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R&D Input and Technological Innovation in the China's Environmental Protection Industry

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Abstract: Technological innovation is an important driving force in the development of the environmental protection industry. This is particularly important under the new normal to upgrade and transform this industry. Based on data taken from the fourth national survey of environmental technology-related research and development (R&D), which included 23 820 enterprises in the environmental protection industry, the present article analyzes R&D input and technological innovation in the China's environmental protection industry in 2011 to examine the driving factors. This analysis provides a basis for decision-makers' overall understanding of R&D input and output in the environmental protection industry.

Keywords: environmental protection industry; technological innovation; research and development input; policy suggestions

1. Introduction

All countries in the post-crisis era have agreed to rely on innovation and technological progress to stimulate demand for major development, raise effective supply, and provide backup to the vigorous development of emerging industries and establishment of an innovation-driven country [1]. The environmental protection industry, as a strategic, emerging industry in China, faces industrial upgrading and transformation while maintaining its rapid growth. As this industry involves pollutant treatment and disposal, the construction and operation of environmental protection facilities, comprehensive utilization of waste, resource recycling, and clean production; covers a wide range of activities; and has high technological requirements, it must be established based on high technology. Technological innovation is both a direct driving force of the environmental protection industry's development and a key factor to breakthroughs in the industry's progress [2].

The China's economy in the Thirteenth Five-Year Plan Period will move from a rapid growth stage to one of medium growth, as well as from a quantity expansion growth stage to one of growth in quality improvement. The country's economic structure and growth power will also change under the new normal, following changes in the implications of both the late-mover advantage and supply and demand conditions [3,4]. The environmental protection industry is in a new innovation and reform era, and it must rely on the drive of innovation to upgrade, transform, and ultimately survive in the long term. R&D input is an important factor in the technological innovation of environmental protection enterprises, as the level of R&D directly affects the industry's capacity for development and international competitiveness [5,6]. The environmental protection industry should thus increase not only its R&D funding and personnel, but also the efficiency of its technology transformation. For this, we must first describe the R&D input and technological innovation in the China's environmental protection industry to ensure its enterprises become the main players of independent innovation and guide them to invest in core technological innovation.

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The present article, based on data taken from the fourth national environmental R&D technology survey of 23 820 enterprises in the environmental protection industry, analyzes R&D input and technological innovation in the China's environmental protection industry in 2011, using descriptive statistics. Further, the article qualitatively analyzes the factors influencing technological innovation in this industry, providing a basis for decision-makers' overall understanding of its R&D input and output.

2. Technological Innovation in the Environmental Protection Industry

Table 1 illustrates the technological innovation of the China's environmental protection industry.

The China's environmental protection industry had 23 820 enterprises in 2011, including 2 385 with R&D capacity. Enterprises carrying out R&D activities (or for which the input of R&D funds was not zero) accounted for 11.8% of all enterprises in this industry, or slightly higher than the proportion of enterprises carrying out R&D activities among China's industrial enterprises (approximately 10%). The proportion of enterprises carrying out R&D activities among core environmental protection fields was 15.6%, higher than the proportion of enterprises carrying out R&D activities in the environmental protection industry.

Environmental technology-related R&D funds for enterprises in the China's environmental protection industry totaled 34.273 billion yuan, only accounting for 1.11% of operating income. This is much lower than the average level of 3.82% for developed countries. Technology-related R&D funds in the China's environmental protection industry are dominated by enterprises' equity funds, supplemented by support from both governments and financial institutions. Government funds among total R&D funds were 2.711 billion yuan, enterprises' equity funds comprised 27.933 billion yuan, financial institutions' loans comprised 3.046 billion yuan, and other funds were 601 million yuan. Fig. 1 displays the structure of technology-related R&D funds.

Regarding R&D personnel, the China's environmental protection and relevant industries had 3.195 million employees, including 170 400 R&D personnel, accounting for 5.33% of all employees. Regarding technological innovation, the industry researched and developed 3 698 technologies; 2 081 technologies reached industrial production [7] and 30 116 patents were granted, including 6 728 invention patents, 14 233 utility model patents, and 9 154 design patents. Fig. 2 displays the proportions of patent types. Meanwhile, after environmental technologies were industrialized, newly formed products generated 222.147 billion yuan of sales, accounting for approximately 7% of the industry's total output value; the foreign exchange earned through exports of newly formed products was 4.511 billion dollars, accounting for approximately 13% of the total foreign exchange earned through exports in the environmental protection industry.

