

An Empirical Study on the Efficiency of Green Innovation Supported by Urban Financial Development in the Pearl River Delta Cities

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Abstract: Green innovation is the technological innovation under the premise of environmental protection, energy conservation and emission reduction. Both technological innovation and green development need a lot of financial support. Does financial development effectively support the promotion of green innovation? This article selects 2009- 2018 panel data of nine cities in the Pearl River Delta and uses the non-radial direction distance function (NDDF) method of Data Envelopment Analysis to measure their efficiency of green innovation. Then, we use the Tobit model to verify to the effects of financial development on green innovation. The results showed that the index reflecting financial development scale of the Pearl River Delta's cities, there is significantly negative correlation between the number of financial institutions and green innovation; the number of practitioners in financial institutions, the proportion of fiscal expenditures on science and technology, energy saving and environmental protection in total expenditures showed an evidently positive correlation between them. It indicates that financial development of the nine cities is good for the improvement of green innovation efficiency. Further, this paper uses substitution variables to conduct robustness test, and the above conclusions are still valid.

Keywords: Pearl River Delta; Green innovation efficiency; Financial development

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1. Introduction

1.1. Foreword

At present, the issues of energy, environment and climate change have become increasingly prominent in globalization. Sustainable development has become a necessary task for human. The Pearl River Delta urban agglomeration is one of the manufacturing bases in China. However, the manufacturing industry is the main source of environmental pollution. Therefore, it is an inevitable trend for enterprises in the Pearl River Delta region to follow the country's sustainable development policy to transform the economic development mode and improve the green innovation technology. In recent years, Guangdong has been committed to green financial reform and innovation and promoting the construction of National Green Development Demonstration Zone. Currently, no scholars have studied the impact of urban financial development in the Pearl River Delta on green innovation in the literature information. This paper fills in the research gap of the impact of regional financial development on green innovation. At the same time, the Guangdong government should adopt differentiated financial policies to improve the efficiency of green innovation according to the different levels of green innovation in the Pearl River Delta urban

agglomeration, provide reference for countermeasures and measures to promote the overall level of green innovation in Guangdong.

1.2. Literature review

Lin Limei ^[1] selected the panel data of 31 provinces in China from 2004 to 2015 and used the Entropy Weight Method to study the impact of China's financial development on the growth of green economy, and concluded that financial development had a positive effect on the growth of green economy. Rioja F ^[2] studied the influence of the degree of financial development on the sources of growth of different countries, then he used the dynamic Gaussian Mixture Model (GMM) panel model to test the panel data of 74 countries. The results showed that finance had a significant positive impact on the growth of developed economies' TFP. Some scholars believe that finance may inhibit green innovation efficiency. Buera FJ et al. ^[3] developed a quantitative framework to explain the relationship between financial development and total factor productivity (TFP) in various countries, pointing out that financial friction distorts the allocation of capital and entrepreneurial talents in various production sectors and has a negative impact on total factor productivity. In addition, the theory that financial development supports green innovation will be affected at all level, Zeng Wanqiang ^[4] analyze finance supports mechanism of green total factor development from five aspects such as capital allocation, financial support, risk diversification, corporate governance, and the effect of green finance, pointing out that there exist market failure problems and the impact of finance on green total factor productivity is uncertain in the direction. Fanta and Makina ^[5] believe that the impact of financial development on total factor productivity may vary with the differences of regions, the positive link between finance and economic growth may be caused by the aggregation of countries in different stages of economic growth and financial development.

It can be seen from the literature review that the scope of domestic and foreign scholars' researches is mostly at the national level, so there are certain limitations in the regional research. On this basis, this paper adopts the panel data of cities in the Pearl River Delta to construct NDDF and Tobit models to study the finance supports for green innovation in the Pearl River Delta.

2. Measurement of green innovation: Efficiency of green innovation

Green innovation efficiency refers to the ratio of capital, labor and energy input and expected output to non-expected output in the process of green innovation. Zhou ^[6] proposed the non-radial direction distance function (NDDF). NDDF is a model based on the traditional Data Envelopment Analysis (DEA), but it surmounted DEA's limitations. It is non-angular and non-radial, and can make the expected output and non-expected output change in different proportions and directions. Taking labor, energy and capital as inputs, GDP, patent authorization amount and value of new industrial products as expected outputs, and industry as unexpected outputs, this paper uses Stata16 and standard deviation method to calculate the three wastes to obtain comprehensive index of environmental pollution, and then uses NDDF model to calculate the green innovation efficiency.

