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The Difference Effect of Environmental Regulation on Two Stages of Technology Innovation in China's Manufacturing Industry

Abstract This paper divides technological innovation into two stages: technology development and technology transfer. Then the authors use the panel data of 28 manufacturing industries during 2003–2012 to test the econometric regression model for the industry of the sub stages, which is a regulation on technological innovation in the environment. The results show that: (1) environmental regulation has a significant role in promoting China's manufacturing technology research patent achievements, and technology into new products, and this indicated that "Porter hypothesis" in the manufacturing sector has been verified; (2) R&D and transfer expenditure have a positive impact on technological innovation. Finally, the authors put forward the corresponding policy recommendations for industry of the environmental regulation on the impact of technological innovation in phases.

Keywords: environmental regulation, technology innovation, stage difference, manufacturing

1 Introduction

China's manufacturing output of 8.2 trillion CNY in 2003, was up to a level of 73.34 trillion CNY in 2011, an increase of over 900%. This rapid development of the manufacturing sector brought serious damage to China's ecological environment.

China's manufacturing waste water was 16.996 billion tons in 2012 (105.6% increase since 2003). Waste gas, was 42.02 trillion cubic meters (147.57%) over the same period. Solid waste emissions came up to 990 million tons in 2012, which is + 215.88% as compared to the 2003 levels.

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Over-reliance on extensive industry resources causes these high manufacturing waste emissions. The lack of technological innovation and industrial development drive are also big factors. However, the current study, focused on the overall impact of environmental regulations on technological innovation. It failed to further investigate differences in R&D and technology transfer between the two phases. Therefore, this paper divides technological innovation into two stages: (1) technology development and (2) technology transfer. Then the authors use the panel data of 28 manufacturing industries during 2003–2012, to test the effect of environmental regulation and technological innovation.

2 Literature review

The impact of environmental regulations on technological innovation has been the focus of academic attention at home and abroad. Porter (1991, 1995) earlier put forward the famous "Porter hypothesis" that the appropriate environmental regulation can stimulate technological innovation of enterprises, this innovative effect can make up the investment of pollution regulation to realize the economic growth and environmental protection "win-win".

2.1 Support on "Porter hypothesis"

Managi, Hibiki, and Tsurumi (2009) found that technological innovation can expand global energy consumption and reduce greenhouse gas emissions in the same time.

Popp, Hafner, and Johnstone (2011) found that there is a positive correlation between domestic and overseas environmental regulations and paper industry technological innovation.

Dechezleprêtre and Glachant (2014) used wind power industry panel data of OECD countries analysis of the impact of environmental regulations on domestic technological innovation, the study found that domestic and foreign environmental regulation policies on domestic technological innovation have had a positive impact.

Ford, Steen, and Verreynne (2014) used Australian oil and gas industry panel data on the relationship between environmental regulation and the impact of various types of innovative empirical analysis, the researchers found that environmental regulations to promote a variety of products and services, including technical innovation and service innovation.

Zhao and Sun (2015) found that flexible application of controlled environmental regulation has a significant positive impact on business innovation.

2.2 Opposition on "Porter hypothesis"

Chintrakarn (2008) found that controlling emissions of making environmental technology patented invention lack of funds.

Zhang, Yu, and Guo (2010) constructed mathematical model between environmental regulation and technological progress to analyze the environmental regulations on technological innovation affected, the researchers found that the eastern and central regions of weak environmental regulations undermine the company's production of technological progress rate.

Kneller and Manderson (2012) used the manufacturing panel data in UK 2000–2006 to examine the relationship between environmental regulation and enterprise technological innovation, they found that strict environmental regulation reduces the technological innovation of cost, and the effect of environmental regulation on technology research is not positive.

2.3 Argument on "Porter hypothesis"

Alpay, Buccola, and Kerkdie (2002) analyzed the relationship between environmental regulation and productivity effect on American and Mexican food processing industry. It found that the effect of environmental regulation on US food processing industry productivity is negative, but on Mexican food processing industry productivity is positive.

Wang, G. and Wang, D. (2011) found that "Porter hypothesis" in the relatively backward central region are not supported, but in the developed eastern regions are supported.

Doganay, Sayek, and Taskin (2014) have found that reasonable environmental regulation can stimulate increased research and development investment, but technological innovation can offset the compensation effect of cost-effective environmental regulation is unclear.

