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THE MECHANISM AND PATH OF FINANCE PROMOTING THE DEVELOPMENT OF LOW CARBON ECONOMY

Abstract: Promoting the development of low-carbon economy (LCEco) to protect the environment is an important dimension to enhance national competitiveness and an effective path to achieve high-quality national development. Therefore, based on the endogenous LCEco growth theory, from the two dimensions of financial technology innovation (FTI) and financial product innovation (FPI), using the spatial measurement method of SLM and SEM, using the panel data of 30 provinces (municipalities and autonomous regions) from 2009 to 2021, this paper deeply explores the impact of FTI and FPI on the development of LCEco. The results show that: FTI and FPI have synergistic effect and positive spatial spillover effect on the LCEco, whose elastic coefficients for them are respectively (–0.125, $p < 0.05$; –0.084, $p < 0.05$). Different regions have obvious heterogeneous effects on the FTI, FPI and LCEco, whose elastic coefficients for them are (0.318, $p < 0.05$; 0.332, $p < 0.05$). The conclusion not only provides empirical support for the endogenous LCEco growth theory, but also provides effective evidence for the high-quality development path of China's LCEco.

Keywords: FTI, FPI, development of LCEco, environmental protection

Introduction

As an emerging model closely related to the trend of The Times, low-carbon economy cannot be separated from the rapid progress of technology, the protection and support of the government, the input of financial capital and other conditions. As the content of the economic base, the role of finance should not be ignored. In fact, the global promotion of low-carbon economy has also opened a new pattern for the development of the financial industry. For example, the New York Mercantile Exchange, the world's largest physical commodity futures and options exchange, and nine companies, including Morgan Stanley, Merrill Lynch and Tudor Investments, jointly set up the Green Exchange to try to promote the solution of global environmental protection issues through market methods. Constantly establish and improve the industrial credit system, take necessary measures to restrict the development of energy-consuming industries, and then actively develop low-carbon industries on the basis of protecting the environment and saving resources; to promote the development of enterprises. It is of great theoretical value to solve the imbalance of regional development. The development level of LCEco in the three regions of China is uneven, and the trend of regional LCEco appears "regional differentiation". Although the gap between the western regions is slightly smaller, the gap between the eastern and central regions is still increasing, and the problem of regional disparity needs to be solved urgently. It is found that the problem of regional disparity will not only hinder the development of

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LCEco, but also affect the level of social welfare. Thus, LCEco is the key factor to determine regional differences. Wu et al. [1] found that different regions have differences in carbon trading settlement, accounting, taxation, risk control and other aspects. Liu et al. [2] found that the regional LCEco development gap will be more reflected in the green LCEco development gap. Therefore, improving LCEco is the fundamental path to narrow the regional gap and promote the balanced development of various regions, which is an important premise to promote social development and progress, and it is also an important guarantee for the formation of regional LCEco layout with complementary advantages and high-quality development.

Based on the provincial data of China from 2009 to 2021, this paper systematically analyses the impact of financial technology innovation (FTI) and financial product innovation (FPI) on the LCEco. It not only expands the theoretical research framework, but also enriches the research content of influencing factors of LCEco. It is hoped that it can provide certain reference for China to effectively develop and utilise FTI and FPI to promote the LCEco and realise the high-quality development of LCEco.

Literature review and research hypothesis

FTI and development of LCEco

The existing literature has studied the positive effect and the spatial spillover effect of FTI on the LCEco from the regional, provincial and departmental macro levels. Owen et al. [3] studied the current situation, problems and countermeasures of China's LCEco development, and put forward the main measures for continuously accumulating FTI to improve the development level of LCEco. Wang et al. [4] pointed out that there is a nonlinear relationship between FTI and LCEco. The above literature shows that FTI has a significant incentive effect on the LCEco, but whether the positive effect is linear and significant remains to be further confirmed. Based on the above analysis, the following hypotheses are proposed:

Hypothesis H1: there is a nonlinear relationship between FTI and the LCEco, the impact of FTI on the LCEco has a moderate range.

FPI and development of LCEco

In the past, few scholars have studied the impact of FPI on the LCEco: Samargandi and Sohag [5] believed that there is no obvious co-integration relationship between FPI and LCEco. Yuan et al. [6] empirically finds that FPI has a positive impact on regional total factor productivity. The above all literatures shows that FPI has a positive impact on the LCEco, but whether the positive effect is linear and significant remains to be further confirmed. Based on the above analysis, the following hypotheses are proposed:

Hypothesis H2: there is a nonlinear relationship between FPI and the LCEco, the impact of FPI on the LCEco has a moderate range.

