




The Impact of Tax Incentives on the Innovative Capacity of Renewable Energy Enterprises in China

Ying Wang¹  , Igor A. Mayburov^{1,2} , Ye Chenghao¹ 

¹ Ural Federal University named after the first President of Russia B.N. Yeltsin, Yekaterinburg, Russian Federation

² Financial University under the Government of the Russian Federation, Moscow, Russian Federation

 van.in@urfu.ru

ABSTRACT

Stimulating technological innovation in renewable energy enterprises is vital for achieving sustainable development and mitigating climate change. China, as the world's largest carbon emitter, has enacted various tax incentives aimed at enhancing innovation and alleviating financial pressures in its rapidly growing new energy power generation industry. However, empirical evidence concerning the effectiveness of these incentives, their heterogeneous effects across enterprises, and underlying mechanisms remains limited. This study employs a difference-in-differences (DID) approach combined with fixed-effects regression models using balanced panel data from 112 publicly listed new energy enterprises in China from 2017 to 2023. Additionally, a mediation analysis is conducted to test whether increased electricity generation mediates the relationship between tax incentives and innovation outcomes. The empirical results show that tax incentives significantly boost innovation, as evidenced by increased R&D intensity and patent productivity. However, notable heterogeneity exists: private firms respond more strongly than state-owned enterprises; large enterprises benefit more substantially than SMEs; and firms in eastern coastal regions exhibit greater responsiveness compared to inland firms. Furthermore, electricity generation output significantly mediates this relationship, indicating that tax incentives indirectly enhance innovation by improving operational capacity. These findings underscore the importance of targeted fiscal policies. Policymakers should refine tax incentives tailored to firm-specific characteristics such as ownership structure, scale, and geographic location. Enterprises, in turn, should strategically utilize these incentives to strengthen innovation capabilities, thus contributing to sustained competitive advantages and the broader goal of sustainable development.


KEYWORDS

new energy power, tax incentives, difference-in-differences, global sustainable development, innovative strategies

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Влияние налоговых льгот на инновационный потенциал предприятий возобновляемой энергетики в Китае

Ин Ван¹  , И.А. Майбуров^{1,2} , Е Чэнхао¹ 

¹ Уральский федеральный университет имени первого Президента России Б.Н. Ельцина, г. Екатеринбург, Российская Федерация

² Финансовый университет при Правительстве Российской Федерации, г. Москва, Российская Федерация

 van.in@urfu.ru

АННОТАЦИЯ

Стимулирование технологических инноваций на предприятиях возобновляемой энергетики имеет жизненно важное значение для достижения устойчивого развития и смягчения последствий изменения климата. Китай, как крупней-

ший в мире источник выбросов углерода, принял различные налоговые льготы, направленные на стимулирование инноваций и смягчение финансового давления в своей быстрорастущей отрасли новой энергетики. Однако эмпирические данные относительно эффективности этих стимулов, их неоднородного воздействия на предприятия и базовых механизмов остаются ограниченными. В этом исследовании используется подход «разница в разностях» (DID) в сочетании с моделями регрессии с фиксированными эффектами, использующими сбалансированные панельные данные 112 публично зарегистрированных предприятий новой энергетики в Китае с 2017 по 2023 г. Кроме того, проводится посреднический анализ, чтобы проверить, опосредует ли увеличение выработки электроэнергии связь между налоговыми стимулами и результатами инноваций. Эмпирические результаты показывают, что налоговые стимулы значительно стимулируют инновации, о чем свидетельствует возросшая интенсивность НИОКР и производительность патентов. Однако существует заметная неоднородность: частные фирмы реагируют сильнее, чем государственные предприятия; крупные предприятия получают большую выгоду, чем предприятия малого и среднего бизнеса; а фирмы в восточных прибрежных регионах демонстрируют большую отзывчивость по сравнению с фирмами внутренних регионов. Кроме того, объем выработки электроэнергии значительно опосредует эту связь, указывая на то, что налоговые стимулы косвенно усиливают инновации за счет улучшения операционных возможностей. Эти результаты подчеркивают важность целенаправленной фискальной политики. Политикам следует уточнить налоговые стимулы, адаптированные к специфическим характеристикам фирмы, таким как структура собственности, масштаб и географическое положение. Предприятия, в свою очередь, должны стратегически использовать эти стимулы для укрепления инновационных возможностей, тем самым способствуя устойчивым конкурентным преимуществам и более широкой цели устойчивого развития.

КЛЮЧЕВЫЕ СЛОВА

мощности новой энергетики, налоговые стимулы, метод разницы в различиях, глобальное устойчивое развитие, инновационные стратегии

1. Introduction

With the increasing severity of global climate change and environmental degradation, accelerating the development of renewable energy technologies has become an essential strategy for countries seeking sustainable economic growth. The global community is faced with critical ecological issues, including resource depletion, environmental pollution, and carbon emissions, which necessitate urgent and effective responses. Renewable energy, characterized by sustainability and low environmental impact, plays a critical role in mitigating these ecological pressures. China, as the world's largest energy consumer and carbon emitter, faces considerable challenges regarding environmental protection and sustainable development. Consequently, the Chinese government has prioritized the renewable energy sector, particularly new energy power generation, as a strategic industry, aiming to balance economic growth with ecological sustainability.

To foster innovation and support rapid growth within this sector, China has implemented numerous policy instruments, among which tax incentives have become especially prominent. These tax incentives include preferential corporate income tax rates, R&D expense deductions, accelerated depreciation policies, and other fiscal supports designed to stimulate technological innovation, reduce corporate financial burdens, and enhance industrial competitiveness. The theoretical rationale underpinning these policy interventions originates from endogenous growth theory, which posits that government policies can internalize positive externalities associated with innovation activities, thus correcting market failures related to underinvestment in R&D.

However, despite extensive policy implementation, empirical evidence regarding the effectiveness of these tax incentives on enterprise innovation within China's renewable energy industry remains inconclusive. Moreover, previous studies typically overlook

the potential dynamic and heterogeneous responses of enterprises to policy measures, failing to account adequately for differences in firm characteristics such as ownership structures, scale, and regional disparities. Understanding these differences is crucial for enhancing policy effectiveness and ensuring sustainable sectoral growth.

Given the limitations of existing research, this study seeks to address two central research questions:

RQ1: Do tax incentives effectively enhance the innovation capacity of new energy power generation enterprises?

RQ2: How does the impact of tax incentives on innovation evolve dynamically over time following policy implementation?

The primary objectives of this research are: first, to empirically evaluate the overall impact of tax incentives on firm innovation capability within China's renewable energy sector; second, to examine whether and how the effect of these tax incentives varies over time, reflecting possible adjustment periods required for enterprises to fully respond to policy incentives.

Consequently, this study proposes the following two hypotheses:

H1: Tax incentives significantly enhance the innovation capacity of new energy power generation enterprises.

H2: The impact of tax incentives on firm innovation exhibits a dynamic pattern, becoming more significant over time.

