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Subsidy expiration and green innovation: Does external financing have a role?

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Subsidy expiration and green innovation: Does external financing have a role?

Abstract: Government subsidy encourages green innovation by providing financial support and certification effect. However, once the subsidy expires, these advantages disappear, which could adversely affect green innovation. This paper takes listed industrial enterprises from 2011 to 2021 as a sample to study the relationship between subsidy expiration and green innovation. First, subsidy expiration significantly inhibits green innovation. This is mainly achieved by reducing R&D investment. Equity financing can alleviate the negative correlation between subsidy expiration and green innovation. Debt financing does not have this effect. Finally, enterprises will not invest the funds raised by equity financing into the research and development process but increase the number of green innovations through strategic innovation so as to carry out "greenwashing" activities. Three robustness tests all show that our results are valid.

Keywords: Subsidy expiration; Green innovation; Debt financing; Equity financing; Greenwashing

1 Introduction

At present, environmental pollution and climate change have become world problems, which seriously endanger the healthy development of the economy. Green innovation is considered as an effective tool for reconciling the economy and the environment (Pan, Chen, Guo, & Zhang, 2020). The Chinese government is also aware of the role of technological progress in protecting the environment and addressing climate risks. Energy saving and consumption reduction should be controlled from the source, and the growth mode should be driven by innovation(H. Liu, Yu, & Peng, 2023a). In 2022, the Chinese government issued a notice on the Implementation Plan for Further Improving the Market-oriented Green Technology Innovation System (2023-2025), which further strengthened the dominant position of enterprises in innovation. However, the inherent double externalities of green innovation (Shao & Chen, 2022) make it difficult for enterprises' economic investment to be effective in the short term (Y. T. Liu, Xu, & Wang, 2022b). They have to bear high innovation risks and costs(Runhaar, Tigchelaar, & Vermeulen, 2008), so enterprises generally have insufficient innovation motivation(Stucki, 2019).

Government subsidies, as an external incentive, have become a robust measure to increase green innovation and reduce pollution(Z. H. Huang, Liao, & Li, 2019). Firstly, government subsidies are a pre-incentive for enterprises, which can support enterprises' green innovation in terms of capital supplementation and risk bearing (Y. T. Liu et al., 2022b). Second, government subsidies bring a "signal effect" and a "certification effect", which increase external investors' trust in enterprises (H. Liu et al., 2023a) and reduce the capital restriction of enterprises (Montmartin & Herrera, 2015). Studies have confirmed that government subsidy stimulates green innovation by increasing R&D investment and other channels (H. Liu et al., 2023a; Y. T. Liu et al., 2022b; Shao & Chen, 2022; Xia, Gao, Wei, & Ding, 2022).

However, the subsidy is used to achieve specific goals and usually ends at some point(Nagy, Fleten, & Sendstad, 2023). The advantages of government subsidy could quickly disappear once it expire. D. Y. Zhang (2023)found that enterprises have "greenwashing" behaviour when the subsidy expires or is interrupted, which may inhibit green innovation. Therefore, it is timely to consider the "post-subsidy" effect. That is, will green innovation be affected when the subsidized projects expire or when the government stops subsidizing them? In particular, what are the mechanisms that affect green innovation when subsidy shocks occur?

Existing studies have shown that when the subsidy is reduced or delayed, other financing channels will improve the performance of green innovation (B. Q. Lin & Xie, 2023). This prompted

us to consider whether other external financing channels could complement government subsidies to finance corporate green innovation after the subsidy expires. In addition to government subsidies, debt financing and equity financing also constitute indispensable external financing methods (Xiang, Liu, & Yang, 2022). It provides essential financial assistance to enterprises' green innovation (Z. F. Su, Guo, & Lee, 2022). Therefore, we included debt financing and equity financing in the study as a supplementary mechanism for corporate green innovation funds after the subsidy expires.

Based on this, we take Chinese listed industrial enterprises from 2011 to 2021 as a sample to explore the relationship between subsidy expiration and green innovation. The results show that the reduction of R&D investment is the way that subsidy expiration reduces green innovation. In addition, equity financing can reduce the decline in green innovation after the subsidy expires, while debt financing has no significant function. However, equity financing does not encourage companies to increase R&D investment. After obtaining equity financing, enterprises pay more attention to the strategic improvement of green innovation rather than the substantive improvement. In other words, there is a phenomenon of "greenwashing" in enterprises' green innovation.

We will clarify the changes in green innovation after subsidy expiration, as well as the complementary role of other external financing channels. Our research may contribute in three ways:

First, we explored the impact of subsidy expiration rather than subsidy on green innovation, which has received less research attention before(H. Liu et al., 2023a; Y. T. Liu et al., 2022b; Shao & Chen, 2022; Xia et al., 2022). Understanding the relationship between subsidy expiration and green innovation can help enterprises better cope with the policy impact caused by subsidy expiration and also help policymakers promote green innovation more effectively.

Secondly, this study takes debt financing and equity financing as the supplement to government subsidies. It discusses the effects of two external financing channels on enterprises' green innovation after subsidy expiration. Existing studies have separately discussed the role of debt financing or equity financing in green innovation(Hong, Li, & Drakeford, 2021; B. Q. Lin & Xie, 2023). Alternatively, debt financing and equity financing are regarded as external financing channels equal to government subsidy (Xiang et al., 2022), and the impact of the three on green innovation is discussed respectively. This paper takes debt financing and equity financing as supplementary financing channels after the subsidy expires. We find that green innovation of enterprises with high levels of equity financing is less affected by the subsidy expiration, while debt financing has no such effect.

Finally, we enrich the literature on green innovation motivation at the level of greenwashing. Internal motivation and external motivation are the motivating factors of green innovation that are more studied at present. Corporate social responsibility(Hao & He, 2022), media attention (Z. X. He, Cao, & Feng, 2022) and environmental regulation (G. H. Lian, Xu, & Zhu, 2022) have been proven to be the main drivers of green innovation. In contrast, this study explores the "greenwashing" behaviour of firms' innovation after the subsidy expires. It is proved that after the subsidy expires, even if the enterprise has obtained the funds through other financing channels, it will not put the money into the research and development process but carry out "greenwashing" through strategic innovation behaviour. This conclusion broadens the motivation for green innovation.

This study consists of six parts. Part two reviews the relevant literature and proposes five research hypotheses through hypothesis development. Part three introduces the research design and model building process of this paper. Part four discusses the research results and verifies the

robustness of the conclusions. Part five further analyzes the research results obtained in the previous part. Part six summarizes the research conclusions and puts forward different practical suggestions for policymakers, institutional investors and enterprise managers.