FPI and FTI

Based on the above literature review, we can find that: FTI and FPI are the decisive factors affecting the TFP level of a country, but there are few literatures on the impact of FTI and FPI on the LCEco from provincial data in China. There are few literatures that FPI is included in the influencing factors of LCEco. However, this paper establishes the theoretical relationship between FTI, FPI and LCEco with the help of endogenous LCEco

growth theory, and carries out empirical test in the following paper: FTI or accumulation of FPI will lead to the promotion of LCEco, this shows that FTI and FPI play an important role in LCEco growth. FTI affects the ability to optimise the allocation of factors, and FPI affects the ability to obtain external resources [7, 8]. When the allocation is in an effective state, the increase of output depends on the further acquisition of external resources. Therefore, the coordination of FTI and FPI is conducive to the coordinated promotion of the optimal allocation of factors and the acquisition of external resources, which is conducive to promoting the LCEco and promoting the continuous realisation of high-quality development in the region [9]. Based on the above analysis, the following hypotheses are proposed:

Hypothesis H3: the joint effect of FTI and FPI has a significant positive impact on the LCEco.

Setting and calculation of LCEco development model

The spatial weight matrix is the matrix representing the spatial autoregressive process of the explained variables. When constructing the model, the spatial weight matrix is exogenous, including the exogenous information of spatial relations between adjacent regions. Its basic form is as follows:

$$W = \begin{bmatrix} W_{11} & W_{12} & \ldots & W_{1m} \\ W_{21} & W_{22} & \ldots & W_{2m} \\ \ldots & \ldots & \ldots & \ldots \\ W_{n1} & W_{n2} & \ldots & W_{nn} \end{bmatrix} \tag{1}$$

where W_{ij} is a member of the space weight matrix W, i = 1,2,..., n, j = 1,2,..., m. W is an n by n symmetric matrix, whose principal diagonal element is 0.

Estimation of inter provincial LCEco based on Solow residual method

This paper selects the panel data of 30 provinces (cities, autonomous regions) from 2009 to 2021 as the research object, estimates and analyses the LCEco. The LCEco can reflect the regional financial development capacity, so we use the development of LCEco as the output value of regional LCEco. The growth rate of total output is calculated by: (GDP value of current year - GDP value of last year) / GDP value of last year.

Financial capital investment K_{it} is calculated using the perpetual inventory method $K_{i,t} = (1-\delta)K_{i,t-1} + |I_{it}|$, which has been adopted in other studies. $|I_{it}|$ represents the financial capital formation of i provinces (cities and autonomous regions) in year t. δ refers to the depreciation rate of financial capital.

Labour input L_{it} refers to the actual labour input in the production process. It is expressed by the total number of employment at the end of the three industries. The growth rate of labour input is calculated based on (labour input value of the current year - labour input value of the previous year) / labour input value of the previous year. All the above indicators are from China Statistical Yearbook 2010-2020.

According to the principle of Solow residual method regression model for each province (city, autonomous region) is established:

$$\ln\left(\frac{Y_{it}}{L_{it}}\right) = \ln A_{it} + \alpha_i \ln\left(\frac{K_{it}}{L_{it}}\right) + \varepsilon_{it} \tag{2}$$

where: i = 1, 2,…, 30, t = 2009, 2010,…, 2019.

Then the parameter α_i in the model is estimated based on OLS (Ordinary least squares), and the development value of LCEco in each province can be estimated according to Formula (2).

Empirical analysis on the impact of FTI and FPI on the LCEco

This paper makes an empirical analysis of the LCEco on the western region from the perspective of LCEco products and sustainable economic development in the western region.

Index selection of FTI and FPI

This paper will measure FTI from the aspect of financial investment. This paper selects the average financial investment of each province to measure the level of FTI (HC). The gap of FTI level among provinces have been reflected that Beijing with 12.104, Shanghai with 11.215 and Tianjin with 10.878 have the highest level of FTI; In addition, Hebei, Shanxi and Liaoning provinces with higher level of FTI; The lowest level of FTI is Yunnan, only 7.319. It shows that there is a certain gap in FTI investment among provinces in China. Whether this difference has an impact on the development of inter provincial LCEco will be an important issue in this paper.

Selection of main control variables

Based on previous studies [10-14], this paper selects financial expenditure (*FINAN*), industrial structure (*IND2* and *IND3*), opening up (*UFI* and *IMEX*), resource endowment structure (*RES*), financial degree (*EL*), science and technology level (*STL*), urbanisation (*CITY*), infrastructure level (*ROAD*) as control variables. The definition and description of the main variables selected by the author are shown in Table 1.

