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Which is More Effective: The Carrot or the Stick? Environmental Policy, Green Innovation and Enterprise Energy Efficiency–A Quasi-Natural Experiment From China

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As the concept of carbon neutralization is valued, attention is paid to how environmental protection policies affect enterprises. However, little is known about how environmental policies affect enterprise energy utilization efficiency and green innovation. Based on Porter's effectuation and deterrence theory, this paper proposes that an incentive environmental protection policy (environmental protection incentive) and punitive environmental protection policy (environmental protection regulation) have different impact mechanisms on enterprise green innovation and energy utilization efficiency. The following conclusions are drawn by using the data of listed enterprises since implementing the new environmental protection law in China and using the PSM-DID method to construct a quasi-natural experiment. 1) Environmental protection incentives are not conducive to improving energy utilization efficiency; 2) Environmental protection regulation can improve enterprise energy utilization efficiency; 3) Environmental protection incentives are not conducive to green innovation; 4) Environmental protection regulation is conducive to the green innovation of enterprises; 5) Green innovation plays a complete intermediary role in the relationship between environmental protection policies and enterprise energy utilization efficiency; 6) Different policies have heterogeneity on Enterprises: environmental protection incentives are conducive to the improvement of energy utilization efficiency of state-owned enterprises but not conducive to non-state-owned enterprises; The effect of environmental protection regulation on non-state-owned enterprises is more potent than that of state-owned enterprises. This study compares the impact of different environmental protection policies on enterprise green innovation and energy utilization efficiency and puts forward more effective and realistic targeted policy suggestions. This paper tries to understand the policy mechanism through comparison; The government has promoted green innovation and efficient and clean production by implementing policies for enterprises.

Keywords: green innovation, environmental subsidies, environmental regulation, enterprise energy efficiency, PSM-DID

INTRODUCTION

With the development of China's economy, China's environmental quality is challenged (Wang, 2018). The increasingly severe environmental pollution harms people's lives and health and hinders the healthy development of the economy (Hao et al., 2017). Facing the environmental challenges in this emerging economy, the Chinese government has gradually increased its requirements for environmental protection and paid more attention to environmental treatment. The government began to guide enterprises to carry out cleaner production. For enterprises, high energy consumption and high pollution result from excessive utilization of existing resources and low production efficiency (Linde, 1995). Therefore, research on how the government promotes enterprises to improve energy efficiency through behavior is urgent.

As the most significant emerging economy at present, China's government has issued many relevant policies on environmental protection. At present, China has formulated, promulgated, and implemented more than 20 environmental laws, more than 40 regulations, more than 500 standards, and more than 600 normative documents (Hsu, 2000). These policies can be structured into incentive policies and regulatory (punishment) policies when implemented in enterprises. It can put forward targeted regulations and requirements for environmental decisions of enterprises that do not comply with the requirements of environmental regulation and effectively control the pollution behavior of enterprises (Chen et al., 2018). The typical implementation mode of this policy in China is implementing China's new environmental protection law in 2015. According to the law, China will impose fines, suspend business for rectification, deal with pollution (Li and Wu, 2017). The environmental protection incentive is that the government promotes enterprises to achieve energy-saving and emission reduction through environmental subsidies and enterprise-oriented environmental innovation projects (Ren et al., 2021). Typical policies for environmental protection incentives take the policies of Shenzhen, China in 2019 as an example: The operating procedures for the special fund support plan for green and low-carbon industry development of Shenzhen ecological environment bureau is to standardize the management of special funds for the development of strategic emerging industries (green and low-carbon) in Shenzhen, to ensure the safe, scientific and efficient use of special funds, organized and implemented the special fund support plan for the development of green and low-carbon industries.

These two types of policies have different economic effects on enterprise production and innovation. Scholars analyze environmental problems from the "externality" of innovation, the "transaction cost" of the innovation process, the "information asymmetry" of enterprises, and the "free-rider tendency" within enterprises and other diverse perspectives (Anderson, 1992). However, they ignore the dynamic role of government external behavior and enterprise internal innovation. Regarding the relationship between environmental protection and economic growth and enterprise benefits, it is generally accepted that there is an inverted U-shaped relationship (Katircioglu and Katircioglu, 2018). Generally, people believe that the adverse impact of environmental pollution on the economy mainly includes the following two categories: 1) The structural effect of the transfer of pollution-intensive industries from developed countries to developing countries; 2) Green technology innovation is conducive to the efficient use of energy (Yi et al., 2019).

Porter hypothesis analyzes the role of government environmental policy regulation on enterprise innovation (Porter and Linde, 1995). Porter hypothesis holds that the application of appropriate environmental regulation can promote enterprises to carry out more innovation activities, improve the productivity of enterprises, and finally offset the costs brought by environmental regulation. The discussion on the existence of Porter effectuation in the existing literature has not reached a unified conclusion in the academic research of developed countries. At the same time, it has not reached a unified conclusion in emerging economies such as China (Wei et al., 2021). The spillover effect of Porter hypothesis is also worth considering. In other words, in government behavior, in addition to the impact of environmental regulation on enterprise innovation, the impact of environmental protection incentives on enterprise innovation is also worth considering as the spillover effect of Porter effectuation. Unfortunately, there are few studies on the spillover effect of Porter effectuation from the perspective of government environmental protection subsidies.

In theory, many pieces of research suggest that green innovation is conducive to the efficient use of energy and the realization of cleaner production (Katircioglu and Katircioglu, 2018). However, this mechanism has not been proved in the market economy. There are various problems, mainly lies in: 1) When enterprises face the problems of environmental pollution and destruction, they often do not have an intuitive feeling about the consequences. Therefore, they lack to determine the direction and intensity of green innovation; 2) Green innovation has environmental externalities and innovation externalities, and its benefits may be less than investment. In the absence of environmental regulation and policy tools, enterprises often have no motivation for green innovation. 3) Green innovation is based on technology, ecology, and other disciplines. In the absence of policy encouragement and regulation, enterprises have a high risk of failure (Huang et al., 2018). Based on the above reasons, it is necessary to build a reasonable environmental policy system to guide enterprises to green innovation. Therefore, it is necessary to systematically study different environmental policy tools' impact mechanisms and practical effects on enterprise green innovation to improve enterprise energy utilization efficiency. In this way, we provide feasible evidence for formulating and perfecting existing environmental policies.

The differences in environmental policies have different influential mechanisms on the impact of enterprise green innovation and energy utilization efficiency. The theoretical basis of environmental regulation, especially punitive environmental regulation, is mainly analyzed from deterrence theory. Incentive environmental policy has an explicit influence process. Specifically, environmental regulations deter enterprises and promote cleaner production or transformation. Realizing cleaner production improves energy utilization and enterprise

production efficiency through technological innovation. This process presents a deterrent effect. The theoretical basis of the deterrent effect comes from the deterrent theory. In 1996, Harlan Ullman and James Wade Jr. believed that taking advantage of the asymmetric advantages of military forces such as information, technology, and vitality, taking sudden and rapid combat actions to carry out precision strikes against the enemy would produce a strong deterrent effect wholly and psychologically destroy the enemy's will to resist (Schaub, 2004). Deterrence theory is widely used in military affairs, food safety, collusion between government and enterprises, anti-corruption, etc. It is also applicable to the implementation of environmental policies. When enterprises conduct polluting production behaviors that do not comply with the provisions of environmental regulations, the government will crack down on enterprises through legal weapons, and punish enterprises by public opinion and economical means such as case publicity and social publicity, resulting in the reduction of economic benefits of enterprises, thus forming a deterrent effect.

This paper mainly answers the following three questions: 1) Do different environmental policy tools (especially for two policy methods: incentive and regulation) have a heterogeneous impact on the improvement of enterprise energy utilization efficiency? 2) What is the impact of green innovation on enterprise energy utilization efficiency? Can this impact promote cleaner production in enterprises? 3) Does the impact of different environmental policy tools have significant differences for heterogeneous enterprises (especially enterprises with different ownership)? In order to answer these three questions reliably, this paper divides environmental protection policies into two types: Environmental protection incentive and regulation, which represent reward and punishment. This paper quantifies the green innovation ability and energy efficiency of enterprises. Based on the data of all listed companies in China from 2016 to 2021, a quasi-natural experiment was constructed through the PSM-DID model to test the impact of different environmental protection policy tools on enterprise energy efficiency. We also analyzes the intermediary effect of green innovation in this mechanism.

This paper mainly has the following theoretical and practical contributions by answering the above three questions. 1) From a theoretical point of view, this paper analyzes the economic impact of Porter effectuation in China and the spillover effect of Porter effectuation from the impact of environmental subsidies on enterprise innovation and energy utilization efficiency; At the same time, from the analysis of the economic effect of environmental protection punishment in China, this paper expands the application boundary of deterrence theory; 2) Considering the results, compared with the predecessors, this paper newly found the positive effect of environmental protection regulation on enterprise innovation and energy utilization efficiency and verified Porter effectuation; At the same time, this paper analyzes the negative effect of environmental protection incentives on enterprise innovation and energy utilization efficiency; The heterogeneity of enterprises in the above mechanism is further analyzed, and interesting results are obtained; 3) From the perspective of practical significance: This paper provides a reference for the more effective construction of an environmental policy tool system.

The significance of this paper is to provide a valuable literature basis and research ideas for the policy impact mechanism of cleaner production and green innovation of Chinese enterprises by answering the above three questions. At the same time, it provides a reference for more effective construction of an environmental policy tool system. The following contents are arranged as follows: *Literature Review and Research Hypothesis* reviews the literature review and puts forward the research hypothesis; *Method and Empirical Model* introduces the method of this paper; *Data and Variable* describes the experimental data; *Empirical Result* analyzes the empirical results; In *Heterogeneity and Robustness Test*, the heterogeneity analysis and robustness test of the results are carried out. Finally, the conclusion explains the research conclusions and puts forward targeted policy suggestions.

