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Do Government Subsidies Induce Green Transition of Construction Industry? Evidence from Listed Firms in China

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Abstract: The construction industry is a major energy consumer and carbon emitter, and identifying the key drivers for its green transition has attracted increasing attention. Although government subsidies are one of the most effective and direct ways to induce a green transition, few academics have examined their effects at a micro level. Therefore, this study used the Chinese construction industry as an example to study the influence of subsidies on its green transition. Given the ambiguity of the green transition concept, this study employed the number of green patents and Environmental, Social, and Governance (ESG) ratings to represent the narrow sense and the wide sense of green transition, respectively. According to the empirical findings, subsidies can successfully induce green technology innovation and thus facilitate a green transition. The results of heterogeneity analysis show that government subsidies have a significant incentive-based effect solely on state-owned firms, but an insufficient effect on private and other enterprises. Furthermore, while government subsidies have little effect on ESG ratings, they can promote green transition of enterprises by increasing ESG ratings. The government should increase the types of subsidy packages available to enterprises, while attaching more importance to social responsibility.

Keywords: construction industry; government subsidies; green transition; ESG

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1. Introduction

The construction sector is a cornerstone of the Chinese economy, playing an important role in promoting urbanization and contributing to the construction of a beautiful China. The rapid growth of the construction industry brings about economic expansion, marked by high energy consumption, severe environmental pollution, and low efficiency [1]. According to a study by the China Association of Building Energy Efficiency, China's real estate and construction industry emitted 3.7 billion tons of carbon in 2020–2021, reflecting a 7% increase from the previous year. This amount surpassed the total carbon emissions of most countries worldwide. China's construction industry urgently requires green transition.

The green transition of the construction industry is essentially a synergistic evolution of technological and social factors [2]. Presently, research predominantly centers on technical dimensions. This includes innovations in construction products such as low-carbon buildings [3], green buildings [4], assembled buildings [5], and zero-carbon buildings [6]. Additionally, there is a focus on innovating building materials by considering the embodied energy within them [7], as well as innovating construction techniques [8]. This is evident in the integration of green practices throughout the life cycle of construction projects. Current research emphasizes the incorporation of sustainable practices across the entire life cycle of construction projects and offers a comprehensive technical perspective [9,10]. Yet, there is a relatively modest focus on the social dimension of the green transition within the construction industry. Primary research efforts involve building evaluation models using qualitative methods. This includes the development of a comprehensive sustainability evaluation index system that incorporates social dimensions [11,12] or designing a distinct indicator system to assess the impact of social factors on sustainability [13,14]. Subsequently, the identified indicators related to social factors are utilized to aid decision makers in evaluating the social sustainability impact of a project [15,16].

Barriers exist to implementing sustainable construction, primarily due to the higher costs associated with sustainable building options and a lack of government incentives [17,18]. The high costs of transitioning to green practices make contractors hesitant to adopt new construction methods [19] and hinder the development of necessary technical construction skills [20]. Additionally, high costs create challenges in acquiring green materials and conducting adequate maintenance [21]. Consequently, relying solely on the market and individual enterprises makes achieving a green transition challenging. In this context, government policies play a crucial role in guiding enterprises toward a green transition. Government subsidies can directly alleviate the financial pressure associated with green transition for enterprises, garnering significant attention [22]. Nevertheless, the focus on the impact of government subsidies on enterprise green transition has primarily centered on technological factors, lacking micro-level research and exploration of social responsibility. There is a need to examine the impact of subsidy policies on the green transition of construction industry enterprises, with a particular emphasis on social sustainability. Hence, this study can offer valuable insights for scholars and policymakers in the realm of green building.