Table 1

Symbols and names of main variables

Variable symbol	Variable name
FINAN	Expenditure
IND2	Industrial structure
IND3	
UFI	Opening up
IMEX	
RES	Resource endowment structure
EL	Financial degree
STL	Science and technology level
CITY	Urbanisation
ROAD	Infrastructure level
HC	FTI level
SCW	Network financial transaction
SCF	NetEase financial market

Establishment of spatial lag model and spatial error model

Panel data regression based on spatial lag model

A spatial lag model to investigate whether the dependent variable has spillover effects among regions:

$$y_{all} = \rho W y + X\beta + \varepsilon \tag{3}$$

According to Formula (3), the spatial lag model (SLM) is established on the basis of the original ordinary panel model as shown in the following formula:

$$\begin{aligned} TFP_{all} = c + \rho W \times TFP_{it} + \beta_1 HC + \beta_2 SCW + \beta_3 SCF + \beta_4 HC \times SCW + \beta_5 HC \\ \times SCF + \beta_6 HC \times HC + \beta_7 SCW \times SCW + \beta_8 SCF \times SCF \\ + \beta_9 FINAN + \beta_{10} IND2 + \beta_{11} IND3 + \beta_{12} UFI + \beta_{13} IMEX \\ + \beta_{14} RES + \beta_{15} EL + \beta_{16} STL + \beta_{17} CITY + \beta_{18} ROAD + \varepsilon_{it} \end{aligned} \tag{4}$$

where i = 1,2,…, 30, t = 2009, 2010,…, 2021. ρ is the spatial autoregressive coefficient. TFP_{all} and TFP_{it} represent the development level of FTI and financial product innovation FPI, and TFP_{all} is the result of the iterative calculation of TFP_{it}.

Panel data regression based on spatial error model

The spatial error model that represents the influence of the error of the dependent variable in the neighbouring regions of a region:

$$\begin{aligned} Y &= X\beta + \varepsilon \\ \varepsilon &= \lambda W \varepsilon + \mu \end{aligned} \tag{5}$$

According to Formula (5), the spatial error model (SEM) is established on the basis of the original ordinary panel model.

Analysis of spatial econometric model results

MATLAB R2021A is used to estimate the spatial error and the spatial lag that presented in the brackets respectively. The results are shown in Table 2.

According to the empirical results in Table 2, in terms of spatial effect, both the coefficient ρ and λ of LCEco are significantly positive, indicating that the promotion has spatial effect, TFP of each province will have spatial interaction, and the improvement of LCEco for surrounding provinces and cities will promote the rise of LCEco for provinces and cities.

In terms of the effect of the second term of FTI on the LCEco, the elasticity coefficient is –0.125 ($p < 0.05$) and –0.084 ($p < 0.05$), which indicates that there is an inverted U-shaped non-linear relationship between FTI and LCEco. It has negative effect on FTI, and hypothesis H1 is confirmed.

In terms of the impact of FPI quadratic term on LCEco, when SCW is used to measure FPI, the elasticity coefficient of FPI quadratic term on LCEco is –0.745 ($p < 0.01$) and –0.245 ($p < 0.01$), respectively, indicating that there is an inverted U-shaped nonlinear relationship between FPI and LCEco, GFP has an incentive effect on FPI in the early stage. After reaching the inflection point, it has negative effect on FPI, and hypothesis H2 is confirmed. When SCF is used to measure FPI, the elasticity coefficient of FPI quadratic term to LCEco is 0.569 ($p < 0.05$) and 0.365 ($p < 0.05$), respectively, which indicates that there is a U-shaped nonlinear relationship between FPI and LCEco. In the early stage, GFP hinders FPI, and after reaching the inflection point, it has incentive effect on FPI, hypothesis H2 is further confirmed.

Table 2

Analysis results of influencing factors for LCEco

Variable name	SLM1	SLM2	SLM3	SEM1	SEM2	SEM3
HC	0.091 (–1.05)			0.088 (–1.46)		
SCW	0.208 (0.53)			0.225 (0.74)		
SCF	–0.083 (–1.03)			–0.072 (–1.19)		
HC×SCW		0.251*** (2.71)			0.250** (2.51)	
HC×SCF		0.221*** (3.02)			0.235** (3.24)	
HC×HC			–0.125** (–2.35)			–0.084** (–2.46)
SCW×SCW			–0.745*** (–3.13)			–0.245*** (–3.43)
SCF×SCF			0.569** (2.64)			0.365** (2.41)
FINAN	–0.149* (–1.67)	–0.132* (–1.54)	–0.197** (–3.01)	–0.150* (–1.64)	–0.130* (–1.50)	–0.208** (–2.91)
IND2	0.085* (1.67)	0.146** (2.25)	0.723* (1.86)	0.091* (1.58)	0.141** (2.12)	0.713** (1.90)
IND3	0.287 (1.23)	0.246 (0.93)	0.268 (1.52)	0.301* (1.32)	0.252* (1.13)	0.279* (1.05)
UFI	0.324** (2.13)	0.401** (2.98)	0.346** (2.27)	0.345** (2.01)	0.402** (3.02)	0.349** (2.16)
IMEX	0.045* (1.13)	0.081* (1.63)	0.065* (1.51)	0.040 (1.01)	0.071 (1.20)	0.052 (1.72)
RES	–0.021** (–2.01)	–0.027* (–2.43)	–0.015* (–1.65)	–0.013** (–1.83)	–0.031* (–1.82)	–0.016* (–2.41)
EL	0.070* (1.52)	0.160* (3.46)	0.174 (1.49)	0.080* (1.59)	0.165* (3.58)	0.164 (1.54)
STL	0.112*** (2.89)	0.125*** (3.85)	0.121*** (3.74)	0.110*** (2.65)	0.118*** (3.42)	0.124*** (3.79)
CITY	–0.030 (0.06)	–0.026 (0.05)	–0.022 (0.04)	–0.036 (0.07)	–0.021 (0.05)	–0.024 (0.06)
ROAD	0.006 (0.00)	0.008 (0.00)	0.008 (0.00)	0.006 (0.00)	0.007 (0.00)	0.008 (0.00)
ρ	0.080*** (2.68)	0.086*** (2.87)	0.079*** (2.35)			
λ				0.269*** (3.02)	0.254*** (3.15)	0.267*** (3.12)
R^2	0.504	0.512	0.514	0.621	0.614	0.608