LITERATURE REVIEW AND RESEARCH HYPOTHESIS

Policy Background

Countries around the world have issued relevant policies on promoting green development. At present, the pressure of climate negotiations worldwide, such as the Kyoto agreement and the Paris Agreement, makes developing countries hope to promote national green development through a broader range of cleaner production in their territory (Fankhauser et al., 2013). As the world's largest emerging economy, China has introduced a series of environmental protection policies in recent years to promote national development in the green direction (OECD, 2016). In 2015, China issued a new environmental protection law to restrict high-polluting enterprises in China to encourage cleaner production. In 2018, China hoped to enhance residents' awareness of environmental protection by promoting the lifestyle of waste classification at the public level. At the level of national awareness, China's political leaders frequently emphasize the importance of environmental protection in China and put forward China's goals of "carbon peak" and "carbon neutralization" in 2020.

As far as China is concerned, the environmental policies that have been issued are mainly environmental incentive policies and environmental regulatory policies. This paper reviews the environmental protection regulation policies from the implementation of China's New Environmental Protection Law in 2015. On April 24, 2014, the eighth session of the Standing Committee of the 12th National People's Congress voted and adopted an Amendment to the Environmental Protection Law. The new law was implemented on 1 January 2015. So far, the "basic law" in China's environmental field has been revised for the first time in 25 years. Its implementation scope includes various natural and artificially transformed natural factors affecting human survival and development in China. At the same time, local governments at all levels in China have the responsibility to exercise law enforcement power.

For enterprises, the "daily penalty" system is added in the New Environmental Protection Law, that is, daily and continuous fines for continuous environmental violations. This law means that the longer the violation lasts, the more fines will be imposed for illegal emission, excessive emission, and detection evasion. The fines for environmental violations stipulated in the previous law are fixed. The amount is not large, resulting in low illegal costs. Hence, many enterprises are lazy about pollution control. After implementing the "daily penalty" in the new law, the number of fines will not be capped, which will force illegal enterprises to correct their pollution behavior quickly. On 18 November 2018, the opinions of the CPC Central Committee and the State Council on establishing a more effective new mechanism for regional coordinated development further highlighted key regions, industries, and pollutants and effectively prevented ecological and environmental risks on the premise of adhering to the strictest system and the strictest rule of law to protect the ecological environment, strengthening environmental supervision in undertaking industrial transfer to prevent cross-regional pollution transfer. At the same time, local governments have issued relevant policies and measures to regulate environmental pollution. On 23 February 2022, the Beijing government announced Soliciting Opinions on the Measures for the Linkage Implementation of the Environmental Impact Assessment of Beijing Industrial Park Planning and Environmental Impact Assessment of Construction Projects (Trial) (Draft for comments). In industrial parks where the environmental quality meets the relevant assessment requirements of the state and the city and the environmental management system is relatively sound, the linkage reform of planned environmental assessment and project environmental assessment should be implemented.

This paper reviews the policies related to environmental incentives and environmental subsidies from the Eleventh Five-Year Plan (2016). During the Eleventh Five-Year Plan period (2006–2010), the importance of environmental protection has been increasing. The Eleventh Five-Year Plan takes energy conservation and environmental protection as the national development policy, aiming to save resources and the environment and encourage environmental innovation. In 2007, the Ministry of Finance issued the Interim Measures for the Administration of Special Funds for Emission Reduction of Major Pollutants of the Central Government, allowing Chinese provincial governments to formulate local environmental subsidy policies and establish a national fund for emission reduction of major pollutants. All provinces have issued related environmental subsidy policies. In 2010, China established a perfect national environmental subsidy system to encourage environmental innovation. The Twelfth Five-Year Plan period (2011–2015) is committed to strengthening these efforts. Local governments must gradually increase the budget of environmental subsidies in annual financial planning and improve capital investment and coverage of environmental subsidies. During the Twelfth Five-Year Plan period, the total investment in environmental protection exceeded 4.4 trillion yuan. According to the 2015 annual report of Chinese listed companies, 41.2% of Chinese listed manufacturing enterprises have received environmental subsidies. In some cases, these subsidies account for a large proportion of their total assets.

Regarding the economic mechanism of environmental protection incentives, China's environmental subsidies are distributed in centralized management and local implementation. The provincial government encourages enterprises to apply for these environmental subsidies. It then forwards their applications to the central government (such as the Ministry of Ecological Environment and the Ministry of Finance) for evaluation. Finance is jointly managed by the Ministry of Finance and the Ministry of Ecological Environment. The former is responsible for budgeting and managing funds, and the latter is responsible for evaluating and supervising funded environmental innovation projects. Funded projects are generally expected to be completed within 12 months and subject to government inspection within 3 months after completion. These environmental subsidies encourage enterprises to achieve the goal of reducing environmental pollution through environmental innovation. In essence, they help enterprises economically compensate enterprises for their expenditure on pollution control (Ren et al., 2021). At the same time, this subsidy is considered an incentive for enterprises to innovate in environmental protection to some extent (Tor, 2000).

Green technology is the general name of various processes and products that promote the efficient utilization of resources and energy (Yi et al., 2019). The realization process of green technology is called the green innovation process. This innovative process combines ecological and environmental protection with economic development. The nature and practical utility of green innovation determine that green beds are a crucial way to fundamentally solve the problem of cleaner production and realize social benefits. At the same time, this technology is also a meaningful way to promote green development. Green technological innovation and practice is the way for technological innovation to adapt to the ecosystem, including the whole process of putting forward the concept of green technology R&D achievement transformation and practice (Song and Wang, 2018). The research and development of green technology and its application in production are conducive to improving the utilization efficiency of existing energy and promoting enterprises to achieve efficient production. In particular, if green technology is advanced, it can achieve synergy between green development and economic development and promote the joint development of enterprises and the environment.

As an essential part of the regional economy, enterprises are a driving force for green innovation. According to the production value chain theory, enterprises have accumulated many resources such as capital, human capital, and market advantages and have the strength to carry out green innovation. However, under the condition of the modern market economy, due to the risks and costs of green innovation, enterprises do not have the power to carry out green innovation (Huang et al., 2018). For the above reasons, the Chinese government has issued relevant policies in recent years to promote the green innovation of enterprises. As is stated above, the most common are mainly two categories: 1) Environmental protection incentive: in the form of

environmental protection subsidies that encourage enterprises that tend to carry out green innovation or cleaner production; 2) Environmental protection regulation: enterprises are forced to carry out green innovation to realize cleaner production by setting pollution emission standards and carrying out regular inspections and punishment.

Theoretical Review and Analysis

Porter Hypothesis

Porter hypothesis analyzes the role of government environmental policy regulation on enterprise innovation (Porter and Linde, 1995). Porter hypothesis holds that the application of appropriate environmental regulation can promote enterprises to carry out more innovation activities, improve the productivity of enterprises, and finally offset the costs brought by environmental regulation. Existing studies generally believe that the impact of environmental regulation on enterprise innovation is different in different situations and countries (Ambec et al., 2013). Some scholars have verified Porter hypothesis and affirmed the existence of Porter effectuation. They believe that for enterprises, environmental regulation can restrain the pollution emission behavior of enterprises and promote enterprises to approach the innovative behavior of reducing pollution emissions through punitive measures (Fabrizi et al., 2018). From the perspective of the 2018 air refinery act, (Berman and Bui, 2001), Found that it can improve the production quality of oil refineries in the United States.

Similarly, from biofuels, it has been proved that the introduction of the environmental bill has improved the production efficiency of enterprises (Costantini et al., 2015). In emerging economies, Porter effectuation has also been confirmed in some studies. Environmental regulation has always been one of the guiding directions of green innovation in different regions of China to promote green growth (Wang et al., 2019).

Analogously, environmental regulation promotes the innovation behavior of enterprises (Hille and Möbius, 2019), and it also guides the innovation behavior of enterprises (Ma et al., 2019). Environmental regulation validates Porter's hypothesis and validates the pollution paradise hypothesis (Ranocchia and Lambertini, 2021). This game process also promotes the realization of Porter hypothesis (Li et al., 2018).

However, other researchers reject the Porter hypothesis. The environmental protection innovation behavior of enterprises is contrary to the principle of enterprise production and operation: profit maximization (Palmer and Portney, 1995). The existing empirical results show that environmental regulation does not help improve the competitiveness of enterprises (Stoever and Weche, 2018). Empirical results in emerging economies also verify this statement. Wang et al. (Wang et al., 2017) found that environmental regulation undermines the development of the rare Earth market, which is harmful to the productivity improvement of the rare Earth enterprises.

Based on a systematic review of Porter hypothesis and the Porter effectuation, this paper attempts to analyze whether Porter effectuation still exists in the case of increasingly strict environmental regulation in China, an emerging economy. In addition, whether there is a spillover effect of Potter effect has not yet been verified for environmental incentives.

Deterrence Theory

The theoretical basis of the deterrent effect comes from the deterrent theory. In 1996, Harlan Ullman and James Wade Jr. believed that by taking advantage of the asymmetric advantages of military forces such as information, technology, and vitality, taking sudden and rapid combat actions to carry out precision strikes against the enemy would produce a strong deterrent effect wholly and psychologically destroy the enemy's will to resist (Schaub, 2004). Research on the impact of deterrence has been applied in law, criminology, sociology, social psychology, and other disciplines. At the same time, deterrence theory has also been applied in economics in recent years (D'arcy and Herath, 2011). In many fields, the punishment for criminal acts is gradually increasing its deterrent to criminal acts (Becker, 1968). Similarly, under the influence of fines and arrest probability, the probability of crime is also decreasing (Hansen, 2013). In economics, the theory of deterrence is applied to corporate corruption (Abbink and Renner, 2002), fraud (Nagin, 2003), and government supervision of enterprises (Friesen, 2012).

This paper attempts to apply deterrence theory to the innovation behavior and production efficiency improvement process of enterprises under the deterrence of government environmental policies to expand the application scope of deterrence theory.

