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Environmental regulation effect study of the environmental protection tax law during strict epidemic control: based on heavy pollution enterprises sample data test

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Abstract

The implementation of the Environmental Protection Tax Law was seriously affected by strict pandemic control. The Environmental Protection Tax Law imposed environmental taxes on enterprises based on measuring their pollution emissions to restrain their bad environmental behaviour and stimulate their green technological innovation ability. However, during the pandemic control period, the green technological innovation ability of enterprises was not developed. Therefore, it is necessary to optimize the environmental regulation effect of the environmental protection tax. This study is based on sample data covering heavily polluting enterprises in China collected from December 20, 2022, to January 7, 2023. It finds that the follow cost effect existed, but the value compensation effect obviously declined, which leading to a decline in the green technological innovation ability of heavily polluting enterprises. The study shows that although strict pandemic control maintained the environmental protection function of the environmental protection tax, it weakened the economic driving function, which will not only damage the long-term economic development potential but also make the environmental protection function unsustainable.

Keywords Environmental protection tax law, Pandemic control, Environmental regulation, Green technological innovation, Heavily polluting enterprises

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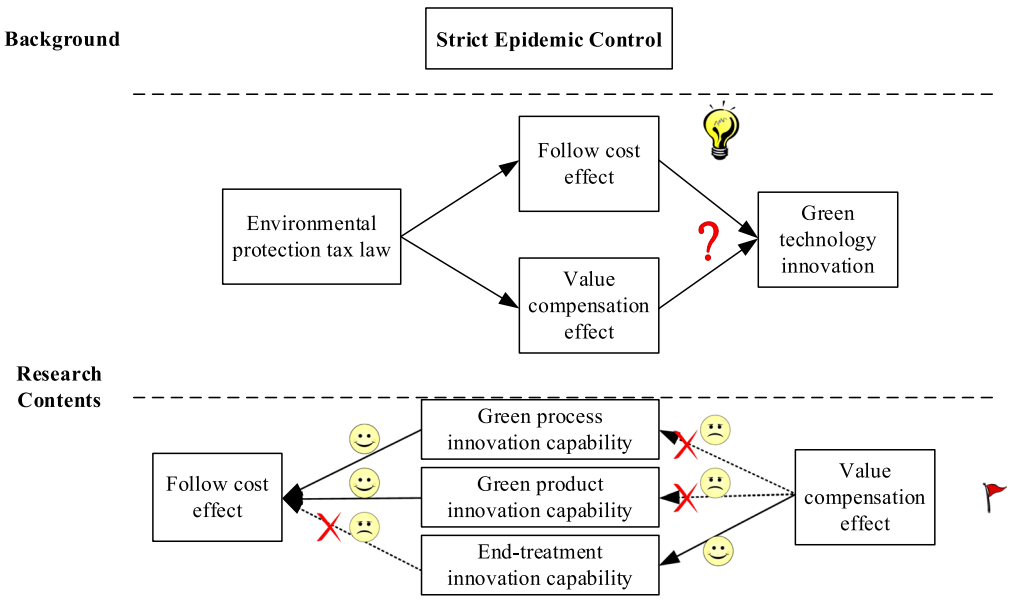
Graphical Abstract



Introduction

As a public good, the environment is easily subject to the abuse of business operations, resulting in a tragedy of the commons. To further protect the ecological environment, control carbon emissions, and realize the coordinated development of the economy and environmental protection [6], the Chinese government implemented the Environmental Protection Tax Law and uses environmental taxes to curb the bad environmental behaviour of enterprises. However, the implementation process of the environmental protection tax has suffered from a serious uncertainty crisis. From the beginning of 2020 until the end of 2022, we experienced three years of strict pandemic control. This is another special three-year period since the founding of the People's Republic of China, and it has had a significant impact on China's socio-economic development. Therefore, it is necessary to summarize and reflect on the gains and losses of these three years to provide goals and directions for economic recovery and social stability after the end of strict pandemic control. Economic recovery and even development only require more resources, thus placing greater pressure on the environment [24]. Therefore, it is necessary to consider the impact of the government's environmental policies to ensure sustainable development.

The Environmental Protection Tax Law came into effect on January 1, 2018, marking the official establishment of China's environmental tax system. The goal of the law is to protect the ecological environment while also ensuring the continued growth of China's economy, and it has had a significant impact on China's socio-economic development [65]. However, after only two years of implementation, the Environmental Protection Tax Law was suddenly subject to strict pandemic control, which inevitably greatly affected the quality and effect of implementation. The normal implementation process was shaken, old problems were not solved, and new problems emerged. Whether the setting of existing tax rates, taxpayers and tax collection scenarios is effective needs to be further verified [58]. Therefore, with strict pandemic control having come to an end, it is necessary to analyze in depth and understand the progress in and obstacles to the implementation of the Environmental Protection Tax Law during the three-year control period to further promote its effectiveness. Corporate social responsibility can effectively encourage enterprises to complete green technological innovation [9], the use of environmental regulation can further strengthen the innovation willingness of enterprises on the basis of responsibility, and policy support can be established for enterprises' green technological innovation.

The Environmental Protection Tax Law is a typical environmental regulation with command-and-control, market-incentive, and voluntary participation characteristics [59]. Different characteristics of the Environmental Protection Tax Law have differences in the cultivation of enterprises' green technological innovation ability

[53]. The promoting effect of environmental regulation on technological innovation is mainly reflected in two aspects: the follow cost effect and the innovation compensation effect. The former means that under environmental regulation, enterprises increase their investment in pollution control funds, resulting in higher costs and inhibiting their technological innovation. The latter means that under environmental regulation, enterprises increase their investment in technological innovation to meet the cost challenge and strengthen their green technological innovation, which can not only compensate for the cost of pollution control but also improve enterprises' performance through the promotion of green technological innovation [22], which in turn will optimize the sustainable development ability of enterprises [10]. However, environmental regulation will also place serious pressure on business operations, thus forcing enterprises to engage in negative behaviours to deal with government regulation. Different enterprises will have different responses to government regulation, which will affect the policy effect of the Environmental Protection Tax Law [7]. Therefore, it is necessary to consider the mechanism of the impact of environmental protection taxes on the green technological innovation of enterprises to provide theoretical support for the optimization of environmental protection taxes.

Similarly, the Environmental Protection Tax Law will also produce a follow cost effect and an innovation compensation effect during its implementation. When the Environmental Protection Tax Law has an environmental regulation effect on an enterprise, ideally, the innovation compensation effect can compensate for the follow cost effect and thus improve the environmental competitiveness and market competitiveness of the whole enterprise, which will manifest as an increase in the overall green technological innovation ability of the enterprise [17]. He et al. [25] used Chinese stock market data to find that the innovative compensation effect can significantly promote the utility of the Environmental Protection Tax Law. However, for enterprises at different stages, the subsidies or penalties provided by the Environmental Protection Tax Law have different effects on technological innovation [34].

Existing studies show that the follow cost effect was fully offset by the innovation compensation effect in the first two years of Environmental Protection Tax Law implementation, i.e., 2018 and 2019, resulting in a significant competitive advantage of green technology for firms. Liu et al. [42] used a threshold regression model to test data based on a sample of listed enterprises in the chemical industry from 2010 to 2019. They found that the Environmental Protection Tax Law not only increased the environmental protection investment of chemical enterprises but also significantly promoted an increase in the green technological innovation ability of chemical enterprises under the threshold effect [42]. Based on sample data covering industrial A-share companies listed on the Shanghai and Shenzhen stock markets from 2015 to 2019, Li [35] used a difference-in-differences model to find that the implementation of the Environmental Protection Tax Law enhanced the green technological innovation of enterprises and, in particular, promoted an increase in green invention patents and green utility model patents. The study by Wang et al. [55], based on sample data covering heavily polluting A-share enterprises listed on the Shanghai and Shenzhen stock markets from 2015 to 2019, found that the Environmental Protection Tax Law promoted the transformation of green production methods, improved total factor productivity, increased the green technological innovation ability of heavily polluting enterprises, and, in particular, significantly enhanced source control technological innovation. However, the promoting effect on end-management green technological innovation was not significant. Based on semi-annual financial data covering A-share manufacturing companies listed on the Shanghai and Shenzhen stock markets from 2015 to 2019, Liu [41] used a difference-in-difference-in-differences model to introduce corporate green patent data using the implementation of China's environmental protection tax reform as a natural experiment. The study found that the implementation of the Environmental Protection Tax Law effectively promoted green technological innovation in energy, petroleum, chemical and other heavily polluting enterprises and, in particular, promoted an increase in end-treatment innovation ability [41]. However, Chen [5] argued that too much emphasis on government regulation will not be conducive to improving enterprises' innovation ability. The sustainability of enterprises has been investigated from the perspective of environmental control, and the empirical results show that excessive environmental control will harm the technological innovation ability of enterprises [60]. In comparison, informal environmental regulations can facilitate "strategic" and "substantial" innovation in green technologies [1]. The coordination of environmental governance policies can also promote technological progress and industrial structure optimization and thus realize green development [44]. Environmental protection taxes have an environmental regulation effect, but whether this effect truly promotes the technological innovation ability of enterprises needs to be verified. Therefore, how to maintain and strengthen the environmental regulation effect of the environmental protection tax under a sudden crisis to use the environmental tax to optimize green

technological innovation needs to be further discussed under real-world conditions.

