



Impacts of environmental regulation on innovation in the context of the Internet

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Abstract

The relationship between environmental regulation and innovation has long been a key issue of scholarly interest. The Porter hypothesis posits that environmental regulations can effectively promote innovation. However, with the rapid development of the Internet, the relationship between environmental regulation and innovation has changed. Through a theoretical analysis, this paper finds that the development of the Internet can not only directly promote innovation but also inhibit innovation through environmental regulations. This paper uses Chinese city-level data from 2014 to 2016 to empirically test the relationship among the Internet, environmental regulation, and innovation. The study finds that (1) the increase in the Internet level and in the intensity of environmental regulations promotes innovation, and the results remain stable after the replacement of the Internet level metrics, (2) the increase in the Internet level inhibits the positive effect of environmental regulations on innovation, but its inhibitory effect is lower than the promotion effect of the Internet on innovation, and (3) the Internet and environmental regulations have a significant promotion effect on the application and acquisition of three types of patents, including invention patents, utility model patents and design patents, with the application and acquisition of utility model patents having the greatest promotion effect, and (4) the analysis of heterogeneity shows that environmental regulation has a greater effect on innovation in eastern and provincial capital cities, and the Internet has a greater effect on innovation in western and non-provincial capital cities. Finally, this article puts forward policy recommendations based on three aspects: strengthening Internet construction, implementing environmental regulations and policies based on local conditions, and increasing support for R&D and innovation.

Keywords Internet · Environmental regulation · Innovation · China

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1 Introduction

Since joining the World Trade Organization, China has achieved a comparative advantage with low labor costs and low factor prices that have enabled it to achieve rapid economic growth. However, the rapid growth of GDP and the acceleration of urbanization have affected China's environmental quality. According to the "2020 Global Environmental Performance Index" survey report jointly issued by authoritative institutions, such as Yale University and Columbia University, China's air quality ranks 120th among the 180 economies in the world, which is a relatively low ranking. In recent years, the Chinese government has repeatedly emphasized high-quality development to implement new development concepts, build a new development pattern, and promote sustainable economic and social development. The government no longer aims to pursue GDP growth but gives more attention to environmental issues and emphasizes the harmonious coexistence of people and the environment. Therefore, it is of great significance to implement environmental regulations during economic development.

However, neoclassical economists believe that the implementation of strict environmental regulations leads to an increase in production costs and, thus, to a decline in the international competitiveness of enterprises. This is especially true in the present, as the advantage of low prices of production factors disappears and strict environmental regulations affect the economy. Growth has a certain negative impact. However, since the Porter hypothesis was put forward in the 1990s, scholars have offered different views. Although the implementation of environmental regulations leads to an increase in enterprise-related expenses, it can also force enterprises to innovate. The benefits of innovation can partially or completely compensate for enterprises' losses caused by environmental regulations and play a positive role in promoting social development. However, whether environmental regulations can promote innovation is still controversial.

At present, the rapid development of the Internet has brought new changes to the field of environmental regulation. The emergence of new industries and changes in business models have brought both great challenges and new opportunities to traditional enterprises. On the one hand, the Internet's characteristics of not being restricted by time and space have provided great convenience to environmental supervision, and the supervision cost of government departments has been reduced. Moreover, the public can supervise polluting companies in real time, which improves the effectiveness of environmental regulations. On the other hand, the development of Internet technology has changed the production and operation process of enterprises. Enterprises can use Internet technology to transform their production processes and sales methods. The transformation of enterprises with the help of Internet technology can reduce production costs and promote an increase in corporate income. In addition, the internal and external communication methods of enterprises are gradually replaced by the more convenient Internet, which reduces the transaction costs of enterprises. Therefore, the characteristics of environmental regulation and innovation in the context of the Internet are a question worthy of discussion.

The innovation of this article is to study the relationship between environmental regulation and innovation in the context of the Internet. This work has important theoretical significance in deepening the Porter hypothesis from the perspective of the Internet. However, the current literature mainly focuses on the relationship between environmental regulation and innovation, without considering the influence of the Internet on the relationship between the two, and there is no systematic study of environmental regulation and innovation in the context of the Internet. This article uses China's urban data from 2014 to 2016

to study this issue. However, this article has some shortcomings. First, due to the difficulty of obtaining direct data on environmental regulations and the Internet, this article refers to the literature to construct environmental regulations with two single indicators: the sulfur dioxide removal rate and the industrial smoke and dust removal rate. The comprehensive index uses the city's total telecommunications business or the number of Internet users to represent the city's Internet development level. However, these variables can only partially reflect the intensity of urban environmental regulations and the level of Internet development and fail to fully reflect the actual situation. Second, the city patent data of the China Research Data Service Platform (CNRDS) are provided only from 2014 to 2016, and some cities have not disclosed data on certain indicators. As a result, the data used in this article cover a short period and have certain deficiencies. These problems may lead to some biases in the conclusions of this article.

According to the research needs, the rest of this article is arranged as follows. The second section of this article offers a literature review and theoretical analysis. The third section presents the model construction and data explanation. The fourth section is the results analysis. The fifth section summarizes the research conclusions and research significance. Finally, the sixth section provides policy insights.

2 Literature review and theoretical analysis

2.1 Literature review

The literature on the influence of the Internet on innovation started relatively late, but it has become one of the hotspots of scholarly research in recent years, along with the link between environmental regulation and innovation. The current literature is rich in research content on environmental regulation and innovation. The following is a literature review of three aspects: the influence of the Internet on innovation, the influence of environmental regulation on innovation, and the mechanism of environmental regulation on innovation.