China has formed a relatively complete policy system for the development of green buildings at the national level. In 2006, China issued the "Green Building Evaluation Standards", which was the first comprehensive evaluation system for green buildings, dividing buildings into one star, two stars, and three stars. Based on this evaluation standard, the Implementation Opinions on Accelerating the Development of Green Buildings in China were issued in 2012, implementing a financial reward system for high-star-rated green buildings. In 2013, the Green Building Action Plan was introduced, which further increased the incentive policies for star rated green buildings [23]. The Chinese government has introduced diverse measures to facilitate the decarbonization of the construction industry. The main incentive mechanisms in China mainly include subsidies, credit incentives, tax incentives, rewards, etc. For instance, the People's Government of Beijing Municipality offers incentive funds of RMB 50/m^2 and RMB 80/m^2 for projects that have achieved two-star and three-star green building labels, respectively. The maximum incentive for a single project does not exceed RMB 8 million (https://www.beijing.gov.cn/zhengce/zhengcefagui/202004/t20200425_1881940.html, accessed on 30 January 2024). Table 1 summarizes the issuance of incentive policies in 30 provinces and cities in China (excluding Hong Kong, Macao, Taiwan, and Xizang). A checkmark indicates that the province has corresponding incentive measure. It can be seen that subsidies are the most commonly used incentive measures, and provinces without subsidies will also supplement them through rewards. The formulation of credit preferential policies is relatively vague, and specific implementation measures for green buildings are not listed. The application of tax incentives is relatively limited. Nevertheless, it is crucial to investigate whether the subsidy funds received by enterprises effectively promote the transition to green practices. Specifically, the paper selects listed companies in China's construction industry as the research subject, employing econometric methods to assess the impact of government subsidies on the green transition of these construction enterprises.

To summarize, this paper utilizes panel data from listed companies to investigate the influence of subsidy policies on the green transition of construction industry enterprises. Building on the identified criticisms and gaps, this study aims to address two key questions: (1) What is the impact of government subsidies on the green transition of construction industry enterprises, and how does it affect sustainable transition at the societal level? (2) Does the subsidy policy exert similar effects on the green transition across different types of enterprises? In response to these questions, this paper makes two primary contributions. Firstly, it offers new evidence for evaluating the impact of government subsidy policies, broadening the evaluation from enterprise innovation performance to enterprise Environmental, Social, and Governance (ESG) considerations, thereby expanding the content and scope of the policy evaluation. The second contribution is an exploration of the impact of subsidies on various types of enterprises. This paper investigates the diverse effects of subsidies on the green transition of different enterprise categories, including state-owned enterprises, private enterprises, and other groups, as well as high-value and low-value enterprises. Additionally, this paper offers empirical support for the influence of government subsidies on the green transition of the construction industry. The research findings address the gap in micro-level evidence and contribute to enhancing the efficacy of subsidy policies and promoting the sustainable development of the construction industry.

Table 1. Summary of incentive measures in each province.

	Subsidies	**Credit Incentives**	**Tax Incentives**	**Rewards**
Beijing	√	√		√
Tianjin	√	√		
Hebei	√		√	
Shanxi	√	√		
Inner Mongolia				√
Liaoning				√
Jilin	√	√		
Heilongjiang				√
Shanghai	√			
Jiangsu	√			
Zhejiang	√		√	
Anhui	√			
Fujian	√	√		
Jiangxi		√		
Shandong	√			
Henan				√
Hubei	√	√		√
Hunan				√
Guangdong	√	√	√	√
Guangxi				√
Hainan		√		√
Chongqing	√			
Sichuan		√		√
Guizhou	√	√	√	
Yunnan				√
Shaanxi	√			
Gansu	√			
Qinghai		√		√
Ningxia	√	√		√
Xinjiang	√	√		√

The remainder of this paper is structured as follows: Section 2 reviews relevant literature and presents two theoretical hypotheses. Section 3 provides detailed information on model specifications, methods, and data. Section 4 discusses the estimation results and describes a robustness check. Finally, Section 5 presents the study's conclusions and offers some remarks.

2. Literature Review and Hypothesis

2.1. Literature Review

The literature review centers on the green transition of construction enterprises, particularly in the context of measuring this transition, and the intricate relationship between government subsidies and green transition.

