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FINANCIAL DEVELOPMENT AND ENVIRONMENTAL POLLUTION CONTROL - AN ANALYSIS OF INTERMEDIARY EFFECT BASED ON TECHNOLOGICAL INNOVATION

Abstract: Based on the rapid development of green finance and the panel data of 30 provinces in China (excluding Tibet, Taiwan, Hong Kong and Macao) from 2007 to 2020, to deeply discuss the relationship between financial development (FD), technological innovation and environmental pollution (EP) control is the centre of this article by using panel fixed-effect and intermediary effect model. The influence of FD on EP is tested by building a benchmark regression model. In addition, the intermediary effect model is adopted to explore how FD affects EP control through technological innovation mechanism. The conclusions show that China's FD can effectively promote regional EP control on the whole, and FD can improve EP through technological innovation mechanism, but there is significant regional heterogeneity: compared with high government intervention areas, FD can promote EP control through technological innovation in low government intervention areas. Therefore, it is suggested that all regions promote the construction of financial infrastructure, upgrade the level of regional financial marketisation, speed up the realisation of regional technological innovation and EP control. This work is conducive to the formulation of appropriate government policies to promote the improvement of the financial system and the establishment of innovative mechanisms, and the reasonable reduction of government intervention and the improvement of the efficiency of financial resource allocation based on the needs of financial market players.

Keywords: FD, EP, technological innovation, intermediary effect

Introduction

As China's economic and social development continues to progress, it is imperative for the government and relevant environmental protection departments to devise scientific methods to enhance environmental protection, accelerate the reconstruction of ecological civilisation in the new era, and embark on a path of green development that is commensurate with the times.

In recent years, China's economic scale has witnessed a remarkable expansion. As the hub of modern economy, the level of development of the financial industry has emerged as a pivotal factor that impacts the high-quality progress of China's economy [1, 2]. Given the advent of the "new normal" era of economic growth, it has become indispensable to boost the level of financial system reform, augment the ability of financial services to bolster the physical economy, stimulate the reform of the supply-side structure and industrial structure,

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and vigorously promote green finance as one of the avenues to foster green economy and build a picturesque China. The significant direction of financial structure reform in the new period and aims to develop digital finance and green finance via technological innovation to realise the main economic and social objectives of progress in ecological civilisation construction and an enhancement in national governance capacity.

Therefore, FD and EP control are vital problems in China's economic progress. It is of great realistic importance to explore the relevance among FD, technological innovation and EP. How FD can achieve EP control through technological innovation, which is of great practical meaning to promote the high-quality progress of China's economy. This article uses the panel data structure of 30 provincial regions in China (except Tibet, Taiwan, Hong Kong and Macao) from 2007 to 2020, and adopts the intermediary effect model to explore how FD affects EP control through technological innovation mechanism.

Literature review

At the present moment, scholars have carried out a lot of study on the relevance between FD and technological innovation [3, 4]. Most studies have confirmed that FD can significantly accelerate the growth of total factor output. FD is the direct reason for the increase of enterprise R&D (research and development) investment and technological progress [5]. With the progress of economy and the construction of financial infrastructure, the role of FD on technological innovation has been strengthened, and the average level of technological innovation efficiency promoted by FD has been continuously improved.

At present, there is no unanimous opinion on the influence of technological innovation on EP. Most scholars' studies have confirmed that technological innovation could significantly improve EP. As a front-end prevention of EP control, enterprise technological innovation contributes to improving environmental quality and is a core methods of green development [6]. Enterprises increase the innovation and obtain environmental protection technology patents can effectively reduce pollution emissions of enterprises, so as to optimise industrial structure and play an overall role in energy conservation and emission reduction [7].