3. The empirical analysis of green innovation supported by urban financial development in the Pearl River Delta

3.1. Indicators and variables selection

3.1.1. Explained variable: green innovation efficiency

The green innovation efficiency of the nine Pearl River Delta (PRD) cities measured by the NDDF model is the explained variable in this paper. Relevant indicators needed to calculate the efficiency of green innovation include:

(1) Input index

Labor input: the input of scientific and technological personnel. This paper selects the number of scientific and technological personnel engaged in R&D activities as the labor input.

Capital input: innovation input. This paper selects the expenditure of R&D activities as the index of capital input.

Energy input: the input of power resources. In this paper, industrial power consumption is selected as the energy input.

(2) Expected output index

GDP output: In this paper, the annual GDP of a city is selected as an indicator to measure the level of economic.

Patent output: This paper selects the number of patents granted yearly in cities as a technical indicator to measure green innovation.

New product output of enterprises: This paper selects the annual output value of new products of industrial enterprises in cities as the efficiency index to measure green innovation.

(3) Unexpected output index

The comprehensive index of environmental pollution: it refers to the index to measure the undesired output of green innovation calculated from industrial waste water, industrial waste gas and industrial solid waste by the standard deviation method. The calculation method is described below.

3.1.2. Explanatory variable: Financial development indicator

Size of financial institutions: financial institutions are part of the financial development system, which are financial intermediaries engaged in the financial industry. This paper selects the following two indicators to measure financial development.

(1) The number of financial institutions

(2) The number of financial practitioners

(3) The proportion of fiscal expenditures on science and technology, energy saving and environmental protection in total expenditures

In this paper, fiscal expenditure on science and technology, energy saving and environmental protection are selected as the index to measure financial development. The government's financial support can make up for the deficiency of internal innovation of enterprises and promote green technology innovation of enterprises.

(4) Loan-to-deposit ratio

The ratio of deposits and loans is used by commercial banks measuring the liquidity of bank and operating risks. The ratio of total loans and total deposits multiplied by a percentage is the ratio of deposits and loans. The higher the ratio, the higher the liabilities, indicating the lower the liquidity of a bank and the higher the operating risks.

3.1.3. Control variables

In order to more accurately analyze whether finance supports green innovation, this paper referring to other relevant literatures, selects "actual foreign investment" as the control variable to measure whether financial development supports green innovation. The actual amount of foreign investment can measure the degree of opening to the outside world. Foreign investments bring technology and capital, promote industrial upgrading and technological innovation, and have an impact on the efficiency of green innovation.

3.2. Data sources and processing

3.2.1. Source of data

The relevant data of Pearl River Delta cities from 2009 to 2018 are derived from *Guangdong Statistical Yearbook*, *Guangdong Science and Technology Yearbook*, Guotaian Database and Market Supervision Administration of Guangdong. Partial missing data were filled with mean value method.

3.2.2. Calculation of comprehensive index of environmental pollution

In this paper, three industrial wastes are selected as the undesired output. As the units of the three indicators are different, in order to combine the three indicators, the standard deviation standard method is adopted by Stata16 and the weight of industrial waste water, industrial waste gas and solid waste is set to be 0.4 and 0.37 respectively, referring to the research of Han Jing [7]. 0.23, the comprehensive index of environmental pollution was obtained by using formula of Li Jiamei [8] to calculate the environmental pollution index.

3.2.3. NDDF model to measure the efficiency of green innovation

(1) Theoretical basis and calculation method of DEA-NDDF model construction

Referring to Zhou et al., for the NDDF model considering unexpected output, and can be expressed as:

$$\overline{ND}(K, L, E, Y_1, Y_2, Y_3, P; g) = \sup \{ w^T \beta : [(K, L, E, Y_1, Y_2, Y_3, P) + \text{diag}(\beta) * g] \in T(x) \}$$

Where, K represents capital input, L represents labor input, and E represents energy input. Y_1 , Y_2 , Y_3 respectively represent expected output GDP, the number of patents granted and output value of new industrial products. P represents comprehensive index POLLUTE. matrix values set by Ning Zhang [9] and Yin Qingmin [10], it is believed that input, expected output and unexpected output are equally important, and the three indicators account for 1/3 each. Input is composed of capital, labor and energy, and the three factors of input are equally important, accounting for 1/9 each. Therefore, the weight vector is set up:

$$w = \left(\frac{1}{9}, \frac{1}{9}, \frac{1}{9}, \frac{1}{3}, \frac{1}{3} \right)^T$$

(2) Calculation results of green innovation efficiency

Using DEA-NDDF model and sample data, Stata16 software was used to calculate and evaluate the green innovation efficiency of cities in the Pearl River Delta. The fruit is as follows in **Table 1**.