Heavily polluting industries refer to industries that emit a large amount of pollutants in the process of production and operation, which in turn will seriously damage the ecological environment. They are the key object regulated by the Environmental Protection Tax Law. The use of environmental taxes can promote a reduction in carbon emissions and the development of green technological innovation [30]. Direct environmental supervision can ignore the property rights of enterprises and thus form a generally significant green technological innovation incentive for heavily polluting enterprises [26]. With the environmental protection tax as the external target, heavily polluting enterprises must adopt more green behaviour to cope with the additional costs [2]. The control and management of emissions from heavily polluting industries are highly valued in all countries around the world, and China is no exception. At the same time, heavily polluting industries have most sensitively and quickly responded to the implementation of the Environmental Protection Tax Law, which can more directly reflect the effectiveness and problems of Environmental Protection Tax Law implementation [4].

Most existing studies are based on an analysis under normal economic conditions, and analysis of the environmental regulation effect of the Environmental Protection Tax Law during the strict pandemic control period is lacking. Facing the worldwide security crisis, there were inevitable loopholes in the implementation of the Environmental Protection Tax Law. A large number of studies have verified that the environmental protection tax can effectively reduce the carbon emissions of enterprises and optimize the technological innovation ability of enterprises, but there is no in-depth discussion on the role of the follow cost effect and innovation compensation effect. Enterprise green technological innovation will inevitably account for a share of enterprise profit before strict pandemic control can compensate for losses through innovation, but during the period when the management of enterprises is under serious threat, green investment is unsustainable, and more enterprises will choose negative behaviour to deal with business crises. As a result, the Environment Protection Tax Law cannot play a role. Existing research has rarely involved this content.

The implementation of the Environmental Protection Tax Law was remarkably effective before the three-year period of strict pandemic control. However, during this period, the effectiveness of the Environmental Protection Tax Law was unclear because existing studies were only about the period before pandemic control and did not address the period after pandemic control. Therefore, this study intends to take heavily polluting enterprises as the research object, analyse the environmental regulatory mechanism of the Environmental Protection Tax Law during the three-year period of strict pandemic control, determine the weaknesses and propose countermeasures. Doing so will not only gradually improve the implementation of the Environmental Protection Tax Law but also make the law more useful in the future economic recovery and development of China.

As an important part of the world community, China's environmental issues are of great global importance, and the Chinese economy is becoming increasingly prominent in the global economic system. Therefore, how to reconcile the economy and the environment not only is crucial for China's future development but also affects the future of the world. From the perspective of enterprises, the existence of an environmental tax will increase awareness of the need to reduce the production of pollution, thereby improving the overall environment [36]. By studying heavily polluting enterprises in China, we can identify the driving mechanism of the Environmental Protection Tax Law with regard to ecology and the economy, thus paving the way for countries around the world to integrate ecological and economic development. As a country with a full range of industrial systems, China's implementation of the Environmental Protection Tax Law holds strong reference significance for global environmental regulation. For China, environmental taxes not only are a tool for controlling pollution but also affect the technological innovation ability of the whole region [57]. Summarizing China's experience in environmental protection will drive countries around the world to take active measures to address their own environmental problems, promote the healthy development of the global environment, and jointly safeguard human's home.

This article makes the following contributions. First, it studies the environmental regulation effect of the Environmental Protection Tax Law under strict pandemic control and fills the gap in research on the effect of the development of the green technological innovation ability of enterprises under the uncertainty crisis. Second, it reveals the mechanism of the mandatory nature and rationality of the Environmental Protection Tax Law and its effect on environmental regulation. Third, the paper analyses the internal mechanism of the follow cost effect and value compensation effect on the green technological innovation ability of enterprises. This research will provide theoretical support for the government to adjust the Environmental Protection Tax Law and better encourage enterprises to realize green technological innovation.

The structure of this article is as follows. The second section presents the research hypotheses of the paper and the design of the research model through literature

analysis. The third section explains the specific content of the questionnaire and verifies the validity of the questionnaire through an analysis of the survey data to carry out model verification and determine the research hypotheses that did not pass the model test. Finally, based on the results of the model test, the fourth section proposes highly targeted policy recommendations to address actual problems in reality and concludes by pointing out the limitations of this study.

Literature review and hypothesis development

Analysis of the mandatory environmental regulation effect of the Environmental Protection Tax Law

The mandatory nature of the Environmental Protection Tax Law refers to the extent to which it is strongly enforced. The higher the mandatory nature is, the more obvious the environmental regulation effect, and the more significant the follow cost effect and value compensation effect. The mandatory nature of the Environmental Protection Tax Law is mainly reflected in implementation by local governments, monitoring by environmental protection agencies, collection by taxation agencies, advocacy by higher authorities, and so on. First, for local governments, implementing the Environmental Protection Tax Law is mandatory. The presence of environmental taxes can significantly reduce the performance of companies in the first stage; thus, government coercion is needed as a guarantee [43]. Otherwise, enterprises will be encouraged to take a negative attitude and take greenwashing measures to deal with the environmental protection tax [27]. In the current international situation, environmental protection has become the common goal of all humankind. As an economic power, China must take the corresponding responsibility in environmental protection to win the world's respect, build good international relations and thus create good conditions for economic development. Therefore, all levels of government in China are trying their best to promote the in-depth implementation of the Environmental Protection Tax Law [51]. Second, for environmental protection agencies monitoring the implementation of the Environmental Protection Tax Law is mandatory. Environmental protection agencies rely on advanced technology, equipment, experience and professional staff to measure the emissions of enterprises and then provide emission data to the taxation department, which provides strong support for the scientific, reasonable, and fair collection of environmental protection taxes. The existence of digital technology effectively ensures the data validity of the monitoring process [11]. In this process involving environmental agencies, which are administrative departments, pollution monitoring behaviour is supported and guaranteed by state power [20]. Third, for tax authorities, the collection of taxes is mandatory under the Environmental Protection Tax Law. The taxation department accounts for and collects taxes from enterprises based on the emission data provided by environmental protection agencies, reflecting the will of the state, backed by law, which is not only enforceable but also gratuitous in nature [54]. Finally, for the higher authorities of heavily polluting enterprises, paying taxes is mandatory under the Environmental Protection Tax Law. For companies, with the widespread implementation of environmental protection taxes, the additional costs of producing pollution are becoming increasingly expensive [50]. The implementation of the Environmental Protection Tax Law responds to national development and social progress, meets the environmental needs of enterprises for long-term development, and has been approved and embraced by the entire nation. The headquarters of conglomerates of heavily polluting enterprises should supervise their subsidiary enterprises to pay environmental protection taxes on time and prohibit speculative behaviour in environmental protection tax payment [28].

Based on the analysis above, the following research hypotheses are formulated:

> H11: The mandatory nature of the Environmental Protection Tax Law can drive the follow cost effect on heavily polluting enterprises.
> H12: The mandatory nature of the Environmental Protection Tax Law can drive the value compensation effect on heavily polluting enterprises.