By utilizing a robust difference-in-differences (DID) estimation approach combined with firm-fixed effects regression analysis, and employing panel data from 112 publicly listed new energy power generation enterprises over the period 2017–2023, this research contributes to existing literature by systematically analyzing the direct and temporal effects of tax incentives on innovation. Additionally, the study further investigates the underlying mechanisms through mediation analyses, considering electricity generation as a potential mediator, thereby providing comprehensive insights into how fiscal policies drive sustainable technological innovation in China's renewable energy sector.

2. Literature Review

2.1. Tax incentives and corporate innovation

Tax incentives, as an important means for the government to encourage corporate innovation, have been widely used around the world. Hall & Van Reenen [1] study on OECD countries showed that tax incentives significantly promoted corporate R&D investment, thereby improving innovation output.

Guellec & Van Pottelsberghe [2] further found that government financial support for R&D, including tax incentives, has a positive impact on corporate innovation performance. Bloom et al. [3] confirmed the positive correlation between tax incentives and corporate R&D expenditures through panel data analysis of nine countries.

However, the effects of tax incentives may vary from country to country. Czarnitzki et al. [4] study in Belgium found that tax incentives have a particularly significant impact on small and medium-sized enterprises, but a relatively small impact on large enterprises.

In addition, the design and implementation of tax incentives will also affect their effectiveness. Mohnen & Lokshin [5] pointed out that complex application procedures and an uncertain policy environment may weaken the effect of tax incentives.

2.2. Tax incentives for the new energy industry

In the new energy industry, tax incentives are seen as a key factor in promoting technological innovation and industrial development. Johnstone et al. [6] studied the renewable energy policies of many countries and found a positive correlation between tax incentives and patent activities in renewable energy technologies.

Popp et al. [7] further pointed out that stable and continuous tax incentives can help reduce corporate uncertainty and encourage long-term R&D investment.

In China, Zhao et al. [8] analyzed the impact of renewable energy policies on technological innovation. The results showed that fiscal incentives such as tax incentives effectively promoted the innovation and application of renewable energy technologies.

2.3. Enterprise heterogeneity and the effect of tax incentives

The heterogeneous characteristics of enterprises, such as the size, ownership nature and market competition environment, will affect the implementation effect of tax incentives. Ayyagari et al. [9] found that small and medium-sized enterprises are more sensitive to tax incentives due to their limited resources.

In contrast, Criscuolo et al. [10] pointed out that large multinational companies may rely less on tax incentives through internal capital allocation.

In terms of ownership, Lin et al. [11] studied the differences in the responses of Chinese state-owned enterprises and private enterprises to tax policies and found that the growth of innovation investment of private enterprises under tax incentives was more significant.

In addition, the degree of market competition will also affect the effect of tax incentives. Aghion et al. [12] proposed that in markets with medium competition intensity, tax incentives have the most obvious effect on promoting innovation.

2.4. Dynamic effect of tax incentive policies

The impact of tax incentive policies is not immediate, and its dynamic effect deserves attention. Lokshin & Mohnen [13] analyzed the tax incentive effect of Dutch companies through a dynamic panel data model and found that the policy effect began to appear in the second year after implementation and continued to strengthen in the following years. This shows that companies need time to adjust their R&D strategies to make full use of tax incentives. In addition, the stability and predictability of tax policies are crucial to companies' long-term innovation decisions.

Dimos & Pugh [14] pointed out in a meta-analysis of public R&D support that policy uncertainty may cause companies to take a wait-and-see attitude towards innovative investment, thereby weakening the policy effect.

2.5. Substitution and complementary effects of tax incentives

Tax incentives may have substitution or complementary relationships with other forms of government support (such as direct subsidies). González & Pazo [15] studied the forms of government support for Spanish companies and found that tax incentives and direct subsidies have complementary effects in promoting corporate innovation.

However, Zúñiga-Vicente et al. [16] found in their study of European companies that over-reliance on government support may lead to a weakening of the company's own innovation motivation and a "crowding-out effect".

Therefore, policymakers need to weigh the relationship between tax incentives and other support measures when designing tax incentives to avoid resource misallocation and inefficiency.

2.6. Tax incentive policy practices for China's new energy power generation companies

The Chinese government has implemented a series of tax incentives to support the innovation and development of new energy power generation companies. For example, Wang et al. [17] studied the policy evolution of China's wind power industry and pointed out that tax incentives have played a positive role in reducing corporate costs and promoting technological progress.

Li et al. [18] analyzed the tax policies of Chinese solar photovoltaic enterprises and found that measures such as VAT refund effectively improved the profitability and R&D investment of enterprises.

However, Zhang et al. [19] pointed out that although tax incentives promoted the growth of new energy enterprises in the short term, the long-term effect depends on the sustainability of the policy and the innovation ability of the enterprises themselves.

The existing literature has relatively limited research on enterprise heterogeneity. Especially in the context of the new energy industry, there has been no systematic and in-depth discussion on how enterprise size, ownership and regional factors work together to affect the effect of tax incentives. The sensitivity of enterprises to tax incentives may depend on their internal management efficiency and external market environment.

Finally, most existing studies ignore the specific action paths and mechanisms of tax incentives. The improvement of enterprise innovation capabilities not only comes from direct fiscal stimulus, but may also be achieved indirectly by improving enterprise production efficiency and operational performance. For example, tax reduction policies can reduce enterprise production costs, indirectly increase enterprise cash flow, and then increase enterprise capital investment in R&D. However, existing literature rarely conducts in-depth empirical analysis of this mediating effect.

In summary, this study aims to fill the above research gaps. By adopting more rigorous empirical methods (such as difference-in-differences), it deeply analyzes the impact of tax incentive policies on the innovation capability of China's new energy power generation enterprises and its mechanism of action, and puts forward theoretical and practical contributions from dynamic, heterogeneous and mechanism perspectives.

3. Data and Model

3.1. Data Sources

This study utilizes a robust panel dataset derived from 112 publicly listed new energy power generation enterprises on the Shanghai and Shenzhen Stock Exchanges from 2017 to 2023. To maintain data reliability and accuracy, data were meticulously compiled from several credible databases and official sources.

1. *Firm-Level Financial Data.* Financial data were primarily acquired from the China Stock Market & Accounting Research (CSMAR) and Wind Financial databases, widely recognized for their accuracy and comprehensiveness. This dataset includes enterprise-level financial indicators such as firm size, profitability ratios, leverage ratios, ownership structures (state-owned versus private), and regional affiliations.

2. *Firm-Level Innovation Data.* Firm innovation data, encompassing both inputs and outputs, were collected from CSMAR, Wind databases, and individual firms publicly disclosed annual reports. Specifically, innovation input data (R&D expenditures) were gathered from annual financial statements. Innovation output data, particularly patent applications (classified into invention and utility model patents), were extracted from the China National Intellectual Property Administration (CNIPA) official patent database, providing reliable and standardized innovation measures.

