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Research on the relationship between environmental regulation, technological innovation and employment: focused on China

Chang Li and YunSeop Hwang
Kyung Hee University, Seoul, Republic of Korea, and
Cheon Yu
Mokpo National University, Jeonnam, Republic of Korea

Abstract

Purpose – The purpose of this paper is to explore the relationship between formal environmental regulation (FER) and informal environmental regulation (IER), technological innovation and employment.
Design/methodology/approach – This paper uses data from the 30 provinces of China during 2003–2015. The impacts of formal and IER and technological innovation on employment are estimated by generalized least squares, and the eastern region of China is analyzed separately.
Findings – First, both formal and IERs have different degrees of significant impact on employment, and the relationship is not a simple linear. FER has an inverted U-shaped relationship with employment, but IER has a U-shaped relationship. However, in the test including technological innovation, the results of the national sample and the eastern sample are different. In the eastern sample, the relationship between informal regulation and employment has an inverted U-shaped curve. Second, the results of model 3 and model 6 show that technological innovation has a significant negative effect on employment both in the national and the eastern region sample.
Research limitations/implications – This paper puts forward corresponding policy implications: first, in designing environmental regulations, it is necessary to consider not only the stringency but also the type of regulation. Second, environmental regulations need to be differentiated by region. Finally, when designing environmental regulations, it is necessary to consider more flexible employment policies that are contingent on the stringency of regulations, in order to prevent employment decline due to technological innovations.
Originality/value – The conclusions about the influence of environmental regulation on employment reached are not consistent in China. Most existing research studies seldom consider environmental regulations into categories and focus only on the whole environmental regulation. This paper pays attention to the influences of different types of environmental regulations on employment. It analyzes the eastern region separately to explore whether there is a difference in the effects of environmental regulations. Furthermore, this considers the effect of technological innovation as a mediator.

Keywords Environmental regulations, Employment, Technological innovation, Non-linear effect
Paper type Research paper

1. Introduction

In the past three decades, China has achieved a rapid economic growth. However, the achievement was at the expense of the decline in environmental quality. In 2014, China ranked 118th in the Environmental Performance Index (EPI) among 178 countries. The EPI ranking reflects the environmental situation of China and indicates the Chinese economy

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would face serious environmental problems in the near future. The Chinese government recognizes this situation and puts pressure on the enterprises in high polluting industries, forcing them to improve their pollution emission behavior. This move of government to promote a more sustainable growth, which considers economic growth together with environmental quality, urges firms to make their production and operation activities in a more environment-friendly way. Under these circumstances, firms get easily to face cost pressure that can deteriorate the competitiveness of the product and possibly result in the decrease in employment. Not only China but other developing countries have tried hard not to fall into this dilemma. With the market-oriented reforms, China's labor market has been in a state of oversupply, and it is expected to continue in the near time. At present, China undergoes huge employment pressure, but the future situation does not look very optimistic. For this reason, it is vital to examine whether environmental regulations would act as a crucial factor in employment, as they increase costs for companies and limit their production activities.

Prior studies have focused on the effects of environmental regulation on economic development and stability. However, it is generally believed that environmental regulation has a negative relationship with economic factors including employment (Morgenstern *et al.*, 2002; Walker, 2011). Thus, we would focus on the effect of environmental regulation on employment in this study.

However, other studies revealed that industrial and regional specific characteristics can also change the relationship between them (Bezdek *et al.*, 2008; Bovenberg and De Mooij, 1997). Despite the uniqueness of these studies, it is not easily generalized in explaining the relationship between them because most of the focused industries are related to environmental protection, and the regions are implemented with specific government policies.

There have been a few studies that verified environmental regulation types and their diversified impact on economic performance. They found that different types of environmental regulations have different influences on the cost of pollution control through different mechanisms. This would necessarily affect the business decision-making of enterprises and then affect their employment. Thus, how to set up environmental regulations has become a subject of growing interest for governments and scholars.

To take into account both the stringency of regulation and the structure of the instrument, we divide environmental regulations into two categories: formal and informal environmental regulations (IERs). Then we examine whether different categories of environmental regulations have different influences on employment. This paper adopts an empirical analysis method to collect, process and arrange a large amount of statistical data, and selects suitable alternative indicators of environmental regulation for quantitative analysis. Finally, this paper shows the regression results for the influences of environmental regulations on employment. Besides, a separate regression analysis for the eastern region of China was conducted to check whether the impact of environmental regulations differs in different regions. The environmental pollution becomes increasingly serious day by day and its treatment urges companies to reallocate resources, which may reduce investment in technological innovation. Technological innovation is very important, and especially new technologies are essential to reduce pollution and improve production efficiency. Thus, we also consider the effect of technological innovation.