Analysis of the environmental regulation effect of the rationality of the Environmental Protection Tax Law

Different from the mandatory nature, the rationality of the Environmental Protection Tax Law depends more on the degree to which laws and regulations are convincing. The high rationality of environmental regulation is conducive to enterprises' voluntary compliance with the Environmental Protection Tax Law, and the rationality of the Environmental Protection Tax Law is the extent to which it has been reasonably implemented. The higher the rationality is, the more obvious the environmental regulation effect, and the more significant the follow cost effect and value compensation effect. Effective environmental protection taxes will significantly improve the environmental investment of enterprises, thus achieving the expected effect of environmental regulation [40]. A reasonable environmental tax rate can significantly optimize the green technological innovation ability of enterprises. Lower and higher levels can bring a higher tax burden to restrain the improvement in innovation ability [33]. The rationality of the Environmental Protection Tax

Law is mainly reflected in the appropriate tax rate, precise measurement, fairness and transparency, preferential disclosure and other aspects. First, the more appropriate the tax rate is, the more companies will be willing to comply with the requirements of the Environmental Protection Tax Law and then invest more in emission treatment and green technological innovation. Environmental taxes can be used to achieve economic and ecological progress, but a reasonable environmental tax base needs to be set [39]. A high tax rate is not conducive to supporting the green behaviour of enterprises and places great financial pressure on enterprises [23]. Considering the differences in economic development, resource endowment and concentration of talent among regions, the Chinese government has adopted a flexible tax rate setting for the Environmental Protection Tax Law, granting local governments a great deal of discretionary power. Local governments need to set tax rates that strike a balance between environmental protection and economic development to effectively exert the incentive and constraint effects of environmental protection taxes [29]. Second, the more accurate the measurement of pollutant emissions by environmental protection agencies, the more willing heavily polluting enterprises will be to reduce their pollution emissions, and thus, the more willing they will be to invest in pollutant emission management and green technological innovation. If there is a large deviation in the measurement of pollutant emissions by environmental protection agencies, it is likely to not only frustrate the motivation of heavily polluting enterprises to carry out pollution control but also discourage them from paying attention to green technological innovation and seek other solutions [19]. Third, the more fair and transparent the tax authorities are in accounting for and collecting taxes, the more effectively the sanctity of the Environmental Protection Tax Law can be upheld and the more effective the regulation can be. The loss of fairness and transparency in tax collection will encourage the opportunistic behaviour of taxpaying enterprises and undermine the authority and practical effectiveness of tax laws [31]. Finally, the more open the exemption and preferential policies of the Environmental Protection Tax Law are in implementation, the greater the incentive for heavily polluting enterprises to invest in environmental protection, and the more beneficial it will be in tapping the potential of environmental protection and the economic driving force of the tax law. If there are secret operations in reduction and preference, they may encourage enterprises to covertly engage in rent-seeking behaviour, thus breaking the order of free and fair market competition [15].

Based on the analysis above, the following research hypotheses are formulated:

H21: The rationality of the Environmental Protection Tax Law can drive the follow cost effect on heavily polluting enterprises.

H22: The rationality of the Environmental Protection Tax Law can drive the value compensation effect on heavily polluting enterprises.

Follow cost effect analysis

The follow cost effect of China's Environmental Protection Tax Law is reflected in two aspects. The first is the crowding-out effect of innovation funds. That is, under the strong promotion of local governments, environmental protection agencies, and taxation agencies, enterprises have to reduce their investment in technological research and development due to the increase in emission costs, thus inhibiting their technological innovation. The second is the crowding-out effect of investment funds. That is, under the environmental regulations of the Environmental Protection Tax Law, enterprises will shift some of their investment to areas with weaker environmental regulations to obtain more investment income due to the rising cost of pollution treatment [47]. Under the dual role of environmental policy and market pressure, the only strategy that enterprises can choose is to avoid environmental costs, which in turn will affect the green technological innovation of enterprises [48].

Under the Follow cost effect, the senior management of heavily polluting enterprises will pay more attention to the internal treatment of pollution emissions, formulate long-term emission reduction plans, and make energy savings and emission reduction an important direction of the company's development strategy. At the same time, the financial capital budget will be tilted towards the sewage treatment business because from a cost-accounting perspective, the increase in internal sewage treatment costs is generally less than the expenses of being penalized by the levying authority for the same amount of emissions. Thus, companies will prefer to increase their budgets for sewage treatment costs. To avoid the accumulation of waste emissions, companies will also increase labour in sewage treatment or even set up specialized sewage treatment departments, invest more manpower in sewage treatment, and train a group of skilled workers in the direction of waste treatment. This means that the existence of environmental taxes motivates companies to take on more workers, which indirectly contributes to socio-economic development [18]. When enterprises have sufficient funds, heavily polluting enterprises will also purchase more advanced sewage treatment equipment to improve the efficiency of sewage treatment. In the long run, the purchase of advanced sewage discharge equipment does not increase the cost of sewage

discharge; rather, it reduces the total cost of sewage discharge [3].

In short, under the follow cost effect, heavily polluting enterprises may reduce their investment in technological innovation, thus weakening their green technological innovation ability. Green innovation ability is the compound of multiple green innovation ability elements, mainly including the three basic elements of green process innovation ability, green product innovation ability and end-treatment innovation ability.

Based on the analysis above, the following research hypotheses are formulated:

> H31: The follow cost effect of the Environmental Protection Tax Law inhibits the green process innovation ability of heavily polluting enterprises.
> H32: The follow cost effect of the Environmental Protection Tax Law inhibits the green product innovation ability of heavily polluting enterprises.
> H33: The follow cost effect of the Environmental Protection Tax Law inhibits the end-treatment innovation ability of heavily polluting enterprises.

Value compensation effect analysis

The value compensation effect of China's Environmental Protection Tax Law is reflected in two aspects. First, under the strong impetus of local governments, environmental protection agencies, and tax authorities, enterprises will vigorously improve their pollution treatment technologies to reduce pollutant emissions to reduce the cost burden of pollutant discharge. Second, under the environmental regulation of the Environmental Protection Tax Law, the environmental value of various resources will rise, and enterprises will have to develop technology to improve their production efficiency and compensate for the costs incurred by environmental regulation [37]. The purpose of the Environmental Protection Tax Law is to use environmental taxes to urge enterprises to strengthen their technological innovation to promote a win–win situation between the economy and the environment [64].

Under the value compensation effect, the executives of heavily polluting enterprises will also pay more attention to green technological innovation and incorporate green technological innovation into the strategic planning of the enterprise, which gradually rise to become the top priority of strategy implementation. Developing heavy polluting technologies against society will cause companies to bear more production losses and seriously jeopardize their market competition potential [32]. Environmental taxes gradually become an important driver for enterprises to develop green technological innovation [52]. In the modern economic system, the value of enterprises mainly comes from green technological innovation, which senior executives know all too well, while the existence of environmental protection taxes once again strengthens the willingness of enterprises to conduct green business [63]. At the same time, companies' financial budget will also increase support for green technological innovation, and companies will invest more money in material procurement, product design, manufacturing, quality inspection and other aspects to lay a solid financial platform for green operations. The competition of today's enterprises largely depends on the competition of talent. Therefore, to promote green technological innovation more effectively, enterprises will not only increase the training of existing technical personnel but also vigorously introduce first-class professional talent from outside. Similarly, to maintain the sustainability of green technological innovation, enterprises will try to improve the technological innovation environment and create favourable conditions for the acceleration of technological innovation. Such conditions will be reflected not only in financial support but also in humanistic care [56].

In short, under the value compensation effect, heavily polluting enterprises will invest more in technological innovation and thus enhance their green technological innovation ability.

Based on the analysis above, the following research hypotheses are formulated:

> H41: The value compensation effect of the Environmental Protection Tax Law promotes the green process innovation ability of heavily polluting enterprises.
> H42: The value compensation effect of the Environmental Protection Tax Law promotes the green product innovation ability of heavily polluting enterprises.
> H43: The value compensation effect of the Environmental Protection Tax Law promotes the end-treatment innovation ability of heavily polluting enterprises.