The China's environmental protection industry, in light of its

Table 1. R&D input and technological innovation in the China's environmental protection industry[†].

Item	Number of enterprises	Number of enterprises carrying out R&D activities	Input of R&D funds (billion yuan)	Input intensity of R&D funds (%)	Input of R&D personnel (persons)	Input intensity of R&D personnel (%)	Number of obtained patent certificates	Sales value of newly formed products (billion yuan)	Foreign exchange earned through exports of newly formed products (billion dollars)
China	23 820	2 385	34.272	1.11	170 400	5.33	30 116	222.147	4.511

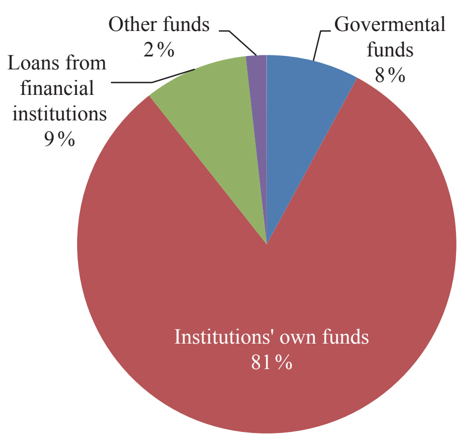

Fig. 1. Structure of R&D funds in the China's environmental protection industry[‡].

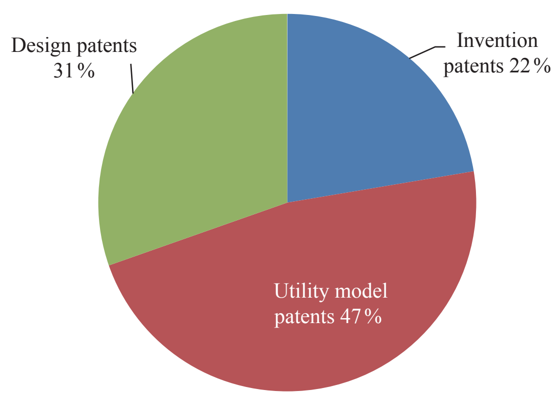

Fig. 2. Proportion of patent certificate types granted to the China's environmental protection industry[††].

[†, ‡, ††] Source: The fourth national survey of the environmental protection and related industries.

general R&D situation, has few enterprises carrying out R&D activities; of all environmental protection enterprises, 90% possess no R&D capacity and ordinary enterprises do not voluntarily perform R&D. Moreover, environmental protection enterprises carrying out R&D activities have an R&D funds input that is much lower than the average level in developed countries. The current R&D situation parallels the reality of industrial development in that domestic environmental protection enterprises seldom focus on technology-related R&D, resulting in high homogeneity, low technology content, and poor product competitiveness. As foreign enterprises increasingly enter the China's environmental protection market, if domestic enterprises do not focus on product-level R&D, they will experience difficulty in obtaining economic benefits in the future.

3. Regional differences in technological innovation in the environmental protection industry

The China's environmental protection industry's R&D input and technological innovation show significant differences among Mainland China's 30 regions (data are unavailable for Tibet), as noted in Table 2.

Table 2. R&D input and technological innovation in the environmental protection industry by region.