Literature Review and Hypothesis

Environmental Protection Incentive, Green Innovation and Enterprise Energy Utilization Efficiency

Technological progress has a far-reaching impact on the natural environment of economic activities. New technologies may increase or reduce pollution. This concern about technological progress is inherent in economic development (Jaffe, 1995). Therefore, in recent years, environmental economy and policy research has taken technological progress as an endogenous variable to analyze the relationship between environmental policy and economic growth (Chen et al., 2016). Some related concepts are derived from the above concepts, such as ecological innovation (Fussler and James, 1997; Sanni, 2017) and environmental innovation (Rennings et al., 2006). In the past 20 years, the dynamics characteristics types driving factors and their impact on the economy and society of green technology innovation have been fully analyzed (Rennings, 2000; Chen et al., 2006; Wurlod and Noailly, 2016; Arfi et al., 2018).

Since 1990, the World Energy Council (WEC) has proposed "energy efficiency" for the first time (Ya-Xi and Wang, 2016). Many countries have begun to attach importance to the energy efficiency management of enterprises and continue to look for ways to improve energy efficiency (Sun et al., 2019). With the continuous consumption of global energy resources, a consensus has been reached that enterprises can reduce energy consumption and pollutant emissions and promote the development of environmental protection in the world by improving energy utilization efficiency. In order to realize the comprehensive evaluation of energy efficiency authoritative institutions of various countries, it applies to the evaluation index system of

enterprise energy efficiency (Besikci et al., 2016). In order to further study the energy efficiency level of enterprises, more and more scholars are taking enterprises as the research object for energy efficiency analysis. In order to provide theoretical support for enterprises to improve energy efficiency, scholars try to establish an evaluation index system (Wei et al., 2019). It is necessary to study the influencing factors of energy utilization efficiency from the micro-level of enterprises. In many evaluation systems, the role of enterprise innovation ability has been recognized. Unfortunately, few empirical studies on enterprise energy utilization efficiency lack analysis of enterprise environmental protection production mechanisms.

We clarify the importance of analyzing the influencing factors and interactions through the above review of green innovation and enterprise energy utilization efficiency. Next, we make assumptions about how environmental protection incentives and regulations affect them.

Agency theory shows that incentive measures are used for crucial agents at the top of the organization and impact all principals in each hierarchy of a given goal (Deutsch et al., 2011). However, the free-rider theory points out that incentives often cannot improve enterprise performance because employees can share the return of the improvement of joint output without paying more for themselves (Alchian and Demsetz, 1972). Therefore, incentive beneficiaries across different levels are more likely to achieve specific goals consistent with the whole organization (Welbourne and Gomez-Mejia, 1995). In reality, the government's purpose of environmental protection incentives for enterprises is to promote cleaner production and more intensive green innovation (Li Y. et al., 2020). In emerging economies such as China, a more extraordinary situation is that politically related enterprises are more likely to receive environmental protection subsidies (Lin et al., 2015). In other words, the corruption that this political connection may lead to is suspected (Kyle, 2018). Therefore, the effect of government environmental protection incentives may be hindered. From the perspective of enterprise cost, green innovation can be divided into active and passive. For enterprises that get environmental protection incentives, if there is no mandatory requirement to promote enterprises to carry out green technology innovation, enterprises tend to prefer non-innovation due to the uncertainty of technological innovation (Chen H et al., 2016). It is generally agreed that the green innovation and energy utilization efficiency improvement of enterprise production requires the tremendous efforts of the company's supply chain product design team and R&D personnel (Gulati et al., 2005). This effort from the top to the bottom of the enterprise R and D personnel is unwilling to invest because of increasing costs (Dahlmann et al., 2017). When there are no rigid constraints, enterprises do not improve their energy utilization efficiency after receiving environmental protection incentives.

Based on the above analysis, we propose hypothesis H1a - hypothesis H1d:

H1a: Environmental protection incentives cannot promote the improvement of enterprise energy utilization efficiency.

H1b: Environmental protection incentives cannot promote green innovation of enterprises.

H1c: Green innovation can positively promote the improvement of enterprise energy utilization efficiency.

H1d: Green innovation plays an intermediary role in the relationship between environmental protection incentives and enterprise energy utilization efficiency.

Environmental Protection Regulation, Green Innovation and Enterprise Energy Utilization Efficiency

Regarding environmental protection regulation policy, the most typical is "Porter Hypothesis" (Porter and Linde, 1995). It believes that appropriate environmental regulation will stimulate technological innovation and bring "innovation compensation" and competitive advantage. Scholars have conducted a large number of empirical tests on Porter hypothesis.

Firstly, the view that environmental protection regulation can promote enterprise innovation has been confirmed by scholars (Yang et al., 2012); However, this view is questioned by some empirical evidence. For example, through theoretical research, Ramanathan et al. show that strict environmental regulation does not significantly promote technological innovation of enterprises because the enterprise does not have enough power and efficiency to make up for the cost of environmental management, leading to the decline of enterprise profits (Ramanathan et al., 2010). At the same time, higher pollutant emission prices will reduce the innovation of enterprises in emission reduction technology, and the relationship between environmental protection regulation and enterprise innovation is nonlinear (Calel, 2011; Vollebergh and Werf, 2013).

In enterprises, the impact of environmental regulation on enterprise innovation is more reflected in the impact on green enterprise innovation. In order to refine our research object, we need to review the green innovation of enterprises. Green innovation is divided into developmental and exploratory green innovations (Sun and Sun, 2021). In terms of the economic effects of green technological innovation, green technological innovation has dual externalities of environmental externality and innovation externality (Rennings, 2000). At the same time, environmental regulation helps technological innovation and positively affects product innovation (Chan H et al., 2016). Existing studies believe that because the negative externality of green technology innovation is the characteristic of most environmental problems and the market incentive degree of green technology innovation is lower than that of other innovations, the government's environmental protection regulation will be conducive to green innovation (Horbach, 2008). The innovation of green technology is conducive to improving enterprises' environmental performance and reducing the energy consumption per unit output (Sun et al., 2021). Therefore, green technology innovation will be conducive to the improvement of enterprise energy utilization efficiency at the same time.

Based on the above analysis, this paper puts forward the hypothesis H2a–H2d:

H2a: Environmental protection regulations promote the improvement of enterprise energy utilization efficiency.

H2b: Environmental protection regulations promote green innovation of enterprises.

H2c: Green innovation can positively promote the improvement of enterprise energy utilization efficiency.

H2d: Green innovation plays an intermediary role in the relationship between environmental protection regulation and enterprise energy utilization efficiency.

METHOD AND EMPIRICAL MODEL

Method

In order to study the policy effects, most of the existing literatures use the DID model. DID model, especially dynamic DID model, has the advantage of grouping samples to evaluate the effect of policy. However, considering the following two reasons, directly comparing enterprises implementing environmental protection regulations or incentives and enterprises that have not implemented environmental protection regulations or incentives as "treatment group" and "control group" may lead to deviations in results.

(1) The non-randomness of environmental protection incentive and regulation cannot be ruled out. On the one hand, most of the enterprises encouraged by environmental protection are concentrated in the new energy and environmental protection industries; Most of the enterprises selected for environmental protection regulation are concentrated in industries with high pollution and high energy consumption. On the other hand, in China, the choice of listed companies encouraged by environmental protection is very accidental, which is related to the political background of senior executives in some cases.
(2) There are many influencing factors of environmental protection regulation and incentive, non-environmental protection regulation and incentive. These factors lead to the "treatment group" and the "control group" cannot meet the common trend hypothesis of DID model, and may also causes deviations in the empirical results.

Based on this, the paper refers to method of Löschel et al. using the PSM-DID model for estimation. This paper studies the green innovation and energy efficiency of enterprises from two aspects: Environmental protection incentive and regulation. Compare their different effects, so we carried out the same steps twice in the empirical process. The only difference is that we changed the variables and constructed different new samples, and the formulas and procedures are the same. Due to space limitations, this paper only shows the formula of environmental protection incentive in the method part, and all the results will be shown in the result part.

Firstly, we use the propensity score match (PSM) to find the "control group" similar with enterprises that receive environmental protection incentive subsidies to eliminate the selectivity of samples, so that the "treatment group" and the "control group" have a common trend. Then, the real policy effects of environmental protection incentive subsidies, including the effect on enterprises' green innovation incentive and improvement of energy efficiency, are estimated with DID method, which can ensure the accuracy of empirical results to a large extent. The same method is adopted for the policy effects of environmental protection regulations. The matching process is as follows.

First, the propensity scores of the "treatment group" and the "control group" were estimated based on the Logit model. The aim is to facilitate the matching of subsequent tendency scores. As shown in **Eq. 1**:

$$P(X) = \Pr(T = 1|X) = \frac{\exp(d\beta x)}{1 + \exp(d\beta x)} \tag{1}$$

where, $X = (x_1^{'}, x_2^{'}, x_3^{'}, \ldots, x_n^{'})'$ is the control variable matrix, $x_i^{'}$ is the i-th control variable vector. Referring to existing research, we choose firm size (Size), age (Ages), asset-liability ratio (Leverage), ownership structure (SOE), and ownership concentration (COCEN) as control variables. P(X) is the propensity score of the "treatment group" and the "control group" under the control variable matrix X.

Second, the "treatment group" and the "control group" are matched or resampled according to the matching method. The purpose is to calculate the distance or weight between the "treatment group" and the "control group" sample by the propensity score, and then find the counterfactual sample similar to the "treatment group" from the "control group". This paper uses the nearest neighbor matching method by R studio. The specific process is shown in **Eq. 2**:

$$D(m,n) = \min_{n} \left| p_{1j} - p_{0j} \right| \leq \varepsilon \tag{2}$$

where P_{1i} and P_{0j} are the propensity scores of the i-th "treatment group" and the propensity score of the j-th "control group", respectively, and ε is a predetermined tolerance for matching or a caliper. In this paper, according to Kau and Rubin (1985), one-quarter of the standard deviation of the propensity values of the sample estimates is used as the caliper size (namely $\varepsilon \leq 0.25\ \sigma$, where σ is the standard deviation of the propensity value of the sample estimate).