With the concept of green development has win the support among the people, finance as a significance factor to improve technological innovation and high-quality economic development, the environmental effect of FD has also been widely concerned. Most of the studies found that the financial environment can reduce pollution [8]. Considering spatial factors, it is found that the environmental effect of improving technological innovation level has spatial spillover, which can not only improve the local environmental pollution, but also significantly promote the environmental pollution control in neighbouring areas. The spatial spillover effect of technological innovation brought about by increasing R&D investment helps to realise energy conservation and emission reduction in neighbouring areas. However, with the processive expansion of the scale of FD, the restraining effect of FD on EP has a marginal diminishing phenomenon [9]. In the period of low FD, FD can significantly promote EP emissions, while in the period of high FD, it can significantly inhibit EP, that is, there is an inverted U relationship between FD and carbon emissions. financial development can play a more powerful role in emission reduction in regions with lower financial supervision intensity. In the period of low financial development, financial development can significantly promote environmental pollution emissions, while in the period of high financial development, it can significantly inhibit environmental pollution,

that is, there is an inverted U relationship between financial development and carbon emissions.

To sum up, most of the literature studies the influence of FD and technological innovation on EP, and also mentions the correlation between FD and technological innovation, but few studies on the role of technological innovation in the influence of FD on EP control.

Theoretical mechanism and research hypothesis

The enhancement of financial development not only boosts the level of technological innovation but also facilitates the advancement of environmental pollution mitigation and green economic development in China.

Undeniably, finance stands as a crucial source of sustenance and progression for enterprises. However, due to the presence of credit mismatch, numerous non-state-owned businesses encounter obstacles in securing affordable credit, which thwarts their development and creates a considerable space for FDI to be introduced [10]. Financial development transmutes the knowledge spillover effect of foreign direct investment into tangible productivity, thereby catalysing the elevation of total factor productivity of enterprises. In essence, under the backdrop of financial development, FDI plays an instrumental role in propelling technological innovation, and the incorporation of advanced foreign direct investment augments technological innovation in pollution control and regional pollution mitigation [11, 12].

On the other hand, financial development can reduce the financing cost of enterprises to a certain extent, promote enterprises to increase R&D investment and achieve innovation breakthrough. Financial development can significantly alleviate the financing constraints of enterprises, and the financing constraints have a significant inhibitory effect on the R&D investment of a large number of non-state-owned enterprises. Furthermore, financial development can accelerate the transformation and upgrading of industrial structure through technological innovation mechanism, which is conducive to promoting local energy conservation and emission reduction and green economic development [13].

In addition, with the development of Finance and the popularity of green finance, environment-friendly and energy-saving and environmental protection enterprises will get more advanced financial services. Green finance is a measure to support the development of low pollution, low energy consumption and high efficiency enterprises and projects to a certain extent, which provides financial support for environmental pollution control projects and R&D guarantee for green innovative enterprises [14]. Therefore, financial development supports the development of green industry and the strength of environmental protection. Based on the above analysis, this paper puts forward three hypotheses:

H1: FD helps promote technological innovation

H2: Technological innovation helps promote regional EP control

H3: FD helps promote regional EP control through technological innovation

Government strategy is an important factor affecting financial development. The government needs to formulate corresponding financial institutional arrangements according to the actual development needs of the real economy, so as to adapt to the development of industrial institutions and avoid environmental pollution emissions caused by the mismatch between the degree of financial development and the degree of industrial development. Compared with areas with high government intervention, financial

development has a more significant effect on environmental pollution control through technological innovation in areas with low government intervention.

Model design

Variable selection

This article selects the panel data of 30 provinces in China (excluding Tibet, Taiwan, Hong Kong and Macao) from 2007 to 2020. The data are from China Environmental Statistical Yearbook, China Industrial Statistics Yearbook, China Financial Yearbook and the official website of the National Bureau of Statistics.