Region	Input of R&D funds (million yuan)	Input intensity of R&D funds (%)	Input of R&D personnel (persons)	Input intensity of R&D personnel (%)	Number of obtained patent certificates	Sales value of newly formed products (billion yuan)	Foreign exchange earned through exports of newly formed products (million dollars)
Beijing	2 256.26	1.14	10 140	7.38	11.39	5.809 42	48.18
Tianjin	673.12	0.57	2 953	5.15	26.17	2.371 07	32.15
Hebei	444.91	0.82	7 450	6.81	3.31	1.768 48	4.69
Shanxi	148.78	0.45	1 714	3.06	2.57	2.011 84	0
Inner Mongolia	77.03	0.86	487	1.26	38.88	0.776 86	0.25
Liaoning	487.72	0.35	9 408	4.87	25.16	1.545 33	24.46
Jilin	463.77	0.17	2 482	3.89	6.79	0.283 17	0.57
Heilongjiang	724.94	2.33	2 148	2.66	4.80	0.393 17	9.98
Shanghai	3 634.81	1.08	8 955	7.38	1.25	66.565 94	14.83
Jiangsu	9 075.48	2.41	23 639	6.39	2.37	17.884 88	219.34
Zhejiang	1 864.36	0.84	11 829	4.68	8.56	8.387 38	173.78
Anhui	722.89	0.52	9 194	6.52	14.40	4.817 55	51.9
Fujian	1357.33	1.36	7 910	6.62	5.57	31.069 77	3 273.21
Jiangxi	955.22	1.19	3 297	3.85	10.14	15.934 26	17.81
Shandong	2 927.59	2.17	13 441	6.58	6.42	12.817 22	103.67
Henan	972.62	0.98	4 774	3.66	17.30	3.500 24	56.75
Hubei	1 874.09	1.18	7 939	6.09	6.50	5.179 21	81.04
Hunan	994.04	1.85	3 439	4.43	1.64	5.258 57	25.91
Guangdong	1 569.96	0.49	22 885	6.50	8.57	20.977 96	357.44
Guangxi	476.65	1.56	1 194	2.53	89.63	5.501 26	0.54
Hainan	115.21	0.98	148	1.51	80.05	0.021 6	0
Chongqing	477.74	0.47	3 588	2.95	8.04	3.634 75	6.55
Sichuan	719.53	1.20	5 546	4.64	8.47	2.522	1.94
Guizhou	110.26	0.35	625	1.47	20.72	0.071 49	0.51
Yunnan	280.29	2.88	844	3.26	11.61	0.792 61	0.04
Shaanxi	465.78	1.45	2 464	7.36	3.59	1.339 4	0.58
Gansu	44.66	1.01	299	3.58	2.51	0.160 37	0
Qinghai	35.72	1.05	536	4.29	16.88	0.179 99	0
Ningxia	35.54	1.30	304	2.23	10.97	0.062 42	3
Xinjiang	286.74	2.15	754	1.97	3.75	0.508 72	2.84

Source: The fourth national survey of the environmental protection and related industries.

3.1. The environmental protection industry's R&D input is regionally unbalanced, with the input of R&D funds and personnel concentrated in eastern regions

Environmental protection enterprises in eastern regions, including Jiangsu, Shanghai, Shandong, Beijing, Zhejiang, Guangdong, and Fujian, are the backbone of innovation in this industry. Overall, their total R&D input is higher than the national average. In particular, Jiangsu is ahead of other regions, with its inputs of R&D funds and personnel standing at 26% and 13% of the national total, respectively. These inputs in western regions are both lower than the national average. The ratio of R&D input parallels the development levels of both the environmental protection industry and the regions' local economies.

3.2. The reason for high R&D input intensity varies by region and R&D input intensity is relevant to both industrial structure and industrial policies

Regional R&D intensity in the China's environmental protection industry does not match the distribution characteristics of the eastern, central, and western regions. The eastern region has the highest total amount of R&D input; however, R&D input intensity is somewhat similar to the total amount of R&D input. The high input intensity of R&D funds in Jiangsu reflects the capital-intensiveness of the region's high-tech industry. Guangdong and other coastal regions have many small and medium-sized enterprises, and here the total amount of R&D input is large, while intensity is low. Comparatively, some western regions have few environmental protection enterprises, low operating income, significant governmental financial support, and high R&D input intensity.

3.3. The structure of the sources of R&D funds varies by region, and some regions essentially rely on the government's financial support

China's environmental protection enterprises' R&D funds primarily come from the government, their own funds, and financial institutions. The structure of R&D funds varies by region (Fig. 3). Some regions such as Guangxi, Hainan, and Inner Mongolia primarily rely on the government's financial support, and their environmental protection enterprises have not grown into primary forces of technological innovation. The eastern region's R&D funds, within an advanced environmental protection industry, primarily come from enterprises' equity funds and a preliminary mechanism for independent innovation has formed. On the contrary, financial institutions in Beijing, Shanghai, and other developed regions do not have an advantage.

3.4. Environmental protection enterprises with more patent certificates are mostly located in the eastern and central regions, and the structure of patent types influences each region's industrialization of technologies

Regions with over 1000 patent certificates obtained from environmental technology-related R&D include Jiangsu, Guangdong, Sichuan, Shandong, Beijing, Zhejiang, Shanghai, Hubei, and Hunan. They are also in the eastern and central regions, contributing to 79% of the patent certificates obtained in China. Qinghai, Ningxia, and other regions in the western region obtained fewer than 10 patents. The regional distribution of obtained patent certificates is thus consistent with the distribution characteristics of R&D input.