Third, a balanced test is performed on the matched samples. The aim is to ensure that there is no significant statistical difference in covariates between the "treatment group" and the "control group" after matching. Generally, it is examined by t-test analysis and "standardized bias" of each covariate, as shown in **Eq. 3**:

$$\frac{\left| \overline{x_1} - \overline{x_0} \right|}{\sqrt{S_{1x}^2 + S_{1x/2}^2}} \tag{3}$$

where s_{1x}^2 and s_{0x}^2 are the sample variances of the "treatment group" and "control group" covariates x, respectively. It is generally required that this standardization gap does not exceed 10%, and if it is exceeded, the second or first step is repeated until there is no significant difference.

Finally, the matched samples are used for DID estimation. The purpose is to estimate the impact of environmental protection incentives and regulations on enterprises green innovation and energy efficiency, on the basis of eliminating the shortcomings of sample non-random selection.

Empirical Model

Based on the above research method, in order to test the research hypothesis H1 and hypothesis H4, the model (4) is set in this paper. This is because both environmental protection incentives and regulations are binary variables, and only the variables need to be replaced in the test. Limited by space, this paper puts them in the same formula to achieve the goal of more conciseness.

$$EUE_{i,j,k,t} = \alpha_{i,j,k,t} + \theta \times Exci\left(Regu\right)_{i,j,k,t} + \gamma \times Control_{i,j,k,t} + Prov_i + u_k + v_t + \varepsilon_{i,j,k,t} \quad (4)$$

Where the subscripts i, j, k, and t represent the firm, province, industry, and year, respectively. $INQ_{i,j,k,t}$ is the green innovation matrix. Exi (Regu) is a 0–1 binary matrix, which represents innovation incentive (innovation regulation). When the sample is "treatment group", it is assigned as 1, otherwise it is assigned as 0. $Control_{i,j,k,t}$ is the control variable matrix, including the control variables described above. Because the status of green innovation varies greatly between different regions and different industries, this paper also controls the individual effects of the industry, province and time, namely prov, u, v. Finally, 3 represents a disturbance term.

In order to verify hypothesis H2 and hypothesis H5, this paper establishes a model (5). It should be noted that the model (5) needs to be verified by two data sets constructed by the previous PSM method when verifying hypothesis H2 and hypothesis H5.

$$INQ_{i,j,k,t} = \alpha_{i,j,k,t} + \delta \times Exci\left(Regu\right)_{i,j,k,t} + \gamma \times Control_{i,j,k,t} + Prov_i + u_k + v_t + \varepsilon_{i,j,k,t} \quad (5)$$

In order to verify hypothesis H3 and hypothesis H6, this paper establishes a model (6) and a model (7) to analyze the intermediary role of green innovation.

$$EUE_{i,j,k,t} = \alpha_{i,j,k,t} + \delta \times INQ_{i,j,k,t} + \gamma \times Control_{i,j,k,t} + Prov_i + u_k + v_t + \varepsilon_{i,j,k,t} \quad (6)$$

$$EUE_{i,j,k,t} = \alpha_{i,j,k,t} + \delta \times INQ_{i,j,k,t} + \theta \times Exci\left(Regu\right)_{i,j,k,t} + \gamma \times Control_{i,j,k,t} + Prov_i + u_k + v_t + \varepsilon_{i,j,k,t} \quad (7)$$

DATA AND VARIABLE

Data Source and Processing

This paper takes all the A-share listed firms in China as the initial sample from 2016 to 2020. All control variables and observation variables in this paper are from CSMAR database. And we deal with the raw data as follows.

(1) Sample selection: The main goal of this paper is the impact of environmental protection policies on enterprise environmental protection innovation, so as to improve enterprise energy efficiency. China's new environmental protection law was implemented in 2015, which is one of China's most important environmental protection policies. In recent years, China's environmental regulation policy and environmental incentive policy are based on the new Environmental Protection Law. At the same time, due to the availability of data, we can only select the data up to 2020. Therefore, the sample selected in this paper starts from 2016 to 2020. At the same time, we excluded the samples of financial industry and non-physical industry.

(2) Missing value and outlier processing: The metrological analysis tool in this paper is R studio. Because the missing values in R studio are infectious (it means that if there are missing values in the sample, the final output results are all missing values), this paper will eliminate the samples with missing values. At the same time, in order to eliminate the influence of extreme values and outliers, Winsorize processing is performed on 1 and 99% percentile of continuous variables. The following data reports are based on the processed data results. In the end, a total of 991 listed firms were included, with a total of 59,482 observations.

Variable and Definition

Environmental Protection Regulation

Environmental protection regulation is to control the production behavior of enterprises through laws, policies and systems. The administrative organ authorized by environmental protection regulation is the main body of the authority (Spulber, 1989). The government's action on the negative externality of enterprise pollution is called social environmental protection regulation. This behavior generally has departments exercising power in addition to the government. Environmental protection regulation is divided into two categories: formal regulation and informal regulation (Pargal et al., 1997).

With the development of environmental protection regulation their quantitative method has been gradually clarified. The existing quantitative methods are mainly analyzed from the perspective of regulatory means such as pollutant discharge permit period management (Bi et al., 2011) environmental tax (John and Labro, 2015) information disclosure etc. On this basis the types of environmental protection regulation are divided into administrative regulation market regulation and public participation regulation (Zhang et al., 2020). In this paper when quantifying environmental protection regulation referring to the research methods of (Ren et al., 2016) the public disclosure of environmental negative information is taken as the quantitative data of environmental protection regulation.

Combined with deterrence theory and the actual situation of China, we take the public disclosure of environmental negative information as the quantitative data of environmental protection regulation. This is because in China, the government will deal with relevant environmental cases of enterprises with negative environmental behavior, and will inspect such enterprises after

90 days to determine whether they have changed in accordance with environmental protection laws and regulations. The information on these environmental penalties is decided by Chinese courts at all levels. However, due to China's attention to the environment in recent years, most environmental cases are supervised by superior supervision departments. Therefore, there are few cases of political rent-seeking and fraud. In other words, the data we obtained can truly reflect the implementation of environmental protection regulations. We believe that this kind of government punishment is a better quantification of enterprise environmental protection regulation. We assign a value of 1 to the enterprises that have environmental pollution related cases in the current year, otherwise it is assigned a value of 0.

Environmental Protection Incentive

Existing studies generally analyze the role of environmental protection subsidies on enterprise innovation (Xu et al., 2021). Referring to the existing methods if the government provides environmental protection incentives and subsidies to enterprises in the current year the value is 1; Otherwise, the value is 0. It should be noted that although the financial resources of these environmental protection subsidies are provided by the central government, their allocation methods are independently determined by various local governments. In terms of specific levels, they mainly include provincial and municipal levels. Therefore, we no longer divide the types of environmental incentives. For enterprises, we also divide the environmental protection incentive subsidies received by subsidiaries into parent companies, because for listed companies, consolidated statements are required for audit at the end of the year, and the environmental protection subsidies received will also be uniformly divided into the item of "government subsidies" in the financial statements of parent companies.

Green Innovation

Academic circles often use patent information to measure the innovation of enterprises. However, for the information of green innovation patent data, there is a more consistent quantitative method in recent years. Specifically, the green patents involved in this paper are mainly invention, utility model and design patents with green technologies as the invention theme, which are conducive to saving resources, improving energy efficiency and preventing and controlling pollution. Its variable type is numeric. In terms of the way to obtain green patents, we have sorted out the complete green patent database through CSMAR database and matched it with other data in the follow-up. At present, it is generally believed that the more green patents in the year, the stronger the green innovation ability of the enterprise. This paper adopts this view (Chang, 2011).

Enterprise Energy Utilization Efficiency

The existing research on the quantitative measurement of high energy consumption and energy utilization efficiency of traditional enterprises is relatively mature (Zhang et al., 2020). This paper will migrate this kind of method to most Chinese enterprises. Specifically this paper uses energy output efficiency as an alternative index of energy utilization efficiency. This index is quantified by the ratio of enterprise energy consumption value to industrial output. Since most listed enterprises in China replace their industrial output value with operating income value this paper changes the quantitative method of enterprise energy utilization efficiency to the ratio of enterprise energy consumption to enterprise operating income.

Control Variable

Many studies have shown that firm's characteristics are also important variables affecting the enterprise behavior and enterprise decision. Based on this, we add five control variables, including firm size and its age, asset-liability ratio, ownership structure and ownership concentration. The firm size is expressed as the natural logarithm of the total asserts of the enterprise. The age (Ages) is expressed as the difference between and the year of establishment. The asset-liability ratio is expressed as total liabilities/total assets. SOE is expressed as a binary variable, if it contains state-owned shares, it is 1, otherwise it is 0. The degree of ownership concentration (COCEN) is expressed in the proportion of the first largest shareholder (%). The variable definitions are shown in **Table 1** (Raw data for all tables has been placed in **Supplementary Materials**).

Descriptive Statistics

Variable Descriptive Statistics

Based on the above variables, we will focus on the descriptive statistical information of variables such as environmental protection regulation, environmental protection incentive, green innovation and enterprise energy utilization efficiency. As can be seen from **Table 2**, the mean of green patents of 991 listed firms in China in 2016–2020 was 38.59; The average energy utilization efficiency of enterprises is 13.69, which shows that Chinese enterprises have paid attention to green innovation and efficient energy utilization in recent years. The average value of environmental protection incentive is 0.23, indicating that about one quarter of enterprises in China can obtain environmental protection incentive; The average value of environmental protection regulation is 0.55, indicating that more than half of China's listed companies are constrained by environmental protection regulation.

Descriptive Statistics of Policy Coverage by Industry

The coverage of environmental protection incentives and regulations in various industries is shown in the table below. Specifically, we divide the enterprises in each industry that receive the government's environmental protection incentive from the total enterprises in the industry, and obtain the results shown in the (**Supplementary Table S1 Appendix**). Policy Coverage Status. Among them, the industry is subject to the division of CSMAR database.

EMPIRICAL RESULT

Propensity Score Matching

Based on the PSM-DID method described in the third part, this paper uses the nearest neighbor matching method in the MatchIt

TABLE 1 | Variables and definition.