2.1.1 The influence of the Internet on innovation

Innovation comes from the accumulation of internal knowledge within the enterprise and the spillover effect brought about by the overall development of external technology. Lucas (2009) believes that technological changes in enterprises originate from communication between people, and the exchange of knowledge and viewpoints through this communication generates new knowledge and brings innovation. The Internet offers advantages that improve the way that companies communicate with the outside world and has changed the spread of new technologies and knowledge. Companies can quickly learn new knowledge to promote corporate innovation through the Internet (Bygstad & Aanby, 2010) because of its characteristics of transcending geographical and time–space restrictions. The convenience of Internet use can not only attract a large number of customers but also collect frequent customer feedback. User feedback can help companies develop new products and services; especially with the current advanced instant messaging technology, companies can collect feedback and suggestions in real time through their own official platforms or other Internet means. Based on the corresponding feedback, the relevant software and hardware facilities can be improved through innovation to attract more customers, thereby increasing the company's revenue (Cheng Liru, 2013). The study of Shahiduzzaman and

Alam (2014) in Australia found that Internet-related investment promotes technological progress, and a large part of the reason is the spillover effect created by the development of information technology (IT). Kong et al. (2018) studied the impact of Google's withdrawal from China on corporate innovation and found that companies that rely on foreign technology continue to be negatively impacted in terms of the intensity and quality of innovation. Google's refusal to provide search services in China significantly reduces the availability of corporate innovation information. The availability of information is regarded as one of the determinants of enterprise innovation, and its absence can reduce technology-dependent enterprise innovation. Goldfarb and Tucker (2019) believe that the development of Internet technology has reduced the costs to enterprises in five aspects, including search, copy, transportation, tracking and verification costs. Among them, the reduction in search costs can improve the efficiency of information matching between two parties and increase the utilization of capital (Dana & Orlov, 2014) and the efficiency of information communication and organization (Agrawal & Goldfarb, 2008); the reduction in copy costs can improve the knowledge or experience of public goods supply (Brynjolfsson & Saunders, 2010; Lerner, 2006). In general, the Internet significantly reduces transaction, contract, agency and governance costs and innovation perception differences in the process of enterprise innovation, magnifies the positive effect of technical personnel and R&D investment on innovation, and reduces the level of corporate governance required for enterprise innovation, thereby improving corporate innovation.

Internet use not only directly affects a company's R&D process but also promotes corporate R&D by increasing productivity and promoting efficiency. A study by Roller and Waverman (2001) estimated the micromodel and macroproduction function of telecom investment in OECD countries from 1970 to 1990. There is a strong causal relationship between telecommunications infrastructure and productivity that emerges only when telecommunications services reach a certain threshold close to the universal level. Koutroumpis (2009) estimates the impact of broadband infrastructure and productivity by incorporating broadband investment into the production function based on data from 22 OECD countries from 2002 to 2007. The results show that there is a significant causal relationship between broadband investment and productivity. Wilson, (2009) uses a sample of 2,000 companies in 1998 to find that computer capital has a significant positive effect on total factor productivity. Atrostic and Nguyen (2005) use the data of approximately 30,000 companies in 1999 to find that the labor productivity of companies that use the Internet is 3.7–7.2% higher than that of companies that do not use the Internet. Bloom (2005) utilizes the data of 7000 companies from 1995 to 2004 to find that IT has a significant positive impact on productivity.

The above studies show that the Internet directly promotes the improvement in enterprise R&D efficiency and indirectly affects R&D investment by promoting the increase in enterprise revenue. The reduction in transaction costs can not only lead to the decline in corporate R&D costs but also increase the probability of corporate innovation, and corporate performance increases with the use of the Internet. Therefore, the Internet can significantly increase the probability of corporate innovation.

2.1.2 The impact of environmental regulations on innovation

First, the impact of environmental regulations on innovation is still controversial in academic circles. The Porter hypothesis, the classic theory put forward by Porter in the 1990s, posits that appropriate environmental regulation can promote enterprise innovation; that is,

environmental regulation has an "innovation compensation effect" (Potter, 1995). Among the scholars who support this view, some believe that there is a nonlinear relationship between environmental regulation and enterprise innovation (Iraldo et al., 2011; Lanjouw & Mody, 1996; Popp, 2006). Lei (2018) finds that in the short term, environmental regulations have a depressing effect on carbon emissions and technological innovation. In the long term, environmental supervision can strengthen technological innovation and reduce the impact of carbon emissions. Overall, the impact of environmental regulations on technological innovation is not linear but nonlinear with fluctuations. Other scholars believe that there is a linear relationship between the two. He et al. (2021) indicate that environmental regulatory policies mainly affect corporate productivity by reducing corporate innovation capabilities, increasing intermediate costs, and weakening corporate financing constraints. Although the entry rate of companies in heavily polluting industries is declining and the exit rate is rising, these changes do not bring about the restructuring of the industry or the improvement in the efficiency of enterprise resource allocation.

However, some scholars believe that environmental regulations have not had a significant impact on technological innovation. The reason is that various interfering factors, such as human capital, the enterprise scale, and the industrial structure, have a regulatory effect. Brunnermeier and Cohen (2003a, 2003b) conducted an empirical study on the relationship between environmental regulations and corporate innovation and found that environmental regulations have no positive impact on corporate innovation. Tong and Zhang (2012) revealed that environmental regulations did not significantly promote the innovation performance of enterprises in the central and western regions of China. Cesaroni and Arduini (2001) empirically tested the Porter hypothesis and concluded that the capital expenditure of environmental regulations has no significant impact on corporate innovation. In addition, the increase in innovation input caused by environmental regulations has a significant impact on business performance and performance in general. The impact of environmental performance is not significant. Other studies have supported the finding that environmental regulation has no effect on innovation (Becker, 2011; Brunnermeier & Cohen, 2003a, 2003b; Caley & Dechezleprêtre, 2012; Shadbegian & Gray, 2005). In addition, some scholars have found a disincentive effect of environmental regulation on innovation. Scholars have also argued that cost and crowding-out effects from environmental regulation can be detrimental to innovation (Gray & Shadbegian, 2003; Greenstone et al., 2012; Hancevic, 2016; Lanoie et al., 2008).

Based on the above review, most scholars agree that environmental regulations have an effect on corporate innovation. Only a small number of scholars hold objections because of the interference of other factors. Environmental regulatory policies can have both linear and nonlinear effects on enterprise innovation.

3 Research on the mechanism of environmental regulation on innovation

The mechanism by which environmental regulation affects innovation can be roughly divided into the following two aspects.