2.1.1. The Measuring of Green Transition

Taking a micro perspective, the high demand for technology in green buildings distinguishes green building technologies (GBTs) as the decisive factor in achieving the green development of the construction industry, in contrast to traditional buildings. Hence, the innovation of green building technologies becomes an imperative for construction enterprises to successfully accomplish green transition. The economics of innovation elucidates that innovating in green technology enhances economic performance by optimizing factor allocation efficiency, reducing production costs, expanding the scale, increasing the market share, and reaping the benefits of patent licensing for green technologies [24]. Additionally, the number of green patents is regarded as the primary measure of innovation in GBTs [25]. Besides concentrating on the environmental benefits of green technology, the enterprise's green transition must also strike a balance between economic and social values. The concept of sustainability in buildings encompasses multidimensional pillars [26]. The concept of ESG perfectly fits this requirement.

The ESG concept introduces a fresh perspective on green transitions. Through a comprehensive evaluation of the three dimensions—environment, society, and governance—ESG assessment can capture a holistic view of sustainable development and serve as a foundation for sustainable investment. ESG management offers an effective approach to evaluating the sustainability practices of enterprises. The construction industry is in the early stages of adopting ESG practices, with only a few listed firms willing to disclose reports related to sustainable development. Park (2023) conducted an analysis of the sustainability of South Korea's construction industry, focusing on key issues derived from ESG materiality evaluation data [27]. Wu (2022) contends that the ESG system can drive the transition of product structure, reduce pollution emissions per unit of output value, and regulate the financial constraints of corresponding subjects in the process of green transition [28]. Kempeneer (2021) integrates users of the building into the ESG research framework and suggests that a user-centered intelligent real estate transition is a solution to enhancing a building's environmental and social sustainability, ultimately increasing its investment value [29]. Many scholars concur that the performance of green transition can be assessed by the level of green technology in a narrow sense, aligning with the broader concept of ESG. However, there is limited literature utilizing ESG ratings as a measure of green transition. Hence, this paper employs both the number of green patents and ESG ratings to gauge the green transition performance of the construction industry, thereby broadening the interpretation of green transition indicators.

The primary areas of concern for different institutions and organizations are largely similar, with differences primarily arising in the selection and treatment of specific indicators within each area. ESG evaluation organizations in China have integrated more indicators aligned with the current stage of development in China. These include the quality of information disclosure, penalties imposed by the Securities and Exchange Commission (SEC), and precise poverty alleviation. Additionally, they cover a larger number of A-share listed companies. Consequently, this paper utilizes the Sino-Securities Index (SNSI) ESG Ratings [30].

2.1.2. The Relationship between Government Subsidies and Green Transition

There is also a significant amount of research devoted to the impact of government subsidies on the green transition of enterprises. Governments utilize subsidies to propel the green transition of enterprises, guided by three primary motivations. Firstly, green transitions exhibit characteristics of environmental externalities. Appropriate policies are necessary to internalize environmental costs and address externalities, encouraging enterprises to voluntarily pursue green transitions [31]. Secondly, the green transition of enterprises is marked by high investment. Enterprises require financial support to implement green buildings. Policy guidance is essential due to the limited economic benefits of prefabricated buildings, ultra-low-energy buildings, and near-zero-energy buildings. Subsidies should encourage technical innovation while substantially reducing costs and achieving economies of scale. Thirdly, the green transition of enterprises is fraught with risk. The state of the economy significantly impacts the success of a transition. Market demand for green buildings is influenced by the rate of economic development, subsequently affecting company investment profits. Consequently, government policy tools must be employed to balance income fluctuations resulting from transition risks. Additionally, existing research on the conclusions regarding the impact of subsidy policy on green transition yields mixed results. Acemoglu et al. (2016) considered the technology shift from "dirty" to "clean" based on an exogenous model and argued that research and development (R&D) subsidies play a crucial role [32]. Chen et al. (2017) suggested that governments should incentivize collaborative innovation through subsidies to achieve welfare goals [33]. Fowlie et al. (2012) found that the impact of subsidies is contingent on market characteristics, with results varying between positive and negative outcomes [34]. Nie et al. (2016) argued that excessive subsidies could negatively affect energy efficiency, but within limits, they could incentivize innovation and reduce emissions [35]. Yang (2016) discovered that the production and innovation strategies of renewable energy firms hinge on the intensity of subsidization [36]. Yang (2020) classified technologies into mature and immature categories based on the difference in innovation risk, using a two-stage model to identify diverse impacts of incentives on green transition. The study found that subsidies can stimulate innovation and green transition when the technology is mature and that subsidies are the most effective means of advancing a green transition when the technology is immature [37].