Variable Classification	Variable Symbol	Variable definitions
Independent variable	Environmental excitation (Exci)	As mentioned above
	Environmental regulation (Regu)	As mentioned above
Intermediary variable	Green Innovation (INQ)	As mentioned above
Dependent variable	Enterprise energy efficiency (EUE)	As mentioned above
Control variable	Size	ln (total assets)
	Ages	As mentioned above
	Leverage	Total liabilities/total assets
	SOE	The actual controller of the firm is the central and local SASAC, government agencies, state-owned firm, the variable is 1, otherwise 0
	COCEN	The proportion of the 1st largest shareholder ( ), taken logarithm
	ROA	Return on assets is usually expressed as a percentage of a company's annual earnings divided by its total assets
	Current Ratio (CR)	Current ratio is the ratio of current assets to current liabilities in the current year

TABLE 2 | Descriptive statistics.

Variable	Min	Median	Mean	Max	SD
COCEN	0	0.53	0.507	0.995	0.19
SOE	7.82	38	39.61	86.01	16.537
Size	0	1	0.694	1	0.461
Leverage	20.4	24.37	24.41	28.54	1.37
Green Inn	1	9	35.07	536	71.944
Enterprise	0	0	14.843	2282.506	156.628
Exci	0	0	0.249	1	0.432
Regu	0	1	0.602	1	0.49
Ages	6	20.25	19.97	40.92	4.987
ROA	−0.565	0.017	0.024	0.246	0.037
CR	−2.3	1.2	196.4	352,271.2	82.355

TABLE 3 | PSM logit regression results about excitation.

Variable	Coefficien	s.t.	Z value	*p* value
Variable	−0.295	0.003	−93.759	<2e-16***
Size	−0.001	0.000	−2.387	0.007**
COCEN	0.692	0.010	72.104	<2e-16***
SOE	0.081	0.001	98.850	<2e-16***
Ages	1.152	0.025	45.453	<2e-16***
ROA	4.023	0.114	35.151	<2e-16***
CR	−0.228	0.005	−44.054	<2e-16***

package in Rstudio to match the samples of "treatment group" and "control group" 1:1, and makes an empirical analysis on the obtained samples and the original data. Our purpose is to compare the reliability of data based on the analysis of realistic mechanism.

Tables 3, **4** show the estimation results of Logit model for environmental protection incentive and regulation respectively. As can be seen from **Table 3**, all variables are significant at the significance level of 0.005%. This result shows that there is a significant non-randomness in the choice of enterprises with environmental protection incentives in China. It should be noted that the coefficient of company size is significantly negative. This is because China has more policy support for small enterprises in the process of subsidies for environmental protection enterprises. For example, China's financial institutions have special loan types for small enterprises; China opened a new stock exchange in 2021 to support China's small scientific and technological innovation enterprises.

TABLE 4 | PSM Logit regression results about regulation.

Variable	Coefficien	s.t.	Z value	*p* value
Size	0.069332	0.002592	26.753	<2e-16 ***
COCEN	−0.00583	0.000217	−1.361	0.165
SOE	−0.06988	0.007857	−8.894	<2e-16 ***
Ages	0.089581	0.00071	126.179	<2e-16 ***
Leverage	0.454681	0.018588	2.117	0.095
ROA	1.880752	0.090587	20.762	<2e-16 ***
CR	−0.00564	0.000219	−25.757	<2e-16 ***

As can be seen from **Table 4**, some variables are not significant. This conclusion shows that China's choice of enterprises for environmental protection regulation is not completely random. On the contrary, China's environmental protection regulation requirements for enterprises apply to all industries. In reality, although environmental protection laws and treaties apply to all Chinese enterprises, enterprises with high pollution and high energy consumption are more regulated. It should be noted that the growth of enterprise age often leads to the expansion of enterprise scale. At this time, enterprises are not only easy to obtain environmental protection subsidies, but also vulnerable to environmental protection supervision due to their great popularity.

In order to verify the reliability of the matching results, this paper conducts a balance hypothesis test on the control variables of the matched samples in the way described above. **Table 5** shows the balance test results of control variables of matching samples of environmental protection incentives. It showed that the average difference of all control variables was significant at the level of 5% before propensity score matching. However, after the matching operation, the average difference of all variables between the "control group" and the "treatment group" is no

TABLE 5 | PSM balance test about excitation.

Variable	Sample	Control group		Treatment group		Mean difference
		N	Mean	N	Mean	
COCEN	Unmatched	5,948	0.496361	1,368	0.5409363	–0.0445753***
	Matched	1,360	0.5270905	1,360	0.5409363	–0.0138458
SOE	Unmatched	5,948	39.95091	1,368	38.5746	1.37631***
	Matched	1,360	39.02775	1,360	38.5746	0.45315
Size	Unmatched	5,948	0.6646288	1,368	0.7829912	–0.1183624***
	Matched	1,360	0.7871518	1,360	0.7829912	0.0041606
Leverage	Unmatched	5,948	24.48742	1,368	24.18597	0.30145***
	Matched	1,360	24.12106	1,360	24.18597	–0.06491
Green Innovatio	Unmatched	5,948	42.36992	1,368	13	29.36992***
	Matched	1,360	29.15126	1,360	13	16.15126
Enterprise energ	Unmatched	5,948	15.96694	1,368	11.4446	4.52234***
	Matched	1,360	11.29374	1,360	11.4446	–0.15086
Ages	Unmatched	5,948	19.41409	1,368	21.64616	–2.23207***
	Matched	1,360	20.19075	1,360	21.64616	–1.45541
ROA	Unmatched	5,948	0.0240901	1,368	0.02514148	–0.00105138***
	Matched	1,360	0.0270236	1,360	0.02514148	0.00188212
CR	Unmatched	5,948	260.92353	1,368	1.228723	259.69481***
	Matched	1,360	1.312054	1,360	1.228723	0.083331

TABLE 6 | PSM balance test about regulation.

Variable	Sample	Control group		Treatment group		Mean difference
		N	Mean	N	Mean	
COCEN	Unmatched	5,948	0.4940793	3,304	0.5162916	–0.0222123***
	Matched	1706	0.4940793	1706	0.5677971	–0.0737178
SOE	Unmatched	5,948	490.07341	3,304	1.90692	488.16649***
	Matched	1706	41.16412	1706	38.57901	2.58511
Size	Unmatched	5,948	0.6814937	3,304	0.7023752	–0.0208815***
	Matched	1706	0.6814937	1706	0.7524483	–0.0709546
Leverage	Unmatched	5,948	24.39411	3,304	24.42463	–0.03052***
	Matched	1706	24.39411	1706	24.44727	–0.05316
Green Innovatio	Unmatched	5,948	36.04466	3,304	34.42075	1.62391***
	Matched	1706	36.04466	1706	38.54509	–2.50043
Enterprise energ	Unmatched	5,948	2.951841	3,304	22.714427	–19.762586***
	Matched	1706	2.951841	1706	20.921965	–17.970124
Ages	Unmatched	5,948	18.69666	3,304	20.81141	–2.11475***
	Matched	1706	18.69666	1706	21.02032	–2.32366
ROA	Unmatched	5,948	0.0235816	3,304	0.0248612	–0.00127965***
	Matched	1706	0.0235816	1706	0.0252905	–0.00170893
CR	Unmatched	5,948	490.07341	3,304	1.90692	488.16649***
	Matched	1706	42.0341	1706	1.147886	40.886214

longer significant. **Table 6** also reflects that the average difference of control variables in the matched samples of environmental protection regulation is no longer significant. This shows that the matched samples have passed the reliability test, thus ensuring the reliability of subsequent empirical results.

Effect of Environmental Protection Incentive on Green Innovation and Enterprise Energy Utilization Efficiency

Firstly, we regress the effect of environmental protection incentives on enterprise energy utilization efficiency, and analyze the intermediary effect of green innovation. The results are shown in **Table 7**. Where, (1a)–(1d) are the regression results of sample DID before matching, and (2a)–(2d) are the regression results of PSM-DID after matching. It should be noted that in order to eliminate the autocorrelation and heteroscedasticity of sample time series, we use FGLS method for regression analysis in order to ensure that the results are more robust.

Compared with the regression results of DID and PSM-DID, the impact of environmental protection incentives on enterprise energy utilization efficiency and green innovation is different, but the impact direction and significance are the same. This result preliminarily shows that our analysis is robust. From the regression coefficient (1a) between environmental protection

TABLE 7 | Environmental excitation induced effect regression results.

Variable	DID				PSM-DID			
	EUE	EUE	INQ	EUE	EUE	EUE	INQ	EUE
	(1a)	(1b)	(1c)	(1d)	(1a)	(1b)	(1c)	(1d)
Treated*Post	−47.49***	−39.59***		−36.42***	28.12***	−31.29***		−29.05***
	−55.252	−18.94		−17.36	43.20	−17.55		−16.23
Green Innovation			0.10***	0.07***			0.09***	0.08***
			27.86	18.22			16.38	13.64
COCEN	−0.85***	−0.37***	−0.47***	−0.43***	−0.50***	−0.19***	−0.18***	−0.23***
	−130.63	−23.21	−28.89	−26.30	−69.75	−9.76	−9.40	−11.67
SOE	−20.74***	−24.87***	−28.65***	−26.26***	−10.93***	−21.35***	−21.67***	−22.22***
	−86.19	−42.49	−48.87	−44.50	−44.00	−31.37	−31.78	−32.53
Size	22.51***	−2.77***	−1.43***	−1.26***	14.75***	0.81***	0.81***	1.99***
	285.67	-14.43	-6.81	-6.04	182.76	3.66	3.43	8.38
Leverage	−9.88***	−12.6***	−14.72***	−13.26***	−7.09***	−10.20***	−17.95***	−10.77***
	−18.05	−9.46	−11.11	−9.96	−11.35	−5.96	−10.44	−6.29
Ages	0.01	−1.46***	−1.05***	−1.46***	−0.13***	−1.35***	−0.72***	−1.36***
	0.40	−28.68	−21.09	−28.68	−5.99	−23.29	−12.70	−23.47
ROA	2.49	−189.40***	−152.60***	−189.20***	−32.54***	−52.94***	−14.52	−55.54***
	0.90	−28.07	−22.70	−28.06	−10.91	−6.48	−1.78	−6.80
CR	−0.09***	0.00	−0.08**	0.00	2.07***	5.04***	3.12***	5.21***
	−7.52	−1.28	−2.65	−1.49	16.96	15.07	9.32	15.56
Provice	YES	YES	YES	YES	YES	YES	YES	YES
Industry	YES	YES	YES	YES	YES	YES	YES	YES

incentives and enterprise energy utilization efficiency, the regression coefficient of PSM-DID is greater than that of DID. From the regression coefficient (1c) of environmental protection incentive and green innovation, the regression coefficient of PSM-DID is greater than that of DID. The regression coefficients of other control variables and other regression relationships are also greater than those of the original DID, indicating that the effect of the overall variables is greater. It can be seen that the empirical results obtained by PSM-DID regression method are more robust. Therefore, in the following analysis, we use the results of PSM-DID to explain the mechanism.

