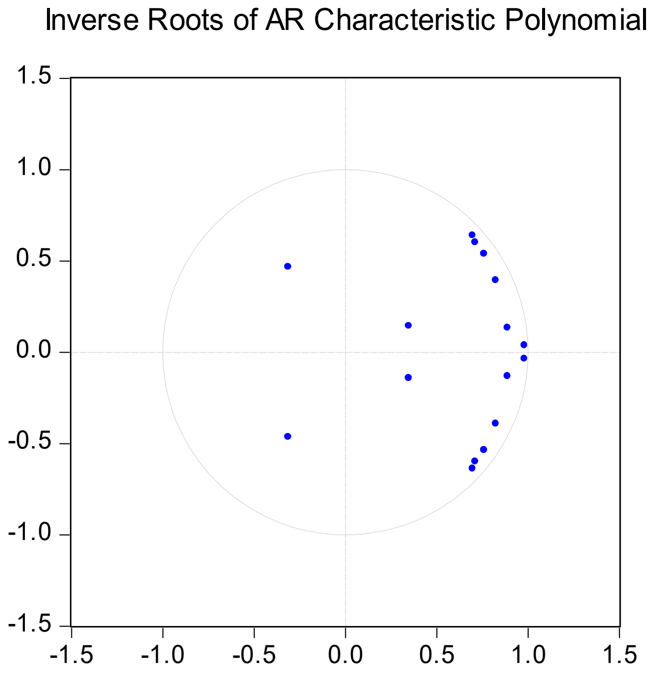

Fig 1. Model stability test results

4.3. Co-integration Analysis

According to the results of variable stationarity test, variables QE, LNEC, LNEN and LNIN are single-integration series of the same order, which meet the conditions of co-integration test. In this paper, Johansenz method is employed to carry out co-integration test on the sequence to determine whether there is a long-term equilibrium relationship between variables. The test results are shown in table 5: at the 1% significance level, there is no null hypothesis of the co-integration relationship between rejecting variables, indicating that there is a long-term co-integration relationship among variables.

Table 5. Johansen Co-integration Test Results

Null Hypothesis	Trace Statistic	P
None *	83.79865	0.0000***
At most 1 *	48.11986	0.0002***
At most 2 *	17.82783	0.0219**
At most 3 *	4.501775	0.0338**

Data source: calculated by the author by operating EViews 10.0.

Note: *** and ** mean significant at 1% and 5% level respectively.

ISSN: 2688-8653

4.4. Granger Causality Test

The co-integration test shows that there is a stable long-term relationship between energy consumption, exhaust emissions, scientific and technological innovation and the Li Keqiang index. However, whether there is a causal relationship between them and the direction of the causal relationship is not clear. Therefore, Granger causality test is conducted on the relationship between these variables in this paper, and the test results are shown in table 6: at the level of 5% significance, (1) the total energy consumption is Granger cause of the Li Keqiang index; (2) there is a two-way Granger causality between industrial waste gas emission and Li Keqiang index; (3) there is no causal relationship between the number of patent licensing and the patent licensing index.

Table 6. Granger Causality Test Results

Null Hypothesis	F-Statistic	P	Result
KQ does not Granger Cause LNEC	0.59363	0.6689	Accept
KQ does not Granger Cause LNIE	6.27594	0.0004***	Reject
KQ does not Granger Cause LNPA	0.25781	0.9034	Accept
LNEC does not Granger Cause KQ	4.67177	0.0029***	Reject
LNIE does not Granger Cause KQ	3.50747	0.0138**	Reject
LNPA does not Granger Cause KQ	1.67768	0.171	Accept

Data source: calculated by the author by operating EViews 10.0.

Note: *** and ** mean significant at 1% and 5% level respectively.