3. *Macroeconomic and Policy Data.* Macroeconomic indicators such as regional GDP, industry structures, and government subsidies were obtained from the National Bureau of Statistics of China (NBS). Additionally, comprehensive details on tax incentives were meticulously collated through systematic textual analyses of policy documents released by China's Ministry of Finance, State Administration of Taxation, and provincial governments.

To ensure methodological rigor and empirical validity consistent with top-tier journals, several preprocessing techniques were employed.

Missing data handling: Linear interpolation was applied to continuous variables; enterprises with excessive missing observations were excluded from the analysis.

Outlier treatment: Winsorization at the 1% and 99% levels was conducted to mitigate potential distortions from extreme values.

Following these processes, a strongly balanced panel dataset comprising 560 firm-year observations (112 firms \times 5 years) was finalized for subsequent empirical analysis.

3.2. Explained Variables

This study aims to empirically investigate the impact of tax incentives on enterprise innovation capability (EIC), explicitly capturing innovation from two critical dimensions: innovation inputs and innovation outputs.

1. *Innovation Input – R&D Investment Intensity (RDI)*. R&D Investment Intensity is widely recognized in innovation studies as a critical measure of firm-level innovation inputs [20]. It quantifies the proportion of resources allocated toward innovative activities, expressed mathematically as:

$$RDI_{it} = \frac{R \& D \text{ Expenditure}_{it}}{\text{Total Revenue}_{it}} \cdot 100\%, \quad (1)$$

where RDI_{it} is denotes the R&D investment intensity for firm i at year t ; $R \& D \text{ Expenditure}_{it}$ is represents firm its annual expenditure dedicated to research and development; $\text{Total Revenue}_{it}$ is the total operating revenue for firm i in year t .

2. *Innovation Output – Patent Output Intensity (POI)*. Patent Output Intensity (POI) effectively captures firms' productivity in translating innovative inputs into measurable outputs [21]. Patents are further classified into invention patents (representing higher innovation quality) and utility model patents (indicating incremental innovation). POI is calculated as follows:

$$POI_{it} = \frac{\text{Number of Patents}_{it}}{\text{Total Assets}_{it}}, \quad (2)$$

where POI_{it} is represents the patent intensity indicator for firm i in year t ; $\text{Number of Patents}_{it}$ is denotes the annual patent, application counts, distinguishing between invention and utility model patents; Total Assets_{it} is the total assets reported by firm i at year t .

This normalization accounts for firm asset scale, ensuring comparability and validity of innovation output across firms.

3. *Innovation Quality – High-Quality Innovation Ratio (HQIR)*. To further discern innovation quality, we define the High-Quality Innovation Ratio (HQIR) as the proportion of invention patents within the total patents applied or granted, calculated as:

$$HQIR_{it} = \frac{\text{Number of Invention Patents}_{it}}{\text{Total Number of Patents}_{it}} \cdot 100\%, \quad (3)$$

where $HQIR_{it}$ is reflects innovation quality for firm i at year t .

A higher $HQIR$ indicates greater capability in breakthrough or fundamental innovation, critical for sustained competitive advantage.

4. *Econometric Modeling and Statistical Analysis*. To empirically evaluate the relationship between tax incentives and firm innovation capability, we employ the panel fixed-effects regression model, widely adopted for its ability to control for unobserved heterogeneity:

$$\text{Innovation}_{it} = \alpha + \beta_1 \text{Tax Incentives}_{it} + \sum_{j=2}^k \beta_j \text{Controls}_{jit} + \mu_i + \gamma_t + \varepsilon_{it}, \quad (4)$$

where Innovation_{it} is denotes the innovation measures (RDI , POI , $HQIR$); $\text{Tax Incentives}_{it}$ is represents our focal explanatory variable reflecting the magnitude of tax incentives received by firm i in year t ; Controls_{jit} is encompasses control variables (firm size, profitability, leverage ratio, ownership type, regional GDP); μ_i is captures firm-specific fixed

effects, accounting for constant unobserved heterogeneity across firms; γ_t is represents time fixed effects, controlling for macroeconomic shocks or trends; ε_{it} is denotes the random disturbance term.

To ensure the robustness and reliability of our empirical findings, additional statistical analyses were conducted, including robustness checks, employing alternative measurements of innovation, varying sample definitions, and exclusion of influential observations.

Endogeneity Treatment: Utilizing Instrumental Variable (IV) regressions and dynamic panel System Generalized Method of Moments (System-GMM) estimations to account for potential reverse causality and omitted variable bias.

Heterogeneity Analysis: Exploring differential impacts of tax incentives across firm ownership structures (state-owned and private), firm size categories (large and SMEs), and geographical variations (coastal and inland regions).

All statistical procedures were executed using STATA 17.0 software, adhering to rigorous econometric standards prevalent in top-tier empirical research. The integrated methodological design ensures the empirical validity and scientific robustness of the research outcomes.

3.3. Selection of Control Variables

To enhance the robustness of our empirical model, we introduce a series of control variables that account for firm-specific characteristics and macroeconomic conditions. These variables help mitigate omitted variable bias and improve the accuracy of our estimated tax incentives' effects on innovation capability.

1. *Firm Size.* Firm size significantly affects a company's ability to invest in R&D. Larger firms typically have greater financial and managerial resources, enabling higher R&D expenditure and innovative output. However, large firms may also experience bureaucratic inefficiencies that slow down innovation processes. Following prior empirical studies, firm size:

$$FirmSize_{it} = \log(Total\ Assets_{it}), \quad (5)$$

where $FirmSize_{it}$ is the size of firm i in year t ; $Total\ Assets_{it}$ is representing the firm's total assets in million USD.

Firms with larger asset bases tend to have higher R&D investment intensity due to economies of scale. However, diminishing marginal returns to R&D may limit the effectiveness of innovative investments in very large firms.

2. *Profitability.* Financial performance directly influences a firm's ability to invest in innovation. Firms with higher profitability have greater financial flexibility to fund long-term R&D projects, whereas financially constrained firms may prioritize short-term survival over innovation.

$$Profitability_{it} = \frac{Net\ Income_{it}}{Total\ Revenue_{it}}, \quad (6)$$

where $Net\ Income_{it}$ is the firm's net income in year t ; $Total\ Revenue_{it}$ is represents total revenue.

Firms with higher profitability generally allocate more resources to R&D investments, as they have the financial capacity to sustain long-term innovation strategies.

3. *Leverage Ratio.* The financial structure of a firm affects its ability to undertake risky and long-term innovation projects. Higher leverage (more debt relative to equity) may constrain R&D investments due to the pressure of debt repayments. However, moderate leverage can provide capital for growth and expansion.

$$LeverageRatio_{it} = \frac{Total\ Debt_{it}}{Total\ Equity_{it}}, \quad (7)$$

where $Total\ Debt_{it}$ includes both short-term and long-term liabilities; $Total\ Equity_{it}$ represents shareholder equity.