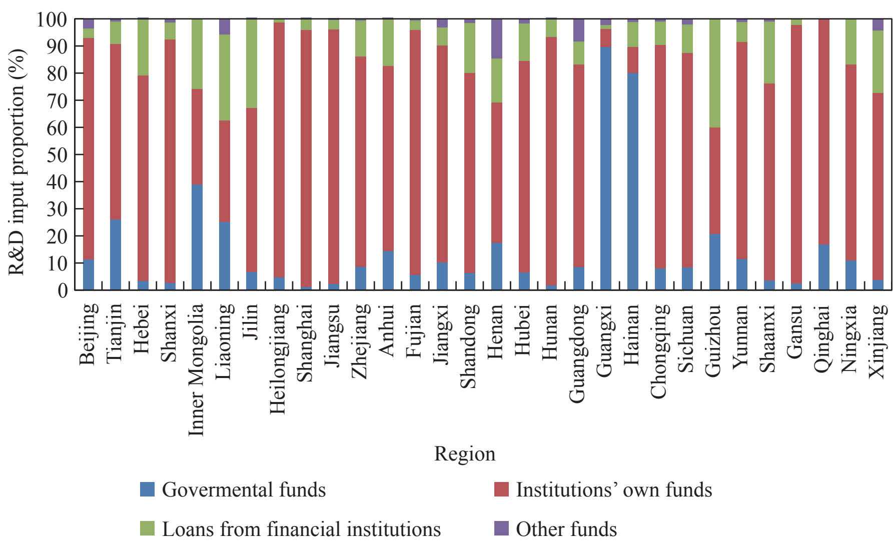

Fig. 3. Region-specific structure of R&D funds in the China's environmental protection industry[†].

[†] Source: The fourth national survey of the environmental protection and related industries.

The structure of patent types varies by region (Fig. 4). Ningxia has only invention patents, while Gansu and Qinghai have only invention and utility model patents. The overall patent implementation rate in China in 2011 was approximately 70%. The implementation rate of invention patents was 59%, utility model patents was 68.6%, and design patents was 74.9% [8].Patent implementation data in China indicate that the implementation rates of utility model and design patents are higher than those of invention patents, which is more conducive to the industrialization of patented technologies. For example, the number of obtained patent certificates in Beijing is 1.8 times higher than that in Shanghai, whereas the sales value of newly formed products in Shanghai is 11.5 times higher than that in Beijing and the industrialization efficiency of technologies in Shanghai is clearly higher than that in Beijing. The proportion of invention and utility model patents in Beijing is higher than that in Shanghai, while the proportion of design patents (39.7%) in Shanghai is much higher than that in Beijing (8.59%). China's environmental protection enterprises, by referencing developed countries' experiences in technological innovation, should thus be encouraged to emphasize design patent R&D.

3.5. The sales value and foreign exchange earned through exports of newly formed environmental technology products are unbalanced among regions

Different regions in China have enormous differences in sales value and foreign exchange earned through exports of newly formed environmental technology products. The top 10 regions in terms of the sales value of newly formed products contribute 85% of the national total; Fujian registers the highest amount of foreign exchange earned through exports of newly formed products, or 3.273 billion dollars, which accounts for 73% of the national total. Shanxi, Hainan, Gansu, and Ningxia contribute zero foreign exchange through exports of newly formed environmental technology products.

4. Industrial Differences in Technological Innovation in the Environmental Protection Industry

Technological innovation in China's core environmental protection fields shows significant industrial differences (Table 3).

4.1. Status in water, air, and soil pollution control technology fields

The water and air pollution control technology fields are crucial to environmental technological innovation, as the number of enterprises with R&D capacity and input of R&D funds account for 69% and 70% of all fields, respectively. Further, the number of obtained patent certificates, sales value of newly formed products, and foreign exchange earned through the exports of these products account for 73%, 92%, and 68% of all fields, respectively. By contrast, the fields of soil pollution control and restoration, and radiation pollution prevention have weak R&D capacity, as the number of enterprises with R&D capacity and input of R&D funds account for 1% of all fields. The industrial characteristics of R&D input in the environmental protection industry parallel the reality of China's environmental protection management. Recently, China's technologies related to conventional sewage treatment, electric precipitation, and bag-type dust removal have reached advanced levels globally. Membrane separation technology and related products have also achieved certain breakthroughs and have been widely applied in small-scale sewage treatments, while desulfurization equipment has become localized. Further, desirable progress has been made in denigration technology and catalysts [9]. As