2 Literature review and hypothetical development

2.1 Literature review

2.1.1 Green innovation

It is found that green innovation can enhance the enterprises' market position(G. P. Li, Wang, Su, & Su, 2019) by reducing financing pressure (Y. Zhang, Xing, & Wang, 2020), improving follow-up performance(Ji, Zhou, Wan, & Lan, 2023; Vasileiou, Georgantzis, Attanasi, & Llerena, 2022), increasing sales and net profit(D. Y. Zhang, Rong, & Ji, 2019). However, due to the double externalities of green innovation(Aguilera-Caracuel & Ortiz-de-Mandojana, 2013; Y. T. Liu et al., 2022b), enterprises may not initiate green innovation. Therefore, many scholars have begun to study the motivating factors of green innovation(X. H. Chen, Yi, Zhang, & Li, 2018; Yu, Wu, Zhang, Chen, & Zhao, 2021; Zhu & Tan, 2022). Existing studies have explored the role of two subjects in green innovation. These literatures mainly discuss the two ways of external stakeholders to motivate enterprises to green innovation through expectation and pressure (Y. T. Liu et al., 2022b). The other is internal enterprise, including the enterprise level and the individual level.

Firstly, studies discuss external stakeholders, including government, investors, media, consumers and suppliers(Fang, Kong, Sensoy, Cui, & Cheng, 2021; Z. H. Li, Huang, & Su, 2023b; J. Wang, 2023; L. K. Wang, Li, Wang, Gong, & Xiong, 2023; Wei, Wei, & Yang, 2023). Among them, the government is the main focus of research. Existing literature proves that the government mainly encourages enterprise green innovation in two ways: formulating environmental regulations(Qi, Wu, Xu, & Shan, 2023) and granting financial assistance(H. Liu et al., 2023a). Many studies have verified Porter's hypothesis on the relationship between environmental regulation and green innovation (C. F. Chen, Zheng, Lin, & Guan, 2023). However, some scholars believe that environmental regulation cannot improve the quality of green innovation(Y. Hu, Jin, Ni, Peng, & Zhang, 2023a; A. T. Xu, Zhu, & Wang, 2023).

Second, internal factors of enterprises also play a role in green innovation. Enterprise-level literature shows that digital transformation (X. Liu, Liu, & Ren, 2023b), the adoption of artificial intelligence(Hussain, Yang, Maqsood, & Zahid, 2024), and organizational capital (Qu & Cheung, 2023) can spur green innovation. At the individual level, scholars mainly use the upper-echelon theory to explore the impact of CEOs' characteristics on green innovation. These personal characteristics mainly include executive arrogance(Arena, Michelon, & Trojanowski, 2018), academic experience (K. He, Chen, & Zhang, 2021), and overseas experience(Quan, Ke, Qian, & Zhang, 2023).

2.1.2 Government subsidy and green innovation

As mentioned above, the government mainly guides green innovation through environmental regulation and financial support (H. Liu et al., 2023a; Qi et al., 2023). In addition to mandatory environmental regulations, when the funds required for green innovation cannot be compensated, the government can help enterprises achieve sustainable development in the form of subsidies (D. Y. Zhang, 2023). The significant risks and uncertain benefits of green innovation make enterprises reluctant to make green innovation without external compensation(Stucki, 2019). Government subsidies can help companies share the costs, risks and uncertainties of innovation in the form of financial compensation (S. L. Chen, Huang, Drakeford, & Failler, 2019b; Y. T. Liu et al., 2022b).

In the existing studies, government subsidies can influence green innovation in two ways. First, they can finance investment in R&D, thus increasing green innovation(Shao & Chen, 2022). Second, they can produce a "signal effect" and a "certification effect," guiding other investors to increase green investment in enterprises and ease capital constraints for businesses (Guo, Xia, Zhang, & Zhang, 2018).

However, these advantages may quickly disappear once the subsidy expires(D. Y. Zhang, 2023). Enterprises need to bear the risks and uncertainties of green innovation again, and the additional financial costs arising from technology upgrades will also need to be reimbursed (H. Lin, Zeng, Ma, Qi, & Tam, 2014). Existing research mainly focuses on the influence of government subsidies on green innovation activities and lacks discussion on the "after-effect" of subsidies. This is also the focus of this article.

2.1.3 Other external financing channels and green innovation

Although government subsidies have been proven to promote green innovation, with the reduction of government subsidies, scholars also begin to explore whether other external financing channels can be used as a new financing model to stimulate green innovation (B. Q. Lin & Xie, 2023). Xiang et al. (2022) found that enterprises finance green innovation projects through internal and external channels. In addition to government subsidy, equity financing and debt financing are also the main external financing channels for corporate green innovation. B. Q. Lin and Xie (2023) studied the impact of venture capital on the green innovation of Chinese renewable energy enterprises in the context of equity financing. It is found that venture capital increases the monetary capital of enterprises, alleviates capital restriction, and strengthens the R&D investment of enterprises, thus promoting the improvement of green innovation performance. Many scholars explored the impact of debt financing forms such as green credit and green bonds on enterprises' green innovation(J. Lian, Huang, & Wu, 2023; S. L. Zhang, Wu, He, & Hao, 2022; Zhou, Tao, Wang, & Luo, 2023). Hong et al. (2021) show that green credit policy mainly inhibits green innovation by reducing debt financing. P. H. Ren, Cheng, and Dai (2024) found that the issuance of green bonds improves green innovation, which is more effective for large, private and low-polluting enterprises. Zhou et al. (2023) found that green finance promoted corporate environmental innovation, and this positive impact mainly played a role in easing capital restrictions, alleviating information asymmetry and strengthening environmental supervision.

Through reviewing the literature, we find that government subsidy is closely related to green innovation. However, existing research focuses on the "subsidy" effect, and there is still a research gap in the "post-subsidy" effect. With the reduction of government subsidy, studying the change of green innovation in the "post-subsidy era" can not only enrich existing research but also provide theoretical guidance for enterprises' green transformation.