In (2a), environmental protection incentives have a negative impact on enterprise energy utilization efficiency. This result is incompatible with common sense. The Chinese government hopes to promote enterprise energy utilization efficiency through environmental protection incentives such as environmental protection subsidies. However, contrary to our wishes, through our data, we find that the government's environmental protection incentives cannot promote enterprises to improve energy utilization efficiency. The reason comes from two aspects. On the one hand, the quantitative way of environmental protection incentive selected in this paper is the quantitative way of government environmental protection subsidy. It is different from the existing way of quantifying environmental protection incentives by environmental protection investment (Vanickova, 2020). The new quantitative method brings a new research perspective. At the same time, we also use data to give new results. On the other hand, the existing research on environmental protection incentives mostly focuses on tax relief for high polluting enterprises (Zhang et al., 2020). This paper expands the scope of enterprises to all listed enterprises, and obtains different research from the previous research. In China, for the purpose of reducing costs and increasing profits, high polluting enterprises are more likely to obtain government tax relief by improving their energy utilization efficiency. However, for most enterprises in non-high pollution industries, their energy utilization efficiency is not low (Zhang et al., 2020). This makes enterprises have insufficient motivation to improve their energy utilization efficiency through technological innovation and production process improvement, so as to exchange for government environmental protection subsidies.

In (2b) environmental protection incentives have a negative impact on enterprises' green innovation. For this result we explain it from two aspects: theoretical reason and practical reason. In terms of theory existing studies generally believe that if the government does not distinguish between environmental protection subsidies and subsidies in a general sense for enterprises it often does not have practical and effective effects (Li X et al., 2020). Due to the consensus in the economics of sustainable development if the government does not distinguish the incentive mode of direct environmental protection subsidies for enterprises it often will not bring the improvement of innovation benefits of enterprises (Chen et al., 2019). Many studies have also demonstrated this view from the perspective of data: government subsidies have a threshold effect on enterprises' green innovation and cannot completely promote it (Liu et al., 2020). In reality there is a special phenomenon in China: some enterprises out of their own interests defraud government subsidies through false publicity but do not actually invest the amount of subsidies in green innovation (Chen and Li, 2021). Due to the existence of this type of enterprises the government's environmental protection incentive has lost its role to a great extent and has become a means for some enterprises to make illegal profits.

TABLE 8 | Environmental regulation induced effect regression results.

Variable	DID				PSM-DID			
	EUE	EUE	INQ	EUE	EUE	EUE	INQ	EUE
	(2a)	(2b)	(2c)	(2d)	(2a)	(2b)	(2c)	(2d)
Treated*Post	27.75***	54.43***		56.64***	23.57***	44.79***		46.14***
	46.16	37.78		39.24	33.92	32.93		33.88
Green Innovation			0.10***	0.08***			0.08***	0.06***
			27.86	22.03			24.13	17.32
COCEN	−0.83***	−0.36***	−0.10***	−0.42***	−0.88***	0.10***	−0.30***	0.05**
	−125.62	−22.53	−27.86	−26.25	−99.51	5.53	−17.86	2.58
SOE	−22.53***	−23.91***	−28.65***	−25.70***	−30.41***	−24.46***	−25.01***	−26.20***
	−92.96	−41.17	−48.87	−43.85	−99.07	−40.71	−41.49	−43.03
Size	23.86***	−4.25***	−1.43***	−2.348***	25.18***	−2.86***	−1.09***	−1.41***
	301.77	−22.42	−6.81	−11.28	269.25	−15.63	−5.37	−7.05
Leverage	−15.06***	−9.88***	−14.72***	−11.08***	−22.41***	−16.14***	−9.84***	−17.43***
	−27.28	−7.46	−11.11	−8.37	−32.35	−11.90	−7.40	−12.84
Ages	−0.38***	−1.65***	−1.05***	−1.68***	−0.19***	−0.96***	−0.73***	−0.97***
	−17.86	−32.38	−21.09	−32.98	−7.47	−19.39	−14.87	−19.61
ROA	−24.21***	−176.00***	−152.60***	−178***	−33.61***	−172.10***	−121.60***	−174.00***
	−8.67	−26.31	−22.70	−26.61	−9.57	−25.02	−17.76	−25.31
CR	−0.04**	0.00	−0.07**	0.00	−0.04***	0.00	−0.05*	0.00
	−3.10	−0.89	−2.65	−0.99	−3.27	−0.51	−2.13	−0.61
Provice	YES	YES	YES	YES	YES	YES	YES	YES
Industry	YES	YES	YES	YES	YES	YES	YES	YES

TABLE 9 | Heterogeneity test about excitation.

Variable	State-Owned Shares firms				Non-state-owned Shares firms			
	EUE	INQ	EUE	EUE	EUE	INQ	EUE	EUE
	(3a)	(3b)	(3c)	(3d)	(4a)	(4b)	(4c)	(4d)
Treated*Post	42.32***	1.71**		42.31***	−14.76*	−26.42***		−7.13
	53.23	3.08		53.22	−2.14	−16.71		−1.01
Green Innovation			−0.04***	−0.01			−0.21***	−0.10***
			−10.94	−1.57			−11.80	−5.29
COCEN	−0.05***	−0.16***	−0.04***	−0.05***	−0.39***	−0.67***	−0.66***	−0.46***
	−3.92	−20.27	−3.64	−3.99	−5.41	−37.38	−8.83	−6.23
Size	−0.00***	−0.00***	−0.00***	−0.09***	−0.00***	0.00***	−0.00***	−0.00***
	−6.98	−9.37	−16.55	−7.02	−11.11	31.01	−7.58	−10.25
Leverage	7.10***	−11.54***	−4.10***	7.04***	−3.10	70.16***	−10.52	3.90

In (2c) and (2d), green innovation has a positive impact on the enterprise energy utilization efficiency, and green innovation plays a complete intermediary role. Green innovation has a positive impact on the improvement of enterprise energy utilization efficiency, which has been confirmed. Existing studies have studied Chinese industrial enterprises and generally found that green innovation has a positive impact on the improvement of enterprise energy utilization efficiency (Miao et al., 2020). This is because green innovation mostly focuses on improving the production efficiency of enterprises and improving the existing production processes of enterprises. The improvement of the above steps can significantly reduce energy consumption and improve the output of the enterprise, so as to bring positive external benefits to the enterprise. Based on the process of (2a)–(2d), we can find that the government's environmental protection incentive cannot bring about the green innovation of enterprises, nor can it improve enterprise energy utilization efficiency; However, the green innovation of enterprises can improve enterprise energy utilization efficiency. In the impact mechanism of environmental protection incentive-green innovation-energy utilization efficiency, green innovation plays a complete intermediary role, which can explain part of the impact mechanism of environmental protection incentive-energy utilization efficiency.

Effect of Environmental Protection Regulation on Green Innovation and Enterprise Energy Utilization Efficiency

We regress the effect of environmental protection regulation on enterprise energy utilization efficiency, and analyze the intermediary effect of green innovation. The results are shown in **Table 8**. Where, (3a)–(3d) are the regression results of sample did before matching, and (4a)–(4d) are the regression results of

TABLE 10 | Heterogeneity test about regulation.

Variable	State-Owned Shares firms				Non-state-owned Shares firms			
	EUE	INQ	EUE	EUE	EUE	INQ	EUE	EUE
	(5a)	(5b)	(5c)	(5d)	(6a)	(6b)	(6c)	(6d)
Treated*Post	1.056***	15.27***		1.30*	143.40***	1.18		143.40***
	19.72	19.02		2.43	29.23	0.63		29.26
Green Innovation			0.02***	0.02***			0.20***	0.07***
			12.37	12.00			24.81	8.90
COCEN	0.09***	−0.29***	−0.03***	0.08***	0.11	−1.29***	−1.07***	0.02
	13.34	−29.19	−4.56	12.62	1.92	−58.39	−19.01	0.73
Size	−0.00***	0.00***	−0.00***	−0.00***	−0.00***	0.00***	−0.00***	−0.00***
	−19.38	30.84	−14.90	−18.61	−6.95	35.42	−10.13	−5.91
Leverage	−13.40***	−16.28***	−7.68***	−13.66***	−1.35	115.70***	2.03	7.26
	−28.03	−22.71	−16.65	−28.55	−0.24	53.82	0.35	1.27
Ages	−0.48***	−0.99***	−0.10***	−0.49***	1.74***	−2.14***	−2.14***	1.58***
	−25.46	−35.52	−5.39	−26.26	9.50	−30.76	−12.38	8.59
ROA	55.36***	45.46***	72.12***	56.09***	−675.60***	−162.80***	−592.20***	−687.70***
	20.81	11.40	27.03	21.08	−29.97	−19.01	−26.70	−30.46
CR	0.00	−0.00***	−0.00**	0.00	0.01	0.02*	0.01	0.01
	−1.16	−7.57	−2.97	−1.34	0.43	2.31	0.26	0.49
Provice	YES	YES	YES	YES	YES	YES	YES	YES
Industry	YES	YES	YES	YES	YES	YES	YES	YES

TABLE 11 | OLS robust standard error regression results about excitation.