The existing literatures were more focused on the econometric methods, rather than environmental regulations and technological innovation. Therefore the overall impact of the relationship does not reach the same conclusion.

The reason may be that previous studies neglected the different resource endowments in different regions. Also different levels of emissions in different sectors and of different R&D and technology transfer between different industries. These are together with generalization of different stages of technological innovation, resulting in the conclusion of the one-sidedness.

Therefore, in order to compensate for the lack of the above studies, this paper makes the following contributions: first, the technical innovation into technological R&D stage and technology transfer stage; second, using panel data of manufacturing in 2003–2012 to analysis environmental regulation on technological innovation.

3 Model building

According to endogenous growth theory, technological innovation is an economic phenomenon, its manifestations is an output, technological innovation activities of enterprises represents the production function is available. Therefore, this paper constructs Cobb-Douglas production function $y = f\ (K,P,O)$ based on a measure of technical progress to build the econometric regression model, where K is the fund investment of technology innovation, P is labor input of technology innovation, O are the other factors may influence the output of technology innovation. So the econometric regression model in the stage of technology R&D and technology transfer seen as follows:

The technology R&D stage:

$$patents_{it} = \lambda_1 ER_{it}^{\alpha}\ RGP_{it}^{\gamma}\ RDC1_{it}^{\beta}\ RDP1_{it}^{\delta} \tag{1}$$

Taking logarithm:

$$\ln\ patents_{it} = \alpha \ln\ ER_{it} + \gamma \ln\ RGP_{it} + \beta \ln\ RDC1_{it} + \delta \ln\ RDP1_{it} + c_1 + \varepsilon_1 \tag{2}$$

The technology transfer stage:

$$ptoducts_{it} = \lambda_2\ ER_{it}^{\alpha'} RGP_{it}^{\gamma'} patents_{it}^{\theta}\ RDC2_{it}^{\beta'} RDP2_{it}^{\delta'} \tag{3}$$

Taking logarithm:

$$\ln\ products_{it} = \alpha' \ln ER_{it} + \gamma' \ln RGP_{it} + \beta' \ln RDC2_{it} + \delta' \ln\ RDP2_{it} + \theta \ln\ patents_{it} + c_2 + \varepsilon_2 \tag{4}$$

where $patents_{it}$ are the patents of technology R&D stage in industry i and year t, represented by industry patents granted; $products_{it}$ are the products of technology transfer stage in industry i and year t, represented by sales of new products; ER_{it} is the environment regulation in industry i

and year t, represented by industry waste water, waste gas, solid waste pollution control costs; $RDC1_{it}$ is the physical capital of technology R&D stage in industry i and year t, represented by the internal expenses of industry basic research, applied research; $RDC2_{it}$ is the physical capital of technology transfer stage in industry i and year t, represented by the internal expenses of industry test development; $RDP1_{it}$ is the human capital of technology R&D stage in industry i and year t, represented by the full-time equivalent staff (person-years) of industry basic research, applied research; $RDP2_{it}$ is the human capital of technology transfer stage in industry i and year t, represented by the full-time equivalent staff (person-years) of industry test development; RGP_{it} is the GDP of industry i and year t, represented by industry output value. Besides, where RDC_{it}、RDP_{it}、RGP_{it} are control variables, c_1、c_2 are constant term, α'、θ、β'、δ are parameters to be estimated, ε_1、ε_2 are random disturbance, $\varepsilon_1, \varepsilon_2 \in N(0,1)$.

4 Date collection and process

The study sample used in this paper is the Chinese manufacturing 2003–2012 panel data, including waste water, solid waste pollution abatement cost data from "China Environment Yearbook" (2004). Together with "China Environment Statistical Yearbook" (2005–2013) patents granted, new products, research and development of internal expenditures, industry scientific and technological activities. Industry output data are from the "China Science and Technology Statistics Yearbook" (2004–2013).

Of particular note, in order to eliminate the effects of inflation; this articles industry output data, utilizes the price index provided by the OECD to convert current prices data into 2003 prices.

Table 1 defines each variable in Eqs. (2) and (4).

Table 2 includes the descriptive statistics for each variable in Eqs. (2) and (4).