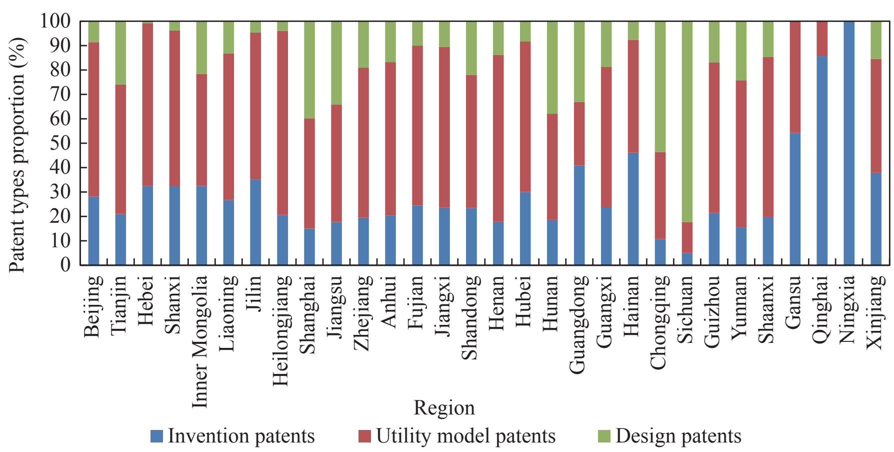

Fig. 4. Region-specific structure of the types of patent certificates obtained in the environmental protection industry†.

† Source: The fourth national survey of the environmental protection and related industries.

Table 3. R&D input and technological innovation in the environmental protection industry by field.

Field	Number of enterprises with R&D capacity	Input of R&D funds (billion yuan)	Number of obtained patent certificates	Sales value of newly formed products (billion yuan)	Foreign exchange earned through exports of newly formed products (million dollars)
Water Pollution Control	793	4.208 23	4 365	8.623 45	40.65
Air Pollution Control	563	4.715 12	5 788	97.392 58	111.83
Solid Waste Treatment and Disposal	182	1.072 97	1 179	3.281 64	11.97
Noise and Vibration Control	58	0.263 8	323	0.636 86	11.66
Radiation Pollution Prevention	6	0.033 21	53	0.078 44	0
Soil Pollution Control and Restoration	19	0.181 36	37	0.256 17	0
Ecological Remediation and Protection	47	0.141 93	94	0.309 49	8.56
Environmental Monitoring	147	0.702 89	849	1.454 76	5.18
Environmental Service	164	1.338 04	1 131	2.966 49	32.24

Source: The fourth national survey of the environmental protection and related industries.

China focuses on the soil pollution control and restoration field in the 13th Five-Year Plan period, enterprises will shift their emphasis of environmental technology-related R&D to this field.

4.2. The environmental service field is crucial for transforming and upgrading the environmental protection industry, and its technological innovation must be further improved

Currently, only 1.9% of environmental service enterprises conduct R&D activities, which is much lower than other fields in the environmental protection industry. Developing the environmental service industry is thus vital, as environmental industries in developed countries have already evolved from a growth stage to a mature stage. Following the continuous development of the China's environmental protection industry, a comprehensive environmental service industry should gradually become a mainstay business within this sector. Therefore, innovation must drive the environmental service industry's development to allow it to constantly explore new environmental service fields and provide broad effective supply, extend the environmental protection industry chain, and uncover potential demand.

4.3. Some differences exist among fields regarding the structure of both R&D funds and types of obtained patents

Some differences can be noted among fields regarding the structures of R&D fund sources (Fig. 5). Specifically, the fields of soil pollution control and solid waste treatment and disposal receive the highest support from government funds, accounting for 23% and 19% of total input in the fields' R&D funds, respectively, which plays a role in supporting technology-related R&D in these fields.

Differences can also be observed in fields regarding the structures of obtained patent certificates (Fig. 6). For example, in the fields of both water and air pollution control, the proportions of invention, utility model, and design patents are 24%, 56%, and 20%, and 16%, 49%, and 35%, respectively. The sales value of newly formed products and foreign exchange earned through exports of newly formed products in the air pollution control field are 11.3 and 2.8 times as much as those in water pollution control, respectively. Hence, the quantity and structure of obtained patent certificates influence the fields' technological industrialization.

5. Factors Influencing Technological Innovation in the Environmental Protection Industry

The environmental protection industry's technological innovation is internally influenced by the characteristics of enterprises and externally influenced by both external funding support and existing science and technology systems.

5.1. Influence of enterprises' characteristics on R&D input

R&D input is a material guarantee of environmental protection enterprises' technological innovation. These enterprises' R&D input is primarily influenced by enterprise scale, listing status, business type, and ownership.