2. Literature review

2.1 Environmental regulation

Environmental regulation refers to social regulation that regulates the economic activities of enterprises by formulating and implementing corresponding policies, laws and regulations to achieve pollution reduction and environmental protection. Environmental regulations can be classified into formal and IERs according to implementing mechanisms. Traditionally, environmental regulations are mainly formal environmental regulations (FERs) in that the

government sets the outline of playing boundaries and the role of participants. Formal regulations are generally conceived as forceful punishment when violated and uneasy to alter. In recent years, with the continued investment in environmental protection, the skills for environmental regulation have also been incrementally improved, and with the development of information and communication technologies, various kinds of public participation in environmental preservation are activated to complement formal regulations. The informal regulations supplement the stringent and insufficient aspect of formal regulations and promote more flexible response to regulation changes.

FER refers to the government and government-related institutions that control or intervene in the economic behavior of market entities by formulating corresponding laws, policies and adopting relevant measures. It is well-known that adequate and well-designed formal regulations play an important role in improving the ecological environment while developing the economy (Porter and Van der Linde, 1995). FERs include wastewater discharge standards, the formulation of technical standards for production, the establishment of designated environmental monitoring systems, regular or irregular environmental inspections, the collection of pollution taxes, etc. It forces companies to choose the most adequate technology for production and operation in an environmentally friendly way. However, formal regulations may face a rent-seeking behavior of participants and other unexpected externalities caused by the regulation itself.

IER refers to mass petitions or media exposure to achieve an improvement of an environment standard or quality of life when government-implemented FERs are malfunctioning or under public's expectation. At that time, the organizations related to environmental protection or other interest groups would form a public's spontaneous actions or negotiate with the companies of environmental pollution, or apply pressure to them or local governments. Thus, IERs could reflect reasonable demands of social groups or residents for the quality of surrounding environment, which is also an effective monitoring method for environmental protection. The definition of IER was first proposed by Pargal and Wheeler (1996). In earlier studies, IERs were considered to compensate for FERs when they failed or were not fully implemented. As the economy keeps growing, people's awareness of environmental protection has also increased, and the role of non-governmental entities in environmental governance has become increasingly prominent. IERs are regarded as an external manifestation of people's awareness of the ecological environment and have gradually become an important means of environmental governance. They are not just a supplement to FERs but have significant linkages with them.

2.2 Environmental regulations and employment

Environment protection policy is divided into regulation, economic method and the use of information. The regulation refers to the way of direct control of government on environmental activity. On the contrary, the economic method mainly uses market mechanism instead of government intervention on environmental activity. The use of information refers to delivering adequate information to stakeholders and inducing voluntary participation in environmental activity (Callan and Thomas, 2009). It is generally believed that environmental regulation has a negative effect on employment. The stronger the environmental regulation, the more the enterprises are forced to reduce emissions, which can increase the production costs of enterprises in terms of physical and human capital. The cost pressure corrodes the competitive advantage of a company, and this will consequently lead to a decrease in the employment of a company (Greenstone, 2003; Henderson, 1996). Morgenstern *et al.* (2002) point out that the increase in spending on reducing emission activities by the US manufacturing companies would lead to a reduction in employment of the number of companies. Walker (2011) finds that eight years after the

implementation of the Clean Air Act (CAA) amendment, employment has fallen by 15% compared to the average employment in 1990.

Although the traditional view is still used to explain the effect of environmental regulation on employment, other researchers insist that the relationship can change by the industry or regional characteristics. Together with the environmental regulation, industry/regional characteristics have positive or negative effects on employment. Such a complex impact mechanism has not been explicitly analyzed yet. Bovenberg and De Mooij (1997) find that after the government levied a pollution tax, the environmental quality has been significantly improved, but at the same time, it has also led to an increase in employment, achieving a win–win outcome in environment and employment. Bezdek *et al.* (2008) focuses on the relationship between the firm size and employment of the US environmental protection industry. He finds that increasing investment is conducive to promoting employment in the environmental protection industry through a comprehensive analysis of the relationship between the two with relevant data. Contrary to prior results, some scholars reveal little or complex effect between the two variables. Goodstein (1996) shows environmental regulation has little effect on the unemployment rate in the United States, while macroeconomic factors have a greater impact on the unemployment rate. McEvoy *et al.* (2000) insist that environmental regulations can have positive or negative influences on employment according to industry characteristics. Enhancing environmental regulations for energy-intensive industries may reduce employment, but at the same time, it can promote innovation in the industry, increase productivity and reduce product prices, which can increase output and employment. Such complex results do not allow us to easily conclude the direction and/or significance of the relationship of the two focal variables. Zhong *et al.* (2021) find that, in the case of China, implementing environmental regulation would generate a "compliance cost effect" and "innovation offset effect". The compliance cost effect shows a positive relationship with the employment of high-skilled labor while it is negatively related to that of low-skilled labor. The innovation offset effect, however, shows a positive relationship with the employment for both high-skilled and low-skilled labor. The empirical result shows that the employment of high-skilled labor would grow along with the intensification of environmental regulation while that of low-skilled labor would decline first and then rebound, showing a U-shaped relationship.