5 The empirical results and analysis

5.1 Data stability and cointegration test

5.1.1 Data stability test

To accurately test stationary data, this study tested LLC, ADF-Fisher test, PP-Fisher test three unit root tests on the variables tested (Li, Dang, & Han, 2014). Specific test results are shown in Table 3, according to test results.

Table 1

The Definition of Variables in Eqs. (2) and (4)

Variable	Definition	Unit	Expect symbol
Patents	Industry patents granted	Unit	
Products	Sales of new products	Million	
ER	Industry waste water, waste gas, solid waste pollution control costs	Million	+
RDC1	The internal expenses of industry basic research, applied research	Million	+
RDP1	The full-time equivalent staff (person-years) of industry basic research, applied research	Person-years	+
RDC2	The internal expenses of industry test development	Million	+
RDP2	The full-time equivalent staff (person-years) of industry test development	Person-years	+
RGP	Industry output value	Million	+

Table 2

The Descriptive Statistics of Variables in Eqs. (2) and (4)

Variables	Mean	Maximum	Minimum	Standard deviation
lnPatents	6.785	11.334	2.485	1.572
lnProducts	15.573	19.026	11.706	1.461
lnER	11.238	15.267	6.924	1.755
lnRGP	17.814	20.041	14.800	1.167
lnRDC1	5.066	11.114	1.909	2.392
lnRDP1	3.055	7.574	0.000	1.197
lnRDC2	6.078	11.229	1.946	1.895
lnRDP2	3.841	7.460	0.693	1.513

Table 3

Stability Test

Variable	LLC test	ADF-Fisher test	PP-Fisher test	Conclusion
lnER	−11.538***	106.113***	142.004***	Steady
lnPatents	−16.582***	143.951***	180.162***	Steady
lnProducts	−10.875***	98.415***	224.850***	Steady
lnRGP	−13.926***	118.332***	253.823***	Steady
lnRDC1	−16.341***	126.962***	172.248***	Steady
lnRDP1	−12.946***	115.260***	164.540***	Steady
lnRDC2	−10.939***	87.103***	108.262***	Steady
lnRDP2	−33.806***	119.939***	113.903***	Steady

Note: The unit root test selection with the intercept and time trend, ** and *** denote parameter estimates at 0.05, 0.01 significance level.

5.1.2 Data co-integration test

Prior to each variable parameter regression estimation, there is a need to examine environmental regulation and technology research and development. Plus the co-integration relationship between environmental regulation and technology transfer. This is necessary in order to determine the existence of a stable relationship which, to avoid spurious regression. Co-integration test results are shown in Table 4 and Table 5, therefore, the authors believe that environmental regulation and technology innovation is co-integrated.

5.2 Gradual impacts of environmental regulation on technological innovation

During econometric estimates of environmental regulation on a random effects model, technology R&D and technology transfer stages were tested by Hausman. The result shows that fixed effects model is more suitable for estimation of this article. Fixed effects model estimation results are shown in Table 6, from the output point of view, R^2 and adjust R^2 are high after a two-stage adjustment, indicating the effect of a two-stage evaluation model fits better.

5.2.1 The technology R&D stage

From environmental regulations estimation, result of technological innovation research and development stage shows: the elasticity coefficient of environmental regulation on manufacturing technology is 0.285. This is significantly positive and consistent with earlier

Table 4

Co-integration Test in Technology R&D Stage

Statistics	Hypotheses	Results	
Statistics in the group	H_0:ρ = 1 H_1:ρ < 1	Panelv-stat	6.187***(0.000)
		Panelrho-stat	−0.120(0.4524)
		PanelPP-stat	−11.912***(0.000)
		PanelADF-stat	−6.195***(0.000)
Statistics between the group	H_0:ρ = 1 H_1:ρ < 1	Grouprho-stat	2.693 (0.9965)
		GroupPP-stat	−14.374***(0.000)
		GroupADF-stat	−7.076***(0.000)

Note: ** and *** denote parameter estimates at 0.05, 0.01 significance level, which number in parentheses is concomitant probability.