Table 1. Descriptive statistics of green innovation efficiency in each city

City	Observations	Mean	Standard deviation	Minimum	Maximum
Guangzhou	90	1	0	1	1
Shenzhen	90	1	0	1	1
Zhongshan	90	0.9891289	0.0343774	0.891289	1
Huizhou	90	0.9824643	0.0377404	0.8962134	1
Zhuhai	90	0.939043	0.0988216	0.7776827	1
Foshan	90	0.9139048	0.084233	0.7926244	1
Dongguan	90	0.881468	0.1094148	0.7385219	1
Zhaoqing	90	0.7795788	0.2225422	0.2931889	1
Jiangmen	90	0.7765168	0.1338099	0.5960757	1

The NDDF model can calculate the inefficiency of each input factor and output $\beta_K, \beta_L, \beta_E, \beta_{Y_1}, \beta_P$. The inefficiency value is the value of not using resources effectively under the condition of given labor, capital,

energy input and technology. The total inefficiency value is expressed by β and it can be obtained by weight that $\beta = \frac{1}{9} \times (\beta_{Y_1} + \beta_{Y_2} + \beta_{Y_3}) + \frac{1}{3} \times \beta_P$, $\beta_{Y_1}, \beta_{Y_2}, \beta_{Y_3}, \beta_P$ respectively represent the output of GDP, patent and newly industrial product, the inefficient value of environmental pollution index, and the green innovation efficiency index $1 - \beta$, GIN (Green Innovation Efficiency) is used, $GIN = 1 - \frac{1}{9} \times (\beta_{Y_1} + \beta_{Y_2} + \beta_{Y_3}) - \frac{1}{3} \times \beta_P$, if GIN is closed to 1, the higher Green Innovation efficiency will be.

(3) Empirical results of financial development support for green innovation in the Pearl River Delta Cities. The descriptive statistics of each variable are shown in **Table 2**.

Table 2. Descriptive statistics of variables related to the regression model

variable	Observations	Mean	The standard deviation	Minimum	Maximum
Number of financial institutions	90	1144.156	685.6295	371	2792
Number of agency staff	90	24997.4	21710.66	6291	91595
Loan-to-deposit ratio	90	0.6304577	0.0764953	0.4473771	0.8053065
Financial investment ratio	90	0.0348706	0.0164927	0.0138389	0.0942731
Actual foreign investment	90	255757.6	184280.8	18133	776395.3
Green innovation efficiency	90	0.9180116	0.1309503	0.2931889	1

In this paper, the green innovation efficiency calculated based on the DEA-NDDF model is a set of data between 0 and 1. Due to the limited value of the dependent variable, the Tobit model is more appropriate. Therefore, Tobit regression model is adopted to analyze the impact of financial development on green innovation efficiency, avoiding the bias of using traditional Ordinary Least Square Method (OLS) regression method.

The Tobit regression model was constructed with the green innovation efficiency index as the explained variable, the number of financial institutions, employees in financial institutions and the ratio of deposit and loan as the explanatory variable, and the control variables as the proportion of fiscal expenditure in science and technology, energy conservation and protection and the actual amount of foreign investment.

The model is as follows:

$$GIE_{it} = \beta_0 + \beta_1 NUM + \beta_2 NUME + \beta_3 RMB + \beta_4 EAN + \beta_5 FOI + \varepsilon_{it}$$

i represents cities in the Pearl River Delta, and the number is 9; t indicates the year, (the year from 2009 to 2018); GIE_{it} is the green innovation efficiency index of the nine Cities in the Pearl River Delta calculated above, ε_{it} is the random error.

(4) Analysis of regression results

Stata16 is used to carry out Tobit regression analysis on the impact of financial development on green innovation, and the regression results are shown in **Table 3**.

Table 3. Tobit regression results

Independent variable	Dependent variable: Green innovation efficiency index			
	Coefficient	T value	P value	Log-likelihood estimate
Intercept	1.200***	4.15	0.000	Log likelihood=-61.01
Number of financial institutions	-0.001***	-2.88	0.005	
Number of agency staff	0.000***	2.87	0.005	
Loan-to-deposit ratio	-0.483	-1.09	0.277	
Financial investment ratio	7.333***	2.82	0.006	
Foreign investment	-0.000	-1.64	0.105	

Note: “***”, “**” and “*” indicate significant at the statistical level of 1%,5% and 10%

(5) The impact of the number of financial institutions on green innovation

The number of financial institutions and green innovation efficiency have significantly negative correlation, which means the growth of financial institutions could suppress green innovation efficiency. Financial institutions’ development too fast may be led to the growth of credit or equity financing, which will make leverage of market entities get increased and accumulate asset bubbles, finally will cause market valuation to deviate from the actual level.