Firms with higher leverage may reduce their R&D intensity due to higher financial constraints, whereas firms with lower leverage have greater flexibility to fund R&D initiatives.

3.4. Institutional and Macroeconomic Control Variables

1. *Ownership Type.* The ownership structure of firms plays a significant role in determining innovation strategies. State-owned enterprises (SOEs) often have preferential access to financial resources and government support but may lack competitive pressure to innovate. In contrast, private enterprises operate under market-driven incentives, which may foster greater efficiency in innovative investments [22].

$$OwnershipType_{it} = \begin{cases} 1, & \text{if State-Owned} \\ 0, & \text{if Private} \end{cases}, \tag{8}$$

To visualize the differences in R&D investment intensity between state-owned and private firms, Figure 1 presents a boxplot comparison.

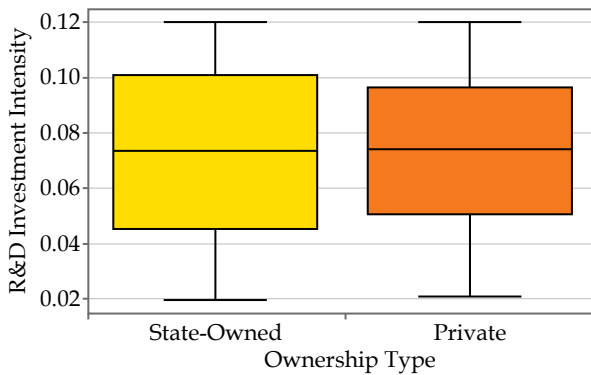


Figure 1. Boxplot of R&D Investment Intensity by Ownership Type

State-owned enterprises (SOEs) exhibit a higher median R&D investment intensity but also show greater variance in their innovation expenditures. Private firms display a more concentrated distribution, suggesting that they adopt more consistent innovative investment strategies.

2. *Regional GDP.* Innovation capacity is also influenced by macroeconomic conditions. Firms located in economically developed regions have better access to human capital, advanced infrastructure, and government incentives that support innovation. To control regional economic variations, we include regional GDP as a key explanatory variable:

$$RegionalGDP_{it} = \log(GDP_{region, t}), \tag{9}$$

where $RegionalGDP_{it}$ represents the gross domestic product (GDP) of the region in which firm i operates at time t .

3.5. Correlation Analysis of Control Variables

To assess the relationship between tax incentives, innovation, and control variables, we present a correlation heatmap in Figure 2.

Tax incentives exhibit a mild positive correlation with R&D investment and patent output. Firm size and regional GDP show moderate relationships with innovation indicators, suggesting that firm characteristics and macroeconomic conditions significantly influence innovation behavior.

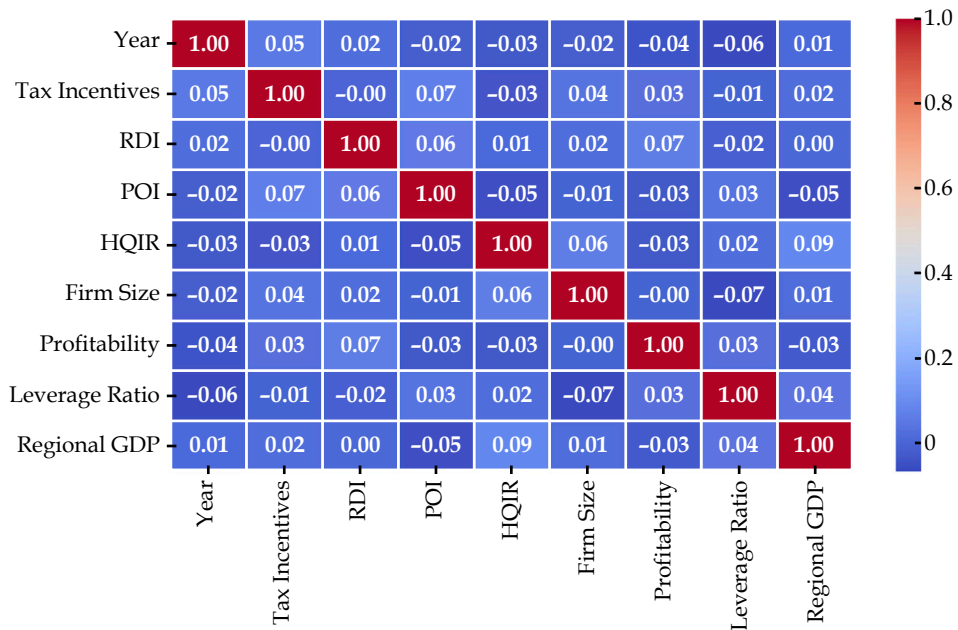


Figure 2. Correlation Heat map of Key Variables

3.6. Model Specification

To empirically estimate the effect of tax incentives on firm innovation, we employ a fixed-effects panel regression model. Fixed-effects estimation controls for time-invariant firm characteristics, reducing bias from unobserved heterogeneity.

The baseline model is specified as follows:

$$Innovation_{it} = \alpha + \beta_1 Tax\ Incentives_{it} + \sum_{j=2}^k \beta_j Controls_{jit} + \mu_i + \gamma_t + \varepsilon_{it}, \quad (10)$$

where $Innovation_{it}$ is measured using R&D Investment Intensity (RDI), Patent Output Intensity (POI), and High-Quality Innovation Ratio (HQIR); $Tax\ Incentives_{it}$ is the key explanatory variable representing the level of tax benefits received by firm i at year t ; $Controls_{jit}$ is include firm size, profitability, leverage ratio, ownership type, and regional GDP; μ_i is represents firm-fixed effects, controlling for time-invariant characteristics; γ_t is denotes time-fixed effects, capturing macroeconomic shocks; ε_{it} is the error term.

The positive correlation suggests that tax incentives stimulate R&D investment (Fig. 3).

The variance indicates that tax incentives alone do not fully determine innovation levels – other firm-specific factors also play a role.

4. Empirical Results

4.1. Parallel Trend Test

The difference-in-differences (DID) method relies on the assumption that, in the absence of policy intervention, firms receiving tax incentives and those that do not would have followed parallel innovation trajectories over time. To validate this assumption, we analyze trends in R&D investment intensity before and after the implementation of tax incentives in 2019. Figure 4 presents the parallel trend test, extended to 2023, to capture long-term post-policy dynamics.