A group of researchers show a different approach as they focused on the non-linear relationship between the two variables. Whether it is from the industry (Wang *et al.*, 2016; Lou, 2016) or the region-oriented (Li and Du, 2014), the findings indicate that environmental regulation has a non-linear effect on employment in a significant way. In the study of Wang and Shao (2019), a panel threshold regression model was applied to measure the non-linear impacts of environmental regulations on green growth in Group 20 countries. They divided the environmental regulation into formal and informal types, and found the market-based FER only has significant positive impacts on the green growth of an economy at a high-level phase of regulation stringency while this is not the case in the low-level counterparts. Li (2015) also finds the U-shaped relationship that shows employment decreases at the initial stage of regulation, but it increases after passing a certain point.

2.3 Mechanism of the relationship between environmental regulation, employment and technological innovation

In the course of environmental regulations affecting employment, technology can play an important role. Technology has not a simple relationship only with environmental regulations but with employment also. Does environmental regulation affect technological innovation positively or negatively? And does the technological innovation increase the employment or not?

It is believed that stronger environmental regulations would harm technological innovation (Iraldo *et al.*, 2011). The "constraints hypothesis" is the foundation of this view.

With the strengthening of environmental regulations, it is assumed that enterprises need to invest more resources to reduce pollution, which raises the total cost of a firm. A firm with a cost constraint may reduce the investment to elsewhere, among which the R&D activity can also be affected due to a cost constraint. Jaffe *et al.* (1995) found that there exists a crowding out effect of environmental regulations partly curtailing the investment on the human and financial resources for promoting technological development, as the resources are concentrated on pollution mitigating activities. Contrary to this view, the "Porter hypothesis" supports that the environmental regulation policy and a well-designed regulation can stimulate technological innovation of a firm. Brunnermeier and Cohen's (2003) research shows that the relationship between the number of patent applications for environmental protection and environmental regulations is positive and statistically significant. Krysiak (2011) analyzed from a theoretical perspective and found that a vertical and horizontal technological innovation can be stimulated by environmental regulations.

However, some studies show no significant relationship between environmental regulation and technological innovation. Due to the existence of the industry-specific characteristics and firm heterogeneity, both the "constraint hypothesis" and "Porter hypothesis" may not fully reflect the relationship between the two. Brännlund and Ghalwash (2008) found that the relationship between environmental regulations and productivity growth is not significant. Lanoie *et al.* (2011) used the data for 4,200 companies in 7 OECD countries to verify the three forms of "Porter hypothesis". The empirical results did not support the "strong Porter hypothesis" but partially supported the "narrow Porter Hypothesis".

The effect of technological innovation on employment is another complex topic that is difficult to make a conclusion. Advanced equipment and well-designed production techniques can reduce the demand for human resources and it consequently reduces employment. A widespread technological innovation can significantly reduce employment in industries or regions. Becker *et al.* (2005) assert that certain kinds of technological innovations may harm employment. Since technology and labor are in a substitute relationship rather than a complementary one, technological innovation enables firms to use more capital instead of labor input.

Contrary to this pessimistic view, other groups of researchers assert that technological innovation can create new jobs; therefore, it can increase employment. While technological progress may put various disadvantages on old jobs, it creates new jobs, and employment can be overwhelmingly increased than before. Duhautois *et al.* (2022) find evidence that a product innovation increases both employment and certain dimensions of job quality such as working hours and the number of permanent contracts. However, some social groups may not benefit from technological innovation. Lower-skilled workers are less positively affected by technological innovation in terms of employment and sometimes negatively affected in terms of wage. The positive effects of innovation appear mainly in manufacturing sector, not in services. The labor demand mechanism is also explained by the opportunistic cost theory. Del Rio (2001) shows that technological development may lead to rising interest rates. The increase of capital cost urges firms to use less capital and motivates more demand for labor. This mechanism lessens the capital requirement and leads to an increase in employment.

The mixed results prevent us from consistent inferences for the impact of environmental regulation and technological innovation on employment. In the real economy, environmental regulation can have both positive and negative effects on technological innovation and employment simultaneously. In one sense, regulations limit firm activity through various paths and, consequently, firms' research and development (R&D) activity and employment can also be reduced. Conversely, in another sense, regulations can create a new market opportunity that can stimulate a firm's technological innovation and it, in turn, increases

employment. For this reason, the researchers turned their interest to specific industry/region domains which can explain a partial impact of regulation on innovation and employment mechanisms. This study focused on China facing an economic dilemma of economic growth with the environmental quality. Not only the Chinese government but researchers are interested in the effect of environmental regulation on the economy including economic growth, productivity, technological progress, employment, etc.

It can be seen from the above-mentioned literature that environmental regulation, technological innovation and employment are combined with each other through complex mechanisms and various directions. In order to study the dynamic relationship between them, it is necessary to sort out the influence mechanism (Figure 1).