First, environmental regulation affects the input of innovation resources. Bai and Song (2009) found that environmental regulations mainly impact the allocation of resources in the thermal power industry and increase investment in technological innovation, thereby increasing overall industry productivity. Ramakrishnan et al. (2017) argued, according to

the Porter hypothesis, that appropriate environmental regulations can increase investment in innovation, thereby increasing capital investment and stimulating the innovation compensation effect to not only make up for the “compliance costs” of enterprises but also to increase their productivity and competitiveness. Zeng et al. (2016) identified a significant positive correlation between the degree of environmental regulation and the amount of innovation capital investment. When the environmental regulation is stricter, it is more helpful in increasing the level of innovation investment of polluting enterprises and promoting the transformation of enterprises. Qi et al. (2018) demonstrated that the Porter hypothesis is applicable in China. China’s pilot emission trading policy has induced green innovation activities among companies in polluting industries in the pilot areas compared with nonpilot areas and relative to clean industries. The effect referred mainly to green invention patents, not green utility model patents. Zhou et al. (2018) found that environmental regulations have a significant role in promoting the R&D and innovation investment and innovation output of foreign-funded enterprises. Their impact on the R&D and innovation of foreign-funded enterprises is not only immediate but also continuous; in addition, studies have found that there are differences in the impact of environmental regulations on the R&D and innovation of foreign-funded enterprises of different types of industries. Yu and Zhang (2019) suggest that collecting environmental taxes can be used to improve the resource allocation methods of enterprises. Environmental taxes can significantly promote the green innovation of enterprises, and the current environmental tax significantly improves the level of green innovation of enterprises in later periods.

Second, environmental regulatory policies affect the market environment. Meredith (2016) indicates that industry has undergone major changes due to the development, repeated verification and implementation of environmental regulatory policies. As a result, emission regulation has exacerbated the distortions related to the exercise of market power in the domestic cement market. To adapt to market changes as soon as possible, companies must accelerate the adjustment of resource allocation and enhance their innovation capabilities. Zhang and Yao (2018) believe that environmental regulations influence the technological innovation activities of enterprises to break the original laws of diminishing marginal utility and increasing marginal costs through value enhancement and to realize increasing marginal utility and diminishing marginal cost. By influencing the supply and demand characteristics of technological innovation, environmental regulation reshapes the upper right sloping demand curve and the lower right sloping supply curve. The intersection of the supply and demand curves determines the equilibrium output of technological innovation. The adjustment changes the displacement of the supply and demand curves, which results in a new equilibrium point and demonstrates the evolutionary path of enterprise technological innovation under environmental regulation.

These results show that the research on environmental regulation and innovation is very rich. Although a few scholars believe that environmental regulations do not directly affect corporate innovation, most agree that there is a clear relationship between the two. Some scholars support the Porter hypothesis or follow its framework. However, others indicate that there is a linear relationship or a J-shaped relationship that changes the enterprise’s resource allocation and the external market environment.

3.1 Theoretical analysis

The Porter hypothesis argues that the relationship between environmental protection and economic development cannot be simply dichotomized. Porter contends that appropriate

environmental regulation can lead firms to engage in more innovative activities and that these innovations will increase the productivity of firms, which offsets the costs of environmental protection. This paper continues to follow the analytical framework of Porter's hypothesis and adds the Internet as an important influencing factor when analyzing the impact of environmental regulation on innovation. The theoretical analysis of this paper is divided into two parts: on the one hand, we analyze the mechanism of the Internet's role in promoting innovation, and on the other hand, we analyze the interaction among the Internet, environmental regulation and innovation.

3.1.1 The theoretical mechanism of the Internet to promote innovation

The importance of innovation has been increasingly emphasized in the twenty-first century, and corporate innovation in the Internet era presents unique characteristics. The traditional R&D process generally relies on the R&D personnel of the enterprise itself or cooperative scientific research institutions, but the Internet has changed traditional innovation methods. New ideas and new technologies can be rapidly disseminated as they are produced, and various R&D entities support one another through exchanges. The external effects of innovation behavior are more obvious, especially for the computer software industry, and the use of the Internet can form a scale effect, which greatly reduces R&D costs.

First, the emergence of the Internet has facilitated the diffusion of knowledge, and the probability of enterprises obtaining innovative knowledge has increased. Enterprise production no longer simply involves the process of enterprise R&D, market promotion, and consumers' choice of corresponding products. Upstream and downstream manufacturers and consumers can further participate in the production process, and customization has become a new manufacturing development trend. When enterprises use the Internet, consumers can participate in customization while providing manufacturers with a wealth of innovative materials. The old model of unilateral innovation by manufacturers has been broken, and collaborative innovation and open innovation have become mainstream choices in the Internet era. The use of the Internet by various innovative entities not only increases the probability of obtaining outside knowledge and experience but also enables the real-time exchange of new ideas with the outside world and improves the ability to innovate. In addition, the diffusion rate of knowledge within the enterprise increases, and the knowledge stock of the enterprise increases, which promotes enterprise innovation. Therefore, companies with a high degree of internetization are often more likely to achieve high-quality results.

Second, companies need to search to obtain innovative element resources, and the Internet can significantly reduce search costs. The essence of the Internet is openness and sharing, and companies can use low-cost or zero-cost search platforms or design software for R&D. A search platform can enhance the efficiency of a search for the required innovation elements and reduce the verification cost of the enterprise. Moreover, the Internet can promote cooperation among corporations from different countries. Companies can allocate innovative resources on a global scale and aggregate innovative talent and capital and other elements, which is conducive to the construction of cooperative innovation networks (Henkel, 2006). In addition, the development of applications such as big data and cloud computing facilitates the collection and processing of corporate information. These technologies permeate all aspects of enterprise R&D, production, sales, etc. and not only facilitate the collection of massive product operation data during the production and R&D process but also process and sort Internet-related feedback information after the product is sold so that

it can be more targeted, innovative, and improved. Enterprises, consumers, and external R&D institutions use the Internet to build new innovation networks. Process and product innovation based on Internet technology reduces the R&D time and promotes performance improvement compared with traditional methods (Koellinger, 2008).

In general, companies' Internet use can increase their probability of acquiring the knowledge needed for innovation and can enhance their R&D capabilities. It can also promote innovation by reducing transaction costs in the process of enterprise innovation and by improving the efficiency of the allocation of related innovation resources. Based on this, this paper proposes Hypothesis 1.

Hypothesis 1 An increase in the Internet level has a significant positive effect on innovation.

3.1.2 The Internet, environmental regulation and innovation

In the context of the Internet, the effect of environmental regulations on innovation is weakened to a certain extent. On the one hand, the Internet strengthens the negative effect of environmental regulations on innovation. Environmental regulations influence innovation through positive and negative mechanisms. In the negative mechanism, environmental regulation policy restricts the negative externalities of enterprise production, and enterprises must deal with the pollutants produced before they can discharge them. For example, some environmental regulations and policies impose fines on companies that exceed pollutant discharge standards. In extreme cases, pollutants cannot be treated to achieve a state that meets the discharge standards, and a company may have to stop production. This shows that environmental regulations indeed increase the production costs of enterprises. On the other hand, strict environmental regulation policies force enterprises to innovate, and the main mechanisms are the effect on the innovation investment of enterprises and changes in the market environment. To reduce the pressure imposed by environmental regulations and policies, enterprises must adopt corresponding green technologies to reduce the pollution generated, which leads them to invest more funds in the innovation of new technologies and new processes. In addition, in regions that implement strict environmental regulations, the local government introduces appropriate fiscal policies or loan preferences to provide support to companies that need to innovate and give companies certain financial subsidies or low-interest loans to promote green technology innovations.