Model construction

The benchmark regression model is set as shown in Model (1) to test the influence of FD on EP, we denote it by P_{it} :

$$P_{it} = \beta_0 + \beta_1 fd_{it} + \sum_{i=1}^n \beta_i x_{it} + \varepsilon_{it} \quad (1)$$

where fd refers to financial development, t to the year and i to the region. A set of control variables (including industrial structure, openness, urbanisation and economic development) that affect EP are added. The industrial structure's optimisation and upgrading can significantly promote EP; FDI will aggravate EP, but there are different views that when the extent of opening to the outside increases to a certain extent, it will bring advanced technology and improve environmental quality.

This paper will further use the causal step method to verify whether technological innovation has a mediating role in the influence of FD on EP [15, 16].

The first step is to verify the impact of fd on EP, such as Model (1).

The second step is to verify the impact of fd on technological innovation ($inno$), such as Model (2):

$$inno_{it} = \beta_0 + \beta_1 fd_{it} + \sum_{i=1}^n \beta_i x_{it} + \varepsilon_{it} \quad (2)$$

If the coefficient of FD variable is important, it shows that FD has a significant impact on technological innovation mechanism.

The third step is to add fd and technological innovation ($inno$) to regression, such as Model (3):

$$pollution_{it} = \beta_0 + \beta_1 fd_{it} + \beta_2 inno_{it} + \sum_{i=1}^n \beta_i x_{it} + \varepsilon_{it} \quad (3)$$

If the coefficient of technological innovation mechanism is significant and the coefficient of FD loses significance, or even if it is significant, compared with Model (1), the regression coefficient is significantly lower, indicating that there is a mediation effect, that is, FD significantly improves EP through the mechanism of technological innovation.

Results and discussion

Mediating effect test

Table 1 shows the panel solid effect regression results of financial development level and environmental pollution. The regression results show that the influence coefficient of financial development on air pollution, water pollution and solid pollution is significantly negative at the level of 1 %, that is, financial development can significantly promote environmental pollution control. At the same time, it can be seen that the improvement effect of financial development on air pollution and water pollution is lower than that of solid pollution, which indicates that the impact of regional financial development on local environmental pollution control has certain pollution heterogeneity. In addition, the index coefficients of industrial structure, opening degree and economic development level are significantly negative, which indicates that with the adjustment of industrial structure, the addition of foreign advanced foreign investment and the improvement of economic development level, environmental pollution can be effectively improved. The urbanisation coefficient is significantly positive, indicating that China's urbanisation process will worsen the problem of environmental pollution. Based on the above analysis, the first step of causal step method is verified.

Impact of financial development on environmental pollution

Table 1

Variable	$\ln gp$	$\ln wp$	$\ln sp$
$\ln fd$	-0.034*** (-3.46)	-0.050*** (-3.79)	-0.148*** (3.43)
$\ln ind$	-0.849*** (-5.83)	-0.449*** (-3.58)	-0.641*** (-3.16)
$\ln open$	-0.047* (-1.89)	-0.048** (-2.25)	-0.057*** (-2.65)
$\ln urb$	2.365*** (7.45)	0.834*** (3.05)	1.460*** (3.30)
$\ln pgdp$	-1.717*** (-22.24)	-1.261*** (4.54)	-0.810*** (-7.52)
Constant term	-0.254 (-0.22)	1.198 (1.19)	-2.918* (-1.78)
R^2	0.872	0.873	0.773
Observations	420	420	420

Note: *, ** and *** mean that the significance levels of 1 %, 5 % and 10 % were expressed respectively, R^2 represents the fit coefficient, and the results in bracket represent t value

Robustness test

In order to strengthen the reliability of the empirical conclusions, this paper conducts a further robustness test. The robustness regression results are shown in Table 2: The influence coefficients of financial development on air pollution, water pollution and solid pollution are all significantly negative, indicating that the results of environmental pollution control promoted by financial development are robust. The results of other control variables are also similar to the baseline regression.

To sum up, the regression results in this paper are reliable. According to the logic of causal step method, the results in the first column of Table 3 indicate that the influence coefficient of FD level on technological innovation mechanism is remarkable positive, that

is, FD can promote regional technological innovation, which verifies the second step of causal step method.