First, the influence mechanism of environmental regulation on employment is a mainstream of research design. It can be separated into two categories: the negative cost effect and the positive substitution effect. The enterprises' costs may rise by environmental regulations, and it may force firms with high marginal costs to close production, which may lead to a decline in the output and scale of the entire industry. At the same time, enterprises need to increase labor input that matches the clean governance activities whether they choose an end-of-production management or improve the clean technology of the product on process. Thereby, this leads to an increase in labor demand, that is, a positive substitution effect.

Second, the influence mechanism of environmental regulation on technological innovation is still ambiguous. It also has both the positive compensation effect and the negative offset effect that complicate the influence mechanism and its result. On the one hand, companies need a lot of capital investment for technological innovation, but environmental regulations increase the cost of pollution control for companies. This would have a crowding-out effect on R&D investment. On the other hand, companies can improve their production processes or improve their pollution control capabilities through technological innovation, which increases their productivity levels, decelerate or counteract the increased environmental costs caused by environmental regulations, and generate positive compensation effects.

Third, the impact mechanism of technological innovation on employment is on the path of the mainstream effect of environmental regulation on employment. The influence mechanism of technological innovation on employment mainly includes negative substitution effect and positive compensation effect. Technological innovation would cause the decline of traditional sectors and create new sectors, resulting in an overall decrease in the number of employees, which is called as a negative substitution effect. On the contrary, the improvement of technological innovation would greatly reduce the cost of production of enterprises. With the price advantage and the attractiveness of new products, the demand for those goods would continue to expand. In order to meet the increased market needs, enterprises would require more labor to produce these products, which is called as a positive compensation effect.

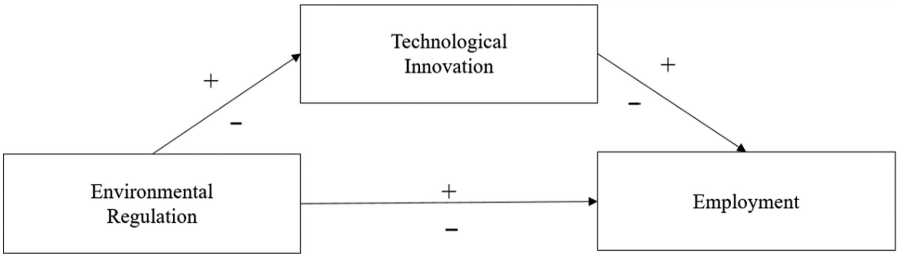

Figure 1.
The relationship between environmental regulation, employment and technological innovation

3. Research methodology

3.1 Research model

The main purpose of this study is to analyze the effects of different types of environmental regulations on employment. In the course of the impact process, technological development and innovation play a critical role in the path of regulation and employment. For achieving our research objective, the mediating effect model is considered to be adequate and the technological innovation is adopted to measure the mediating effect. The mediating effect model in this paper is established based on the "Causal step approach" followed by Baron and Kenny (1986). The following formula is expressed as the specific mediating effect model:

$$\mathrm{Y} = \alpha \mathrm{X} + e_1 \tag{1}$$

$$\mathrm{M} = \beta X + e_2 \tag{2}$$

$$\mathrm{Y} = \mu \mathrm{X} + \gamma \mathrm{M} + e_3 \tag{3}$$

First, test the coefficient α of Equation (1), in other words, the total effect of independent variable X on dependent variable Y. If X variable influences Y in Equation (1) in a significant way, then test the effect of the independent variable X on the mediating variable M, that is, test the coefficient β of Equation (2). Finally, after controlling the mediating variable M, test the coefficients μ and γ of Equation (3). If the coefficients μ and γ are both significant, it indicates that the mediating effect of M is significant with its partial mediating effect; there is a complete mediating effect if the coefficient μ is insignificant, but the coefficient γ is significant.

Theoretical analysis shows that two types of environmental regulations can affect employment through technological innovation. Since the influence of environmental regulation on employment could be non-linear, we add the square terms of environmental regulations to the model. This model measures both formal and informal regulation intensity effect on employment. The weak regulation intensity increases (or decreases) the employment whereas beyond a certain point of intensity it conversely decreases (or increases). The analysis shows that at the initial stage, both formal and informal regulations have a decreasing impact on employment, but after passing a certain point, they have an increasing impact on employment. The mediating effect model equations are established as follows:

Model 1:

$$LnEMP_{it} = \alpha_0 + \alpha_1 LnER_{it} + \alpha_2 (LnER_{it})^2 + \alpha_3 LnOPEN_{it} + \alpha_4 LnLABOR_{it} + \alpha_5 LnGDP_{it} + \alpha_6 LnFDI_{it} + \alpha_7 LnML_{it} + \alpha_8 LnWAGE_{it} + \omega_{it}$$

Model 2:

$$LnTI_{it} = \beta_0 + \beta_1 LnER_{it} + \beta_2 (LnER_{it})^2 + \beta_3 LnOPEN_{it} + \beta_4 LnLABOR_{it} + \beta_5 LnGDP_{it} + \beta_6 LnFDI_{it} + \beta_7 LnML_{it} + \beta_8 LnWAGE_{it} + \varepsilon_{it}$$