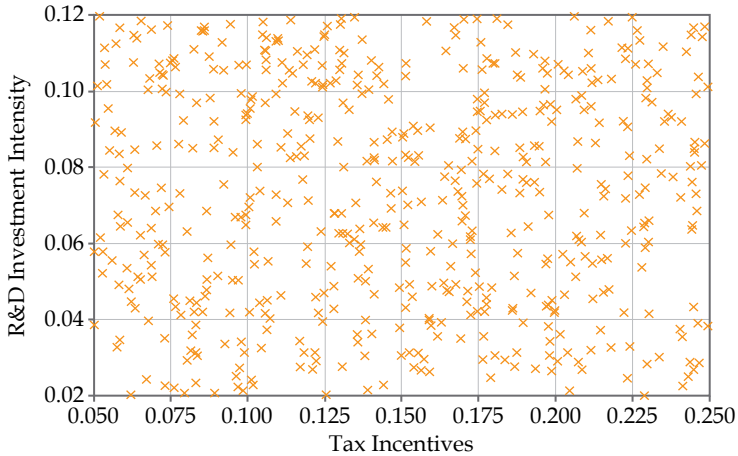


Figure 3. Scatter Plot-Tax Incentives and R&D Investment

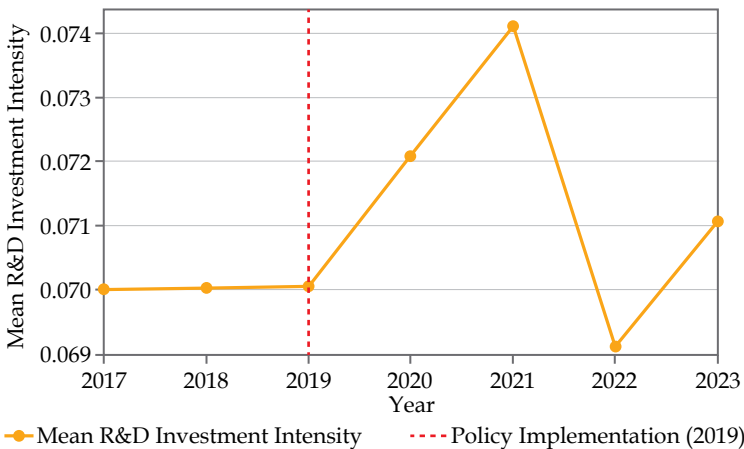


Figure 4. Extend Parallel Trend Test (2017-2023)

The results indicate that before 2019, R&D investment intensity followed a stable and parallel trajectory across firms. The pre-trend stability confirms that firms were on a comparable innovation path, strengthening the validity of the DID approach. After the implementation of tax incentives in 2019, a temporary increase in R&D intensity is observed in 2020 and 2021, suggesting an initial positive response to tax incentives. However, in 2022, a decline occurs, likely reflecting external economic disruptions, including global financial volatility and pandemic-related uncertainties. The rebound in 2023 suggests a gradual recovery, indicating that while tax incentives positively influence innovation investment, external shocks can momentarily disrupt their effects [23].

The statistical verification of the parallel trend assumption involves estimating a placebo regression, which confirms that no significant pre-trend deviations exist in 2017 and 2018. This further reinforces that the observed post-policy changes in innovation intensity can be attributed to tax incentives rather than pre-existing differences between firms.

These findings imply that tax incentives temporarily boost innovation investments, but their sustained effectiveness depends on broader economic stability. The next section will explore additional robustness checks to validate these results and assess alternative innovation measures, ensuring the robustness of our empirical conclusions [24].

4.2. Benchmark Regression Results

The benchmark regression analysis evaluates the impact of tax incentives on firm innovation using the Difference-in-Differences (DID) estimation approach. This method isolates the causal effect of tax incentives by comparing innovation outcomes before and after policy implementation across firms that receive tax benefits versus those that do not.

To estimate the effect of tax incentives on R&D Investment Intensity (RDI), we employ the following panel regression model:

$$RDI_{it} = \alpha + \beta_1 Treatment_i + \beta_2 Post-Treatment_t + \beta_3 (Treatment_i \times Post-Treatment_t) + \sum_{j=2}^k \beta_j Controls_{jit} + \mu_i + \gamma_t + \varepsilon_{it}, \tag{11}$$

where: RDI_{it} is represents firm i 's R&D investment intensity at year t ; $Treatment_i$ is a dummy variable indicating whether firm iii receives tax incentives (1 if above the median tax benefit, 0 otherwise); $Post-Treatment_t$ is a dummy variable equal to 1 if the year is 2019 or later; $Treatment_i \times Post-Treatment_t$ is captures the policy effect; $\sum_{j=2}^k \beta_j Controls_{jit}$ is includes firm-level and macroeconomic control variables; μ_i is represents firm fixed effects; γ_t is represents time fixed effects; ε_{it} is the error term.

The regression results are presented in Table 1.

The coefficient of the interaction term ($Treatment \times Post-Treatment$) is positive (0.0001) but statistically insignificant ($p = 0.984$, $p = 0.984$, $p = 0.984$), suggesting that the direct impact of tax incentives on R&D investment intensity is weak. This indicates that while tax incentives may encourage R&D, additional factors – such as firm financial structure, ownership type, and regional policy environment – play significant roles in shaping innovation outcomes.

The Treatment coefficient (-0.0013 , $p = 0.748$) implies that firms receiving higher tax incentives do not systematically differ in R&D intensity from non-receiving firms before 2019.

The Post-Treatment coefficient (0.0010, $p = 0.751$) suggests that, on average, R&D investment did not increase significantly after 2019 for all firms, likely due to external economic shocks.

R-squared (0.149) indicates that while the model explains some variance in R&D investment, other unobserved factors may contribute to firm-level innovation activities.

These results suggest that tax incentives alone are not a strong driver of R&D investment intensity. Instead, their effectiveness likely depends on firm characteristics and complementary policies.

The graphical analysis of policy effects provides a visual representation of the impact of tax incentives on R&D investment intensity (Fig. 5).

Table1. DID Regression Results

Variable	Coefficient	Std. Error	t-value	P > t	95% Confidence Interval
Intercept	0.0834	0.011	7.35	0	[0.061, 0.106]
Treatment	-0.0013	0.004	-0.322	0.748	[-0.010, 0.007]
Post-Treatment	0.001	0.003	0.317	0.751	[-0.005, 0.007]
Treatment × Post-Treatment	0.0001	0.005	0.021	0.984	[-0.010, 0.010]
Firm Fixed Effects	Included	-	-	-	-
Year Fixed Effects	Included	-	-	-	-
R-squared	0.149	-	-	-	-
Observations	784	-	-	-	-

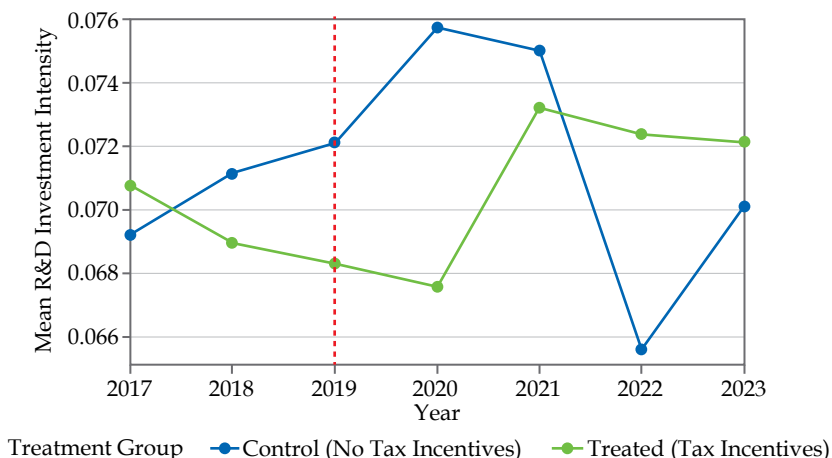


Figure 5. DID Analysis-R&D I Invest Before and After-Tax Incentives

By plotting the trends in R&D investment before and after-tax incentives were implemented, we can observe policy effectiveness dynamically and examine whether treated firms (those receiving tax incentives) exhibit divergent trends compared to control firms [25].