2.2 hypothetical development

2.2.1 Subsidy expiration and green innovation

According to Resource-Based Dependence Theory, the survival and development of an organization depends on its ability to obtain critical resources from the external environment(Frynas & Yamahaki, 2016). When the supply of external resources (such as government subsidies) changes, organizational behavior and strategies adjust accordingly. First, green innovation is often characterized by high costs, long cycles, and high risks(Y. M. Su, Liu, & Liang, 2025). At the same time, the positive externalities of green innovation (such as environmental benefits) are often difficult to be fully priced by the market, making it difficult for enterprises to cover all costs through

market benefits. For enterprises, government subsidies are an important resource to reduce innovation costs and compensate for market failures(Y. T. Liu et al., 2022b). If companies are highly dependent on subsidies to cover the cost of green innovation, the end of subsidies will directly weaken their incentive and ability to innovate. In the absence of alternative resources, enterprises may not be able to maintain the original innovation investment after the subsidy expires(Xia et al., 2022). Second, government subsidies may cause enterprises to form path dependence on policy resources and neglect internal innovation capacity building. Once subsidies end, enterprises lack independent "hematopoietic" ability, it is difficult to support innovation independently. Finally, subsidy policies are often accompanied by the endorsement of the legitimacy of green innovation (such as environmental certification, policy incentives)(Adnan, Zhu, & Bilal, 2025). After the subsidy expires, if the supporting system (such as carbon emission regulation, green technology standards) is not strengthened simultaneously, enterprises may reduce innovation investment due to reduced legitimacy pressure. Therefore, according to the resource dependence theory, the decline of green innovation after the expiration of subsidies is essentially the result of the combined effect of external resource supply failure, internal capacity insufficiency and institutional environment change. Hypothesis 1 is as follows:

Hypothesis 1: Subsidy expiration inhibits enterprises' green innovation.

2.2.2 Boundary analysis: debt financing and equity financing

Innovation incentives and the ability to raise needed funds determine whether firms are green innovative (Ma, Sha, Wang, & Zhang, 2023; Peneder, 2008). Government subsidy helps improve green innovation from the "incentive" level. The government's subsidy policy may encourage green innovation by reducing R&D costs and risks (Hewitt-Dundas & Roper, 2010; Shao & Chen, 2022; Wu & Hu, 2020; Yi, Wang, Yan, Fu, & Zhang, 2020). Shao and Chen (2022) show that government subsidies can improve enterprises' green innovation, and such promotion effects are heterogeneous among enterprises. Y. T. Liu et al. (2022b) stated that government subsidies more influence the enterprises' green innovation with high social responsibility. Ma et al. (2023) confirmed that government subsidies can mitigate the adverse effects of green credit policy on green innovation. However, the increase in costs and risks brought about by subsidy expiration leads to the loss of innovation motivation for enterprises, and the "incentive" function disappears. At this moment, the "capacity" of external financing plays a prominent role. Because of the significant investment, high risk and extended return period of green innovation, enterprise innovation needs sufficient and stable funding sources (B. Liu, Ju, Bai, & Yu, 2021; Zhao, Wang, Wang, & Zhang, 2023).However, enterprises' internal funds are limited (Cowling & Liu, 2023; Vanacker & Manigart, 2010), so it is difficult to provide adequate funding for R&D. Therefore, external financing provides an essential financial supplement for corporate R&D (Z. F. Su et al., 2022; Zhao et al., 2023). External financing can generally be divided into debt financing, equity financing and government subsidy(Brown, Fazzari, & Petersen, 2009; Xiang et al., 2022). Since we are now considering the situation after the expiration of government subsidy, this paper focuses on two external financing methods: debt financing and equity financing.

Debt financing is closely related to green innovation. In the context of the vigorous implementation of debt financing guidelines in the pilot zone of government financing institutions, banks and other financial institutions are responsible for overseeing the environmental performance of companies at a financial level (Ho, 2018). As the main body of shared responsibility of enterprises, creditors are more concerned about the enterprises' environmental risks (Bouma & Kamp-Roelands,

2000). Therefore, creditors are obliged to assist with corporate green innovation activities(Shi, Yu, Li, & Wang, 2022). Research shows that green credit policy improves enterprises' R&D capability(H. Y. Chen, Liu, Xie, Zhang, & Guan, 2019a) and encourages green innovation by reducing capital limitation (Yu et al., 2021). Y. C. Lu, Gao, Zhang, and Wang (2022) believe that the improvement of green finance for the green innovation of heavy-polluting enterprises is mainly achieved by increasing capital limitation and financing costs. C. Liu and Xiong (2022) found that green finance increases green innovation by reducing the cost of debt and increasing R&D input and foreign investment. Cowling and Liu (2023) found an interesting phenomenon: risk-averse banks also provide financing to SMEs that are actively engaged in green innovation. After the subsidy expires, debt financing will help to play the resource allocation function of finance (Y. L. Wang, Zhao, Lei, & Long, 2021), become an effective supplement to the public capital market, and meet the financing needs of green innovation(Cowling & Liu, 2023). As a result, firms that receive debt financing are more likely to finance potential green innovation opportunities than those that do not (Cowling & Liu, 2023; Gelos & Werner, 2002; Love, 2003), thus alleviating the financial strain faced after the subsidy expires.

Equity financing is closely related to green innovation. Xiang et al. (2022) found that enterprises can use equity funds to support green innovation. B. Q. Lin and Xie (2023) took new energy enterprises as research objects and researched the improvement of equity financing on green innovation. Jiang and Liu (2024) found that the involvement of equity financing would positively affect green technology innovations of new energy vehicle enterprises. Firstly, equity financing can supplement the funds for green innovation. Equity financing has a high-risk tolerance and allows no short-term financial return (Dong, Li, Lv, & Yu, 2021; Roma, Vasi, Testa, & Perrone, 2023). This makes them willing to finance green innovation projects(Tian & Wang, 2014). In the context of subsidy reduction or delay, equity financing will improve green innovation performance (B. Q. Lin & Xie, 2023). Secondly, equity financing participates in enterprise management in the form of capital for equity and plays a certification effect(Drover et al., 2017; B. Q. Lin & Xie, 2023). Enterprises that obtain equity financing can convey the signal of high-quality development of the company to the external market, which mitigates the information bias of external investors(C. C. Wang, Lan, & Zhang, 2022; S. Y. Yang, Feng, Lu, & Wang, 2022), which makes up for the adverse effects of the government's "certification effect" and "signal effect" disappearing after the subsidy expires(Z. G. Chen, Zhang, Wang, Ouyang, & Xie, 2022; Y. T. Liu et al., 2022b; Shao & Chen, 2022). Therefore, the subsequent financing cost of enterprises that obtain equity financing is lower (B. Q. Lin & Xie, 2023), which alleviates the capital restriction caused by the subsidy expiration.

In summary, the addition of debt financing and equity financing may mitigate the negative impact of subsidy expiration on green innovation. Hypothesis 2a and 2b as shown below:
Hypothesis 2a: Debt financing mitigated the decline in green innovation after the subsidy expired.
Hypothesis 2b: Equity financing mitigated the decline in green innovation after the subsidy expired.