Note: ***, ** and * represent significant levels of 1 %, 5 % and 10 % respectively, and R^2 represents the fitting coefficient. The number in brackets indicate the statistical test value.

In terms of the joint effect of FTI and FPI on the LCEco, the interaction coefficients of FTI and FPI are 0.251 and 0.250 (SCW is used to measure FPI and SLM model is used). In addition, 0.221 and 0.235 (SCF is used to measure FPI and SEM model is used), and 5 % significance test is passed. It shows that there is a complementary relationship between FTI and FPI. The coordination and superposition of the two will promote the growth of LCEco more effectively. The hypothesis H3 is confirmed. In terms of the impact of FTI on the LCEco, FTI has a positive impact on the LCEco, and the elasticity coefficient is 0.091 and

0.088 respectively, but it fails to pass the significance test of 10 %. In terms of the impact of FPI on the LCEco, when SCW is used to measure FPI, FPI has a positive impact on the LCEco, and the elasticity coefficient is 0.208 and 0.225 respectively, but it fails to pass the significance test of 10 %. When SCF is used to measure FPI, the elasticity coefficient of SCW to LCEco is negative, but it fails to pass the significance test of 10 %. Therefore, financial innovation cannot play an important role in the LCEco, Hypothesis H3 is further confirmed. The regression results of control variables and spatial effects are basically consistent with the above, indicating that the empirical results of SLM are robust.

Policy proposal

Scientific and rational allocation of FTI and FPI plays a key role in accelerating the development of inter provincial LCEco. Therefore, this paper puts forward some suggestions to optimise the allocation of China's FTI and FPI:

(1) To coordinate the investment of FTI and FPI together, provide funds, policies and institutional guarantee for the joint development of FTI and FPI, and further stimulate the positive impact of the two on the development of provincial LCEco. In addition, FTI and FPI should be vigorously invested in the central and western regions of China, and appropriate allocation (not excessive investment) of FTI and FPI should be made in eastern China, so as to achieve the optimal development level of LCEcoin each province.
(2) Regional governments should give full play to their service functions, strengthen the construction of information technology infrastructure such as 5G [15, 16], and build more convenient and intensive social network to promote interpersonal communication and information diffusion, so as to improve the overall level of regional FPI.
(3) Reasonable allocation of financial resources [17-19], strengthen the investment of teaching funds, further improve the quality of personnel training and teaching, cultivate more innovative high-level personnel, and make the LCEco sustainable growth.

Conclusion

How to make good use of FTI, FPI can better promote the LCEco is the main question of this paper. In this paper, by constructing SLM and SEM, using the panel data of 30 provinces (cities, autonomous regions) from 2009 to 2021, this paper explores the driving factors and the spatial spillover effect of LCEco. Research shows that: Whether it is full sample regression or regional regression, the spatial effect coefficient is always positive, indicating that there is a positive spatial spillover effect in the development of China's provincial LCEco. Specifically, the promotion of the LCEco in neighbouring provinces also has a positive impact on the promotion of the province, but the eastern region has no significant spatial spillover effect in the central and western regions. The interaction between FTI and FPI has significant incentive effect on the inter provincial LCEco, and its effect and significance are higher than that of FTI and FPI acting on provincial LCEco in isolation. However, only relying on FTI and FPI to play an isolated role is not enough to effectively promote the rise of inter provincial LCEco, only the interaction of the two can better promote the development and growth. At present, China has not established a complete measurement standard and a systematic data statistical system for green finance, due to the unbalanced development of the green finance system,

relatively insufficient data accessibility, insufficient data samples and few relevant studies. In the future, it is necessary to further enrich the index evaluation system for green finance.

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