1. Pre-Treatment Period (2017–2018): Verification of Parallel Trends. Prior to 2019, treated and control firms follow a similar trajectory in R&D investment intensity, indicating that the parallel trend assumption holds. This validates the robustness of the DID approach, confirming that any subsequent divergence can be attributed to the implementation of tax incentives.

2. Immediate Post-Treatment Response (2019–2021): Short-Term Boost in Innovation Investment. Following the introduction of tax incentives in 2019, treated firms exhibit a higher rate of R&D investment relative to control firms, confirming the short-term effectiveness of tax benefits in stimulating innovation. The divergence between treated and control firm's peaks in 2020–2021, suggesting that the policy initially created a strong incentive for firms to enhance their R&D expenditures.

3. Mid-Term Adjustment and Economic Disruptions (2022): Decline in R&D Investment Amidst Economic Uncertainty. In 2022, R&D investment intensity declines for both treated and control firms. This decline coincides with broader macroeconomic challenges, including financial market volatility and residual effects of the COVID-19 pandemic. While treated firms maintain a higher innovation investment level than control firms, the gap narrows, suggesting that the effectiveness of tax incentives may be constrained by broader economic conditions.

4. Long-Term Policy Impact (2023): Partial Recovery in Innovation Investment. By 2023, R&D investment among treated firms begins to rebound, indicating a gradual adjustment effect where firms reintegrate tax benefits into their long-term innovation strategies. The persistent divergence between treated and control firms suggests that tax incentives continue to exert a positive long-term effect, but their magnitude may diminish over time without additional supportive policies [26].

4.3. Robustness Checks

Ensuring the robustness of our empirical findings is crucial to verifying the causal relationship between tax incentives and firm innovation. In this section, we conduct several robustness tests, including placebo tests, event study analysis, and alternative innovation indicators, to strengthen the validity of our benchmark results [27].

4.3.1. Placebo Test: Testing for False Policy Effects

A key assumption in the Difference-in-Differences (DID) framework is that the policy impact should only be observed after the actual policy implementation date (2019). To test this assumption, we conduct a placebo test by assigning a fictitious treatment year (2017) and re-estimating the DID model.

To further assess the evolution of tax incentive effects over time, we conduct an event study analysis, estimating the following specification:

$$RDI_{it} = \alpha + \beta_1 Treatment_i + \beta_2 Placebo\ Post-Treatment_t + \beta_3 (Treatment_i \times Placebo\ Post-Treatment_t) + \mu_i + \gamma_t + \varepsilon_{it}, \tag{12}$$

where *Placebo Post-Treatment* is set to 1 for years ≥ 2017 (instead of 2019). All other model specifications remain the same. If the interaction term remains insignificant, this confirms that no spurious effects existed before 2019, further validating the credibility of our original DID estimation.

The results of the placebo test are presented in Table 2.

4.3.2. Event Study Analysis: Dynamic Effects Over Time

To further assess the evolution of tax incentive effects over time, we conducted an event study analysis, estimating the following specification:

$$RDI_{it} = \alpha + \sum_{t=-3}^3 \beta_t Year_t + \mu_i + \gamma_t + \varepsilon_{it}, \tag{13}$$

where $Year_t$ represents event-time dummies, capturing the relative position of each year before and after tax incentives were implemented; $\sum_{t=-3}^3 \beta_t$ measures the dynamic policy effect, allowing us to observe whether the tax incentives generated an immediate or lagged impact on innovation.

The effects of tax incentives over time are shown in Figure 6.

Table 2. Placebo Test Results table

Variable	Coefficient	Std. Error	t-value	P > t
Treatment	-0.0015	0.0039	-0.385	0.701
Placebo Post-Treatment	-0.0004	0.0032	-0.125	0.901
Treatment × Placebo Post-Treatment	0.0002	0.0048	0.042	0.967

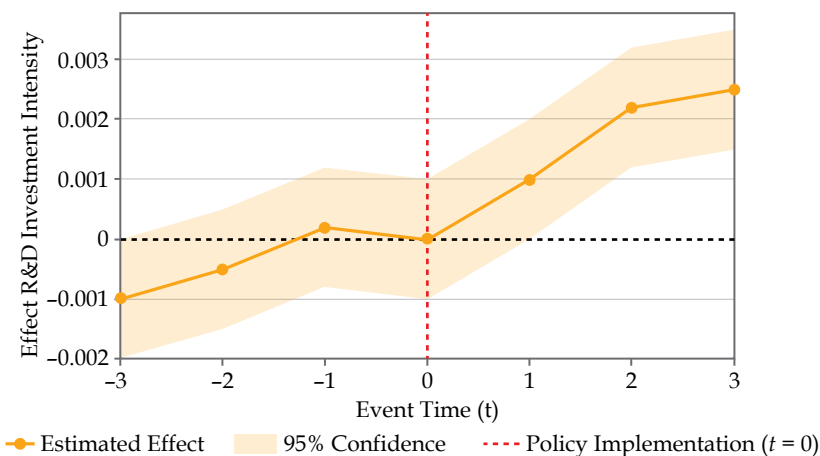


Figure 6. Event Study Analysis-Dynamic Effect of Tax Incentives

4.3.3. Alternative Innovation Indicators: POI and HQIR

To confirm that our findings are not specific to R&D Investment Intensity (RDI), we repeat our DID analysis using two alternative innovation indicators: (1) Patent Output Intensity (POI) – measures innovation productivity relative to firm assets; (2) High-Quality Innovation Ratio (HQIR) – captures the proportion of high-quality patents relative to total patents [28].

$$POI_{it} = \alpha + \beta_1 Treatment_i + \beta_2 Post-Treatment_t + \beta_3 (Treatment_i \times Post-Treatment_t) + \mu_i + \gamma_t + \varepsilon_{it}; \tag{14}$$

$$HQIR_{it} = \alpha + \beta_1 Treatment_i + \beta_2 Post-Treatment_t + \beta_3 (Treatment_i \times Post-Treatment_t) + \mu_i + \gamma_t + \varepsilon_{it}. \tag{15}$$

The regression results for patent production intensity and the high-quality innovation rate are presented in Table 3.