The development of Internet technology affects the impact of environmental regulations on innovation. On the one hand, the rapid advancement of Internet technology leaves polluting companies nowhere to hide. The government can conduct all-weather monitoring of polluting companies at a low cost. Internet-based intelligent detection equipment in various regions can detect air quality anytime and anywhere, and the illegal discharge and super-emission phenomena of certain companies can be effectively curbed, which leads to a corresponding increase in the cost of pollution control for the company. That is, an increase in the Internet level increases the negative effects of environmental regulation policies on innovation. On the other hand, the Internet greatly improves the resource allocation effect and management performance of enterprises. Although strict environmental regulation policies pressure companies to find ways to reduce production costs, the path to improve management or resource allocation is partially cut off. In the Internet era, an effective way for companies to respond to environmental regulations is to carry out green technological innovation, but the reality is that the role of environmental regulations in promoting

green innovation is also partially replaced by the Internet; that is, the rising degree of Internet penetration can inhibit the positive effect of environmental regulations and policies on enterprises.

Based on the above analysis, this paper proposes Hypotheses 2 and 3.

Hypothesis 2 Environmental regulation has both positive and negative effects on innovation, but as a whole, the overall effect is positive.

Hypothesis 3 With the rise of the Internet, the effect of environmental regulations on innovation is inhibited to a certain extent, but the inhibiting effect is smaller than the promoting effect of the Internet on innovation.

4 Model construction and data description

4.1 Empirical model

This article mainly studies the causal relationship between environmental regulation and innovation in the context of the Internet to verify the main conclusions drawn from the theoretical analysis. It adopts the dual fixed effects model to make recommendations, and the regression model is designed as follows:

$$\text{Innovation}_{ict} = \mu_0 + \mu_1 \text{Internet}_{ict} + \mu_2 ER_{ict} + \mu_3 \text{Internet}_{ict} * ER_{ict} + \mu_4 X_c + \varepsilon_{ict}$$

where i , c , and t represent province, city, and time, respectively. Innovation_{ict} is an explained variable that represents the degree of innovation in province i and city c in year t , and follow-up empirical evidence is based on the number of patent applications or acquisitions. ER_{ict} and Internet_{ict} are the core explanatory variables that represent the intensity of environmental regulation and the development level of the Internet in province i and city c in year t respectively, and $\text{Internet}_{ict} * ER_{ict}$ is the interaction term between the two. X_c is the control variable, and ε_{ict} is the random disturbance term.

4.2 Variables and data description

- (1) The explained variable. The explained variable is innovation data at the city level. According to the common practice in the literature, this article uses the number of patent applications or acquisitions of cities as the explained variable of the benchmark regression. In the follow-up examination, this article further subdivides patents into utility model patents and design patents for further examination to examine whether environmental regulations in the context of the Internet have different effects on different patent types.
- (2) Core explanatory variables. This article focuses on the impact of environmental regulations and the Internet on urban innovation, so the core explanatory variables of this article are environmental regulations and the Internet. Because direct data on environmental regulatory measures are difficult to obtain, studies have adopted a variety of alternative indicators to measure the intensity of environmental regulations. Early international scholars used quantitative indicators to measure the intensity of environmental regulations. Among them, the most commonly used early methods are ① GDP

per capita as an alternative indicator of environmental regulations, that is, as income levels continue to rise, environmental regulations become more stringent, and ② the emission intensity of corresponding pollutants, that is, when the intensity of certain pollution emissions is higher, the environmental regulatory measures are stricter. However, these indicators are relatively poor. This article mainly refers to the practice of Yin et al. (2017), adopts the linear weighted sum method, and builds the comprehensive environmental regulation index ER_{ict} . The process specifically includes three steps.

First, this article standardizes the two indicators of the sulfur dioxide removal rate and industrial smoke (dust) dust removal rate. The calculation formula is as follows:

$$PC1_{cj} = [PC_{cj} - \text{MIN}(PC_j)] / [\text{MAX}(PC_j) - \text{MIN}(PC_j)]$$

Where PC_{cj} represents the original value of pollutant j (removal rate of sulfur dioxide, industrial smoke (powder) dust removal rate) in city c , $\text{MIN}(PC_j)$ and $\text{MAX}(PC_j)$ are the minimum and maximum values of pollutant j (removal rate of sulfur dioxide, industrial smoke (powder) dust removal rate) in all cities, and $PC1_{cj}$ is the standardized value of pollutant j (removal rate of sulfur dioxide, industrial smoke (dust) dust removal) in city c after standardized treatment.

Second, this paper further calculates the adjustment coefficient T_{cj} of these two indicators. The reason is that different urban development levels correspond to different industrial development conditions. Therefore, the proportions of sulfur dioxide and industrial smoke (dust) in different cities are different, so it is necessary to adjust each pollution emission index of a city to a different weight to accurately reflect the changes in the pollution emission control efforts of each city. The calculation method of the adjustment coefficient T_{cj} is as follows:

$$T_{cj} = \frac{P_{cj}}{\sum_c P_{cj}} / \frac{gdp_c}{\sum_c gdp_c}$$

where T_{cj} represents the ratio of the proportion of pollutant j emitted by city c to the proportion of pollutant j in the country to the proportion of city c 's GDP in the country's GDP. The principle of using T_{cj} for adjustment is that if a certain pollutant emission in a city is relatively high, then the same pollution removal rate means a stronger degree of environmental regulation, and accordingly, a greater weight ratio is more reflective of the environmental regulation strength.

Finally, according to the calculated standardized values of the sulfur dioxide removal rate, the industrial smoke (dust) dust removal rate and the corresponding weight coefficients, this paper finally obtains the environmental regulation degree ER_{tic} of each province and city c . The calculation formula for the last step is as follows:

$$ER_{ict} = \sum_{j=1}^2 PC1_{cj} * T_{cj} / 2$$

Given the data limitations, this article refers to the practice of Lu and Xu (2019) and uses the total number of urban telecommunication services and the number of Internet users to represent the city's Internet development level.