Research model establishment

Based on the ideas and methods of structural equation modelling (SEM), the research model is constructed as shown in Fig. 1 by synthesizing the research hypotheses above. The model contains a total of 2 independent variables, 2 mediating variables, 3 dependent variables, and 10 causal paths. Through the follow cost effect, the value compensation effect, the mandatory nature and the rationality of the tax law, the Environmental Protection Tax Law can exert an impact on green

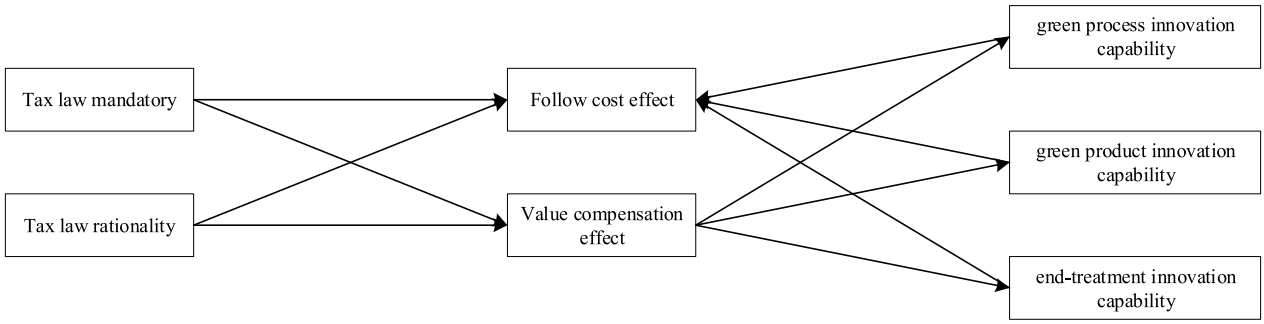


Fig. 1 Research model. "→" represents positive promoting effect; "←" represents reverse inhibition effect

technological innovation ability. The important role of the mandatory nature and rationality of the tax law is to make heavily polluting enterprises pay attention to environmental protection. Through environmental protection taxes, heavily polluting enterprises realize that only by changing their own environmental protection level can they better obtain their target profit. With the help of SEM, the research framework of this study is formed.

According to Hypotheses H11 and H12, there is a positive causal relationship between the mandatory nature, follow cost effect and value compensation effect of the tax law. Therefore, the causal line for the follow cost effect and value compensation effect is established, and the arrow is used to indicate the causal direction. According to assumptions H21 and H22, there is a positive causal relationship between the rationality of the tax law, follow cost effect and value compensation effect, thus establishing a causal line starting from the rationality of the tax law and terminating with the follow cost effect and value compensation effect as end points. According to Hypotheses H31, H32 and H33, there is a reverse causal relationship between follow cost effect and green process innovation ability, green product innovation ability and end-treatment innovation ability. Therefore, the causal line is established with the follow cost effect as the end point and the remaining three variables as starting points. According to Hypotheses H41, H42 and H43, there is a positive causal relationship between the value compensation effect and green process innovation ability, green product innovation ability and end-treatment innovation ability. Thus, the causal line is established with the value compensation effect as the starting point and the other three variables as end points. At the same time, the whole model is formed under the research framework of the effect of the Environmental Protection Tax Law on the technological innovation ability of enterprises. Therefore, the hypotheses above are integrated into a research model, as shown in Fig. 1.

Research model test

The research model is the basis of the model test, and the research model test is divided into the following contents. First, the questionnaire was designed based on the variables of the research model to ensure that the questionnaire elements were designed reasonably. Second, the sample survey was conducted on the basis of the selected respondents, and a sample characteristic table was formed. Finally, the study model was tested using credible data after passing the reliability test, and it was determined whether the model needs to be adjusted based on the goodness-of-fit index. The core investigative question in the research process is based on whether the implementation of the environmental protection tax law promotes the green technological innovation capability of enterprises under the mediating effect of environmental regulation [45, 46].

Questionnaire design

Design of the questionnaire on the effectiveness of the Environmental Protection Tax Law

The design of the questionnaire on the effectiveness of the Environmental Protection Tax Law includes both the mandatory nature and rationality of the tax law.

Drawing on existing research, the mandatory nature questionnaire includes the following items: (i) local government coercion, i.e., local governments strongly enforce the implementation and enforcement of the Environmental Protection Tax Law in administrative management; (ii) environmental protection department coercion, i.e., the environmental protection department seriously, conscientiously and unselfishly monitors the pollutant emissions of heavily polluting enterprises; (iii) tax department coercion, that is, the tax department is strict and fair in the enforcement of the Environmental Protection Tax Law; and (iv) Higher authority coercion, i.e., conglomerates or headquarters of heavily polluting

enterprises require companies to fully comply with the Environmental Protection Tax Law [62].

Drawing on existing studies, the rationality questionnaire includes the following items: (i) the tax rate level is reasonable, i.e., the tax rate level of the environmental protection tax is set appropriately under the leadership of local governments; (ii) the emission measurement is reasonable, i.e., the environmental protection department is accurate in measuring the pollution emissions of heavily polluting enterprises; (iii) the taxation basis is reasonable, i.e., the taxation basis for the taxation of heavily polluting enterprises by the taxation department is fair and transparent; and (iv) the preferential treatment is reasonable, i.e., the enforcement authorities are open and fair in the operation of environmental protection tax preferential treatment for heavily polluting enterprises.

Design of the questionnaire on the environmental regulatory effects of the Environmental Protection Tax Law

The design of the questionnaire on the environmental regulatory effects of the Environmental Protection Tax Law includes both the follow cost effect and the value compensation effect.

Drawing on existing research, the follow cost effect questionnaire includes the following items: (i) follow cost strategy guidance, i.e., corporate executives pay attention to the environmentalization of emissions in the design and implementation of the strategy; (ii) follow cost budget additions, i.e., enterprises continuously add to their absolute or relative budgets for emission treatment; (iii) follow cost human input, i.e., enterprises continuously invest various human resources in the treatment of emissions; and (iv) follow cost equipment investment, i.e., enterprises invest in more and better pollution treatment equipment for the environmental purification of emissions [13].

Drawing on existing research, the value compensation effect questionnaire includes the following items: (i) value compensation strategy guidance, i.e., corporate executives pay attention to green technological innovation in strategy design and implementation; (ii) value compensation budget additions, i.e., enterprises continuously add absolute or relative budgets for green technological innovation; (iii) value compensation human input, i.e., enterprises continuously invest in scientific and technological human capital in green technological innovation; and (iv) the improvement of the value compensation mechanism, i.e., enterprises continuously improve their research mechanisms to create more favourable research conditions for promoting green technological innovation.

Design of the questionnaires on the green technological innovation ability of heavily polluting enterprises

The design of the questionnaire on the green technological innovation ability of heavily polluting enterprises includes three aspects: green process innovation ability, green product innovation ability and end-treatment innovation ability.

Drawing on existing research, the green process innovation capability questionnaire includes the following items: (i) green procurement innovation ability, i.e., enterprises continuously improve the environmental quality of raw materials; (ii) green equipment innovation ability, i.e., enterprises continuously improve the environmental performance of equipment; (iii) green production innovation ability, i.e., enterprises constantly find ways to reduce pollution emissions from assembly lines; and (iv) green design innovation ability, i.e., enterprises continuously improve their product design solutions to enhance the environmental performance of products [49].

Drawing on existing research, the green product innovation capability questionnaire includes the following items: (i) green transport innovation ability, i.e., products are more environmentally friendly in the delivery chain; (ii) green consumption innovation ability, i.e., the product in the consumption process of harm to the environment is increasingly less; (iii) green recycling innovation ability, i.e., when the product is recycled at the end of the life cycle, the damage to the environment decreases; and (iv) green concept innovation ability, i.e., the application and consumption of products can arouse the public's growing awareness of ecological protection.

Drawing on existing research, the end-treatment innovation ability questionnaire includes the following items: (i) waste residue treatment innovation ability, i.e., the technology and methods of waste residue treatment are constantly updated and upgraded; (ii) wastewater treatment innovation ability, i.e., the technology and methods of wastewater treatment are constantly updated and upgraded; (iii) waste gas treatment innovation ability, i.e., the technology and methods of waste gas treatment are constantly updated and upgraded; and (iv) noise control innovation ability, i.e., the enterprise's noise control technology and methods are constantly updated and upgraded.

Sample survey

In 2012, the China Securities Regulatory Commission (CSRC), in its revised Guidelines on the Industry Classification of Listed Companies, classified heavily polluting enterprises into 16 categories: building materials, chemicals, steel, coal, thermal power, fermentation, metallurgy,

mining, textile, tannery, brewing, electrolytic aluminium, pharmaceutical, cement, paper, and petrochemical.

In this study, a sample data survey was conducted with a sample of heavily polluting enterprises in China using a 7-point Likert scale system and with executives of heavily polluting enterprises as respondents. The survey included not only the 16 types of heavily polluting enterprises delineated by the CSRC but also other types of enterprises that local governments consider to have serious pollution consequences. The executives of heavily polluting enterprises not only have a clear understanding of the environmental regulation effect and the current status of the green technological innovation ability of their own enterprises but also can give a reasonable judgement on the effectiveness of the Environmental Protection Tax Law.