In summary, existing studies have not reached a consensus on the impact of subsidies on the green transitions of enterprises. There has been limited analysis of the construction industry, despite the substantial financial subsidies and incentives received by the sector. This underscores the significance of investigating the impact of subsidies on the green transition of enterprises. This study aims to provide a unique and novel examination of this issue, offering recommendations for achieving sustainability in the construction industry.

2.2. Theoretical Hypothesis

The green transition is steered by resource efficiency and environmental friendliness. The objective is to attain low pollution, low emissions, and high production for green and sustainable development across the entire lifecycle. It is a transition that leads to a win–win scenario, delivering economic and environmental benefits simultaneously [38]. Owing to the dual positive externalities of green transition and the challenge of adequately compensating enterprise transition costs, the intrinsic motivation for enterprises to undertake a green transition is evidently insufficient [39]. Consequently, the presence of market failure frequently serves as the theoretical foundation for government subsidy policies. Previous studies have attributed the impetus for green transitions to government regulation and stakeholder pressure. Due to the presence of technological externalities, when the advantages gained through innovation for the transition are less than the social benefits, the market will naturally perceive that the incentives offered for green transitions are inadequate. The policy implication of subsidies is to motivate transitioning enterprises by aligning transition benefits with social benefits. At the micro level of government subsidies, governments intentionally select projects conducive to green transition through direct special fund subsidies, tax incentives, and other industrial policies. To accomplish this, governments should be capable of accurately identifying the green transition initiatives undertaken by enterprises, necessitating symmetrical information held by both the government and enterprises. Hence, in practice, subsidies are often provided afterward, granted to projects implementing star-rated green buildings, ultra-low-energy constructions, and energy-saving rehabilitation of existing buildings. Simultaneously, governments at all levels have proactively revised the evaluation standards of green buildings, enhanced the management of green building labels, and taken other measures to mitigate the risk of resource mismatches. Furthermore, governments should maximize the utilization of diverse forms of subsidy policies and enhance policy flexibility and responsiveness to risks. Building on the above research, this paper puts forward the following hypothesis:

H1: *Government subsidies can induce the green transition of construction enterprises.*

An ESG score is derived from the disclosure of environmental responsibility, social responsibility, and corporate governance information by enterprises. This score is calculated by establishing indicators that align with the national context and industry characteristics. ESG primarily advances the green transition of enterprises through three key advantages: diminishing principal–agent costs, mitigating risks, alleviating financing constraints, and fostering increased investment in R&D. In the context of the principal–agent relationship, company operators prioritize performance and may forsake long-term projects with higher risks (Fang, 2014) [40]. ESG ratings can lower the supervision costs for shareholders and stakeholders, steering clear of short-sighted behaviors through enterprise management. Prioritizing the long-term development goals of enterprises contributes to facilitating their green transition. Meanwhile, the social responsibility concept conveyed by ESG also enables enterprises to amass social capital and build business cooperation networks. This not only helps enterprises reduce risks and alleviate resource constraints in the innovation process, but also improves the credibility of signals by continuously transmitting different types of signals according to signal transmission theory [41]. If a company attempts to build a responsible corporate image and reputation through ESG, it will inevitably improve the quality of financial information disclosure and further alleviate financing constraints [42]. In addition, ESG construction also attracts creative employees and enhances internal trust and cooperation by meeting the needs of employees to realize their self-worth [43]. This cooperative efficiency forms a virtuous circle of internal and external resources, further boosting enterprise innovation investment. Thus, ESG ratings serve to connect enterprises with the market, enhancing the external information environment, reducing information asymmetry between enterprises and external stakeholders, facilitating the operation of market incentive mechanisms and external supervision mechanisms, and assisting enterprises with outstanding ESG performance to gain more support from stakeholders, thereby internally propelling enterprises toward green transition.