- (3) Control variables. There are many influencing variables for urban innovation. With reference to the literature, this article controls for the following variables.

- ① The level of regional economic development is expressed by GDP per capita. The innovation level of a region is closely related to local economic development.
 - ② The level of foreign capital utilization is measured by the actual use of foreign investment measured in logarithm. Foreign investment may bring advanced technology and management experience and may have a certain impact on the local innovation level. In particular, the innovation and R&D process of foreign-funded enterprises is no longer confined to a country but rather integrates technical and human resources from all over the world to share technology, knowledge and information to achieve complementary advantages and synergistically enhance corporate technological innovation. Thus, this article needs to control it.
 - ③ The fiscal budget accounts for a proportion of GDP, and part of the incentives for corporate innovation come from government subsidies. This impact on local innovation cannot be ignored. Therefore, this article also needs to control the fiscal budget share of GDP.
 - ④ The level of financial development is expressed by the proportion of the balance of deposits and loans of financial institutions in GDP. Innovation requires financial support, and many enterprises need loans for innovation. Therefore, the level of local financial development has a certain impact on local innovation.
 - ⑤ Human capital is controlled for by the local population.
- (4) Data source. The data used in this article come from two data platforms. One is the CNRDS, which mainly provides the explained variable for this article—urban patent applications and acquisitions. This platform includes the total number of patents applied for and obtained in major cities in China and the number of subdivided utility model patents and design patents each year. This article uses these data to measure the innovation level of the city. Due to the availability of data, the sample time span of this study is from 2014–2016. The data of the core explanatory variables and control variables are from the "China City Statistical Yearbook." This article directly derives the corresponding data from the EPS global statistical data/analysis platform and then matches the two. Then, based on the GDP index of the "China Regional Economic Statistics Yearbook," all price-type indicators are adjusted to the level of the first year (2014) to eliminate the influence of price factors. In addition, to eliminate the influence of possible extreme values on the regression results, this paper winsorizes the variables other than region and year.

4.3 Descriptive statistics

The sample time span of this study was from 2014 to 2016 and contained 285 prefecture-level cities, and the descriptive statistics of the relevant variables are reported in Table 1. As given in Table 1, the mean value of the number of invention patents obtained for the main explanatory variables in this study is 0.53, its minimum value is 0.014, the maximum value is 3.774, and the standard deviation is 0.961. From the standard deviation and the extreme value, it is found that there is a significant difference between the innovation level of core large cities (Shenzhen, Xi'an, etc.) and small cities in China, and there is a trend of concentration of patent acquisition. Meanwhile, indicators such as the number of utility model patents obtained in the same year and the number of design patents obtained in the same year also show the same situation. In addition, the highest application approval rate was for design patents, with an average of 955 design patents approved for every 1000

Table 1 Descriptive statistics

Variable name	Variable	Data Sources	Observations	Average	Standard deviation	Minimum	Max
<i>Explained variable</i>							
Number of invention patents obtained that year (thousands)	Invq	China Research Data Service Platform (CNRDS)	855	0.530	0.961	0.014	3.774
Number of utility model patents obtained that year (thousands)	Umq	China Research Data Service Platform (CNRDS)	855	2.295	3.629	0.082	13.918
Number of design patents obtained that year (thousands)	Desq	China Research Data Service Platform (CNRDS)	855	1.178	2.225	0.023	8.487
Number of invention patents applied for in the current year (thousands)	Inva	China Research Data Service Platform (CNRDS)	855	2.214	3.897	0.056	15.327
The number of utility model patents applied for in the current year (thousands)	Uma	China Research Data Service Platform (CNRDS)	855	2.553	4.012	0.096	15.383
Number of design patents applied for in the current year (thousands)	Desa	China Research Data Service Platform (CNRDS)	855	1.233	2.298	0.025	8.717
<i>Core explanatory variables</i>							
Strength of environmental regulations	ER	Calculated according to the formula	812	1.11	0.53	0.40	2.28
Number of Internet users (households)	Internet_a	EPS Global Statistics/Analysis Platform	853	81.85	69.40	16	278
Total telecom business (ten thousand yuan)	Internet_b	EPS Global Statistics/Analysis Platform	844	371,463.7	337,793.1	62.004	1,356,705
<i>Control variables:</i>							
The level of economic development of the region	GDP	City GDP/total population	855	50,939.78	26,095.79	20.724	112,230
Level of foreign capital utilization	FDI	Logarithm of actually utilized foreign investment	803	10.58	1.72	7.10	13.43
Fiscal expenditure level	FE	The proportion of general budgetary expenditures of local finance in GDP*100	854	21.24	8.96	10.43	44.09
Financial development level	FINANCE	The balance of deposits and loans of financial institutions as a percentage of GDP	855	2.38	0.92	1.31	4.74
Human capital	PEOPLE	Number of local population (10,000 people)	855	449	319	20	3,392

applications. The next highest rate is for utility model patents, with an average of 2295 patents granted for every 2553 applications filed each year, which represents a pass rate of 89.89%. The requirements for applying for invention patents are the most stringent, with a pass rate of only 23.94%.

In terms of the core explanatory variables, the mean value of environmental regulation intensity in Chinese cities is approximately 1.11, the standard deviation is 0.53, the minimum value is 0.40, and the maximum value is 2.28. The maximum value is approximately 5 times the minimum value, which indicates that there are large differences in the degree of environmental regulation in different regions, mainly because the distribution of resource-based cities leads to large differences in the intensity of environmental regulation. In terms of the number of international Internet users and the total amount of telecommunication services, there are also certain disparities among cities. Developed regions such as Beijing and Shanghai have a significantly higher number of international Internet users and total telecommunication services than the less developed areas in the central and western regions. However, unlike environmental regulation, the differences in the number of international Internet users and total telecom services are not within the distribution of resource-based cities, but are related more to the development level of each prefecture-level city. In addition, we report the basic information of the control variables such as the level of foreign capital utilization and the level of fiscal expenditures. The above data indicate that the data sample used in this study not only can better reflect the development status of each region in China but also contains rich variability and data dimensions and can provide better quality material for the ensuing analysis.