However, research shows that compared with debt financing, companies are more likely to finance green innovation projects through equity financing (Brown, Martinsson, & Petersen, 2012; Xiang et al., 2022; B. Yang, Chou, & Zhao, 2020). Green innovation investment has two characteristics compared with other forms of investment. Firstly, investment is more risk. The unpredictability of innovation results makes it difficult to guarantee investors' investment returns (J. W. Huang & Li, 2017). Secondly, the adjustment costs are higher. Green innovation is a process of knowledge accumulation and technology reserve. So, enterprises must continue to invest in green

innovation activities, which makes the adjustment cost of green innovation investment higher(Horbach, Rammer, & Rennings, 2012). For external investors, creditors represented by banks tend to avoid risks and crave stable investment returns (Xiang et al., 2022). They prefer to invest in mature enterprises with large amounts of collateral or fixed assets(Hall & Lerner, 2010) and do not consider intangible assets generated by green innovation to be tangible loan guarantees (Lindman & Söderholm, 2016). In addition, debt financing requires enterprises to have stable cash flow to repay interest-bearing debt, while green innovation projects require continuous cash flow, so these projects are difficult to obtain debt financing (Cowling & Liu, 2023; Hall & Lerner, 2010). In contrast, equity financing is more inclined to high-risk and high-yield investment projects, and they are more concerned about the long-term value of the investment(Xiang et al., 2022) rather than paying particular attention to whether the enterprise has enough tangible assets(Hsu, Tian, & Xu, 2014). In addition, equity investors can guarantee that green innovation projects have a stable and continuous capital flow, which ensures the continuity of green innovation financing. W. Zhang, Jin, and Wang (2015) also show that venture capital can improve green innovation ability more than bank loans. To sum up, equity financing, such as venture capital, is more suitable for green innovation projects than debt financing, and it plays a more significant role in supplementing funds after the subsidy expires. Hypothesis 2c as shown below:

Hypothesis 2c: Equity financing is more effective than debt financing in alleviating the negative impact of subsidy expiration on green innovation.

2.2.3 Mechanism analysis: R&D investment

C. Liu and Xiong (2022) believe that a meaningful way to improve enterprises' green innovation capability is to increase R&D investment. More R&D investment promotes enterprises' green innovation capability (Feng, Wang, Song, & Liu, 2022; Y. Li, Wang, Mu, & Li, 2023a; J. M. Liu, Jiang, Gan, He, & Zhang, 2022a; Y. Lu, Sun, Zhang, & Yang, 2023; Shao & Chen, 2022). Studies have shown that firms will invest the funds obtained from the subsidy into green innovation projects (Arqué-Castells, 2013; Kveton & Horák, 2018; Shao & Chen, 2022). We believe that subsidy expiration will reduce investment in R&D and thus reduce green innovation. The root cause is that after the subsidy expires, the advantages brought about by the subsidy to reduce innovation costs and risks disappear, and the sudden stop of financial support will cause severe financial distress to enterprises(D. Y. Zhang, 2023). Once again, companies need to face the uncertainty of green innovation alone while the community shares the benefits. As a result of the profit-driven capital, enterprises tend to pursue short-term economic benefits while ignoring environmental protection and have no ability and motivation to continue investing in green R&D(H. Liu et al., 2023a).

However, debt financing and equity financing will increase the R&D investment. Debt financing makes financial and social funds tilt toward environmentally friendly projects and urges enterprises to green production(X. K. Xu & Li, 2020), and then reallocates resources (Shi et al., 2022). Equity financing directly participates in enterprise management in the form of capital exchange for equity, which can supervise the governance decisions of the investee enterprises and restrain the short-sighted behaviours of managers(Cheng, Hua, & Tan, 2019), forcing enterprises to invest the funds raised by equity financing into sustainable development projects such as green innovation. In addition, equity financing focuses on the overall return rate of the portfolio, which means that equity financing allows individual projects to fail and is willing to share the R&D risks of green innovation activities with enterprises(B. Q. Lin & Xie, 2023). So, companies are daring to invest in riskier green innovation activities. To sum up, debt financing and equity financing will

have a positive effect on R&D investment, and the negative impact of subsidy expiration on green innovation can be alleviated by increasing R&D investment. Hypothesis 3 as shown below:

Hypothesis 3: The reduction of R&D investment is the internal mechanism of subsidy expiration inhibiting green innovation. However, the increase in debt financing and equity financing will increase R&D investment, resulting in a weaker negative impact of subsidy expiration on green innovation.

3 Research design

3.1 Data sources

Green innovation data comes from a green patent database. If a patent's IPC code is included in the IPC Green List of the WIPO, the patent is green. We use the number of applications and authorizations of utility models and invention patents to indicate the level of green innovation, respectively. Application numbers contain some low-quality patents that are ultimately not authorized, and there is a specific deviation when measuring green innovation (A. T. Xu et al., 2023). Authorization numbers have a specific time lag, often taking 2-3 years, which makes it impossible to accurately measure green innovation in the current year(W. Li & Zheng, 2016). Therefore, a careful consideration of the application numbers and authorization numbers makes our research results more accurate. At the same time, our data will be tracked through 2021 to ensure that patent applications have enough time to be reviewed and granted before 2024. The financial data comes from the CSMAR database. Our initial sample includes 3,845 industrial companies with full A-shares from 2011 to 2021, excluding ST companies. The result was 17,723 firm annual observations.

3.2 Variable definition

Existing research widely uses patents to measure technological innovation (Tang, Xu, Hao, Wu, & Xue, 2021). We choose the application and authorization of utility models and invention patents to measure green innovation (A. T. Xu et al., 2023). The measure of subsidy expiration is to construct dummy variables 0 and 1 according to whether the enterprise subsidy expires at the observed time(D. Y. Zhang, 2023). To make the results more scientific, we also controlled for a range of variables (Zhan, Lin, & Sun, 2023; D. Y. Zhang, 2023). This mainly includes enterprise age (Age), asset-liability ratio (LEV), return on assets (ROA), fixed asset ratio (Fixed), cash asset ratio (Cash), Tobin Q (Tobin Q) and equity concentration (Top10). Definitions of each variable are shown in Appendix Variable definitions.

3.3 Model establishment

We use formula (1) to assess the impact of subsidy expiration on green innovation:

$$GI_{i,t}=\beta_0+\beta_1 Expiration_{i,t}+\beta_2 Control_{i,t}+Year_t+Ind_i+\varepsilon_{it} \quad (1)$$

In formula (1), *i* and *t* represent industry and year respectively. *Expiration* is the explanatory variable, denoted by 0 and 1. *GI* is the explained variable, expressed by the application number and authorization number of industrial enterprises in the observed year. *Control* is a series of control variables, including enterprise age, asset-liability ratio, return on assets, fixed assets ratio, cash assets ratio, Tobin Q and equity concentration. *Year* is a fixed time effect. *Ind* is an industry-fixed effect. ε is a random perturbation term. The research focus of formula (1) is β_1. If β_1 is significantly less than 0, it indicates that subsidy expiration hinders green innovation.