5.1.1. Influence of enterprise scale

A scale economy causes scale effects, as a large-scale enterprise is more conducive to adapting to mass production and division of labor as well as modern production management and technological development. Although the China's environmental

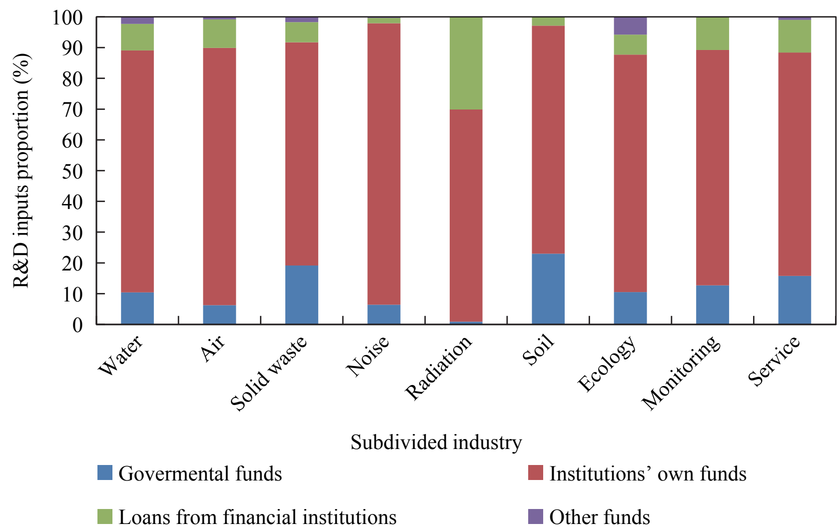

Fig. 5. Structure of R&D funds' input in the environmental protection industry by field†.

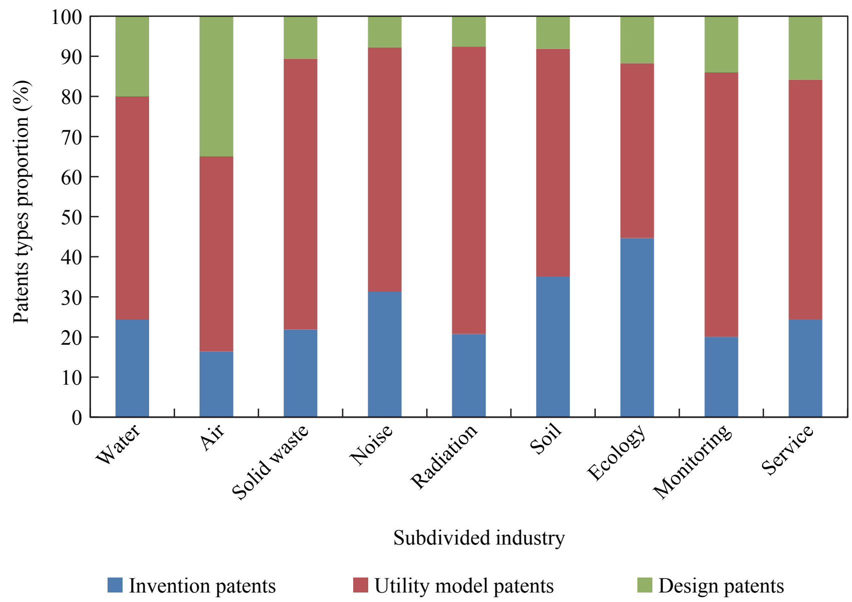

Fig. 6. Structure of obtained patent certificate types in the environmental protection industry by field‡.

protection industry is in a rapid development stage, its enterprises are characterized by large quantities, small scales, and obscure scale benefits [6]. For example, in the product production and operations sector in this industry, 1.56%, 30.69%, 48.42%, and 18.93% of enterprises are respectively classified as large, medium, small, and microenterprises, and the input ratios for their R&D funds are 19.05%, 62.61%, 16.56%, and 1.78%, respectively. It can thus be observed that large and medium-sized enterprises form the core of R&D in the China's environmental protection industry. Although small and micro-enterprises account for nearly 70% of all enterprises, they contribute less than 20% of the total R&D funds' input, indicating that most small and micro-enterprises do not have the capacity for R&D and that their R&D funds' input is extremely inadequate.