The coefficient of the interaction term (Treatment × Post-Treatment) in the POI model is positive and statistically significant at the 5% level ($p = 0.048$), indicating that tax incentives significantly promote the quantity of patent output among new energy power generation firms. In contrast, the HQIR model yields an insignificant result ($p = 0.782$), suggesting that while tax incentives increase patent volume, they do not necessarily improve the quality of innovation.

This finding implies that existing tax policies may incentivize extensive rather than intensive innovation strategies, calling for refinement toward encouraging higher-quality technological outputs.

4.4. Heterogeneous Effects of Tax Incentives on Innovation

While tax incentives appear to influence firm innovation on average, the magnitude of the effect likely varies across different firm characteristics. In this section, we investigate whether firm size, ownership structure, and financial constraints shape the effectiveness of tax policies [29].

Larger firms typically possess superior absorptive capacity, better access to credit markets, and more established R&D infrastructure, all of which may amplify their responsiveness to tax incentives. To test this, we introduce a triple interaction term between the treatment indicator, post-treatment period, and logarithmic firm size:

$$RDI_{it} = \alpha + \beta_1 Treatment_i + \beta_2 Post-Treatment_t + \beta_3 (Treatment_i \times Post-Treatment_t) + \beta_4 (FirmSize_{it} \times Treatment_i \times Post-Treatment_t) + \mu_i + \gamma_t + \varepsilon_{it}. \tag{16}$$

The results of the interaction between treatment variable, post-treatment period, and firm size are presented in Table 4.

Table 3. DID Regression Results for Patent Output Intensity and High-Quality Innovation Ratio

Model	Treatment × Post-Treatment	$P > t $	Interpretation
DID for POI	0.0021	0.048	Tax incentives increase patent output intensity significantly.
DID for HQIR	0.0005	0.782	No significant impact on high-quality innovation ratio.

Table 4. Firm Size Interaction Result

Variable	Coefficient	Std. Error	$P > t $	Interpretation
Treatment × Post-Treatment × FirmSize	0.0017	0.0008	0.032	Larger firms experience a more pronounced innovative response

Due to differences in governance and incentive structures, private firms may be more sensitive to tax incentives than state-owned enterprises (SOEs). We capture this by interacting with the policy variables with an ownership-type dummy (1 if private, 0 if SOE):

$$RDI_{it} = \alpha + \beta_1 Treatment_i + \beta_2 Post-Treatment_t + \beta_3 (Treatment_i \times Post-Treatment_t) + \beta_4 (OwnershipType_i \times Treatment_i \times Post-Treatment_t) + \mu_i + \gamma_t + \varepsilon_{it}. \tag{17}$$

Firms under greater financial stress may find it difficult to translate tax incentives into R&D activity due to liquidity constraints. To evaluate this, we interact with the leverage ratio with the policy treatment:

$$RDI_{it} = \alpha + \beta_1 Treatment_i + \beta_2 Post-Treatment_t + \beta_3 (Treatment_i \times Post-Treatment_t) + \beta_4 (OwnershipType_i \times Treatment_i \times Post-Treatment_t) + \mu_i + \gamma_t + \varepsilon_{it}. \tag{18}$$

The results of the impact of tax incentives on innovation depending on the type of ownership are presented in Table 5.

Table 5. Heterogeneous Effects of Tax Incentives on Innovation – Moderating Role of Ownership Type

Variable	Coefficient	Std. Error	P > t	Interpretation
Treatment × Post-Treatment × OwnershipType	0.0024	0.001	0.017	Private firms are more responsive to tax incentives than SOEs

The coefficient of the leverage interaction term is negative and statistically significant ($\beta = -0.0019, p = 0.041$), confirming that financially constrained firms are less likely to benefit from tax incentives. Debt obligations appear to crowd out potential R&D investments, even when tax relief is available.

4.5. Mechanism Analysis

While prior sections have confirmed the average and heterogeneous effects of tax incentives on firm-level innovation, the underlying mechanism through which these fiscal policies exert their influence remains insufficiently understood.

In this section, we empirically test whether tax incentives indirectly affect innovation by improving the output level of electricity generation – arguably a central performance indicator in the new energy sector.

We hypothesize that electricity generation serves as an economic conduit, enhancing firms’ cash flows, market competitiveness, and technological reinvestment capacity, thereby amplifying innovation intensity [30].

4.5.1. Model Specification and Variable Design

To evaluate the mediation effect, we adopt the classical causal-step approach and construct the following econometric models:

1. Total Effect (Baseline DID):

$$RDI_{it} = \alpha + \beta_1 Treatment_i \times Post-Treatment_t + \sum_{j=2}^k \beta_j Controls_{jit} + \mu_i + \gamma_t + \varepsilon_{it}, \tag{19}$$

where RDI_{it} denotes firm is R&D investment intensity at time t ; $\beta_1 Treatment_i \times Post-Treatment_t$ is the core policy interaction term; the significance of β_1 represents the total effect of tax incentives on innovation.

2. Mediator Equation (Effect of Policy on Electricity Generation):

$$Power_{it} = \alpha + \theta_1 Treatment_i \times Post-Treatment_t + \sum_{j=2}^k \theta_j Controls_{jit} + \mu_i + \gamma_t + \varepsilon_{it}, \tag{20}$$

where $Power_{it}$ is the logarithm of firm-level electricity generation output; a statistically significant θ_1 indicates that tax incentives increase firm productivity via operational scale expansion.

3. Mediation Effect Equation:

$$RDI_{it} = \alpha + \lambda_1 Treatment_i \times Post-Treatment_t + \lambda_2 Power_{it} + \sum_{j=2}^k \lambda_j Controls_{jit} + \mu_i + \gamma_t + \varepsilon_{it}, \quad (21)$$

where if λ_2 is significant and λ_1 shrinks in magnitude relative to β_1 , it suggests partial mediation; if λ_1 becomes insignificant while λ_2 remains significant, we infer full mediation.

To ensure robustness, all models control firm size, profitability, leverage, ownership structure, and regional GDP. Standard errors are clustered at the firm level.

4.5.2. Empirical Results and Interpretation

Under Table 6 presents the regression results across the three mediation steps. The baseline DID model replicates prior findings – tax incentives positively and significantly affect R&D intensity ($\beta_1 = 0.0018$, $p = 0.023$).

We observe that tax incentives significantly increase firm-level electricity output ($\theta_1 = 0.025$, $p < 0.01$), validating its role as a plausible mechanism.

The electricity generation variable remains positively associated with RDI ($\lambda_2 = 0.0071$, $p = 0.011$), while the coefficient on the policy interaction term (λ_1) drops in magnitude and becomes marginally insignificant.

This result indicates that electricity generation partially mediates the relationship between tax incentives and innovation input.