Model 3:

$$LnEMP_{it} = \gamma_0 + \gamma_1 LnER_{it} + \gamma_2 (LnER_{it})^2 + \gamma_3 LnTI_{it} + \gamma_4 LnOPEN_{it} + \gamma_5 LnLABOR_{it} + \gamma_6 LnGDP_{it} + \gamma_7 LnFDI_{it} + \gamma_8 LnML_{it} + \gamma_9 LnWAGE_{it} + \tau_{it}$$

where α, β and γ are regression coefficients of each variable; ω_{it}, ε_{it} and τ_{it} represent the random error terms. The subscript i refers to the province, t indicates the year. EMP_{it} is employment. ER_{it} indicates the environmental regulations, TI_{it} indicates technological innovation, FDI_{it} is foreign direct investment, GDP_{it} is the gross domestic product, $WAGE_{it}$ is the wage, ML_{it} is Marketization level, $LABOR_{it}$ is labor productivity and $OPEN_{it}$ is trade openness.

3.2 Variable definition and measurement

In this paper, the dependent variable is employment (EMP), which is measured by the number of people employed at the end of the year of each province in China.

For independent variables, FER and IER are measured as follows. To measure the FERs, we referred to Xu and Tao's (2017) method that uses the amount of investment and treatment expenditures per unit of pollutants as the independent variables.

This paper uses the following method to measure FERs. Because of the availability of data, the cumulative amount of industrial SO_2, wastewater and solid waste emissions are used as a measure of total pollutant emissions—PE_{it}. If the pollution control investment is IV_{it}, the calculation formula for environmental regulation is:

$$FER_{it} = \frac{IV_{it}}{PE_{it}}$$

The higher the investment expenditure for the treatment of unit pollutants is, the stricter are the environmental regulations. IER refers to people's participation in environmental protection activities, and it is a concentrated expression of environmental protection awareness. This article draws on the method of Shen and Jin (2020) that measures IERs by the geometric mean of the frequency of environmental petitions and population density. The calculation formula of IER is as follows:

$$IER_{it} = \sqrt{pet_{it} * dop_{it}}$$

Among them, the pet_{it} is the number of annual environmental letters and visits, and the dop_{it} is the province's permanent population to the total area.

Since environmental regulations can affect employment by influencing technological innovation, this paper chooses technological innovation (TI) as the mediating variable. In the 1960s, people believed that the scope of innovation was not a single activity but very wide including R&D, production and sales. Based on this definition, we consider the number of R&D results to reflect the level of regional innovation, that is, the number of invention patents obtained. Thus, from the perspective of innovation output, this paper uses the number of utility model and invention patent applications to measure technological innovation.

The following are the control variables

(1) Economic growth (GDP). To measure the level of economic growth, this paper uses regional real GDP. The higher the regional real GDP is, the higher is the level of economic growth. Higher economic development would bring more employment opportunities.

(2) Labor productivity (LABOR). We employ the proportion of the total value of industrial output to the number of employees in each province to measure labor productivity. There is a dual effect of high labor productivity on employment. The high labor productivity makes the enterprise more competitive and occupies a larger market share. Therefore, the enterprise would expand the scale of production and increase the demand for labor; if the goal of an enterprise is to maintain the original output, the high labor productivity may harm employment by reducing the demand for labor.

(3) Trade openness (TRADE). To measure trade openness, this paper uses the ratio of the total amount of import and export to GDP. Mao's (2009) research shows that labor demand in the manufacturing industry is affected by export scale and trade openness. Expanding export and trade openness would promote manufacturing employment, especially in the labor-intensive manufacturing sector.

(4) Wage (WAGE). This paper uses the average annual salary of employees to measure wage levels. Rising wages would prompt companies to use more capital to replace labor units, leading to a reduction in labor demand.

(5) Foreign direct investment (FDI). We employ the total amount of FDI used by each province in the year to measure FDI. It is often carried out in the form of investment or establishment of factories that would have a significant impact on local labor demand, especially for foreign investors whose main driving factor is cheap labor cost, which would promote a rapid increment in local employment.

(6) Marketization level (ML). It is expressed by the marketization index.

The data are from 30 provinces in China. We exclude Tibet, Taiwan, Hong Kong and Macao due to the availability of data. The time period is from 2003 to 2015. The sources of data are "China Statistical Yearbook", "China Environmental Yearbook", "China's marketization index report by province (2016)" and "China Industrial Economic Statistical Yearbook". The measurements and data sources of variables are in Table 1.

4. Results

4.1 The relationship between environmental regulation, employment and technological innovation

The descriptive statistics are presented in Table 2. And the results of the unit root test of each variable, checked with LLC, PP, IPS and ADF test, are also presented in Table 2. Based on the 4 types of unit root test, each variable rejects the null hypothesis, which indicates that the variable is a stationary series. So we can effectively carry out the related statistical analyses.