4.5. Impulse Response Analyze

Impulse response mainly measures the impact of a standard deviation shock from the random error term on the current and future value of endogenous variables, describing the change of endogenous variables on the impact of unit change, which can dynamically reflect the impact between variables. This paper focuses on the affection of green innovation factors on high-quality development, so it mainly analyzes the response of QE to QE, LNEC, LNEN and LNIN impacts, and the results are shown in figure 2. When the high-quality development QE produces a positive impact, the Li Keqiang index has a strong positive response to itself in the early stage. This response decreases with time, turns from positive to negative in the 6th period, reaches the maximum value of negative in the 9th period and then gradually rises and approaches zero after the 14th phase, which indicates that high-quality development in the early stage can significantly promote high-quality development in the later stage in a short period of time. However, long-term reliance on the previous achievements will hinder high-quality development, which may be due to the high quality of early development providing substantial material and non-material resources for later development, which helps to improve the starting point for later high-quality development. But such resources are not enough to support high-quality long-term development. The response of the Li Keqiang index to the impact of energy consumption LNEC shows an inverted N-word change. During the 0-4 period, the response gradually decreases from 0 to the negative direction, and in the 4th, it reaches the maximum value of the negative response, and in the 4-13 period it shows an upward trend. In the 8th period, it changes from negative to positive, and the maximum value of the positive response is reached in the 13th period, then gradually decreases, and disappears to zero in the 19th phase. This change indicating that the influence of energy consumption on the development of high quality is complex, and energy consumption plans should be made in the light of different stages. When the environment LNEN creates a positive impact, the response of Li Keqiang index is relatively weak, then a significant negative response occurs after the 5th period, increasing with time and reaching the maximum value of the negative response around the 11th period. This

ISSN: 2688-8653

curve shows that environmental pollution has no significant influence on the development of high quality in the short term. In the long term, due to the limited self-purification ability of the environment to pollution, the accumulation of pollution effects has been an obstacle to the development of high quality. The Li Keqiang index has a weak response to innovative LNIN. Firstly the Li Keqiang index has a gradually increasing negative response, reaching the negative response maximum in the third period, then the negative response gradually decreases. In phase 5 the response is turned from negative to positive and exhibits a very gradual inverted U-shaped change. This change indicates that scientific and technological innovation will hinder high-quality development because of high input and low output of scientific research in the early stage. When innovation input is converted into innovation achievements over a period of time, scientific and technological innovation will continuously promote high-quality development. However, at the present stage, due to reasons such as uneven economic transformation effect of innovation achievements, it plays a small role in high-quality economic development.

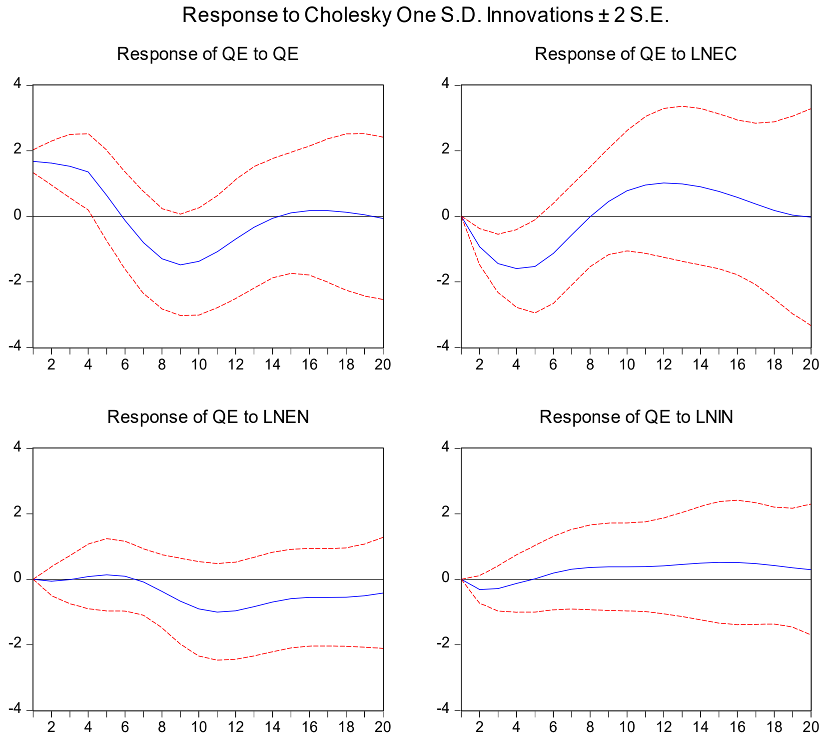

Fig 2. Impulse Response Analysis Results

4.6. Variance Decomposition

Variance decomposition is to analyze and compare the importance of explanatory variables in the system by analyzing the contribution degree of a structural shock to endogenous variable change (Zhou, 2019). In this paper, variance decomposition is proceeded for high-quality development variable QE, and the results are shown in table 7: the Li Keqiang index's self fluctuating has the highest contribution rate, followed by energy consumption LNEC and environmental pollution LNEN. The contribution rate of patent licensing LNIN to the Li Keqiang index is lower. Among them, the contribution rate of the Li Keqiang index to itself is higher than 40%, but there is an obvious trend of gradual decline, which shows that the economy is a solid foundation for high-quality development, providing funds and other material basis for high-quality development. However, the dependence of high-quality development on economic resources gradually decreases with the increase of time and economy volume, which is identical to the trend of the current world economic development; Since the fourth phase, energy