The increased number of financial institutions increases the financing cost of enterprises, which may reduce the funds invested by enterprises in green technological innovation and finally restrains the development of green innovation.

(6) The impact of the number of institutional practitioners on green innovation

There is a significant positive correlation between the number of practitioners in financial institutions and green innovation efficiency. The increase of investments in human capital may improve the production efficiency of green innovation. The development of science and technology and the progress of innovation depend on the improvement of human capital. The personnel of financial institutions promote the development of green innovation and improve the efficiency of green innovation by absorbing foreign technology or improving the level of internal innovation.

(7) The impact of loan-to-deposit ratio on green innovation

The ratio of deposit and loan is negatively correlated with green innovation efficiency, but the coefficient is not significant. It is the ratio of the balance of RMB loans to the balance of RMB deposits of financial institutions. The higher the ratio of deposit and loan means the greater the loan balance, which means that the amount of funds borrowed by enterprises from commercial banks increases and the investment in green technology innovation of enterprises will have a stable source of funds, which is conducive to the improvement of green innovation efficiency. However, the research in this paper does not support this conclusion, indicating that the increase of loan balance ratio does not effectively increase the efficiency of green innovation, which may be due to the fact that loans are not effectively directed to green innovation-related purposes.

(8) The impact of financial innovation, energy saving and environmental protection investment on green innovation

Financial innovation and energy saving and environmental protection investment are positively correlated with green innovation efficiency, and the statistical significance is significant. It is likely that the

government's investment in science and technology has led to increased funding for research and development of green technology products. Moreover, the government's investment in energy conservation and environmental protection can make up for the lack of enterprises' investment in governing pollution, so that enterprises have more funds and resources to invest in green innovation and improve the efficiency of green innovation.

(9) The impact of foreign actual investment on green innovation

The foreign actual investment is negatively correlated with green innovation efficiency, but the regression coefficient is not significant, but it is close to be significant at the level of 10%. It shows that foreign investment has a certain degree of inhibiting effect on green innovation. Foreign investment may provide financial and technical support for domestic companies, but also to bring some of the polluting industries. China's manufacturing industry is the main object of foreign investment, but manufacturing is the main source of environmental pollution, part of the foreign direct investments in polluting industries have a negative impact on China's ecological environment. Although the two explanations crossed influence green innovation, the negative effect of pollutant generation caused by the foreign investment is greater than the positive effect of the output of capital and technology, which has a certain degree of inhibition effect on green innovation efficiency.

(10) Robustness test

There are many indicators to measure financial development scale, and the number of financial institutions the article selects is one of the indicators to measure financial development scale, so this paper selects another index of financial development scale as the explanatory variables instead of the number of financial institutions in the robustness test, namely the ratio of the deposit amount and GDP (Fin), other explained variables are unaltered. Since the explained variable is still the green innovation efficiency index (GIN), the Tobit model is still selected as the regression model. The robustness test of results are basically consistent with the estimates in **Table 3**. Therefore, it can be considered that the conclusion of this paper is robustness.

4. Conclusions and countermeasures of finance supporting green innovation in the Pearl River Delta city

To sum up, financial development can support green innovation, but also inhibit green innovation. The number of financial institutions has a significantly negative correlation with green innovation efficiency, while the number of employees in financial institutions has a significantly positive correlation with green innovation efficiency. The ratio of deposit and loan is negatively correlated with green innovation efficiency, but its coefficient is not significant. Financial innovation and energy conservation investment are positively correlated with green innovation efficiency, while foreign investment is negatively correlated with green innovation efficiency.

4.1. Based on the above conclusions of research, this paper puts forward the following policy recommendations

First, we will strengthen supervision of the financial sector. While deepening the financial reform, we should guard against the abnormal problems of financial deepening, and avoid the financial overgrowth leading to the excessive supply of credit and the rapid inflation of prices of financial asset.

Second, improve the talent mechanism of financial institutions. The investment of human capital plays a significant role in promoting the efficiency of green innovation. Governments at all levels may introduce or train innovative technical personnel and implement an award system to enhance their enthusiasm for

innovation.

Third, increase the support of fiscal expenditure for green innovation and give full play to the regulatory functions of the government. National expenditures on science and technology and energy conservation directly promote the improvement of green innovation efficiency. The government can increase the proportion of these two expenditures, which can effectively improve the regional green innovation efficiency.

Fourth, pay attention to the environmental pollution effect brought by foreign investment. The government should strictly supervise the investment trends and industry of foreign investment's capital in China, encourage investment in related industries that promote green innovation, and strictly evaluate and supervise the negative externalities caused by the emissions of "three wastes."

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