The survey was conducted from December 20, 2022, to January 7, 2023, and a total of 536 samples were obtained. However, after screening, 400 valid samples were retained after removing unqualified samples. The sample characteristics are shown in Table 1. The criteria of unqualified samples in the screening process were insufficient quality of questionnaire completion, omission of questions, and repetition of questionnaire options, presenting a large number of single choices in the selection of different questions.

Based on the characteristics of the samples, to ensure the reliability of the data, the sample survey involves 16 kinds of heavily polluting industries while taking into account other industries that are not in the pollution directory but whose actual process operations also produce many pollution enterprises. Since regional differences need to be taken into account, this study includes all major regions of China to guarantee the scientific nature of the survey. In China, private enterprises account for the largest share of all enterprises, while state-owned enterprises are second. The number of foreign-funded enterprises is the lowest due to the structure of China's economic development. In the process of data investigation, the characteristics embodied in the attributes of enterprises to meet the structure.

Based on the preliminary processing of the survey data, the sample characteristics were obtained along

Table 1 Sample characteristics

Attributes	Category	Sample size	Share %	Attributes	Category	Sample size	Share %
Sample industry distribution	Building materials	32	8	Sample profit distribution (Yuan)	< 20 M	108	27
	Chemical industry	20	5		20–40 M	86	21.5
	Steel	16	4		40–60 M	68	17
	Coal	18	4.5		60–80 M	66	16.5
	Thermal power	10	2.5		80–100 M	44	11
	Fermentation	22	5.5		> 100 M	28	7
	Metallurgy	28	7	Sample sales income distribution	< 0.2B	82	20.5
	Mining	16	4		0.2–0.4B	70	17.5
	Textile	16	4		0.4–0.6 M	62	15.5
	Tannery	20	5		0.6–0.8B	56	14
	Brewing	22	5.5		0.8–1B	40	11
	Electrolytic aluminum	8	2		1–1.2B	36	8
	Pharmaceutical	34	8.5		1.2–1.4B	28	7
	Cement	6	1.5		> 1.4B	26	6.5
	Paper	12	3	Sample output value distribution	< 0.3B	104	26
	Petrochemical	14	3.5		0.3–0.6B	92	23
	Other	106	26.5		0.6–0.9B	76	19
Sample geographical distribution	Southeast China	60	15		0.9–1.2B	50	12.5
	Southwest China	56	14		1.2–1.5B	38	9.5
	Central and Southern China	72	18		1.5–1.8B	22	5.5
	Eastern China	66	16.5		> 1.8B	18	4.5
	Northwest China	56	14	Enterprise attribute	State-owned enterprises	82	20.5
	Northeast China	32	8		Private enterprise	300	75
	North China	58	14.5		Foreign enterprise	18	4.5

Table 2 Statistical characteristics

Factor	Sample size	Peak value	Least value	Mode	Mean value	Variance
Tax law mandatory	400	7	1	4	3.87	0.22
Tax law rationality	400	7	1	3	3.10	0.17
Follow cost effect	400	7	1	4	3.76	0.10
Value compensation effect	400	7	1	4	3.88	0.18
Green process innovation capability	400	7	1	3	3.22	0.12
Green product innovation capability	400	7	1	3	3.06	0.14
End-treatment innovation capability	400	7	1	4	3.85	0.20

Table 3 Reliability test of Environmental Protection Tax Law effectiveness

Name of index	Tax law mandatory	Tax law rationality
Local governments mandatory	0.838	0.333
Environmental protection department mandatory	0.791	0.238
Tax authorities mandatory	0.935	0.239
Superior department mandatory	0.767	0.222
Tax rate rationality	0.186	0.822
Emission measurement rationality	0.360	0.853
Tax basis rationality	0.414	0.760
Reduction and exemption rationality	0.229	0.775
Cronbach's *α*	0.779	0.729
Explained variance (%)	38.16	29.17
Cumulative variance (%)	38.16	67.33

Table 4 Reliability test of environmental regulation

Name of index	Follow cost effect	Value compensation effect
Follow cost strategy guidance	0.765	0.278
Follow cost budget additions	0.951	0.306
Follow cost human input	0.832	0.406
Follow cost equipment investment	0.762	0.198
Value compensation strategy guidance	0.401	0.782
Value compensation budget additions	0.238	0.815
Value compensation human input	0.300	0.826
Improvement of value compensation mechanism	0.158	0.751
Cronbach's *α*	0.819	0.879
Explained variance (%)	33.15	34.10
Cumulative variance (%)	33.15	67.25

with the statistical characteristics of the sample data, which are shown in Table 2.

In the table of the statistical characteristics of the sample data, the sample size of each element is 400, the maximum value is 7, and the minimum value is 1, which meets the requirement of 400 valid samples. Among the elements, the pluralities are generally distributed in 3 and 4, indicating that the executives of heavily polluting enterprises agree with the questionnaire items but believe that the current implementation process of the Environmental Protection Tax Law is not as envisioned and that there is room for improvement. The reliability of the sample data is verified by the mean and variance.

Research model testing

Reliability test

Based on 400 sample data points, Stata 15.0 software is used to test the reliability of the effectiveness of the Environmental Protection Tax Law, environmental regulation and green technology innovation ability, and the test results are shown in Tables 3, 4 and 5. According to the test results, the reliability test effect of these three factors is good.

According to the test results of the reliability test of the effectiveness of the Environmental Protection Tax Law, among the four indicators of the mandatory nature of the tax law, the indicator test value of the superior department mandatory nature is the lowest (0.767), the indicator test value of the tax authority mandatory nature is the highest (0.935), and the test values of the other indicators are all over 0.7. Cronbach's α is $0.779 > 0.7$, indicating that this factor passes the reliability test.

Among the four indices of the rationality of the tax law, the indicator test value of tax basis rationality is the lowest (0.760), the indicator test value of emission measurement rationality is the highest (0.853), and the test values of the other indices are all over 0.7. Cronbach's α is $0.729 > 0.7$, indicating that this factor passes the reliability test.

According to the test results of the reliability test of environmental regulation, among the four indicators of the follow cost effect, the indicator test value of follow cost equipment investment is the lowest (0.762), the

Table 5 Reliability test of green technology innovation capability

Name of index	Green process innovation capability	Green product innovation capability	End-treatment innovation capability
Green procurement innovation capability	0.778	0.355	0.287
Green equipment innovation capability	0.729	0.400	0.178
Green production innovation capability	0.810	0.296	0.231
Green design innovation capability	0.921	0.277	0.326
Green transport innovation capability	0.111	0.888	0.339
Green consumption innovation capability	0.410	0.832	0.281
Green recycling innovation capability	0.276	0.799	0.411
Green concept innovation capability	0.358	0.765	0.279
Waste residue treatment innovation capability	0.127	0.304	0.872
Wastewater treatment innovation capability	0.286	0.119	0.818
Waste gas treatment innovation capability	0.303	0.225	0.779
Noise control innovation capability	0.271	0.180	0.726
Cronbach's α	0.789	0.719	0.889
Explained variance (%)	27.15	31.02	21.78
Cumulative variance (%)	27.15	58.17	79.95

indicator test value of follow cost budget additions is the highest (0.951), and the test values of the other indicators are all over 0.7. Cronbach's α is $0.819 > 0.7$, indicating that this factor passes the reliability test.

Among the four indices of the value compensation effect, the indicator test value of the improvement of the value compensation mechanism is the lowest (0.751), the indicator test value of value compensation human input is the highest (0.826), and the test values of the other indices are all over 0.7. Cronbach's α is $0.879 > 0.7$, indicating that this factor passes the reliability test.

According to the test results of the reliability test of green technology innovation ability, among the four indicators of green process innovation ability, the indicator test value of green equipment innovation ability is the lowest (0.729), the indicator test value of green design innovation ability is the highest (0.921), and the test values of the other indicators are all over 0.7. Cronbach's α is $0.789 > 0.7$, indicating that this factor passes the reliability test.

Among the four indices of green product innovation ability, the indicator test value of green concept innovation ability is the lowest (0.765), the indicator test value of green transport innovation ability is the highest (0.888), and the test values of the other indices are all over 0.7. Cronbach's α is $0.719 > 0.7$, indicating that this factor passes the reliability test.