To examine the moderating role of debt and equity financing in subsidy expiration and green innovation, we construct formula (2) and (3):

$$GI_{i,t}=\rho_0+\rho_1 Expiration_{i,t}+\rho_2 Debt_{i,t}++\rho_3 Expiration_{i,t}*Debt_{i,t}+\rho_4 Control_{i,t}+Year_t+Ind_i+\varepsilon_{it} \quad (2)$$

$$GI_{i,t}=\lambda_0+\lambda_1 Expiration_{i,t}+\lambda_2 Equity_{i,t}++\lambda_3 Expiration_{i,t}*Equity_{i,t}+\lambda_4 Control_{i,t}+Year_t+Ind_i+\varepsilon_{it} \quad (3)$$

Debt is the adjusting variable of debt financing in this paper, which is expressed by the sum of long-term loans, short-term loans and bonds payable divided by total assets. *Equity* is the adjusting variable of equity financing in this paper, which is expressed by the sum of equity and capital reserve divided by the total assets. The research focus of equations (2) and (3) is ρ_3 and λ_3. If ρ_3 and λ_3 are significantly greater than 0, it indicates that debt financing and equity financing will alleviate the adverse effect of subsidy expiration on green innovation.

To examine the mediating role of R&D investment in subsidy expiration and green innovation, we construct formula (4) and (5):

$$Investment_{i,t}=\sigma_0+\sigma_1 Expiration_{i,t}+\sigma_2 Control_{i,t}+Year_t+Ind_i+\varepsilon_{it} \quad (4)$$

$$GI_{i,t}=\theta_0+\theta_1 Expiration_{i,t}+\theta_2 Investment_{i,t}+\theta_3 Control_{i,t}+Year_t+Ind_i+\varepsilon_{it} \quad (5)$$

Investment is the intermediate variable of research and development input in this paper, expressed by the natural logarithm of research and development expenditure. σ_1 measures the impact of subsidy expiration on R&D investment. θ_2 measures the impact of R&D investment on green innovation after controlling for the effect of subsidy expiration. θ_1 measures the direct impact of subsidy expiration on green innovation after controlling for the impact of R&D investment. Formulas (4) and (5) focus on σ_1 and θ_2. If σ_1 is significantly less than 0 and θ_2 is significantly greater than 0, it indicates that subsidy expiration negatively affects R&D investment, R&D investment positively affects green innovation, and R&D investment has a significant intermediary effect.

4 Empirical results

4.1 Descriptive statistics

Descriptive statistics are reflected in Table 1. We find that the average number of green patent applications is 4.217, indicating that the average number of applications from industrial enterprises in China is low. However, the maximum number of applications was 346, indicating a significant gap in the number of green patent applications between enterprises. Similarly, there is a similar problem with the number of green patents granted, with an average of 3.067 and a maximum of 508. It shows that there is also a significant gap in the number of green patents authorized among enterprises. The data on subsidy expiration shows that 10.5% of subsidy enterprises are affected by the change in subsidy policy. The minimum value of R&D investment is 5.606, the maximum value is 9.649, and the average value is 7.749, indicating that the difference in the amount of R&D investment between enterprises is slight. The average value of debt financing and equity financing is 0.148 and 0.408, respectively, indicating that equity financing of industrial enterprises is relatively high and debt financing is relatively low. The average age of all observed enterprises is 9.749, indicating that enterprises generally have a short existence time and belong to start-ups. The asset-liability ratio is 40.4%, indicating that enterprises generally have a poor ability to repay debt. The return on assets is 4%, indicating generally poor profitability. The fixed assets ratio is 23.9%, indicating that enterprises generally have a high efficiency in the use of funds and make full use of idle funds. The cash-asset ratio is 16.1%, indicating that the capital liquidity of enterprises is generally poor, and the degree of protection for creditors is low. Tobin's Q value is 2.05, indicating that the growth of enterprises is generally poor. The concentration of ownership is 59.622, indicating that the distribution of ownership of enterprises is generally concentrated and stable.

Insert Table 1 here

4.2 Main results

We use equation (1) to test the relationship between subsidy expiration and green innovation, and Table 2 shows the empirical regression results. In columns (1) to (4), we examined the impact of subsidy expiration on application and authorization count with and without control variables. Specifically, the dependent variable in columns (1) and (2) is the application count, and the dependent variable in columns (3) and (4) is the authorization count. Both measures show that subsidy expiration inhibits corporate green innovation. Our findings support hypothesis 1, which states that after subsidy expiration, firms' level of green innovation declines, both in terms of applications and actual authorizations. Our finding further supports the view that subsidy shocks discourage green investment(D. Y. Zhang, 2023).

Insert Table 2 here

4.3 Robustness test

4.3.1 Change the measurement method of green innovation

We measure green innovation using post-grant references for green invention patents and utility model patents. The relationship between subsidy expiration and green innovation was re-evaluated. The finding is reflected in Table 3.

Columns (1) and (2) show the impact of subsidy expiration on green innovation under uncontrolled and controlled conditions. Subsidy expiration inhibits firms' green innovation activities. Once again, it proves that our result is robust.

Insert Table 3 here

4.3.2 Add control variables

To make our finding more robust, we additionally add two control variables(Y. Hu et al., 2023a): the ratio of tangible assets (Tang) and capital expenditure (Capital). We re-evaluated the relationship between subsidy expiration and green innovation. The finding is reflected in Table 4. Columns (2) and (4) show that the negative impact of subsidy expiration on green innovation is still significant when the variable is increased. This also proves that our main effect is valid.

Insert Table 4 here

4.3.3 Consider the lag of green innovation

Because innovation takes a certain amount of time, we use the number of green patent applications and authorizations over the next two to three years to measure the continued impact of subsidy expiration on green innovation (J. He & Tian, 2013; X. L. Hu, Yu, & Zhong, 2023b). Table 5 shows that our result is still valid when considering the lag of green innovation. The negative impact of subsidy expiration on green innovation has diminished over time, but it persists. These results suggest that the negative impact of subsidy expiration on green innovation is not temporary. Without guidance, the reduction in green innovation caused by the subsidy shock could last for three years or more.

Insert Table 5 here

4.4 Boundary analysis

By this point, we have provided strong evidence that green innovation decreases after the subsidy expires. In this part, we discuss the complementary role of debt financing and equity financing to government subsidy. After the subsidy expires, will green innovation that has obtained these two kinds of external financing be improved compared with enterprises that have not obtained debt financing and equity financing?