5 Results analysis

5.1 Benchmark regression results

Following the relevant literature, first, this research uses the fixed effects model. The fixed effects model can control unobservable individual effects and ensure the robustness of the regression results. The Hausman test is also conducted, and the test results show that it is appropriate to choose a fixed effects model. Second, considering the possible heteroscedasticity problem, this paper adopts robust standard errors with clustering adjustment according to the region. Table 2 reports the benchmark regression results obtained by using the fixed effects model in this article. Column (1) reports the results obtained without adding control variables and controlling only provincial fixed effects and time fixed effects. The results show that every time the intensity of urban environmental regulation increases by one point, the number of invention patents obtained increases by 0.213 thousand, and Hypothesis 1 is therefore supported. From the coefficient of the number of international Internet users, it can be seen that when the Internet level is higher, the city's innovation ability is stronger; thus, Hypothesis 2 is supported. In addition, from the interaction coefficient between the intensity of environmental regulations and the number of Internet users, it can be observed that the Internet has a negative impact on the innovative effects of environmental regulations, and the above results are all significant at the 1% level. The reason is that part of the path by which environmental regulations drive corporate innovation is replaced by the Internet. This result is consistent with the theoretical analysis of this article. However, the overall results show that environmental regulations and the Internet

indeed bring regional innovation, and the innovation effect brought by the Internet is generally positive; therefore, Hypothesis 3 is supported.

Columns (2)–(6) are the results of adding the control variables in sequence. From the perspective of the coefficient of the regional economic development level, when the regional economic development level is higher, the regional innovation level is higher. A possible reason is that when an area is more economically developed, the environment is better for local enterprises to innovate, which effectively promotes the innovation of local enterprises. The coefficient of the level of utilization of foreign capital is significantly positive. A possible reason is that the entry of foreign capital brings advanced management experience, which provides a certain boost to regional innovation. When the level of fiscal expenditure is higher, the innovation capacity of the region is stronger because of the mechanism of government subsidies to enterprises for innovation. When the fiscal expenditure is higher, there are more government subsidies, thereby promoting an increase in enterprise innovation. The coefficient of financial development is also significantly positive at the 1% level, which shows that when the financial development of a city is better, more invention patents are obtained. A possible reason for this result is that innovation requires financial support. When financial development is better, more loanable funds are in the local market, which promotes enterprise innovation. In addition, the coefficient of human capital is significantly positive. When there is more local talent, there is more abundant human capital, which provides more basic elements for innovation and effectively improves the local innovation level. To ensure the robustness of the regression, this article further controls the urban fixed effects in column (7). From the results, it can be seen that the direction of the core variables remains unchanged, and the significance and coefficients are slightly reduced. This further indicates the robustness of the research results.

5.2 Differences in patent types

From the application and acquisition of patents, it can be observed that patents are generally divided into three types: invention patents, utility model patents and design patents. This article further divides patents into two categories, namely, application and acquisition, and conducts regressions to determine whether there are differences in the impact of environmental regulations on different types of innovation in the context of the Internet. Tables 3 and 4 report the impact of environmental regulations and the Internet on patent applications and patent acquisition, respectively.

Table 3 shows that in the context of the Internet, environmental regulations have positive effects on the application of the three types of patents, and they are all significant at the 1% level. Among them, utility model patents have the largest coefficient, that is, the strongest effect. Each increase in the intensity of environmental regulation increases the number of utility model patents applied for each year by approximately 1.678 thousand. A possible reason for this is that compared with utility model patents, the cost required to file an invention patent application is higher and the required technology is of a higher level. Unlike utility model patents, which require only substantial progress and characteristics, invention patents must have outstanding characteristics and represent significant progress. This requirement makes it more difficult to apply for invention patents than utility model patents, which in turn leads to a lower number of applications. In addition, the influencing coefficient of environmental regulations on design patents is smaller than the influencing coefficient on invention patents. The reason is that the inverse effect of environmental regulations has less influence on design patents. To deal with strict environmental regulations,

Table 2 Benchmark regression results

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Invg	Invg	Invg	Invg	Invg	Invg	Invg
ER	0.213*** (0.063)	0.454*** (0.064)	0.513*** (0.074)	0.470*** (0.075)	0.420*** (0.074)	0.429*** (0.073)	0.177** (0.078)
Internet_a	0.018*** (0.001)	0.015*** (0.001)	0.015*** (0.001)	0.014*** (0.001)	0.013*** (0.001)	0.012*** (0.001)	0.004*** (0.001)
ER*Internet_a	- 0.009*** (0.001)	- 0.007*** (0.001)	- 0.007*** (0.001)	- 0.007*** (0.001)	- 0.006*** (0.001)	- 0.007*** (0.001)	- 0.002** (0.001)
GDP		0.000*** (0.000)	0.000*** (0.000)	0.000*** (0.000)	0.000*** (0.000)	0.000*** (0.000)	0.000** (0.000)
FDI			0.072*** (0.019)	0.073*** (0.019)	0.070*** (0.017)	0.064*** (0.017)	0.047*** (0.011)
FE				0.006* (0.003)	0.001 (0.003)	0.001 (0.003)	- 0.003** (0.001)
Finance					0.215*** (0.049)	0.225*** (0.050)	0.017 (0.046)
People						0.000** (0.000)	0.000 (0.001)
Constant	- 0.460*** (0.086)	- 1.274*** (0.140)	- 2.033*** (0.220)	- 2.156*** (0.228)	- 2.259*** (0.215)	- 2.349*** (0.219)	- 0.435 (0.442)
Regional fixed effect	Province	Province	Province	Province	Province	Province	City
Time fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	810	810	759	758	758	758	749
R-squared	0.803	0.827	0.832	0.833	0.848	0.851	0.968

Robust standard errors in parentheses, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

it is more convenient for enterprises to improve process and production technology, and these are usually more related to utility model patents and design patents, so the coefficient is only 0.609. When the Internet level is higher, the corresponding innovation promotion effect is greater, and the coefficient of the interaction term is consistent with the conclusion of the benchmark regression.

Table 4 shows the causality of the impact of environmental regulations on patent acquisition in the context of the Internet. In terms of coefficients, environmental regulations also have the greatest impact on the acquisition of utility model patents. Compared with the case of patent applications, the acquisition of invention patents is less strongly affected by environmental regulations in the context of the Internet. The reason is that the examination of invention patents is stricter, and the cycle is relatively long (invention patents require a second review). Therefore, compared with the three types of patent applications, the acquisition coefficient of invention patents is only 0.429. However, this result also indicates the robustness of the benchmark regression results. That is, in the context of the Internet, environmental regulations have a positive effect on innovation.