Among the four indices of the end-treatment innovation capability, the indicator test value of the noise control innovation ability is the lowest (0.726), the indicator test value of the waste residue treatment innovation ability is the highest (0.872), and the test values of the other indices are all over 0.7. Cronbach's α is $0.889 > 0.7$, indicating that this factor passes the reliability test.

Model testing

Based on the reliability test, the study model was tested using SPSS 20.0 and LISREL 8.7 software. The path coefficients represent the degree of association between variables, and a larger value means a stronger association. If the path coefficient is positive, it indicates a positive correlation between variables, and if the coefficient is negative, it indicates a negative correlation between variables. The path coefficient can be used to explore the causal relationship between variables, while the t value is used to judge whether the path coefficient is significant. Only the path coefficient and the t value are tested at the same time to ensure that the causal relationship between variables exists and is significant. Based on the ideas above, the study model was tested with 400 sample data points, and the test results are shown in Table 6.

According to the test results, for the hypothesis that the follow cost effect inhibits end-treatment innovation ability, its path coefficient is -0.05, and the t value of 1.01 is less than 2. Therefore, the hypothesis is not significant and does not pass the test. For the hypothesis that the value compensation effect promotes green process innovation ability, its path coefficient is 0.06, and the t value of 1.72 is less than 2. Therefore, the hypothesis is not significant and does not pass the test. For the hypothesis that the value compensation effect promotes green product innovation capability, its path coefficient

Table 6 Test results of the research model

Hypothesis	Path	Path coefficient	*T* value	Test result
H11	Tax law mandatory → Follow cost effect	0.27	3.16	Supported
H12	Tax law mandatory → Value compensation effect	0.31	4.16	Supported
H21	Tax law rationality → Follow cost effect	0.26	2.98	Supported
H22	Tax law rationality → Value compensation effect	0.35	5.19	Supported
H31	Follow cost effect ← Green process innovation capability	−0.26	3.38	Supported
H32	Follow cost effect ← Green product innovation capability	−0.30	7.29	Supported
H33	*Follow cost effect ← End-treatment innovation capability*	*−0.05*	*1.01*	*Not supported*
H41	*Value compensation effect → Green process innovation capability*	*0.06*	*1.72*	*Not supported*
H42	*Value compensation effect → Green product innovation capability*	*0.04*	*1.29*	*Not supported*
H43	Value compensation effect → End-treatment innovation capability	0.28	3.91	Supported

"→" represents positive promoting effect; "←" represents reverse inhibition effect

Table 7 Research model test goodness-of-fit indices

Fit index type	Fit index name	Fit index value
Absolute fit index	χ^2/df	1.829
	GFI	0.906
	AGFI	0.937
	RMSEA	0.027
Relative fit index	NFI	0.911
	TLI	0.930
	CFI	0.978
Information standard index	AIC	108.19
	CAIC	89.36
	ECVI	0.343

is 0.04 and the t value of 1.29 is less than 2. Therefore, the hypothesis is not significant and does not pass the test.

The goodness-of-fit index is shown in Table 7, and the fit index values of each index are within a reasonable range. In the absolute fit exponent, χ^2/df represents the chi-square-to-degrees of freedom ratio. When the value is strictly less than 3, the sample quality meets the requirements, and there is no error in the model test. According to Table 7, the index of the study model is 1.829, i.e., strictly less than 3, which meets the requirements. The GFI is the goodness-of-fit index, which is greater than 0.9 for the study model. According to Table 7, GFI = 0.906 meets the requirements. The AGFI is the adjusted goodness-of-fit index, which is the GFI after excluding the degrees of freedom. The closer the value is to 1, the better the research model fits the economic reality. In Table 7, AGFI = 0.937 meets the requirements. The RMSEA is the root mean square error of approximation and is the square root of the sum of asymptotic residual squares. The smaller the value is, the closer the reality. In Table 7, RMSEA = 0.027 meets the requirements.

In the relative fitting index, the NFI is the normed fit index, which represents the difference between the independent models of the hypothetical model and no correlation relationship in the variables. The greater the difference is, the more closely the model fits the economic reality. The TLI, the Tucker–Lewis index, is the cancellation of the value range of the NFI, which also represents the difference between the hypothetical model and the independent model. The CFI, which is the comparative fit index, is obtained when comparing the hypothetical model and the independent model. The closer the value is to 1, the better the model fit. The NFI, CFI and TLI values in Table 7 are all close to 1, within a reasonable range.

In the information criterion index, the AIC is the Akaike information criterion, which represents the evaluation of the model overfitting problem, and the CAIC is the consistent Akaike information criterion, which represents the evaluation of the model fitting problem after considering the sample size. The ECVI is the expected cross-validation index. The smaller the value is, the better the consistency between different samples, and the better the predictive validity of the model. The smaller the three indices above are, the better, and the AIC, CAIC and ECVI values in Table 7 are all within the reasonable range.

The research model test effect is good, and no model correction is needed.

In conclusion, the final test results of the research model are shown in Fig. 2. The solid line represents the research hypotheses that pass the test, while the dashed line represents the research hypotheses that fail the test. According to the test results, Hypotheses H11, H12, H21, H22, H31, H32 and H43 pass the test, while Hypotheses H33, H41 and H42 do not pass the test.

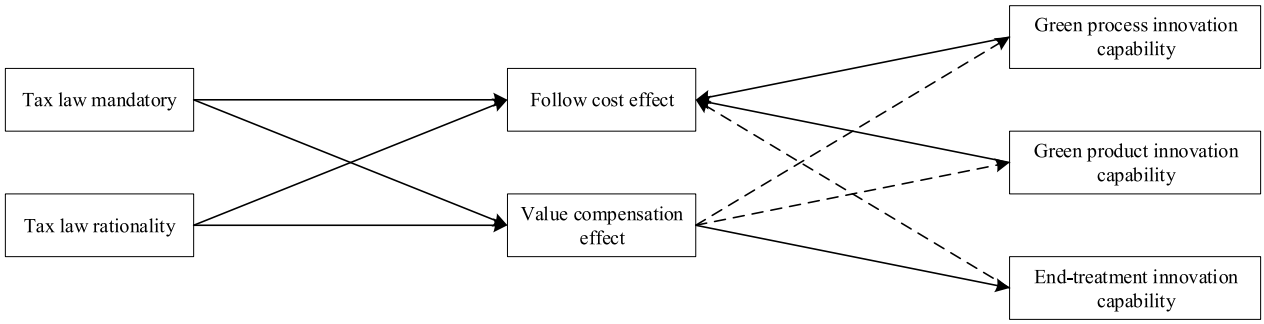


Fig. 2 Results of the research model testing. "→" represents positive promoting effect; "←" represents reverse inhibition effect

Discussion

In this study, structural equation modelling was used to test the environmental regulation effect of the Environmental Protection Tax Law under strict pandemic control. The results show that some of the hypotheses did not pass the empirical test, which indicates that under strict pandemic control, the Environmental Protection Tax Law was not effectively implemented, which had a negative impact on the development of enterprises' green technological innovation ability. Past research has focused more on the environmental regulation effect of environmental protection taxes in a stable state [12, 16, 61]. The factors influencing green technological innovation have been discussed from several perspectives [14, 38]. At the same time, it has also been found that environmental regulation can significantly promote green technological innovation under high economic development [21]. However, the effectiveness of environmental regulation under sudden crises has not been discussed. Based on deficiencies in the implementation process of the Environmental Protection Tax Law under strict pandemic control, the environmental regulation effect can be better promoted, and then, the green technological innovation ability of enterprises can be improved.