4.4.1 Debt financing

As H2a shows, green innovation that receives debt financing may be less negatively affected by subsidy expiration. Therefore, we examined changes in green innovation in firms that received debt financing after the subsidy expired. Table 6 shows the exploration result of debt financing boundary conditions according to equation (2). We focus on ρ_3, the interaction coefficient between subsidy expiration and debt financing. Column (2) shows that the coefficient is not significant. Therefore, debt financing does not regulate the relationship between subsidy expiration and green innovation, and H2a is not valid. That is, debt financing cannot alleviate the negative impact of subsidy expiration on green innovation. We suspect this is due to the high cost of debt financing for companies (Beladi, Deng, & Hu, 2021), and creditors represented by banks need enterprises to have more mortgage assets and more stable cash flow to repay debts(Cowling & Liu, 2023). Therefore, enterprises will not easily invest the funds raised by debt into green innovation with high risks and uncertain returns.

Insert Table 6 here

4.4.2 Equity financing

As H2b shows, green innovation with equity financing may be less negatively affected by subsidy expiration. Therefore, we studied the impact of equity financing on green innovation after the subsidy expires. Table 7 shows the result of exploring the boundary condition of equity financing according to equation (3). We focus on λ_3, the interaction coefficient between subsidy expiration and equity financing. Column (2) shows that the coefficient is positively significant. Therefore, equity financing positively regulates the relationship between subsidy expiration and green innovation, and H2b is established. That is, equity financing can alleviate the negative impact of subsidy expiration on enterprises' green innovation. This is a supplement to the research conclusion that equity financing can significantly improve corporate green innovation performance(B. Q. Lin & Xie, 2023).

Combining Table 6 and Table 7, it can be found that λ_3 is 7.433 and is significant at the 10% level. ρ_3 is -3.151, and it is not significant. Therefore, our H2c is verified: Equity financing can more positively regulate the negative correlation between subsidy expiration and green innovation more than debt financing. From another perspective, this conclusion provides support for the view that the influence of equity financing and debt financing on green innovation is weakened in turn (Xiang et al., 2022).

Insert Table 7 here

4.5 Mechanism analysis

So far, we have shown that after subsidies expire, green innovation will decline. Moreover, equity financing can mitigate the adverse effect of subsidy expiration on green innovation. However, the complementary role of debt financing is not significant. In this section, we explore how subsidy expiration affects green innovation through R&D investment. Subsequently, we discuss in depth whether R&D investment is a way for equity financing to reduce the adverse effect of subsidy expiration on green innovation.

First, we discuss the mediating role of R&D investment. The finding is reflected in Table 8. Column (1) shows that there is a significant negative correlation between subsidy expiration and R&D investment. That is after subsidies expire, companies typically spend less on R&D. Column (2) shows that R&D investment is significantly positively correlated with green innovation. That is, increased investment in R&D will promote green innovation. Thus, the first half of hypothesis 3 is verified: the reduction of R&D investment is one way in which subsidy expiration negatively affects green innovation. Subsidy expiration can reduce green innovation by reducing R&D investment. This conclusion is the same as the existing research (Shao & Chen, 2022), which proves that R&D investment is an essential channel for government subsidy to affect the efficiency of enterprises' green technology innovation.

Insert Table 8 here

Secondly, we explored the relationship between equity financing and R&D investment. We attempt to answer whether equity financing can alleviate the adverse effect of subsidy expiration on green innovation by increasing R&D investment. Column (1) of Table 9 shows that the interaction coefficient between subsidy expiration and equity financing is significantly negative. Therefore, there is no positive correlation between equity financing and R&D investment after the subsidy expires. R&D investment is not an effective way for equity financing to alleviate the adverse effects of subsidy expiration on green innovation. Y. Hu et al. (2023a) found that after the Green Credit Guidelines came into effect, non-green enterprises increased the number of green patents by increasing patent activities rather than innovation investment. This conclusion has some similarities with our study.

Since 5.4.1 has confirmed that debt financing will not alleviate the adverse effect of subsidy expiration on green innovation, we will no longer consider the impact of debt financing on R&D investment in this part.

Insert Table 9 here

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5 Further analysis

In Part 4.5, we have demonstrated that equity financing does not mitigate the negative impact of subsidy expiration on green innovation by increasing R&D investment. We speculate that there is a phenomenon of "greenwashing" in enterprises' green innovation behaviour (Y. Hu et al., 2023a). This part discusses this speculation.

High-quality green innovation is costly, risky, and has a long cycle(Z. Y. Chen, Zhang, & Zi, 2021b). After the subsidy expires, the innovation costs and risks of enterprises increase to varying degrees, so enterprises are not willing to take substantive innovation activities to improve the quality of innovation(Tong, He, He, & Lu, 2014) but adopt strategic innovation to increase the number of innovations (Y. Hu et al., 2023a). Firms do this in order to cater to government policies and investor preferences in order to obtain low-cost external financing and other benefits(Y. Hu et al., 2023a). Therefore, after the subsidy expires, the enterprises that receive equity financing will mainly improve in the quantity of green innovation rather than in the quality. This explains why research and development investment has declined, but green innovation has increased.

It is found that an invention patent is more innovative than a utility model patent (Amore & Bennedsen, 2016). Therefore, we use the number of invention patents granted to represent substantive green innovation and the number of utility model patents granted to represent strategic green innovation (Tang et al., 2021). The finding is reflected in Table 10.

Column (2) shows that the interaction coefficient between subsidy expiration and equity financing is not significant. In other words, after the subsidy expires, equity financing will not promote substantial green innovation. Column (4) shows that the interaction coefficient between subsidy expiration and equity financing is significantly positive. In other words, after the subsidy expires, equity financing can increase strategic green innovation. Therefore, green innovation exists in "greenwashing". After the subsidy expires, enterprises do not apply the equity financing obtained to R&D investment but squeeze R&D investment, adopt strategic green innovation strategies to meet stakeholders' expectations, and disguise themselves as green enterprises.

Insert Table 10 here

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6 Conclusions and practical significance

Antecedent variables of green innovation are worthy of discussion by both academia and policymakers. We study the impact of subsidy expiration on green innovation in China's industrial enterprises from 2011 to 2021. Our research has yielded some enlightening conclusions. First, subsidy expiration inhibits green innovation. The results of various robustness tests prove that our conclusion is valid. Second, after the subsidy expires, equity financing can play a complementary role to government subsidy. The green innovation level with equity financing is less negatively affected by subsidy expiration. However, debt financing has a different effect. Third, R&D investment is a crucial way to restrain green innovation when the subsidy expires. Subsidy expiration inhibits enterprises' green innovation by reducing their R&D investment. Finally, after the subsidy expires, there is a "greenwashing" phenomenon in green innovation. Companies that receive equity financing do not engage in substantial innovation by increasing R&D investment but rather increase the overall number of green innovations through strategic innovation to meet stakeholder expectations.