ISSN: 2688-8653

consumption has contributed significantly to the Li Keqiang index, presenting inverted u-shaped change and is stable at about 35%, indicating that energy consumption plays an important role in high-quality development. To achieve high-quality economic development, attention must be paid to the issue of energy consumption. The problems of efficiency and pollution in the process of energy use will become obstacles to the development of high quality; The contribution of industrial waste gas emissions to the Li Keqiang index was small in the first 10 periods. After that, it increased in a straight line with no downward trend, indicating that environmental pollution has an impact on high-quality development. With the accumulation of environmental pollution effects and the difficulty of environmental restoration, the effect of environmental pollution on high quality is superimposed, which will seriously hinders high-quality development; The number of patent licensing has a small contribution to the Li Keqiang index, accounting for more than 5% after the 15th term. On the one hand, it takes resources and time to convert patents into productivity. On the other hand, the patent quality in China is uneven. Therefore, it leads to a small contribution of technological innovation with patent application as the variable to high-quality development, but it can still be seen that its trend is rising in stages, indicating that technological innovation is increasingly important to high-quality development in the long-term.

Table 7. Variance Decomposition Results of Variable QE

Period	S.E.	KQ	LNEC	LNIE	LNPA
1	1.68	100	0	0	0
2	2.535949	85.07708	13.38176	0.055952	1.485212
3	3.303676	71.56902	26.80904	0.034296	1.58764
4	3.911786	63.04279	35.64804	0.071637	1.23754
5	4.250143	55.64765	43.13735	0.165109	1.049892
6	4.403914	51.91454	46.72306	0.198759	1.163636
7	4.523232	52.3244	45.87828	0.224199	1.573127
8	4.733674	55.27261	41.89139	0.813056	2.022951
9	5.039564	57.38879	37.76793	2.492537	2.35074
10	5.371565	57.07384	35.35152	5.009756	2.564888
11	5.66404	54.96307	34.65411	7.616376	2.76644
12	5.890086	52.21979	35.03595	9.701428	3.042836
13	6.057073	49.68324	35.81353	11.07234	3.430885
14	6.182705	47.69415	36.49843	11.88294	3.924483
15	6.279445	46.26417	36.84686	12.41027	4.478705
16	6.353168	45.27318	36.82365	12.87992	5.023257
17	6.408145	44.57481	36.53595	13.39814	5.491102
18	6.448811	44.05348	36.15614	13.94432	5.846056
19	6.478313	43.65783	35.831	14.41807	6.093105
20	6.498859	43.39216	35.60648	14.73705	6.264313

Data source: calculated by the author by operating EViews 10.0.

5. Conclusion and Suggestion

The above empirical results show that there is a long-term stable equilibrium among energy consumption represented by total energy consumption, environmental pollution represented by industrial exhaust emissions, scientific and technological innovation represented by the number of patent applications and high-quality economic development represented by the Li

ISSN: 2688-8653

Keqiang index. Among them, energy consumption plays a significant role in high-quality development and can have a lasting impact. Slight environmental pollution has little effect in the short term, but if ignore it, the aggravation of environmental pollution will have a great impact on the development of high quality in the long term. Scientific and technological innovation has a long lag in propelling high-quality development and is a long-term driving force for high-quality development. In addition, it is not ideal to measure the level of scientific and technological innovation simply by the number of patents licensing. All in all, at present, energy and environment are the main impetus for green innovation to promote high-quality economic development in Henan Province, while as a long-term reserve force, scientific and technological innovation has a poor performance. In order to expedite green innovation and push high-quality economic development, the following path suggestions are proposed:

(1) Energy consumption should be efficient, clean and sustainable. Energy consumption is the important factor to realize green innovation drive, and energy use mainly exist the following problems: First, energy resources are limited. Because of the hard availability of the renewable energy sources such as wind energy, geothermal energy utilization, China’s energy consumption is still dominated by non-renewable energy. By 2018, about 80% of the total energy consumption in our country was the non-renewable energy, and this energy use structure is adverse to the sustainable development; Second, the environmental pollution is caused by the use of energy, and due to the universality in time and space of energy use, the amount and extent of such pollution is relatively large. To solve these energy problems, first of all, science and technology should be adopted to make the transformation path of renewable energy from material energy to available energy faster, more convenient and more stable. At the same time, the utilization efficiency of non-renewable energy should be improved. At present, China’s energy utilization efficiency is far lower than that of developed countries, with a lot of room for improvement; Second, the government should actively drives the use of existing clean energy by means of energy supply-side adjustment, preferential subsidies and financial support; Finally, lack of fixed thinking modes and learning of energy use is one of the obstacles to the implementation of new energy. People’s ignorance of new energy and dependence on traditional energy need to be changed through knowledge publicity and education, to solve the problem of energy use ideologically.

(2) Pollution emissions should be reduced and timely treatment be guaranteed.The environment is an important part of the high-quality development to meet the requirements of green, ecological and sustainable development. In view of environmental pollution, it should be controlled by two processes: before the fact and after the fact. Prior to the occurrence of environmental pollution, the government shall establish effective supervision, reward and punishment mechanisms via laws and regulations to guide enterprises and the public to conduct clean production and green behaviors in production and life, so as to lessen the occurrence of environmental pollution incidents and lower the degree of environmental pollution; Driven by government specification and sustainable development, the enterprises shall actively practice production, transportation, sales and other business activities with green label; As social media is becoming more and more influential in modern society, it is necessary to give full play to its role of social supervision and consensus propaganda, widely publicizing environmental protection related knowledge and monitoring environmental pollution behaviors of enterprises and the public, to control environmental pollution in advance from the moral aspect; Although the individual pollution capacity of the masses is limited, 7.5 billion individuals in the world are the largest pollution-producing group on the earth. People should start their own green life, advocate green behaviors, and contribute to the protection of the environment. After the occurrence of environmental pollution, first of all, it is required to timely detect contamination accidents through government supervision departments or social media; Secondly, the smooth communication channels between the relevant departments of pollution

treatment is required; Finally, there needs to be efficient pollution treatment technology, which is one of the most difficult parts of pollution treatment. Since it is difficult to control environmental pollution afterwards and solve it in a short time, more attention should be paid to the prior control.

(3) Scientific and technological innovation should focus on quality and practicality. Taking Henan Province as an example, the quality of scientific and technological innovation achievements in China is uneven, especially the high quality innovation achievements account for less, with low conversion rate of achievements and economic benefit. To solve these problems, it's necessary to start from two aspects: investment and mechanism. Investment in scientific research includes funds, talents and platform construction. Increasing investment in scientific research contributes to scientific and technological innovation performance (Tou et al., 2019). However, compared with some innovative countries, the proportion of investment in scientific research in China is still far away; Innovative talents is the key to scientific and technological innovation, for the cultivation of innovative talents, on the one hand, "going out" and "introduction" should be emphasized to strengthen the international talent exchange and improve the international innovative thinking, on the other hand, cultivation of local innovative talents should be concerned, and students' innovative thinking should be cultivated from the perspective of education, so as to provide talent reserve for scientific and technological innovation; Platform is a collection of capital, equipment, talents, information and other resources. To reinforce platform construction, firstly, the number of domestic innovation platforms should be increased, and secondly, the hardware and software construction of platforms should be improved. The mechanism includes the standardization of patent authorization mechanism and the reform of talent reward and punishment mechanism. The non-standard patent authorization mechanism is one of the reasons for the inconsistent growth in the number and quality of patent authorization in China. Therefore, the patent authorization mechanism should be strictly enforced to improve the quality of patent authorization; In terms of the reward and punishment mechanism for talents, it is necessary to raise the level of rewards for high-level innovation achievements, attach importance to rewards for economic transformation of innovation achievements, and turn innovation into a strong impetus for economic development.

References

[1] Allen D, Davis S, Halloran P, et al. Sustainable Materials Management: The Road Ahead[J]. 2009.