Table 5

Cointegration Test in Technology Transfer Stage

Statistics	Hypotheses	Results	
Statistics in the group	H_0:ρ = 1 H_1:ρ < 1	Panelv-stat	10.461***(0.000)
		Panelrho-stat	−0.031(0.5609)
		PanelPP-stat	10.775***(0.000)
		PanelADF-stat	−2.192***(0.0142)
Statistics between the group	H_0:ρ = 1 H_1:ρ < 1	Grouprho-stat	2.117 (0.9829)
		GroupPP-stat	−14.716***(0.000)
		GroupADF-stat	−4.015***(0.000)

Note: ** and *** denote parameter estimates at 0.05, 0.01 significance level, which number in parentheses is concomitant probability.

Table 6

The Estimation Results of ER on Technological Innovation in the Technology R&D and Transfer Stage

Variable	Technology R&D stage	Technology transfer stage
C	−14.481*** (−19.779)	2.511*** (3.628)
lnER	0.285*** (4.697)	0.168*** (4.607)
lnRGP	0.996*** (19.292)	0.515*** (10.723)
lnRDC1	0.110*** (2.662)	
lnRDP1	−0.073 (−1.549)	
lnRDC2		0.086*** (2.895)
lnRDP2		−0.027 (−0.671)
lnPatents		0.232*** (6.399)
R^2	0.926	0.971
Adjusted R^2	0.917	0.968
F	100.054***	262.023***

Note: ** and *** denote parameter estimates at 0.05, 0.01 significance level, *t*-values in brackets.

mathematical derivation of conclusions. This suggests that environmental regulation on China's manufacturing technology R&D has a significant role in promoting. 2012 pollution control operating costs of our manufacturing industry is 127.9 billion CNY. The average annual increase of 166% during 2003–2012, compared with the manufacturing output, industry average annual GDP growth of only 19%. Higher operating costs will increase pollution running costs, forcing companies to look for technology research and development through a new profit growth point to offset the cost of pollution. Elasticity of R&D expenditures is positive and significant, which indicated that R&D expenditure of technology research and development has a significant role in promoting industry development. The elasticity coefficient of human capital in technology development phase is negative, but not significant. The elasticity coefficient of GDP is significant positive.

5.2.2 The technology transfer stage

From environmental regulations, estimation result of technological innovations into stage shows: the elasticity coefficient of environmental regulations on technology transforming is 0.168. This is significantly positive, and consistent with earlier mathematical derivation of conclusions. Such environmental regulation will encourage enterprises to accelerate technology patents conversion. By converting new products, this will add value to the enterprise. But compared with the technology research and development stage, the impact of environmental regulation on technology transfer is less. This indicates that the current policy emphasis, on environmental regulation of manufacturing technology R&D, lacks the policy effects on manufacturing technology transfer. The impact of technology transfer funding for technology transfer is significantly positive. Additionally, investment in human capital and technology into the elastic coefficient is negative, but not significant. Research patent achievements have a significant positive impact on technology transfer. GDP affect industry technology transfer phase is significantly positive; indicating that the growth of industrial-scale manufacturing technology transfer activities of our country has a significant role in promoting.

6 Conclusions and policy recommendations

6.1 Conclusions

Empirical results show that there impact of environmental regulations on technological innovation industry heterogeneity. Overall, the elasticity of environmental regulation on technology research and development phase is greater than the technology transfer phase. This indicates China's manufacturing industry environmental regulations promote technological research and development, more than technology transfer. At the same time, the environment governing the use is based on technology development and funding and technology transfer, to industrial scale conditions. The research findings are not consistent with Li, Dang, and Han (2014). This is because the econometric model of the study, considers the impact of environmental regulation as only a single factor in technological innovation. Such innovation is not considered necessary capital, and manpower and the role that environmental conditions play a role in regulation. The study did not consider the technology development and technology transfer, as a continuous phase, and ignored the technical research and development to technology transfer association.

6.2 Policy recommendations

Policy makers should pay full attention to the difference stage technology research and technology transfer. In the technology development phase, manufacturing enterprises should moderate efforts to strengthen environmental regulation. They should also continue to improve the efficiency of research and development funds, to guide R&D funds to finance green technology patents developed flow. To enhance investment in manufacturing technology research and development of human capital, through reform talent incentive, evaluation mechanism, improving manufacturing green technology patents of independent research and development capabilities. In the technology transfer phase, the manufacturing enterprises should, by way of tax incentives and financial subsidies. Encourage enterprises to create green technology patent for such products. These make up the cost of business in the early stages of market development.

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