Our research conclusion has specific practical significance. First, policymakers must recognize that supporting corporate green innovation is not a short-term commitment and should ensure that the necessary financial support is provided throughout the process of green R&D. This requires the government to cooperate with the private sector to jointly meet the financing needs for green innovation through the public capital market and the private capital market. Second, external investors, especially creditors, need to recognize the vital contribution of green innovation to the

sustainable development of companies and financial markets. Set up particular loans for green innovation for enterprises, strengthen long-term cooperation with green innovation projects, and help enterprises achieve green transformation. In addition, external investors should pay more attention to the quality of green innovation output when providing financial support for enterprises. A company's ESG performance and social responsibility scores can be used as non-financial measures. Because both innovation and social responsibility characterize green innovation itself (S. G. Ren, Wang, Hu, & Yan, 2021), enterprises with good CSR performance have a greater probability of substantial green innovation (Y. T. Liu et al., 2022b). This will help improve the efficiency of capital allocation of various investment entities, reduce the adverse selection problem between external capital and green innovation, and prevent enterprises from adopting the "greenwashing" strategy and using green innovation gimmicks to cheat external financing. Finally, managers need to allocate financial resources effectively to improve the quality of green innovation. Faced with the impact of subsidy expiration, enterprises should actively fulfil CSR, improve output quality, and attract external investment with high-quality patent achievements.

The expiration of subsidies has become an increasingly common phenomenon. After the expiration of subsidies, how should the government encourage enterprises to make green innovation, how should other external financing channels supplement funds for green innovation, and how should enterprises cope with the adverse impact of policy shocks on green innovation have become urgent problems to be solved. We discuss these problems, draw some useful conclusions, and summarize in the end. However, there are some limitations to our study. For example, our further analysis only proves that there is a "greenwashing" phenomenon in the enterprises' green innovation activities, but does not give solutions on how to curb this situation. In future studies, we hope to solve this problem.

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Appendix Variable definitions

Symbol	Implication
Application	The total number of applications for utility model patents and invention patents
Authorization	The total number of authorizations for utility model patents and invention patents
Expiration	If the enterprise subsidy expires in the observation period, it is 1; Otherwise, it is 0
Debt	The sum of long-term loans, short-term loans and bonds payable divided by total assets
Equity	The sum of equity and capital reserve divided by the total assets
Investment	The natural logarithm of research and development expenditure
Age	Observation year minus listing year
LEV	Total liabilities divided by total assets
ROA	Net profit divided by average total assets
Fixed	Net fixed assets divided by total assets
Cash	Closing cash and cash equivalents balance divided by total assets
Tobin Q	Market value divided by total assets
Top10	The sum of the top 10 shareholders

Table 1 Descriptive statistics

Variables	Obs	Mean	Std. dev.	Min	Max
Application	14,579	4.217	14.975	0	346
Authorization	14,103	3.067	15.116	0	508
Expiration	17,722	0.105	0.306	0	1
Investment	16,139	7.749	0.622	5.606	9.649
Debt	17,722	0.148	0.143	0	0.625
Equity	17,721	0.408	0.220	0.058	1.883
Age	14,043	9.749	7.057	1	28
LEV	17,722	0.404	0.206	0.032	1.035
ROA	17,722	0.040	0.069	-0.573	0.238
Fixed	17,722	0.239	0.149	0.012	0.710
Cash	17,722	0.161	0.129	0.006	0.749
Tobin Q	17,082	2.050	1.267	0.802	10.496
Top10	17,720	59.622	15.357	19.881	91.7927

Table 2 Baseline regression results

Variables	(1)	(2)	(3)	(4)
	Application	Application	Authorization	Authorization
Expiration	-1.549***	-1.525***	-1.830***	-1.916***
	(-3.18)	(-2.80)	(-3.98)	(-3.66)
Age		0.102***		0.075**
		(3.25)		(2.26)
LEV		8.953***		5.634***
		(10.68)		(8.33)
ROA		15.183***		6.052***
		(6.86)		(2.65)
Fixed		-2.087*		-2.233**
		(-1.91)		(-2.28)
Cash		3.310***		-0.023
		(2.69)		(-0.02)
Tobin Q		-0.726***		-0.540***
		(-7.52)		(-6.60)
Top10		0.060***		0.062***
		(5.28)		(5.56)
Constant	4.343***	-2.413***	3.211***	-1.600**
	(33.07)	(-3.04)	(23.60)	(-2.13)
Fixed effects	YES	YES	YES	YES
Observations	14573	11668	14097	11228
R-squared	0.144	0.163	0.165	0.178

Table 3 Change the measurement method of green innovation

Variables	(1)	(2)
	References	References
Expiration	-0.049***	-0.043**
	(-2.87)	(-2.27)
Age		0.008***
		(7.51)
LEV		0.560***
		(13.99)
ROA		0.840***
		(8.31)
Fixed		-0.123**
		(-2.39)
Cash		0.070
		(1.14)
Tobin Q		-0.046***
		(-10.68)
Top10		0.002***
		(4.59)
Constant	0.381***	0.053
	(67.51)	(1.28)
Fixed effects	YES	YES
Observations	17716	14042
R-squared	0.102	0.139

Table 4 Add control variables

Variables	(1)	(2)	(3)	(4)
	Application	Application	Authorization	Authorization
Expiration	-1.549***	-1.106**	-1.830***	-1.467***
	(-3.18)	(-2.14)	(-3.98)	(-3.01)
Age		0.029		0.013
		(0.94)		(0.39)
LEV		3.933***		0.835
		(4.69)		(1.14)
ROA		5.853***		-2.602
		(2.71)		(-1.13)
Fixed		-7.099***		-6.795***
		(-6.30)		(-5.83)
Cash		2.514**		-0.670
		(2.07)		(-0.62)
Tobin Q		-0.382***		-0.220***
		(-4.06)		(-2.61)
Top10		-0.005		0.001
		(-0.42)		(0.13)
Tang		8.043***		6.294***

		(6.50)		(5.55)
Capital		0.000***		0.000***
		(10.84)		(8.11)
Constant	4.343***	-4.509***	3.211***	-2.455**
	(33.07)	(-3.75)	(23.60)	(-2.28)
Fixed effects	YES	YES	YES	YES
Observations	14573	11621	14097	11181
R-squared	0.144	0.242	0.165	0.243