Variable	DID				PSM-DID			
	EUE	INQ	EUE	EUE	EUE	INQ	EUE	EUE
	(1a)	(1b)	(1c)	(1d)	(1a)	(1b)	(1c)	(1d)
Treated*Post	−20.46***	−0.11		−2.21***	−16.89***	1.51***		−0.08
	−87.78	−0.20		−3.89	−92.51	3.03		−0.16
Green Innovation			0.10***	0.10***			0.09***	0.09***
			27.86	28.13			16.38	−16.10
COCEN	−0.79***	−0.39***	−0.47***	−0.47***	−0.48***	−0.14***	−0.18***	−0.18***
	−120.98	−24.29	−28.89	−28.97	−66.87	−7.19	−9.40	−9.40
SOE	−18.40***	−26.54***	−28.65***	−28.43***	−10.27***	−20.70***	−21.67***	−21.67***
	−76.05	−45.32	−48.87	−48.27	−41.34	−30.40	−31.78	−31.72
Size	23.04***	−3.85***	−1.43***	−1.48***	14.81***	−0.59**	0.81***	0.81***
	289.87	−20.01	−6.81	−7.07	184.03	−2.66	3.43	3.43
Leverage	−9.08***	−13.09***	−14.72***	−14.02***	−7.68***	−17.23***	−17.95***	−17.95***
	−16.43	−9.78	−11.11	−10.49	−12.23	−10.01	−10.44	−10.44
Ages	−0.21***	−1.00***	−1.05***	−1.03***	−0.18***	−0.70***	−0.72***	−0.71***
	−10.06	−19.84	−21.09	−20.28	−8.58	−12.20	−12.70	−12.50
ROA	−23.28***	−148.90***	−152.60***	−151.20***	−44.59***	−10.36	−14.52	−14.57
	−8.37	−22.10	−22.70	−22.47	−14.96	−1.27	−1.78	−1.78
CR	−0.06***	−0.07**	−0.08**	−0.08***	2.39***	2.89***	3.12***	3.12***
	−4.77	−2.48	−2.65	−2.69	19.56	8.65	9.32	9.32
Provice	YES	YES	YES	YES	YES	YES	YES	YES
Industry	YES	YES	YES	YES	YES	YES	YES	YES

PSM-DID after matching. It should be noted that in order to eliminate the autocorrelation and heteroscedasticity of sample time series, we used the same FGLS method as 5.2 for regression analysis.

In the above regression results, environmental protection regulation has a significant positive impact on enterprise energy utilization efficiency. This shows that government environmental protection regulation can effectively promote enterprises to improve their energy utilization efficiency. This is because the Chinese government has attached great importance to environmental protection in recent years and limited the energy consumption of enterprises. For the purpose of profit, enterprises must obtain higher income under the condition of limited resources, which promotes enterprises to improve energy utilization efficiency. This impact mechanism has been confirmed in previous studies on the EU, and this paper confirms it for the first time for the Chinese environment (Garrone et al., 2017).

In addition, it should be noted that environmental protection regulation can positively promote green innovation, and green innovation plays a complete intermediary role in the impact of

TABLE 12 | OLS robust standard error regression results about regulation.

Variable	DID				PSM-DID			
	EUE	INQ	EUE	EUE	EUE	INQ	EUE	EUE
	(2a)	(2b)	(2c)	(2d)	(2a)	(2b)	(2c)	(2d)
Treated*Post	23.19***	1.06***		22.93***	22.88***	24.48***		24.3***
	47.26	46.96		46.75	8.86	48.56		48.25
Green Innovation			0.10***	0.10***			0.08***	0.08***
			27.86	26.99			24.13	23.48
COCEN	−0.36***	−4.05***	−0.47***	−0.43***	−0.84***	0.02	−0.30***	−0.04***
	−22.37	−61.52	−28.89	−26.86	−94.44	1.35	−17.86	−2.37
SOE	−26.20***	3.23	−28.65***	−28.23***	−28.04***	−26.93***	−25.01***	−29.10***
	−45.13	1.27	−48.87	−48.27	−91.14	−44.88	−41.49	−47.97
Size	−4.15***	2.37***	−1.43***	−1.80***	25.61***	−3.427***	−1.09***	−1.44***
	−21.79	58.24	−6.81	−8.63	272.10	−18.67	−5.37	−7.16
Leverage	−16.42***	2.13***	−14.72***	−17.92***	−22.11***	−21.31***	−9.84***	−23.02***
	−12.41	36.01	−11.11	−13.54	−31.87	−15.75	−7.40	−17.00
Ages	−1.48***	−1.21***	−1.05***	−1.52***	−0.23***	−1.018***	−0.73***	−1.04***
	−29.03	−52.49	−21.09	−29.87	−9.18	−20.73	−14.87	−21.11
ROA	−160.00***	−2.73***	−152.60***	−163.40***	−52.48***	−159.9***	−121.60***	−164.00***
	−23.83	−8.94	−22.70	−24.35	−14.87	−23.24	−17.76	−23.84
CR	0.00	−5.99***	−0.08***	0.00	−0.05***	0.00	0.00	0.00
	−1.19	−4.59	−2.65	−1.37	−4.15	−0.90	−2.13	−1.06
Provice	YES	YES	YES	YES	YES	YES	YES	YES
Industry	YES	YES	YES	YES	YES	YES	YES	YES

TABLE 13 | OLS robust standard error regression results about excitation by changing the size with Enterprise income.

Variable	DID				PSM-DID			
	EUE	INQ	EUE	EUE	EUE	INQ	EUE	EUE
	(1a)	(1b)	(1c)	(1d)	(1a)	(1b)	(1c)	(1d)
Treated*Post	−42.12***	−58.42***		−38.08***	−31.80***	−35.37***		−29.79***
	−20.17	−62.62		−18.16	−17.87	−50.76		−16.64
Green Innovation			0.10***	0.07***			0.08***	−0.06***
			31.43	20.52			14.88	−10.45
COCEN	−0.37***	−0.54***	−0.45***	−0.40***	−0.15***	−0.24***	−0.14***	−0.165***
	−23.41	−76.71	−28.61	−25.62	−7.85	−31.99	−7.48	−8.54
SOE	−29.53***	−1.57***	−32.28***	−29.64***	-21.77***	−0.30	−22.04***	−21.78***
	−51.37	−6.12	−56.50	−51.58	−32.63	−1.15	−33.18	−32.67
Size	−0.24***	019***	−0.22***	−0.22***	−0.19***	0.15***	−0.21***	−0.19***
	−26.74	49.72	−25.03	−25.14	−14.88	29.65	−15.60	−14.19
Leverage	−14.79***	25.51***	−15.03***	−13.02***	−10.35***	7.05***	−18.08***	−9.95***
	−11.42	44.09	−11.65	−10.04	−6.09	10.59	−10.61	−5.85
Ages	−1.37***	−0.43***	−1.00***	−1.40***	−1.34***	−0.26***	−0.73***	−1.36***
	−27.01	−19.09	−20.11	−27.60	−23.13	−11.26	−12.96	−23.38
ROA	−203.20***	19.08***	−165.30***	−201.90***	−58.60***	−2.22	−20.08***	−58.73***
	−30.06	6.32	−24.54	−29.88	−7.17	−0.69	−2.46	−7.19
CR	0.00	−0.00***	−0.00*	0.00	4.74***	−0.84***	2.83***	4.69***
	−1.08	−9.18	−2.52	−1.37	14.30	−6.46	8.53	14.16
Provice	YES	YES	YES	YES	YES	YES	YES	YES
Industry	YES	YES	YES	YES	YES	YES	YES	YES

environmental protection regulation and enterprise energy utilization efficiency. The mechanism between environmental protection regulation and green innovation is that the government regulates the production of enterprises through administrative means such as law and management. Due to the demands of their own development, enterprises choose to meet the requirements of the government through green innovation and improve production efficiency (Li et al., 2018). At the same time, when enterprises are constrained by environmental protection regulations, the original technology is not enough to help enterprises offset the costs brought by environmental supervision and environmental punishment. Therefore, enterprises have to turn to green innovation to reduce production costs.

Interestingly, we compare the two government actions of environmental protection incentive and regulation, and find such a fact: for enterprises, the role of environmental

TABLE 14 | OLS robust standard error regression results about regulation by changing the size with Enterprise income.