[2] Braun E, Wield D. Regulation as a Means for the Social Control of Technology[J]. Technology Analysis & Strategic Management, 1994, 6(3): 259-272.

[3] Blättel-Mink, B, Innovation toward sustainable economy - the integration of economy and ecology in companies. Sustainable development. 1998 6(2),49-58.

[4] Huber J. New Technologies and Environmental Innovation[J]. Books, 2004.

[5] Beise M, Rennings K. Lead markets and regulation: a framework for analyzing the international diffusion of environmental innovations[J]. Ecological Economics, 2005, 52(1): 5-17.

[6] Chen Y S, Lai S B, Wen C T. The Influence of Green Innovation Performance on Corporate Advantage in Taiwan[J]. Journal of Business Ethics, 2006, 67(4): 331-339.

[7] Lin C P, Tseng J M. Green technology for improving process manufacturing design and storage management of organic peroxide[J]. Chemical Engineering Journal, 2012, 180: 284-292.

[8] Lampikoski T. Green innovation games-value creation, managerial roles and managerial capabilities in resource intensive businesses, 2015.

[9] OECD Environmental innovation and global markets. Paris: Organization for Economic Cooperation and Development, 2008.

[10] Kemp R, Arundel A. Survey indicators for environment innovation. Paper Presented to Conference Towards Environment Innovation Systems in Garmisch-Partenkirchen, 2002.

[11] Ghisetti C, Rennings K. Environmental innovations and profitability: How does it pay to be green? An empirical analysis on the German innovation survey[J]. Journal of Cleaner Production, 2014, 75: 106-117.

[12] Claver, Lopez M, Molina J F, et al. Environmental management and firm performance: a case study[J]. Journal of Environmental Management, 2007, 84(4):606-619.

[13] Eiadat Y, Kelly A, Roche F, et al. Green and competitive? An empirical test of the mediating role of environmental innovation strategy[J]. Journal of World Business, 2008, 43(2):131-145.

[14] Walley N. It's Not Easy Being Green[J]. Harvard Business Review, 1994, 72(3): 46-51.

[15] Porter M E, Linde C. Green and Competitive: Ending the Stalemate[J]. Harvard Business Review, 1999, 28(6):128-129(2).

[16] Cherrafi A, Garza-Reyes J A, Kumar V, et al. Lean, green practices and process innovation: a model for green supply chain performance[J]. International Journal of Production Economics, 2018, 206: 79-92.

[17] Hart S L. A natural resource-based view of the firm[J]. WORC Paper, 1994.

[18] Rezende L, Bansi A C, Alves M R, et al. Take your time: Examining when green innovation affects financial performance in multinationals[J]. Journal of Cleaner Production, 2019, 233: 993-1003.

[19] Lin W L, Cheah J H, Azali M , et al. Does firm size matter? Evidence on the impact of the green innovation strategy on corporate financial performance in the automotive sector[J]. Journal of Cleaner Production, 2019, 229: 974-988.

[20] Gupta H, Barua M K. A framework to overcome barriers to green innovation in SMEs using BWM and Fuzzy TOPSIS[J]. Science of the Total Environment, 2018, 633(aug.15):122.

[21] Li J, Lin, B. Green economy performance and green productivity growth in China's cities: measures and policy[J]. Sustainability 2016, 8(9), 947.

[22] Chen W, Lei Y. The impacts of renewable energy and technological innovation on environment-energy-growth nexus: new evidence from a panel quantile regression[J]. Renewable Energy, 2018, 123(AUG.):1-14.

[23] Chen L, Zhang X, He F, et al. Regional Green Development Level and Its Spatial Relationship under the Constraints of Haze in China[J]. Journal of Cleaner Production, 2018, 210: 376-387.

[24] Fankhauser S, Bowen A, Calel R, et al. Who will win the green race? In search of environmental competitiveness and innovation[J]. GRI Working Papers, 2012.

[25] Cao W B, Ying, et al. The Effect of Innovation-Driven Strategy on Green Economic Development in China-An Empirical Study of Smart Cities. [J]. International Journal of Environmental Research & Public Health, 2019.

[26] Barro R J. Quantity and Quality of Economic Growth[J]. Working Papers Central Bank of Chile, 2002, 5 (2):17-36.

[27] Mlachila M, Tapsoba R, Tapsoba S. A Quality of Growth Index for Developing Countries: A Proposal [J]. IMF Working Papers, 2014.