Before carrying out the regression analysis, we test the autocorrelation and heteroscedasticity of error terms. The results of the Wooldridge test and the Wald test reject the null hypotheses, which means the sample data have problems with autocorrelation and heteroscedasticity. Therefore, the generalized least squares (GLS) estimation is applied to deal with these issues, and the result is shown in Table 3.

Variable	Definition	Measurement	Source
LnEMP	Employment	The number of employed people in each province at the end of the year	China Statistical Yearbook
LnFER	Formal environmental regulation	Comprehensive index	China Environmental Yearbook
LnIER	Informal environmental regulation	Comprehensive index	
LnTI	Technological innovation	The number of utility model and invention patent applications	China Statistical Yearbook
LnFDI	Foreign direct investment	Actual use amount of foreign direct investment	
LnGDP	Regional real GDP	Regional real GDP	
LnWAGE	Wage	Average wage of employees	
LnML	Marketization level	Marketization index	China's Marketization index report by province (2016)
LnOPEN	Trade openness	Total amount of import and export trade/GDP	China Statistical Yearbook
LnLABOR	Labor productivity	The ratio of industrial output value to labor force	China Industrial Economic Statistical Yearbook

Table 1.
Measurements and sources of variables

Variable	Mean	S.D	ADF test	PP test	LLC test	IPS test
LnEMP	7.563	0.812	115.130***	491.640***	−3.847***	−1.385*
LnFER	2.893	0.9	165.186***	296.746***	−3.111***	−5.838***
LnIER	7.044	1.123	191.766***	92.200**	−4.164***	−6.510***
LnTI	9.104	1.585	112.266***	288.790***	−3.397***	−2.626***
LnFDI	9.784	0.736	251.516***	151.470***	−3.305***	−5.106***
LnWAGE	−1.634	0.985	377.135***	78.404*	−8.711***	−1.565**
LnGDP	9.075	1.019	271.429***	301.084***	−11.224***	−2.734***
LnOPEN	10.1	0.379	194.214***	264.494***	−30.300***	−4.005***
LnML	9.635	1.616	164.716***	87.020**	−4.365***	−1.457*
LnLABOR	1.785	0.299	223.847***	179.023***	−14.355***	−5.631***

Note(s): ***$p < 0.01$

Table 2.
Unit root test of data and descriptive statistics

The results show that both types (formal and informal) of environmental regulations have different degrees of significant impact on employment, and the relationship is not a simple linear. The coefficients of FER and IER are 0.177 and −0.091, and the square term coefficients are −0.042 and 0.009, respectively. It can be seen that the values of FER and IER that make the turning point of the curve are 2.107 and 5.056, respectively. The effect of FER on employment is positive, and the estimation result indicates that it promotes employment at the initial stage and then inhibits employment, showing an inverted U-shaped relationship. This result is consistent with the research of Chen *et al.* (2014). We conjecture the reason why this happens is that the scale effect of FER on employment in China at the early stage may not be negative. At the early stage, the cost increase caused by FER could be still within the scope of the enterprise's capacity, so the enterprise would not reduce the production scale, and it may not reduce labor demand.

The impact of IER on employment is negative and presents the characteristics of a U-shaped curve. This result is consistent with the research of Cui and Chang (2018). The increase in the intensity of IER has a significant inhibitory effect on employment. The lower intensity of IER in China as a whole could be one of the reasons. With the increased intensity of IER and increased consumer awareness of environmental protection, the general public has become to demand stronger for a high-quality environment. Consumers began to prefer cleaner products, so the market share of polluting companies declined, which reduced company output and demand for labor. However, IER is a kind of public opinion pressure, not a compulsory means. According to the estimation results, IER has a positive effect on employment when the intensity of IER reaches a certain level. Therefore, both types of environmental regulations significantly affect employment. The difference is that FER has an inverted U-shaped relationship with employment, but IER has a U-shaped relationship.

Model 2 in Table 3 shows the relationship between environmental regulation and technological innovation in China. Both the Wooldridge test and the Wald test reject the null hypotheses, which implies that there exist some issues of autocorrelation and heteroscedasticity in the data sample. Therefore, the GLS estimation is an appropriate model to be adopted that is more effective than OLS in this condition. Both FER and IER affect technological innovation in a significant way. There is a non-linear relationship between FER and technological innovation that presents an inverted U-shaped relationship, which promotes the relationship between the two at first and inhibits later on, though the FER's square term is insignificant. That is, the lower strength of FER would promote technological innovation at first, and then inhibit it as the strength of FER rises. The square term coefficient of IER is −0.03, and the coefficient of IER is 0.487. It can be seen that the value of IER that makes the turning point of the curve is 8.117.