In developed countries, the environmental protection industry has a high concentration ratio and is dominated by large enterprises. This industry is a technology- and capital-driven industry, and large enterprises continue to increase their scale and strength, thus having an increased ability to conduct technology-related R&D. The China's environmental protection industry, by continuing mergers and acquisitions, will further increase its concentration ratio, forming a development pattern dominated

†, ‡ Source: The fourth national survey of the environmental protection and related industries.

by industry giants. The formation of these giants will increase the industry's technological innovation.

5.1.2. Influence of listing status

Among the more than 20 000 investigated environmental protection enterprises, 402 are listed companies. The R&D input intensity of listed environmental protection enterprises is 2.75%, higher than that of unlisted enterprises (0.9%). Listed environmental protection enterprises are large, have strong financing capacity, and can conduct technology-related R&D activities.

5.1.3. Influence of business type

The number of part-time enterprises engaged in environmental protection is the same as those specialized in environmental protection. As more traditional energy industries transform themselves and cross industrial boundaries, more part-time environmental protection enterprises are likely to emerge. Indeed, the input intensity of R&D funds in specialized environmental protection enterprises (2.25%) is higher than that in part-time environmental protection enterprises (0.82%). Specialized environmental protection enterprises own core patents and high-level technology talents, and thus have more accurate corporate orientation. Therefore, if more part-time environmental protection enterprises truly aspire to enter this market in the future and achieve long-term development, they must focus on technological innovation as well as research and develop proprietary core technologies by increasing their environmental technology-related R&D input to enhance their competitiveness.

5.1.4. Influence of ownership

China's environmental protection enterprises are state-owned, collective, or private holdings; Hong Kong, Macao, or Taiwanese holdings; or foreign capital holdings. Regarding the total amount of input for R&D funds, state-owned and collective holdings enterprises account for 18% of all enterprises and contribute 21% of R&D funds' input. Further, their average R&D input is higher than that for private holdings enterprises. China's environmental protection enterprises face a constant dilemma in terms of their R&D input in that state-owned enterprises' R&D funds primarily originate from the government and financial institutions, which are characterized by large amounts of R&D input and high intensity and are the cores of R&D input in China. However, these enterprises lack internal capital sources; moreover, the input of private enterprises in innovation has internal incentives, but lacks vigorous support from government finance and loans from financial institutions [1].

5.2. Influence of external financial support on enterprises' technological innovation

Various sources of R&D funds indicate that different supervisory and incentive impact enterprises' R&D, thus influencing their R&D efficiency [10–12]. The external financial support of environmental protection enterprises' R&D input has two primary sources: governmental support and loan support from financial institutions.

Foreign research indicates that government funding plays an active role in promoting enterprises' R&D output; however, R&D returns on the input of R&D funds are lower than those on enterprises' equity funds. Nevertheless, this still indicates a positive influence on enterprises' R&D output [13,14]. Meanwhile, research also indicates that the input of government funds provides information for market fundraisers and mitigates enterprises' financing constraints [15]. The structure of R&D funds varies significantly by region and industry in China. For example, the financial market in the western region is underdeveloped and environmental protection enterprises' R&D funds primarily come from the government's financial support as well as their own equity funds. The government prefers to fund the fields of soil pollution control as well as solid waste treatment and disposal. Compared with the relatively mature fields of water and air pollution control, these two fields have low degrees of industrialization and are more eager to obtain governmental funding.

Financial loans are taken out in the pursuit of profit. Enterprises under loan repayment pressure are forced to increase their R&D efficiency. Moreover, governments prefer to fund patent applications, while financial institutions focus more on the output values of newly formed products. Regarding the environmental protection industry's long-term development, patent inventions and practical technologies are crucial; enterprises should not only pursue their immediate interests. Government funds may constrain environmental protection enterprises' pursuit of monopolized interests, thus maximizing the social benefits [1].

5.3. The influence of existing science and technology systems on the transformation of environmental technology achievements

China's existing technological innovation system is imperfect, as noted by the following aspects: no long-term mechanism has been established for the environmental protection industry's input of R&D funds; the government's financial support is unstable and some problems exist in fund supervision; a technological innovation system has not been established with enterprises as the primary players; a market-based technology transaction, transfer, and diffusion platform has yet to be formed; and the socialized technology achievement transfer mechanism is still imperfect. This results in low achievement transformation rates for key environmental protection technologies in China. These failures to mass industrialize products and equipment critically inhibits technological innovation in the China's environmental protection industry.