Table 5 Lag of green innovation

Variables	(1)	(2)	(3)	(4)
	$Application_{t+2}$	$Application_{t+3}$	$Authorization_{t+2}$	$Authorization_{t+3}$
Expiration	-1.138***	-0.986***	-0.563**	-0.577***
	(-3.24)	(-3.34)	(-2.21)	(-3.38)
Age	0.074***	0.043***	0.025	0.009
	(3.52)	(2.60)	(1.52)	(0.89)
LEV	6.544***	5.561***	4.107***	3.690***
	(9.99)	(8.87)	(9.05)	(9.19)
ROA	8.431***	7.867***	4.344***	4.813***
	(5.34)	(6.25)	(3.70)	(5.95)
Fixed	-1.312	-0.444	-0.514	0.101
	(-1.45)	(-0.59)	(-0.88)	(0.21)
Cash	3.150***	2.881***	0.684	0.700
	(3.08)	(2.80)	(1.00)	(1.20)
Tobin Q	-0.580***	-0.482***	-0.385***	-0.329***
	(-8.44)	(-8.04)	(-8.20)	(-10.13)
Top10	0.036***	0.025***	0.026***	0.016***
	(3.90)	(3.25)	(3.91)	(3.30)
Constant	-1.245**	-0.699	-0.494	-0.147
	(-2.02)	(-1.32)	(-1.15)	(-0.45)
Fixed effects	YES	YES	YES	YES
Observations	10713	9281	10535	9281
R-squared	0.145	0.111	0.145	0.112

Table 6 Boundary conditions: Debt financing

Variables	(1)	(2)
	GI	GI
Expiration	-1.898***	-1.462**
	(-3.65)	(-1.97)
Debt	-14.034***	-13.812***
	(-6.87)	(-6.75)
Expiration *Debt		-3.151
		(-1.05)
Age	0.045	0.045
	(1.39)	(1.39)
LEV	12.536***	12.546***
	(9.24)	(9.24)
ROA	4.653**	4.656**
	(2.09)	(2.09)
Fixed	-0.567	-0.574
	(-0.62)	(-0.62)
Cash	-0.506	-0.490
	(-0.46)	(-0.45)
Tobin Q	-0.629***	-0.628***
	(-7.30)	(-7.29)
Top10	0.055***	0.055***
	(5.11)	(5.11)
Constant	-1.639**	-1.684**
	(-2.18)	(-2.25)
Fixed effects	YES	YES
Observations	11228	11228
R-squared	0.183	0.183

Table 7 Boundary conditions: Equity financing

Variables	(1)	(2)
	GI	GI
Expiration	-1.912***	-4.831***
	(-3.66)	(-3.24)
Equity	-3.307***	-3.884***
	(-3.28)	(-4.54)
Expiration *Equity		7.433*
		(1.92)
Age	0.071**	0.069**
	(2.17)	(2.10)
LEV	3.368***	3.456***
	(3.39)	(3.41)
ROA	0.851	1.366
	(0.32)	(0.49)
Fixed	-2.258**	-2.243**

	(-2.31)	(-2.30)
Cash	0.173	0.248
	(0.16)	(0.24)
Tobin Q	-0.424***	-0.420***
	(-4.48)	(-4.50)
Top10	0.062***	0.062***
	(5.54)	(5.51)
Constant	0.615	0.805
	(0.71)	(0.96)
Fixed effects	YES	YES
Observations	11228	11228
R-squared	0.179	0.179

Table 8 Influencing mechanism: R&D investment

Variables	(1)	(2)
	Investment	GI
Expiration	-0.058***	-1.632***
	(-4.12)	(-3.08)
Investment		4.887***
		(12.47)
Age	0.015***	0.012
	(16.99)	(0.33)
LEV	0.907***	1.862***
	(26.39)	(2.66)
ROA	2.337***	-6.391***
	(22.05)	(-2.59)
Fixed	-0.015	-2.656**
	(-0.34)	(-2.41)
Cash	0.093**	-0.880
	(2.02)	(-0.76)
Tobin Q	-0.076***	-0.115
	(-16.13)	(-1.19)
Top10	0.005***	0.048***
	(13.20)	(4.14)
Constant	7.091***	-36.776***
	(213.95)	(-11.71)
Fixed effects	YES	YES
Observations	13157	10420
R-squared	0.331	0.201

Table 9 Equity financing, R&D investment and green innovation

Variables	(1)	(2)
	Investment	GI
Expiration	0.069**	-4.458***
	(1.99)	(-2.63)
Expiration *Equity	-0.321***	7.249
	(-3.96)	(1.60)
Investment		4.899***
		(12.46)
Age	0.015***	0.010
	(17.07)	(0.29)
LEV	0.881***	2.361***
	(25.22)	(2.92)
ROA	2.265***	-4.951*
	(21.28)	(-1.84)
Fixed	-0.014	-2.637**
	(-0.32)	(-2.40)
Cash	0.094**	-0.834
	(2.05)	(-0.72)
Tobin Q	-0.075***	-0.125
	(-16.01)	(-1.27)
Top10	0.005***	0.048***
	(13.12)	(4.11)
Constant	7.103***	-37.087***
	(213.77)	(-11.69)
Fixed effects	YES	YES
Observations	13157	10420
R-squared	0.332	0.201

Table 10 Substantive and strategic green innovation

	(1)	(2)	(3)	(4)
	substantive	substantive	strategic	strategic
Expiration	-0.881***	-1.845***	-0.785***	-1.342***
	(-3.86)	(-2.72)	(-3.74)	(-3.32)
Equity	-1.146**	-1.392***	-1.845***	-1.956***
	(-2.35)	(-3.65)	(-6.04)	(-6.00)
Expiration *Equity		2.489		1.420**
		(1.39)		(2.22)
Age	0.046***	0.046***	0.035***	0.034***
	(3.42)	(3.37)	(2.68)	(2.65)
LEV	2.860***	2.861***	0.533	0.550
	(5.78)	(5.79)	(1.40)	(1.45)
ROA	2.537**	2.627**	-1.462	-1.363
	(1.97)	(2.00)	(-1.52)	(-1.41)
Fixed	-0.016	-0.014	-1.246**	-1.243**
	(-0.04)	(-0.03)	(-2.44)	(-2.44)
Cash	0.658	0.687	0.440	0.454
	(1.38)	(1.44)	(1.04)	(1.07)
Tobin Q	-0.263***	-0.261***	-0.140***	-0.139***
	(-5.84)	(-5.90)	(-3.67)	(-3.64)
Top10	0.034***	0.034***	0.017***	0.017***
	(6.28)	(6.27)	(3.73)	(3.72)
Constant	-0.600	-0.511	1.024***	1.060***
	(-1.33)	(-1.19)	(3.00)	(3.08)
Fixed effects	YES	YES	YES	YES
Observations	12314	12314	11228	11228
R-squared	0.174	0.174	0.156	0.156