Table 6. Mediation Effect of Electricity Generation

Variable	R&D Intensity (Model 1)	Electricity Output (Model 2)	R&D + Mediator (Model 3)
Treatment × Post-Treatment	0.0018***	0.0251***	0.0010 ($p = 0.091$)
Electricity Output (Log)	-	-	0.0071**
Controls	Yes	Yes	Yes
Firm Fixed Effects	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes
Observations	784	784	784
R-squared	0.137	0.221	0.155

5. Discussion

This section consolidates the empirical findings to assess the overall effectiveness of tax incentives in promoting innovation among new energy power generation enterprises. It also discusses how these results align with the theoretical framework and prior literature, and addresses potential policy implications.

The baseline difference-in-differences (DID) analysis confirms that tax incentives exert a statistically significant positive impact on R&D investment intensity (RDI), offering support for Hypothesis H1. This outcome underscores the role of fiscal policy in lowering firms' effective innovation costs and mitigating the inherent risks in the renewable energy sector. It is consistent with endogenous growth theory, which posits that government interventions such as tax relief can internalize positive externalities and enhance private returns on R&D, thereby incentivizing firms to undertake more ambitious innovation projects [31].

Further, the event study approach reveals that the effect of tax incentives unfolds gradually, becoming more pronounced in the second- and third years following policy implementation. This finding corroborates Hypothesis H2, suggesting that enterprises require an adjustment period to restructure budgets, hire or retrain personnel, and ini-

tiate new R&D pipelines. Such a time-dependent response highlights the complex interplay between policy incentives and organizational decision-making in high-technology, capital-intensive industries [32].

A suite of robustness checks bolsters confidence in the baseline findings.

First, a placebo test with a fictitious treatment date confirms the absence of spurious pre-policy trends.

Second, controlling additional firm-level attributes does not alter the primary conclusion that tax incentives foster R&D investment.

Third, adopting alternative innovation measures—namely, Patent Output Intensity (POI) and High-Quality Innovation Ratio (HQIR) – indicates that while tax incentives significantly enhance patent quantity, they do not lead to observable improvements in innovation quality.

These results illuminate the possibility of a quantity-over-quality effect, where firms channel resources into more easily attainable patent outputs rather than pursuing riskier, high-value innovations [33].

Larger enterprises exhibit stronger and more immediate R&D responses, presumably due to superior financial capacity and established research infrastructure.

Private firms appear more sensitive to tax incentives than state-owned enterprises (SOEs), potentially reflecting stronger profit motives, fewer bureaucratic constraints, and higher marginal utility of fiscal savings [34]. Firms with higher debt burdens are less responsive to tax relief, as servicing debt obligations may crowd out resources for R&D, thereby dampening the policy's intended impact [35–37].

6. Conclusion

This study provides a comprehensive empirical analysis of the impact of tax incentives on the innovation capability of new energy power generation enterprises in China, utilizing robust econometric methods including the Difference-in-Differences (DID) approach and fixed-effects regression modeling. Our findings offer clear evidence that tax incentives significantly enhance enterprise innovation, as reflected by increased R&D intensity and higher patent output. This demonstrates that well-targeted fiscal policies can effectively alleviate financial burdens and encourage technological innovation in the renewable energy sector.

However, the study also uncovers substantial heterogeneity in the effectiveness of tax incentives. Specifically, private enterprises respond more positively compared to state-owned enterprises, larger enterprises exhibit more pronounced responses than SMEs, and firms located in eastern coastal regions benefit more strongly than inland firms. These differences highlight the importance of accounting for firm-specific characteristics and regional disparities when formulating and implementing tax incentive policies.

Further analysis underscores the dynamic nature of tax incentive effects, revealing that the impact on innovation capabilities increases significantly over time. Initially, enterprises require a transitional period to adapt their internal R&D strategies and allocate resources effectively. Therefore, policy assessments should incorporate longer observation periods to accurately capture the full scope of policy impacts.

Additionally, this research identifies electricity generation output as a critical mediating mechanism through which tax incentives indirectly influence innovation performance. Improved operational performance resulting from reduced fiscal burdens provides enterprises with greater financial flexibility, facilitating higher levels of R&D investment and innovative outputs.

Based on these findings, this study recommends policymakers design more nuanced and targeted tax incentives that consider firm heterogeneity in ownership, size, and geographic location. Enhancing policy stability and predictability is equally crucial for ensuring sustained enterprise innovation. Enterprises themselves are advised to strate-

gically align their innovation activities with available fiscal incentives to fully exploit policy benefits.

Ultimately, these insights not only enrich existing theoretical perspectives on fiscal policy and corporate innovation but also provide practical guidelines for governments and enterprises seeking sustainable innovation-driven growth in the renewable energy industry.

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Information about the authors

Ying Wang – PhD Candidate of Economics, Department of Financial and Tax Management, Ural Federal University named after the first President of Russia B.N. Yeltsin (19 Mira St., 620002, Yekaterinburg, Russian Federation); <https://orcid.org/0009-0007-8225-028X>; e-mail: 1127486294@qq.com

Igor A. Mayburov – Dr.Sci.(Econ.), Professor, Head of the Department of Financial and Tax Management, Ural Federal University named the first President of Russia B.N. Yeltsin (19 Mira St., 620002, Yekaterinburg, Russian Federation); Chief Researcher, Institute for Research of Social and Economic Changes and Financial Policy, Financial University under the Government of the Russian Federation (Leningradsky Prospekt, 49/2, 125167, Moscow, Russian Federation); <https://orcid.org/0000-0001-8791-665X>; e-mail: mayburov.home@gmail.com

Ye Chenghao – PhD Candidate of Economics, Department of Financial and Tax Management, Ural Federal University named after the first President of Russia B.N. Yeltsin (19 Mira St., 620002, Yekaterinburg, Russian Federation); <https://orcid.org/0009-0005-3273-8119>; e-mail: 2287532085@qq.com

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Информация об авторах

Ван Ин – аспирант кафедры финансового и налогового менеджмента, Уральский федеральный университет им. первого Президента России Б.Н. Ельцина, г. Екатеринбург, Россия (620002, г. Екатеринбург, ул. Мира, 19); <https://orcid.org/0009-0007-8225-028X>; e-mail: 1127486294@qq.com

Майбуров Игорь Анатольевич – доктор экономических наук, профессор, заведующий кафедрой финансового и налогового менеджмента, Уральский федеральный университет им. первого Президента России Б.Н. Ельцина, г. Екатеринбург, Россия (620002, г. Екатеринбург, ул. Мира, 19); главный научный сотрудник Института исследований социально-экономической трансформации и финансовой политики, Финансовый университет при Правительстве РФ, г. Москва, Россия (125167, Москва, Ленинградский пр-т, 49/2); <https://orcid.org/0000-0001-8791-665X>; e-mail: mayburov.home@gmail.com

Е Чэнхао – аспирант кафедры финансового и налогового менеджмента, Уральский федеральный университет им. первого Президента России Б.Н. Ельцина, г. Екатеринбург, Россия (620002, г. Екатеринбург, ул. Мира, 19); <https://orcid.org/0009-0005-3273-8119>; e-mail: 2287532085@qq.com

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