Nevertheless, ESG investment imposes an increased cost burden on enterprises. Duque-Grisales and Aguilera-Caracue (2021), in a study involving multinational companies in Latin America, discovered a negative correlation between ESG scores and financial performance [44]. This is because ESG investment imposes additional costs on enterprises, and managers are more prone to opt for self-interested behavior, leading to a decline in the financial performance of enterprises. Additionally, information disclosure also escalates the costs for enterprises and diminishes their competitive advantage. Specifically, small and medium-sized enterprises, upon evaluating the cost-effectiveness of ESG in information sharing, may lack the motivation to fulfill their social responsibilities [45].

To alleviate this problem, government subsidies as a market incentive can become a source of funding for ESG investment. Government subsidies not only help enterprises increase ESG investment, enhance social responsibility, and strengthen governance capabilities, but also encourage enterprises to use government funds to reallocate resources and shift the focus of new projects towards green buildings. In addition, companies that benefit from government subsidies can actively cultivate good government enterprise relationships, shareholder relationships, as well as customer and consumer relationships, thereby enhancing their corporate image and improving their ESG ratings. In summary, although ESG investment carries a cost burden, its role in promoting the green transition of enterprises cannot be ignored. By making reasonable use of market incentives such as government subsidies, enterprises can achieve green transition on the basis of balancing costs and benefits. Building on the above research, this paper posits the following hypothesis:

H2: *Government subsidies can promote green transition of enterprises by increasing ESG ratings.*

3. Methodology and Data

3.1. Econometric Model

The primary objective of this study is to examine the influence of subsidies on the green transition of construction enterprises. The data structure, formed by variable and data selection, comprises panel data of A-share construction companies spanning from 2012 to 2021. Therefore, the regression analysis to be performed is panel data regression. The fixed-effect model eliminates the influences of all unobservable invariants, including gender, race, religion, etc., as well as those situational factors that change very slowly [46]. Additionally, fixed-effect estimation addresses unobservable heterogeneity and potential endogeneity issues to some extent. Therefore, this study employs a fixed-effect model to analyze the impact of government subsidies on the green transition of construction enterprises.

$$\mathrm{EGT}_{i,t} = \beta_0 + \beta_1 \mathrm{Sub}_{i,t} + \sum \mathrm{Control}_{i,t} + \mathrm{Year} + \varepsilon_{i,t} \tag{1}$$

where the subscripts i and t denote sample and year, respectively; EGT represents the green transition of construction enterprises; and Sub, Control, Year, and ε denote government subsidies and listed company level control variables, controlling for year fixed effects and the random error term. If the key coefficient β_1 is significantly positive, Hypothesis 1 will be verified. This implies that the greater the subsidies, the higher the performance of enterprises in green transition. In other words, subsidies induce green transition.

3.2. Variables

3.2.1. Green Patent Applications (Lngpl)

In this study, the dependent variable chosen is enterprise green transition. The measurement of enterprise green transition indicators is categorized into two main types: the alternative indicator method, where the effect of green transition is gauged by green technological innovation indicators, and the comprehensive indicator method, which evaluates green transition through a system of indicators. Due to the substantial data requirements for comprehensive indicators, complete dataset collection is impractical. Additionally, the relatively small number of listed companies in the construction industry could impact the sample size, leading to unreliable research results. Therefore, the alternative indicator method is employed, using enterprises' green technology innovation as a proxy variable for the dependent variables. The green technology innovation of enterprises is assessed by the number of green patent applications, as the application of green patented technology signifies that those enterprises are undergoing a green transition. Hence, the number of patent applications is considered a more reflective measure of the degree of green transition than the number of authorizations. It is commonly acknowledged that patents vary in innovativeness, with invention patents, utility model transition patents, and design patents ranked from high to low. Given the emphasis on green innovation, this research selects the number of applications for green invention patents and utility model patents in the current period to signify the green transition of enterprises.