Table 2

Robustness test

Variable	$\ln gpr$	$\ln wpr$	$\ln spr$
$\ln fd$	-0.116*** (-3.46)	-0.131* (1.73)	-0.230*** (3.19)
$\ln ind$	-0.250*** (-3.16)	-0.425*** (-2.85)	-0.233*** (3.11)
$\ln open$	-0.055** (-2.06)	-0.040 (1.59)	-0.0645* (-1.81)
$\ln urb$	2.077*** (6.14)	0.545* (1.68)	1.170** (2.57)
$\ln pgdp$	-1.640*** (-19.93)	-1.184*** (-14.96)	-0.733*** (-6.61)
Constant term	-1.509 (-1.21)	-0.056 (-0.05)	-4.173** (-2.48)
R^2	0.810	0.767	0.815
Observations	420	420	420

Among them, as for the regression results of air pollution and water pollution, technological innovation incentive can significantly improve EP, and the FD coefficient loses significance after the addition of technological innovation variable, as shown in Columns (2) and (3) for the regression analysis of solid pollution, technological innovation incentive can significantly improve EP. After adding technological innovation variables, the FD coefficient is still significant, but it is significantly lower than that in the benchmark regression, as shown in Column (4), which shows that FD indeed promotes EP control through technological innovation mechanism.

Therefore, the above research indicates that FD can promote technological innovation, and the establishment of technological innovation mechanism also helps to promote regional EP control; FD can promote regional EP control through technological innovation, that is, technological innovation plays an intermediary role in the process of FD to improve EP, where Hypothesis 1, Hypothesis 2, and Hypothesis 3 are verified respectively.

Table 3

Mediating effect of technological innovation

Variable	$\ln inno$	$\ln gp$	$\ln wp$	$\ln sp$
Model	(1)	(2)	(3)	(4)
$\ln fd$	2.204*** (8.85)	-0.065 (-0.87)	-0.069 (-1.07)	-0.174* (-1.66)
$\ln inno$		-0.117** (-2.42)	-0.070* (-1.69)	-0.098** (-2.43)
Control variable	Control	Control	Control	Control
Constant term	0.966*** (29.74)	-1.063 (-0.88)	0.710 (0.68)	-3.591** (-2.11)
R^2	0.519	0.874	0.874	0.777
Observations	420	420	420	420

Discussion

This work helps to coordinate the relationship between financial market and government intervention and maximise the environmental effects of financial development. Financial development in areas with low government intervention can play an effective environmental effect. Therefore, it is necessary to combine the promotion of financial marketisation with policy guidance and intervention, formulate appropriate government policies to promote the improvement of financial system and the establishment of innovation mechanism, and reasonably reduce government intervention and improve the efficiency of financial resource allocation based on the needs of financial market subjects.

In view of the availability of data, it is not scientific enough to select indicators of scientific and technological innovation and environmental pollution control efficiency. Therefore, the approximate replacement of relevant indicators may lead to certain errors in empirical research results, which needs to be verified by using more sample data

Conclusion

This article discusses the relevance among FD, technological innovation and EP from the theoretical and empirical levels, and how FD achieves EP control through technological innovation. Based on the panel data of 30 provinces in China (excluding Tibet, Taiwan, Hong Kong and Macao) from 2007 to 2020, this article studies the environmental influence of FD and the mediating influence of technological innovation mechanism by using intermediary effect model. The results show that FD can promote regional EP control through technological innovation mechanism, that is, technological innovation plays an intermediary role in the development of FD to improve EP. Based on the above conclusions, in order to coordinate the relevance between FD, technological innovation and EP, and promote the high-quality development of Chinese economy, we put forward the following policy recommendations that full play should be brought into to the technological innovation mechanism in EP control. Financial institutions should give priority to those technological innovation enterprises for credit subsidies, strengthen the construction of green financial system to promote the efficiency of financial allocation.

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