Table 3.
Regression results of the relationship between environmental regulation, technological innovation and employment

Variables	Model 1 ($LnEMP_{it}$)		Model 2 ($LnTI_{it}$)		Model 3 ($LnEMP_{it}$)	
$LnFER_{it}$	0.177*** (0.022)		0.273*** (0.092)		0.243*** (0.021)	
$(LnFER)^2_{it}$	−0.042*** (0.004)		−0.002 (0.002)		−0.049*** (0.004)	
$LnIER_{it}$		−0.091** (0.040)		0.487*** (0.128)		−0.100*** (0.037)
$(LnIER)^2_{it}$		0.009*** (0.003)		−0.030*** (0.009)		0.010*** (0.003)
$LnTI_{it}$					−0.072*** (0.008)	−0.087*** (0.008)
$LnLABOR_{it}$	−0.815*** (0.012)	−0.821*** (0.011)	−0.0008 (0.049)	0.438*** (0.041)	−0.853*** (0.011)	−0.810*** (0.010)
$LnOPEN_{it}$	−0.005 (0.006)	−0.009 (0.007)	0.034 (0.024)	−0.092*** (0.025)	−0.007 (0.006)	0.003 (0.007)
$LnGDP_{it}$	0.964*** (0.008)	0.958*** (0.008)	1.100*** (0.031)	1.136*** (0.026)	1.065*** (0.012)	1.066*** (0.012)
$LnWAGE_{it}$	−0.067*** (0.019)	−0.092*** (0.019)	0.223*** (0.077)	0.212*** (0.067)	−0.068*** (0.016)	−0.092*** (0.018)
$LnFDI_{it}$	0.034*** (0.005)	0.022*** (0.006)	0.022 (0.024)	−0.059** (0.023)	0.036*** (0.005)	0.014*** (0.006)
$LnML_{it}$	−0.047* (0.025)	−0.018 (0.030)	1.013*** (0.608)	0.787*** (0.101)	−0.012 (0.025)	0.057** (0.027)
Obs	390	390	390	390	390	390
Wooldridge test	141.901***	208.756***	55.057***	54.864***	162.019***	220.587***
Wald test	3146.15***	2220.15***	325.09***	679.50***	6237.71***	3206.93***

Note(s): *$p < 0.1$, **$p < 0.05$ and ***$p < 0.01$

These results are consistent with Guo *et al.* (2020). When the intensity of environmental regulations is at a low level, the improvement of environmental regulations would guide enterprises to carry out technological research and development. During this period, enterprises use technological innovation to compensate for long-term environmental regulation costs. However, with the gradual increase in the intensity of regulations, enterprises need to invest more funds to innovate pollution treatment technologies. For companies, in addition to spending a lot of funds to purchase professional equipment to reduce emissions, other methods have little effect. The excessive cost of pollution control squeezes out the normal technological innovation of the enterprises.

The results of GLS estimation on the relationship between environmental regulations and technological innovation affecting employment in China are presented in model 3 of Table 3. It can be seen from the empirical results that technological innovation has a significant negative effect on employment in China. The square term coefficients of FER and IER are −0.049 and 0.010, and the coefficients are 0.243 and −0.100, respectively. It can be seen that the values of FER and IER that make the turning point of the curve are 2.408 and 5.000, respectively. The possible reasons for the negative relationship between technological innovation and employment are as follows. First, technological innovation has increased the production efficiency of companies, resulting in a reduction of companies' labor demand while the output remains unchanged. Second, technological innovation leads to an increase in production efficiency, which increases the substitution effect on labor demand. Finally, the mismatch between the supply of low-skilled labor and the demand for high-skilled labor leads to a structural unemployment. Both types of environmental regulations significantly affect employment. FER has an inverted U-shaped relationship with employment, but IER has a U-shaped relationship. This is the same result with model 1 in Table 3.

4.2 Results of the eastern region of China

The relationship between the three variables is tested for the eastern region of China. Since the eastern region has a relatively high economic level due to the early opening policy, the results could be different from the case of entire country. The empirical results for the eastern region of China are shown in Table 4. The results of the Wooldridge test and the Wald test reject the null hypotheses, which implies the existence of autocorrelation and heteroscedasticity. Therefore, the GLS estimation is appropriately adopted. Consistent with the regression results under the national sample, FERs still have a significant effect on promoting employment in the eastern region, and also show the characteristics of an inverted U-shaped curve that FERs promote at first and then suppress employment after the inflection point of the curve.

However, different from the research findings under the national sample, IER promotes employment in the eastern region. This result is in line with the findings of Cui and Chang (2018). The intensity of IER in the eastern region is above the average level of the central and western regions and the entire China, which implies the improvement of IER does not necessarily have a sustained negative influence on employment. As the intensity of IER rises, the general public's awareness of environment has increased. This would lead to an enhanced social supervision on environment that could promote the consumption of green products and expand the green products' market share, thereby promoting green production by enterprises and stimulating the development of green industries, which would ultimately promote employment.