6. Policy Suggestions

Generally, the China's environmental protection industry has low R&D capacity and most environmental protection enterprises carry out no R&D activities. No mechanism for enterprises' independent R&D has yet been formed and different regions have significant differences in R&D levels. Environmental protection enterprises in the eastern, central, and western regions are unbalanced in their technological innovation abilities. The eastern region is altogether superior to the central and western regions. The input of R&D funds is primarily distributed to the water and air pollution control fields, while weak R&D capacities are found in the fields of soil pollution control and restoration as well as radiation pollution prevention. Regarding the internal factors influencing technological innovation in the environmental protection industry, larger enterprises receive greater R&D input; listed enterprises' R&D input intensity is higher than that of unlisted enterprises; specialized environmental protection enterprises have higher R&D input than part-time environmental protection enterprises; and state-owned enterprises, with government and loan support, lack internal capital compared with private enterprises as well as support from governmental funding and financial loans. Regarding the external factors influencing technological innovation in the environmental protection industry, the input of external funds plays a promoting role and imperfect science and technology systemsinhibit its development. Therefore, this article posits that efforts should be made to increase technological innovation in the China's environmental protection industry in the following aspects.

6.1. Establish a technological innovation system with enterprises as the main players

Enterprises should be actively cultivated and supportedto become primary R&D input investors. Enterprises' understanding of independent R&D should increase, and environmental protection enterprises not carrying out R&D activities should be encouraged to conduct market-oriented R&D. Enterprises that have conducted R&D activities should be guided to consider the long term, focus on the continuity and stability of their R&D capacity, and maintain continuity in their R&D input. The merger and acquisition, and reorganization of environmental protection enterprises should be encouraged to promote the formation and development of both listed and leading enterprises, thereby increasing technological innovation by raising enterprise scale. Further, technical cooperation between part-timeand specialized environmental protection enterprises should be encouraged and a cross-regional, cross-industry investment cooperation modelpromoted. Finally, a cooperative technological R&D model should be established, under which enterprises can align with R&D and venture capital institutions and other types of enterprises and establish a joint government, industry, university, and research institution innovationsystem.

6.2. Establish a diversified R&D input structure

Multiple channels should be used to increase R&D input for technological innovation in the environmental protection industry. At the government level, financial support for the technological innovation of private holdings enterprises should increase. This should widen supported fields, reduce links with government subsidies and funds during project application, and establish an in-process supervision and achievement audit mechanism to increase the efficiency of government subsidies and funds for R&D.Regarding the introduction of social capital, the establishment of technological innovation funds should be encouraged and multiple new financing platforms should be improved, such as green credit, securities, and insurance. Meanwhile, as R&D input and technological innovation in the environmental protection industry are unbalanced among regions and fields, the government should increase financial support to the central and western regions as well as the fields of soil pollution control and restoration, and radiation pollution prevention when it reformulates its financial support policies.

6.3. Improve market mechanisms for technological innovation

The technological innovation service system in the environmental protection industry should be improved by strengthening the building of systems and mechanisms for intellectual property services, testing and certifying enterprises' technological innovation, establishing a fair and reasonable market rules system, formulating corresponding punishment mechanisms, and forming reverse constraints. A market-based mechanism should be established, under which the market decides the directions of technological innovation, and the government supports technology transformation and its popularization through the assistance and purchase of services, providing full scope to enterprises' role as a link betweenthe market and innovation. Preferential policies should be implemented to encourage enterprises' technological innovation and further efforts should offset taxes by enterprises' funding of R&D and other policies, increasing enterprises' returns from technological innovation. Further, the transformation and popularization mechanisms of technological innovation should be improved to shorten the time to see returns from technological innovation.

6.4. Improve technological innovation achievement transformation platforms

Professional science and technology incubators and intermediary institutions committed to achievement transformation should be established and cultivated. Further, communication should be established between enterprises and scientific research institutions through professionals to guide and encourage universities and institutions to cooperate with environmental protection enterprises, build connections to promote achievement transformations, and accelerate both R&D and the transformation of environmental protection technologies. Further, public information service platforms could be built for small and medium-sized enterprises. Professional technological innovation websites and public technical information databases could provide pertinent market, technological, and policyinformation and consulting services for small and medium-sized enterprises to shorten their technology industrialization cycles. Moreover, institutions could be established to evaluate the benefits from technology achievements, mass production capacities, performance stability, income, and costs of new products as well as the economic benefits for enterprises. This information could be used to strengthen the construction of technology achievement transformation platforms in the western region and provide policy preferences to technical personnel in such aspects as income distribution for technologyachievement transformations, stock option incentives, and technological investment.

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