5.3 Robustness test: replacement of Internet development level indicators

The above analysis uses the number of international Internet users as a substitute variable to measure the level of regional Internet development. In Tables 5 and 6, this paper utilizes the same fixed effects model to regress the total telecom business as a measure of the regional Internet development level. Tables 5 and 6 show that the coefficients of the core explanatory variables have the same direction as those in the results that use the number of Internet users as the measurement index. In general, the regression results are still robust after replacing the metrics of the Internet variables.

5.4 Analysis of heterogeneity

From the perspective of China's development status, different regions correspond to different levels of economic development and different infrastructures. This article divides companies into three groups according to their locations: eastern companies, western companies, and central companies. From the results in columns (1)–(3) of Table 7, it can be found that the Internet has a significant positive impact on the innovation of eastern, western, and central companies, and the improvement effect is greater in the central and western regions than in the eastern region. This may be

Table 3 Impact of environmental regulations on patent applications in the context of the Internet

Variables	(1) Inva	(2) Uma	(3) Desa
ER	1.366*** (0.283)	1.678*** (0.324)	0.609** (0.275)
Internet_a	0.047*** (0.006)	0.052*** (0.006)	0.021*** (0.005)
ER*Internet_a	- 0.027*** (0.004)	- 0.027*** (0.005)	- 0.009** (0.004)
GDP	0.000*** (0.000)	0.000*** (0.000)	0.000 (0.000)
FDI	0.194*** (0.066)	0.191*** (0.065)	0.018 (0.043)
FE	0.013 (0.013)	0.015 (0.011)	0.002 (0.009)
Finance	0.766*** (0.200)	0.437** (0.209)	0.143 (0.144)
People	0.001* (0.001)	0.001 (0.001)	- 0.000 (0.001)
Constant	- 8.056*** (0.956)	- 7.066*** (1.014)	- 1.411** (0.707)
Regional fixed effect	Province	Province	Province
Time fixed effect	Yes	Yes	Yes
Observations	758	758	758
R-squared	0.837	0.865	0.762

Robust standard errors in parentheses, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table 4 The impact of environmental regulations on the acquisition of patents in the context of the Internet

Variables	(1)	(2)	(3)
	Inv _g	Um _g	Des _g
ER	0.429*** (0.073)	1.516*** (0.304)	0.674** (0.269)
Internet_a	0.012*** (0.001)	0.048*** (0.006)	0.021*** (0.004)
ER*Internet_a	- 0.007*** (0.001)	- 0.025*** (0.005)	- 0.009** (0.004)
GDP	0.000*** (0.000)	0.000*** (0.000)	0.000 (0.000)
FDI	0.064*** (0.017)	0.148** (0.058)	0.012 (0.041)
FE	0.001 (0.003)	0.011 (0.010)	0.002 (0.009)
Finance	0.225*** (0.050)	0.390** (0.192)	0.095 (0.132)
People	0.000** (0.000)	0.001 (0.001)	- 0.000 (0.001)
Constant	- 2.349*** (0.219)	- 6.086*** (0.924)	- 1.293* (0.679)
Regional fixed effect	Province	Province	Province
Time fixed effect	Yes	Yes	Yes
Observations	758	758	758
R-squared	0.851	0.863	0.772

Robust standard errors in parentheses, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

because the Internet level in the eastern region is relatively high. In the early periods of Internet development, enterprises in the eastern region of China partially absorbed the efficiency improvements from Internet development, while the Internet development in the central and western regions was slower, and enterprises' access to the Internet was relatively delayed. The dividends brought by the Internet occur within a short period. Therefore, the coefficient is smaller in the eastern region than in the less developed central and western regions. In addition, the effect of environmental regulations on innovation is more obvious in the eastern and central regions. The reason is that the development of the western region is relatively backward. The local governments of the western region give less attention to the protection of the local environment than the governments of other regions with better development because their main aim is to develop GDP growth. Therefore, the intensity of environmental regulation is relatively low, and the driving effect on innovation is insufficient.

Whether a city is a provincial capital city may also have an impact on the results. First, provincial capital cities have stronger policy advantages than nonprovincial capital cities; that is, provincial capital cities generally correspond to higher fiscal and tax incentives. Enterprises in provincial capitals can obtain higher innovation subsidies and other advantages brought about by agglomeration effects. Columns (4) and (5) of Table 7 present the results obtained by a group regression. From the perspective of the

environmental regulation coefficient, provincial capitals are larger than nonprovincial capitals, but provincial capital cities are not statistically significant. It may be that provincial capitals have more high-tech companies and are less affected by environmental regulatory policies, so the coefficient is not significant. However, the direction of action is still consistent with that in the benchmark regression.

6 Conclusion and research significance

6.1 Conclusion

The main purpose of this article is to study the relationship between environmental regulation and innovation in the context of the Internet. In terms of theoretical research, this article through a summary of the literature identifies the ways in which the increase in the urban Internet level and the intensity of environmental regulations promote innovation. Second, further analysis finds that the anti-driving effect of environmental regulations on innovation is inhibited by the rise of the Internet. In terms of an empirical analysis, this paper uses city-level data from 2014 to 2016 to test the above theoretical mechanisms. First, the increase in the Internet level and the intensity of environmental regulations

Table 5 Robustness test (1)

Variables	(1)	(2)	(3)
	Inva	Uma	Desa
ER	22.070*** (3.671)	25.682*** (4.237)	11.418*** (2.966)
Internet_b	2.849*** (0.456)	3.447*** (0.559)	1.608*** (0.412)
ER*Internet_b	- 1.814*** (0.301)	- 2.090*** (0.348)	- 0.927*** (0.246)
GDP	0.000*** (0.000)	0.000*** (0.000)	0.000 (0.000)
FDI	0.233*** (0.081)	0.229*** (0.073)	0.025 (0.052)
FE	0.010 (0.017)	0.008 (0.015)	- 0.000 (0.010)
Finance	0.997*** (0.258)	0.657*** (0.248)	0.241 (0.159)
People	0.002*** (0.001)	0.002** (0.001)	0.000 (0.001)
Constant	- 41.861*** (5.372)	- 47.633*** (6.485)	- 20.323*** (4.553)
Regional fixed effect	Province	Province	Province
Time fixed effect	Yes	Yes	Yes
Observations	749	749	749
R-squared	0.803	0.827	0.752

Robust standard errors in parentheses, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table 6 Robustness test (2)