The results show that the mandatory nature and effectiveness of the Environmental Protection Tax Law effectively promote the follow cost effect and value compensation effect of environmental regulation, and the rationality and mandatory nature of the tax law pass the test path of the follow cost effect and value compensation effect. The mandatory nature ensures that enterprises must complete green production and operations based on the requirements of the Environmental Protection Tax Law, while the rationality of the Environmental Protection Tax Law improves the initiative of enterprises and effectively ensures capital investment in enterprise green technological innovation. Green process innovation ability and green product innovation ability effectively promote the realization of the follow cost effect. The reason is that the green innovation of technology and industry can help enterprises obtain more significant consumer recognition and improve their social reputation. For the market, the evaluation of the green innovation ability of enterprises mainly depends on the evaluation of products. In the context of green consumption, products with more green attributes are more likely to obtain the favour of the market, thus forming the competitive advantage of the green market of enterprises. Therefore, under strict pandemic control, enterprises can gain the right to survive through green products to reverse promote the realization of the follow cost effect of the Environmental Protection Tax Law. The results show that Hypothesis H33 regarding the follow cost effect on end-treatment innovation ability failed the test. For enterprises, end-treatment management is more like the maintenance of public goods such as the environment, which will consume a large amount of resources of enterprises and cannot bring economic benefits. Under strict pandemic control, the survival pressure of enterprises increases sharply, which affects the attitude of enterprises towards the end-treatment management. At the same time, because end-treatment innovation cannot be reflected in enterprise products, it is impossible to attract consumers. Therefore, enterprises are more inclined to violate the Environmental Protection Tax Law to retain more funds to maintain production and operation activities. Therefore, end-treatment innovation ability cannot significantly promote the follow cost effect.

According to the test results, the value compensation effect (H41 and H42) on the promoting effect of green process innovation ability and green product innovation ability did not pass the test. Resource-based companies need innovation to reduce operating costs, but this innovative behavior is difficult to achieve under strict control [8]. Under strict pandemic control, the normal production and operation activities of

enterprises are seriously threatened, resulting in great pressure for survival. The environmental cost generated by the Environmental Protection Tax Law further aggravates the survival crisis of enterprises, and the rate of increase of the value of resources and the environment exceeds the value added rate brought by the technological innovation of enterprises. Because the realization of green technological innovation is a relatively long-term process, enterprises need to continuously invest resources, and the results are uncertain. Although enterprises adopt technological development to improve their production efficiency under the requirements of environmental regulations, the final result fails to meet the expectations under the background of strict pandemic control. The promoting effect of the value compensation effect on the end-treatment innovation ability passes the test. Under the strong requirements of local governments, environmental protection agencies and tax authorities, enterprises with a large number of pollutants will face a greater cost burden. To reduce the comprehensive cost of enterprises, enterprises will invest resources to improve their pollution control technology and compensate for the cost of pollution discharge through end-treatment innovation ability.

According to the results of the model test, the environmental regulation utility of the Environmental Protection Tax Law has been partially realized, but due to the intensified survival crisis of enterprises under the background of strict pandemic control, the Environmental Protection Tax Law cannot fully mobilize enterprises' enthusiasm for green technological innovation, and the utility of the Environmental Protection Tax Law is negatively impacted. Because previous studies do not take into account sudden events and lack consideration of the living environment of enterprises, the effective implementation of the Environmental Protection Tax Law in traditional conclusions is conducive to realizing the green technological innovation ability of enterprises. However, according to the research in this paper, the effectiveness of this law is threatened under a sudden crisis, and it cannot give full play to enterprises' enthusiasm for green technological innovation.

Conclusions and policy implications

Research conclusions

This study takes the tax law mandatory and rationality as independent variables, the follow cost effect and value compensation effect as intermediary variables, and the green process innovation capability, green product innovation capability, and end-treatment innovation capability of enterprises as dependent variables, and constructs a structural equation model (SEM) containing 10 causal paths to verify the mechanism of environmental protection tax law on enterprises' green technology innovation capability. The results of the research model show that the effectiveness of China's Environmental Protection Tax Law decreased under strict pandemic control and that it is difficult to improve the green technological innovation ability of heavily polluting enterprises. The mandatory nature and rationality of the tax law can facilitate the realization of the follow cost effect and value compensation effect. In the model test results, the path coefficient is lower than 0.2, T-value is less than 2.0 indicates that the path cannot pass the test of significance, that is, the hypothesis represented by the path is not valid, path coefficients and *T*-value of the positive and negative on behalf of the positive promotional effect and reverse inhibitory effect, and does not affect the value of the significance of itself. Hypotheses H11 (Tax law mandatory → Follow cost effect, Path coefficient = 0.27 > 0.2, T value = 3.16 > 2.0), H12 (Tax law mandatory → Value compensation effect, Path coefficient = 0.31 > 0.2, T value = 4.16 > 2.0), H21 (Tax law rationality → Follow cost effect, Path coefficient = 0.26 > 0.2, T value = 2.98 > 2.0), and H22 (Tax law rationality → Value compensation effect, Path coefficient = 0.35 > 0.2, T value = 5.19 > 2.0) are subjected to model testing. The existing system of environmental protection under the mandatory nature and rationality of the tax law has a certain effect because green technological innovation can form innovation compensation, and the environmental tax operating cost is not more than the enterprise cost limit, ensuring that enterprises take positive measures to deal with environmental taxes. For the follow cost effect, Hypotheses H31 (Follow cost effect ← Green process innovation capability, |Path coefficient = −0.26| > 0.2, T value = 3.38 > 2.0) and H32 (Follow cost effect ← Green product innovation capability, |Path coefficient = −0.30| > 0.2, T value = 7.29 > 2.0) pass the test, and Hypothesis H33 (Follow cost effect ← End-treatment innovation capability, |Path coefficient = −0.05| < 0.2, T value = 1.01 < 2.0) fails to pass the model test, indicating that green process innovation ability and green product innovation ability inhibit the follow cost effect, while end-treatment innovation ability promotes the follow cost effect. These results show that under the background of strict pandemic control, to reduce operating costs, heavily polluting enterprises are more willing to reduce their investment in production technology and products themselves, to reduce green innovation, and to reduce R&D investment by maintaining the original technology to ensure their production capacity. Heavily polluting enterprises are more willing to use end-treatment innovation ability to avoid an increase in business costs. For heavily polluting enterprises, the adjustment of end-treatment innovation ability is better

recognized by environmental protection authorities, and the resulting costs can be offset by environmental taxes. Green process innovation ability and green product innovation ability involve the entire production process of heavily polluting enterprises, and for cost-saving reasons, they will give up innovation in related areas and thus maintain their existing production technologies at the cost of environmental taxes, thus safeguarding their own profits.

Based on the value compensation effect, the current tax rate standard of the Environmental Protection Tax Law does not urge heavily polluting enterprises to improve their green technology innovation ability. Hypotheses H41 (Value compensation effect → Green process innovation capability, Path coefficient = 0.06 < 0.2, T value = 1.72 < 2.0) and H42 (Value compensation effect → Green product innovation capability, Path coefficient = 0.04 < 0.2, T value = 1.29 < 2.0) fail to pass the test, which shows that under the background of strict market control, the value compensation effect of environmental protection taxes has not been brought into play, and the cost brought by environmental protection taxes greatly accounts for the resources used by enterprises for technological innovation. The aggravation of the survival crisis makes it impossible for enterprises to use the technological advantages obtained by green technological innovation to compensate for research and development costs. As the realization of innovative technology takes time, especially improvements in process innovation and product innovation ability, enterprises need to invest large amounts of funds. Under the pressure of survival, enterprises will adopt conservative strategies to deal with the market crisis, and reducing investment in green technological innovation is an effective way. The value compensation capacity brought by the environmental protection tax does not meet the consumption caused by technological innovation. Thus, heavily polluting enterprises prefer to use improvements in end-treatment innovation ability to obtain value compensation, Hypotheses H43 (Value compensation effect → End-treatment innovation capability, Path coefficient = 0.28 > 0.2, T value = 3.91 > 2.0) pass the test. By optimizing end-treatment innovation ability, the pollutant emissions of enterprises can be significantly decreased, and the tax standard of the environmental protection tax is measured based on the pollutant emissions of enterprises. Therefore, enterprises can reduce their tax payment to obtain more direct value compensation.

Therefore, the inhibitory effect of the follow cost effect on end-treatment innovation ability is not significant, and the promoting effect of the value compensation effect on green process innovation ability and green product innovation ability is not significant. On this basis, it is found that during the period of strict pandemic control, the control ability of environmental protection taxes on heavily polluting enterprises in the country was weakened, and the green technological innovation ability of enterprises was likewise not developed. The environmental regulation effect of the environmental protection tax was not exerted. Under the background of strict pandemic control, enterprises have to take a negative attitude to try to deal with the environmental protection tax, reduce the technical input in the product production process, and use end-treatment technological innovation to reduce pollutant emissions to achieve the purpose of reducing environmental taxes. Although the environmental protection tax under the background of strict pandemic control maintains the promoting effect of the value compensation effect and the follow cost effect, it has great defects in promoting the green technology innovation ability of enterprises. After the release of the regulation, the setting of the environmental protection tax needs to be adjusted based on the implementation experience to ensure the effectiveness of the environmental tax and realize the coordinated development of the economy and the environment.