Model 4 shows that the square term coefficient of FER is −0.075 and the square term coefficient of IER is 0.022. The coefficients of FER and IER are 0.395 and −0.289, respectively. It can be seen that the values of FER and IER that make the turning point of the curve are

Table 4.
Regression results of the eastern region of China

Variables	Model 4 ($LnEMP_{it}$)		Model 5 ($LnTI_{it}$)		Model 6 ($LnEMP_{it}$)	
$LnFER_{it}$	0.395*** (0.046)		0.338*** (0.108)		0.454*** (0.039)	
$(LnFER)^2_{it}$	−0.075*** (0.007)		−0.005 (0.015)		−0.079*** (0.004)	
$LnIER_{it}$		−0.289* (0.156)		0.576*** (0.220)		0.691*** (0.150)
$(LnIER)^2_{it}$		0.022** (0.010)		−0.039*** (0.014)		−0.038*** (0.010)
$LnTI_{it}$					−0.123*** (0.010)	−0.273*** (0.022)
$LnLABOR_{it}$	−1.115*** (0.030)	−0.895*** (0.027)	0.330*** (0.067)	0.632*** (0.058)	−1.106*** (0.023)	−0.695*** (0.033)
$LnOPEN_{it}$	−0.034** (0.015)	−0.031** (0.015)	0.195*** (0.043)	0.022 (0.044)	0.015 (0.010)	−0.048*** (0.018)
$LnGDP_{it}$	1.039*** (0.019)	0.980*** (0.012)	1.208*** (0.045)	1.115*** (0.045)	1.206*** (0.019)	1.383*** (0.030)
$LnWAGE_{it}$	−0.024 (0.028)	−0.103*** (0.039)	−0.034 (0.093)	0.162* (0.092)	−0.006 (0.019)	−0.346*** (0.043)
$LnFDI_{it}$	0.065*** (0.014)	−0.0006 (0.015)	−0.118* (0.061)	−0.130** (0.065)	0.050*** (0.010)	0.056*** (0.020)
$LnML_{it}$	−0.036** (0.047)	0.0006 (0.051)	0.813*** (0.195)	0.658*** (0.160)	0.063** (0.029)	0.201** (0.751)
Obs	143	143	143	143	143	143
Wooldridge test	112.827***	88.182***	42.862***	44.414***	143.747***	142.982***
Wald test	336.02***	431.97***	310.90***	197.18***	393.81***	633.77***

Note(s): *$p < 0.1$, **$p < 0.05$ and ***$p < 0.01$

2.633 and 6.568, respectively. The results of model 5 show that the FERs do not have a significant non-linear effect on employment. The square term coefficient of IER is −0.039, and the coefficient is 0.576. It can be seen that the value of IER that makes the turning point of the curve is 7.385. The results of model 6 show that the square term coefficient of FER is −0.079 and the square term coefficient of IER is −0.038. The coefficients of FER and IER are 0.454 and 0.691, respectively. It can be seen that the values of FER and IER that make the turning point of the curve are 2.873 and 9.092, respectively. The regression coefficients of environmental regulations are all statistically significant, which indicates environmental regulations inhibit employment by affecting technological innovation.

5. Conclusions

This paper is designed to explore the relationship between environmental regulation, technological innovation and employment based on the data from the 30 provinces of China during 2003–2015. The impacts of formal and IER and technological innovation on employment are estimated by GLS, and the eastern region of China is analyzed separately. The summary of the empirical results is as follows. First, both formal and IERs have different degrees of significant impact on employment, and the relationship is not a simple linear. The FER has an inverted U-shaped relationship with employment, but the IER has a U-shaped relationship. However, by incorporating technological innovation into the test, the empirical results show different outcomes between the national sample and the eastern sample. In the eastern sample, the relationship between informal regulation and employment has an inverted U-shaped curve. Second, the results of model 3 and model 6 show that technological innovation has a significant negative effect on employment both in the national and in the eastern region sample.

The implications of this paper are as follows. First, in the national sample, the impact of FERs on employment presents an inverted U-shaped characteristic. Therefore, when implementing such environmental regulations, the intensity of regulations needs to be controlled to prevent an excessively adverse effect on employment. On the other hand, IER suppresses employment at first and then promotes it after passing the turning point of the curve. Employment would only be promoted after reaching a certain intensity of informal regulation. Thus, in designing environmental regulations, it is necessary to consider not only the stringency but the type of regulation also.

Second, regional differences exist in the effect of IERs on employment. IER promotes local employment in the eastern region that has a higher intensity than in other regions, while it inhibits employment in the national sample. Therefore, IER needs to be differentiated by region.

Finally, technological innovation does act as a mediator in the relationship between environmental regulations and employment. Environmental regulations would inhibit employment through technological innovation, due to the characteristics of technological innovation such as an increased production efficiency, a substitution effect of production technology on labor, and the mismatch between the supply of low-skilled labor and the demand for high-skilled workers. Therefore, it is necessary to consider more flexible employment policies that are contingent on the stringency of regulations when designing environmental regulations.

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Corresponding author
Cheon Yu can be contacted at: yu1000@mnu.ac.kr