Variables	(1)	(2)	(3)
	Inv	Um	Des
ER	5.798*** (0.912)	23.915*** (3.904)	11.546*** (2.864)
Internet_b	0.697*** (0.104)	3.187*** (0.510)	1.620*** (0.396)
ER*Internet_b	- 0.472*** (0.075)	- 1.946*** (0.320)	- 0.935*** (0.238)
GDP	0.000*** (0.000)	0.000*** (0.000)	0.000 (0.000)
FDI	0.076*** (0.020)	0.185*** (0.069)	0.020 (0.049)
FE	0.001 (0.004)	0.005 (0.014)	- 0.000 (0.009)
Finance	0.290*** (0.063)	0.590** (0.231)	0.186 (0.142)
People	0.001*** (0.000)	0.002** (0.001)	0.000 (0.001)
Constant	- 10.674*** (1.220)	- 43.632*** (5.891)	- 20.316*** (4.372)
Regional fixed effect	Province	Province	Province
Time fixed effect	Yes	Yes	Yes
Observations	749	749	749
R-squared	0.815	0.826	0.762

Robust standard errors in parentheses, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

promotes innovation, and the results remain stable after changing the measurement variables of the Internet development level. Second, the increase in the Internet development level inhibits the negative effect of environmental regulations, but its effect is lower than the impact of the Internet on innovation. Third, environmental regulations and the Internet significantly promote the application and acquisition of the three types of patents, and they have the greatest effect on the application and acquisition of utility model patents. Fourth, further analysis of heterogeneity shows that the effect of innovation and enhancement created by environmental regulations has a greater impact on eastern and provincial capital cities, and the effect of innovation and enhancement caused by the Internet has a stronger promoting effect on western and nonprovincial capital cities.

6.2 Research significance

This study has important research significance in studying innovation from the two dimensions of the Internet and environmental regulation. First, it enriches innovation theory. Although existing studies have more often studied innovation from a single perspective which is environmental regulation, this study further deepens innovation theory by examining both the Internet and environmental regulation. Second, this study finds a significant impact of the Internet on the relationship between environmental regulation and innovation.

Table 7 Analysis of heterogeneity

Variables	(1)	(2)	(3)	(4)	(5)
	East	West	Central	Province	Nonprovince
	Inv	Inv	Inv	Inv	Inv
ER	0.547*** (0.141)	0.434*** (0.063)	0.483*** (0.130)	0.385 (0.561)	0.359*** (0.070)
Internet_a	0.009*** (0.002)	0.022*** (0.002)	0.016*** (0.003)	0.007** (0.003)	0.010*** (0.002)
ER*Internet_a	- 0.006*** (0.002)	- 0.009*** (0.002)	- 0.010*** (0.002)	- 0.000 (0.002)	- 0.006*** (0.001)
GDP	0.000*** (0.000)	0.000 (0.000)	0.000*** (0.000)	0.000** (0.000)	0.000*** (0.000)
FDI	0.108*** (0.035)	0.013 (0.015)	0.039** (0.017)	- 0.072** (0.032)	0.061*** (0.015)
FE	- 0.006 (0.005)	0.010*** (0.003)	- 0.004 (0.006)	- 0.008 (0.007)	- 0.001 (0.002)
Finance	0.396*** (0.078)	- 0.057 (0.044)	0.055 (0.069)	0.420 (0.267)	0.249*** (0.048)
People	0.000 (0.000)	- 0.000 (0.000)	0.000** (0.000)	- 0.000 (0.002)	0.000 (0.000)
Constant	- 3.343*** (0.391)	- 1.220*** (0.266)	- 1.609*** (0.284)	- 1.769 (2.817)	- 2.045*** (0.253)
Regional fixed effect	Province	Province	Province	Province	Province
Time fixed effect	Yes	Yes	Yes	Yes	Yes
Observations	287	116	355	80	676
R-squared	0.861	0.962	0.820	0.979	0.776

Robust standard errors in parentheses, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

There is a lack of research in the literature that examines the relationship among the Internet, environmental regulation, and innovation, and this study integrates all three into one research framework. Third, this study provides empirical evidence for government innovation policy formulation. The findings of this study suggest that innovation is influenced not only by environmental regulation, but also by the level of Internet development. The government should promote Internet development as an important path to achieve innovation development.

7 Policy insights

The research in this article has strong practical significance for the formulation of relevant policies. To promote high-quality economic development and achieve the goal of not only “both green waters and green mountains but also golden mountains and silver mountains,” the government needs to formulate policies in a targeted manner. First, the construction of Internet infrastructure should be strengthened. The increasing level of Internet

infrastructure can not only enable the better supervision of polluting enterprises but also further promote enterprise innovation. The central government needs to direct fiscal funds to a certain extent to promote faster development in underdeveloped areas, especially in the central and western regions, where Internet infrastructure construction is relatively underdeveloped. Second, environmental regulatory policies should be implemented based on local conditions. The current development trend in China is changing daily. Especially in the face of trade protectionism and the novel coronavirus pandemic, the old path of economic growth with environmental damage is absolutely unworkable. Economic transformation and industrial upgrading are the only ways to achieve high-quality development. The implementation of appropriate environmental regulations not only is conducive to the harmonious coexistence of the natural environment and people but also promotes the healthy and sustainable development of the economy. Therefore, the government needs to formulate environmental regulation policies in line with actual local conditions according to the economic development status, environmental pollution status and industrial structure of various regions, adopt appropriate environmental regulation tools to promote innovation, and protect the environment while the economy develops. Third, increased support is needed for R&D and innovation. Environmental regulations occupy the R&D funds of enterprises to a certain extent, and the government should provide corresponding policy support and loan concessions. On the one hand, low-interest or even interest-free loans can be issued to suitable companies to promote R&D to prevent the pressure caused by environmental regulations and policies from causing damage to high-quality companies. On the other hand, it is necessary to provide corresponding tax incentives and more financing channels for enterprise innovation so that environmental regulations can be good for enterprises. A strong independent innovation ability can be a main support for the domestic big cycle, and the domestic and international double cycles can promote one other in a new development pattern.

This study has conducted in-depth research on environmental regulation and innovation from the perspective of the Internet, and it has drawn some useful conclusions, the research of this study is still not perfect and needs to be conducted in further depth in the future. In the context of the rapid development of the Internet, the scale of the digital economy continues to expand, and the future digital economy is the focus of global economic development. Therefore, in future research, the focus will shift from the Internet to the digital economy and the impact of the development of the digital economy on innovation.

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