Policy implications

Based on the results of the research model test, combined with the investigative understanding of the implementation of China's Environmental Protection Tax Law, the following directions can be proposed for promoting and improving the regulatory focus of China's Environmental Protection Tax Law after the end of strict pandemic control.

First, according to the overall model test results, compared to 2018 and 2019 before pandemic control, during the three-year period of strict pandemic control, the innovation compensation effect of China's Environmental Protection Tax Law was significantly weakened, resulting in a decline in the overall regulatory function, which should attract the attention of government and society. In the first two years of implementation of the Environmental Protection Tax Law, the innovation compensation effect was significantly greater than the follow cost effect, which was reflected in the growth of enterprises' green competitiveness and the simultaneous promotion of energy savings and emission reduction and the performance improvement of enterprises. However, during the 3-year period of strict pandemic control, the innovation compensation effect was severely weakened, while the follow cost effect still existed. Therefore, the innovation compensation effect could no longer compensate for the follow cost effect, resulting in the loss of sustainable development potential, although enterprises achieved some of the functions of cleaner production.

If enterprises fall into this dilemma for a long time, their core competitiveness will decline, and they will have to reduce their investment in waste disposal, which will not only make the value compensation effect disappear but also make the follow cost effect fail and ultimately cause the Environmental Protection Tax Law to lose its expected regulatory effect. To strengthen the innovation compensation effect, the environmental protection tax needs to change the excessive reliance on punishments to ensure that enterprise promote green technological innovation. On the basis of the existing enterprise tax rate, enterprises' green technological innovation performance is responsible for enterprises' preferential tax rate, thus alleviating the pressure of enterprise innovation capital investment and helping enterprises complete technological innovation faster to compensate for innovation.

Second, China's Environmental Protection Tax Law was strongly implemented during the three-year period of strict pandemic control, effectively restraining the environmental damage behaviour of heavily polluting enterprises. According to the test results, Hypothesis H11, H12, H21, and H22 passed the test, it is clear that the mandatory nature and rationality of the tax law stimulate not only the follow cost effect but also the value compensation effect. This shows that China's environmental protection and taxation law enforcement officers were still dedicated to their duties during the pandemic control period. On the other hand, under the supervision of environmental protection and taxation departments, heavily polluting enterprises have not only invested a large amount of money in the treatment of pollution emissions but also invested a certain amount of money in green technological innovation in an attempt to improve their green economic effect. These environmental investments failed to achieve the set targets mainly due to the constraints of pandemic control on supply, production and marketing, which imposed layers of resistance to the cultivation of green technological innovation ability. During an outbreak, to further guarantee green economic development, the implementation of environmental protection taxes needs to give the tax department certain autonomy, in view of the managed control of serious enterprise breaks, and based on enterprises' green behaviour share, enterprises can restore economic vitality from strict controls and want to ensure the authority of the environmental protection tax so that green enterprises guilty of violations receive a higher degree of punishment.

Third, China's Environmental Protection Tax Law has failed to effectively promote the growth of green technological innovation in heavily polluting enterprises, and thus, it has failed to effectively promote the sustainable development of heavily polluting enterprises. According to the test results, heavily polluting enterprises invest a large amount of money in emission control, which restricts the growth of green process innovation ability and green product innovation ability, showing an obvious follow cost effect. On the other hand, although heavily polluting enterprises invest a certain amount of money in technological innovation, they fail to significantly improve their green process innovation ability and green product innovation ability and fail to show an obvious value compensation effect. The Environmental Protection Tax Law has enhanced the capital investment of heavily polluting enterprises in environmental protection but failed to enhance their market competitiveness. Therefore, to better guide enterprise green technological innovation, on the basis of the existing environmental protection tax, the measure of green products should be strengthened because the enterprise production process and production product pollution set tax standards to encourage enterprises to strengthen their green technological innovation while strengthening the supervision mechanism and preventing enterprises from avoiding a drift away from green behaviour due to the environmental protection tax.

Fourth, the Environmental Protection Tax Law's promoting effect on the technological innovation of heavily polluting enterprises occurs only in the initial stage, and breakthroughs are needed in regard to difficult technological innovation. According to the test results, Hypotheses H31, H32, and H43 pass the test and H33, H41, and H42 fail the test, under the follow cost effect and value compensation effect, the Environmental Protection Tax Law obviously promotes an increase in heavily polluting enterprises' end-treatment innovation ability but fails to effectively promote an increase in green process innovation ability and green product innovation ability. According to the experience of environmental protection laws around the world in promoting technological innovation, the growth of end-treatment innovation ability is generally the first to be achieved, while there is greater difficulty in the growth of green process innovation ability and green product innovation ability. Therefore, China's Environmental Protection Tax Law still has a long way to go to promote technological innovation. To better promote the green technological innovation ability of enterprises, the Environmental Protection Tax Law should draw on the advanced experience of other countries and regions and optimize and adjust the existing environmental protection tax in combination with the stage of domestic technological development. At the same time, through the establishment of a green technological innovation sharing platform to support enterprises that lack green innovation ability, with the help of the technical resources and capital resources of different

enterprises, group advantages can be gathered to jointly develop green technology to reduce the survival pressure on enterprises, and government departments can act as third-party supervision agencies to ensure the effectiveness of the sharing platform.

Fifth, after the end of strict pandemic control, improving and deepening the regulation of China's Environmental Protection Tax Law need the joint promotion of the whole society. Despite the end of three years of strict pandemic control, pandemic prevention is not over yet. Humans are exploring ways to live with the virus. Under this situation, the regulation of the Environmental Protection Tax Law needs to be improved by the government, enterprises, people and social organizations, and it cannot just rely on the efforts of environmental protection agencies and tax agencies. The effective implementation of the Environmental Protection Tax Law needs to be based on a reasonable political, economic, social and cultural environment, the continuity of policies, the consciousness of enterprises, the supervision of the public and the extensive participation of various economic subjects. Therefore, the reform of the Environmental Protection Tax Law needs to conform to the tide of the times instead of standing still.

Sixth, the government should establish a more flexible environmental protection tax system and formulate more matching environmental regulation policies based on the characteristics of enterprises. According to the model test results, the mandatory nature and rationality of the tax law can effectively promote the process of enterprise technological innovation. However, due to the different development stages, business operations and technical characteristics of different enterprises, the rigid use of the unified environmental protection tax is not conducive to promoting the green technological innovation of enterprises. Therefore, it is necessary to establish a more flexible environmental protection tax system and formulate environmental protection tax standards that are more suitable for enterprises to develop green technology based on the technical field and development stage of enterprises. The purpose of establishing the environmental protection tax is to control the emission of pollutants and to promote the green technological innovation of enterprises. Only by deeply combining with enterprises can the purpose of promoting green innovation through taxes be achieved.

Limitations and future prospects

Using qualitative and quantitative analysis methods and structural equation modelling, this paper investigates the environmental regulation effects of the Environmental Protection Tax Law in China under strict pandemic control. It also analyses the mandatory nature and rationality of the tax law as well as the follow cost effect and value compensation effect they generate. However, this study has the following limitations. (i) The sample data size is small, and the sample size of different regions cannot highlight various geographical features. Thus, a larger sample survey is needed. (ii) The content of the data survey lacks the participation of government units, which are the executive units of the Environmental Protection Tax Law and are more aware of the specific implementation of the environmental tax and the difficulties that exist. (iii) There is a lack of analysis of the increased survival cost of enterprises during the pandemic after the implementation of the environmental tax. Faced with severe pandemic prevention and control requirements, the survival cost of enterprises increased sharply, which to some extent hindered the enhancement of their green technological innovation ability.

Future research will focus on ways to improve enterprises' green technological innovation ability under the Environmental Protection Tax Law. According to the conclusions of the study, strict pandemic control seriously hindered the Environmental Protection Tax Law from improving the innovation ability of enterprises, while future world competition is more biased towards the competition of innovation ability. Therefore, the survival of enterprises needs to rely on green technological innovation to achieve the harmonious development of the economy and the environment.

Author contributions
WZ responsible for designing research proposals and writing articles; ZJ responsible for proposing research topics, designing paper framework and revising paper; CM responsible for technical support and guidance. All authors reviewed the manuscript.

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Declarations

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