Variable	DID				PSM-DID			
	EUE	INQ	EUE	EUE	EUE	INQ	EUE	EUE
	(2a)	(2b)	(2c)	(2d)	(2a)	(2b)	(2c)	(2d)
Treated*Post	1.06***		21.42***	21.53***	1.75***		23.16***	23.30***
	4.70		43.31	43.59	6.15		45.70	46.04
Green Innovation		0.10***		0.10***		0.08***		0.08***
		31.43		31.81		−27.02		−27.58
COCEN	−0.44***	−0.45***	−0.39***	−0.44***	−0.55***	−0.26***	0.01	−0.03*
	−61.53	−28.61	−24.89	−27.75	−56.96	−15.85	0.65	−2.00
SOE	0.32	−32.28***	−31.63***	−31.60***	−5.51***	−28.51***	−31.63***	−32.08***
	1.24	−56.50	−55.40	−55.40	−16.42	−48.10	−53.03	−53.84
Size	0.02***	−0.02***	−0.02***	−0.02***	0.02***	−0.01***	−0.01***	−0.01***
	58.24	−25.03	−22.07	−19.22	54.68	−20.81	−18.36	−15.76
Leverage	21.25***	−15.03***	−21.2***	−18.97***	15.33***	−10.48***	−25.14***	−23.87***
	36.00	−11.65	−16.43	−14.70	20.59	−8.08	−18.97	−18.02
Ages	−1.21***	−1.00***	−1.31***	−1.44***	−1.26***	−0.63***	−0.83***	−0.94***
	−52.49	−20.11	−25.87	−28.33	−45.95	−13.00	−17.03	−19.13
ROA	−27.53***	−165.30***	−169.70***	−172.60***	−50.49***	−134.90***	−168.20***	−172.40***
	−8.94	−24.54	−25.22	−25.67	−13.01	−19.64	−24.36	−24.99
CR	−0.00***	−0.00*	0.00	0.00	−0.00***	−0.00*	0.00	0.00
	−4.59	−2.52	−1.12	-1.34	−4.96	−2.01	−0.78	−1.01
Provice	YES	YES	YES	YES	YES	YES	YES	YES
Industry	YES	YES	YES	YES	YES	YES	YES	YES

protection incentive in promoting green production is not as good as that of environmental protection regulation. Previous literature has not compared the two mechanisms. This paper holds that when facing environmental protection regulation, enterprises face tough and unavoidable administrative laws, which will require enterprises to make production innovation in line with environmental protection requirements, so as to improve enterprise energy utilization efficiency. Environmental protection incentive is a soft incentive behavior, which hopes that enterprises can achieve cleaner production and green innovation. But in fact, the purpose of the enterprise is to obtain the maximum profit at the minimum cost. Because green innovation requires enterprises to increase R and D investment; The improvement of enterprise energy utilization efficiency also requires enterprises to pay the cost of improving production processes and processes (Li et al., 2018). For the above two reasons, environmental protection regulation and environmental protection incentive have produced two distinct effects.

HETEROGENEITY AND ROBUSTNESS TEST

Heterogeneity Test

The above empirical results show that the difference of enterprise ownership will have an impact on the above mechanism. Therefore, this paper divides the total sample into state-owned joint-stock companies and non-state-owned joint-stock companies by including whether the company's equity includes state-owned shares or not.

Table 9 shows the effect of environmental protection incentive mechanism of different companies. Interestingly, state-owned enterprises and non-state-owned enterprises have completely different mechanisms. For state-owned enterprises, environmental protection incentives can promote green innovation, and then promote the improvement of energy utilization efficiency. However, for non-state-owned enterprises, environmental protection incentives inhibit the green innovation of enterprises and the improvement of energy utilization efficiency. In China, state-owned enterprises not only have profit objectives, but also have certain political tasks. According to the signal transmission theory, the government's environmental protection incentive represents the goal of society and government for environmental protection and cleaner production. State owned enterprises respond to this goal out of their higher sense of social responsibility (Zhu et al., 2016). However, because non-state-owned enterprises are more benefit oriented, it is more rational for enterprises to ignore all the choices that increase enterprise costs. Therefore, the government's environmental protection incentive has the opposite effect on state-owned enterprises and non-state-owned enterprises.

Table 10 shows the effect of environmental protection regulation mechanism of different companies. Environmental protection regulation can promote the green innovation and energy utilization efficiency of state-owned enterprises and non-state-owned enterprises. However, it plays a smaller role in promoting state-owned enterprises. On the contrary, the promotion coefficient for non-state-owned enterprises is large. This shows that compared with state-owned enterprises, environmental protection regulation plays a stronger role in

promoting green innovation and energy utilization efficiency of non-state-owned enterprises.

Robustness Test

OLS Robust Standard Error Estimation

In order to eliminate the influence caused by individual differences, based on the samples obtained by the above PSM method, OLS robust standard error is used for reanalysis. We reanalyze the effects of environmental protection incentives and environmental protection regulations, and the results are shown in **Tables 11**, **12**. Compared with the results obtained by the above FGLS method, the significance of OLS estimation results has not changed. The coefficient of each variable changes, but the coefficient symbol does not change. This shows that the estimation method has limited results on the empirical results.

Quantitative Estimation of Changing Variables

This paper changes the quantitative method of enterprise scale variable from total assets to operating income. The regression is carried out again in the way of FGLS, and the results are shown in **Tables 13**, **14**. The results are still robust.

DISCUSSION AND CONCLUSION

Based on existing research on the different effects of environmental protection incentives and environmental protection regulations on enterprises, this paper compares and analyzes the effects of environmental protection incentives and environmental protection regulations on enterprise energy utilization efficiency and analyzes the intermediary role of green innovation. This paper puts forward assumptions and quantifies the variables involved based on theoretical analysis. Finally, the panel data of Chinese A-share listed companies from 2016 to 2021 and the PSM-DID model are used to test and compare the research hypotheses. We get the following main conclusions.

Environmental protection incentives harm green innovation and enterprise energy utilization efficiency; Green innovation positively impacts enterprise energy utilization efficiency; Green innovation plays a complete intermediary role in the relationship between environmental protection incentives and enterprise energy utilization efficiency. This conclusion shows that environmental protection incentives cannot improve the green innovation of enterprises as expected by the government, the provider of environmental protection incentives, to improve enterprise energy utilization efficiency. Analyzing the reasons, the goal of the enterprise is to make profits. Enterprises carry out green innovation; Improving processes to improve energy utilization efficiency requires enterprises to pay additional costs. The government's extensive environmental protection subsidies have a poor incentive effect on enterprises and cannot stimulate the motivation of enterprises to innovate. This shows that China's environmental protection subsidies have not received the expected effect. The reasons are mainly from two aspects. On the one hand, some enterprises have "defrauded subsidies". However, they did not invest the subsidies in innovation. On the other hand, considering the risk of technological innovation, enterprises choose more stable existing production methods than innovating because of the government's environmental protection subsidies.

Environmental protection regulation has a positive impact on green innovation and enterprise energy utilization efficiency; Green innovation has a positive impact on enterprise energy utilization efficiency; Green innovation plays a complete intermediary role in the relationship between environmental protection regulation and enterprise energy utilization efficiency. This conclusion shows that environmental protection regulations can promote the development of enterprises to a more environmentally friendly mode of production with public power, such as government laws and regulations. Through comparison, we answer this fundamental question: How can we effectively promote the improvement of enterprises to efficient and environmentally friendly production methods? The reason is that, under the constraints of environmental protection regulations, the original technology cannot meet cleaner production requirements. In order to mitigate the impact of "regulatory costs" on enterprise benefits, enterprises will carry out green innovation to produce efficiently and improve production efficiency (Hu et al., 2017). This conclusion shows that the current process of realizing carbon neutralization and promoting the transformation of Chinese enterprises (especially for high polluting enterprises) to cleaner production requires the government to formulate perfect environmental protection regulations. This approach will increase R&D costs and reduce enterprises' earning earnings surplus in the short term, promoting the energy utilization of enterprises and realizing China's industrial upgrading in the long term.

Interestingly, the difference in enterprise ownership will significantly impact environmental protection incentives, green innovation, and enterprise energy utilization efficiency. Environmental protection incentives can significantly promote the green innovation and energy utilization efficiency of state-owned enterprises; However, environmental protection incentives can significantly inhibit the green innovation and energy utilization efficiency of non-state-owned enterprises. This shows that the environmental protection incentive policy can promote the cleaner production of state-owned enterprises. This phenomenon is related to the higher social responsibility consciousness of state-owned enterprises and the more responsive measures of state-owned enterprises to the government (Zhu et al., 2016). On the contrary, whether state-owned enterprises or non-state-owned enterprises, environmental protection regulation can promote green innovation and enterprise energy utilization efficiency. However, it plays a more decisive role in promoting non-state-owned enterprises. As the consequences of non-compliance with environmental regulations are punitive measures, it will damage the business performance of enterprises. However, because managers do not bear the pressure on the operating performance of state-owned enterprises, the role of environmental protection regulation is weak (Dai et al., 2017).

Based on the above conclusions, this paper puts forward the following suggestions on how the government can adopt more progressive policies to promote cleaner production and achieve carbon neutrality:

(1) Formulate comprehensive environmental protection regulations for enterprise production, and conduct regular and irregular environmental protection inspections for enterprises to ensure that the production emissions of enterprises meet the standards.
(2) Fine inspection and management of different types of enterprises. For enterprises with heavy pollution and high energy consumption, lend clean technology upgrading funds based on supervision to achieve the effect of the combination policy of environmental protection incentive and environmental protection regulation.
(3) Pay attention to guidance for state-owned enterprises and mainly adopt the way of environmental protection incentives to promote green innovation and cleaner production. Non-state-owned enterprises pay attention to supervision and mainly adopt the way of environmental protection regulation to force enterprises to carry out green innovation and cleaner production.

At the same time, we put forward the following policy suggestions on how to adapt to government policies and carry out better innovation management:

(1) Carry out production and operation management in strict accordance with the requirements of environmental protection laws and regulations. In China, the illegal cost is high due to the government's efforts to control environmental pollution and related enterprises. Therefore, compared with violating relevant environmental protection regulations, the more rational behavior is to invest this part of the opportunity cost into the green innovation process.
(2) Properly strive for environmental protection incentives to reduce enterprise costs. Due to China's relatively loose regulatory conditions for environmental protection incentives, obtaining environmental protection subsidies can increase corporate reputation at the social level and reduce corporate costs in the process of operation.

This article may have the following limitations. Due to the availability of data, this paper only studies listed enterprises. Nevertheless, the data of this sample is fully reliable and persuasive. However, the lack of non-listed enterprises may lead to some deviation in sample selection. In the future, we will consider cooperating with the government to obtain the data of unlisted enterprises for research.

In future research, the detailed analysis of enterprise business performance and social reputation in implementing enterprise environmental protection incentives could become the further direction of this paper.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/**Supplementary Material**, further inquiries can be directed to the corresponding author.

AUTHOR CONTRIBUTIONS

Conceptualization, YuaW; methodology, YuaW; software, YuaW; formal analysis, YuaW; investigation, YuaW; resources, YuW; data curation, YuaW; writing—original draft preparation, YuaW; writing—review and editing, JH; visualization, YH; supervision, YuaW and YuW; project administration, YuaW; funding acquisition, YuW. All authors have read and agreed to the published version of the manuscript.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fenvs.2022.870713/full#supplementary-material

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