3.2.2. ESG Ratings (ESG)

The ESG ratings adopt the SNSI ESG ratings, offering a comprehensive reflection of the company's ESG management practices, along with significant unexpected risks.

3.2.3. The Ratio of the Number of Green Patent Applications (Rep)

In this study, the ratio of the number of green patent applications is chosen as a substitute indicator to ensure the robustness of the empirical results. The indicator is defined as the ratio of the number of green patent applications by construction companies to the total number of patent applications in the current year [47].

3.2.4. Government Subsidies (Sub)

This study identifies government subsidies as the independent variables. These subsidies encompass various forms, including enterprise support funds, scientific and technological project funding subsidies, tax subsidies, innovation incentives, special funds for industrial development, and other subsidies.

3.2.5. Control Variables

Based on the analysis of relevant literature, this study controlled for some characteristics of enterprises to eliminate the potential impact of these variables on green transition. The size of construction enterprises is related to their green transition, so this study selects enterprise size (Size) to reflect this. Return on assets (Roa) is a key indicator for measuring profitability. The management's decision on R&D expenses depends on their expectations for the current and future performance of the enterprise, which are reflected in the market value [48]. This study uses Tobin Q (Q) to reflect the market value of a company. The financial risk of a company can affect its decision-making process for green transition. This study selects the asset liability ratio (Lev) to measure the company's leverage ratio. The government tends to provide subsidies to state-owned enterprises because of the close relationship between the two (Wu, 2017) [49]. This study selects enterprise property (Property) to reflect this. The size of the board of directors (BSize) is calculated based on the number of board members, and independent directors have a certain influence on the company when making significant decisions. This study uses the promotion of independent directors (Id) to reflect this point. Additionally, year fixed effects (i.Year) are controlled to capture factors that change with time. Refer to Table 2 for a detailed description of the specific indicators.

Table 2. Description and definition of variables.

Variable	Variable Name	Symbol	Definition
Dependent variable	Green Transition of Construction Enterprises (EGT)	Lngpl	LN (number of green patent applications + 1)
		ESG	The SNSI ESG ratings are assigned a score of 1–9 from low to high, reflecting the level of ESG management practices as well as significant unexpected risks.
		Rep	The ratio of the number of green patent applications to the number of all patent applications in the year
Key independent variable	Government subsidy	Sub	LN (government subsidy + 1)
Control variable	Asset–liability ratio	Lev	The ratio of the total liabilities to the total assets of the firm
	Enterprise size	Size	LN (total assets)
	Profitability	Roa	Ratio of net profit to average total assets
	TobinQ	Q	Opportunity cost, LN (market value/ book value)
	Enterprise property	Property	Depending on the nature of the enterprise, state-owned enterprises are assigned a value of 1, while the rest are assigned a value of 0
	Board size	Bsize	LN (the number of board members)
	Proportion of independent directors	Id	Ratio of the number of independent directors to the board of directors
	Time effect	Year	Dummy variable

3.3. Data

This research selected A-share listed companies in the construction industry classification of the China Securities Regulatory Commission from 2012 to 2021 as samples. The above samples were screened and excluded for the following: 1. Samples whose government subsidy data were not disclosed or not counted; 2. enterprises in the ST (special treatment) or ST* categories whose stocks had anomalous financial or other conditions, and the stocks that were at risk of delisting; and 3. samples with incomplete data on major indicators.

Company-level subsidies and financial data were collected from the Wind Economic Database [50], and the number of green patent applications came from the State Intellectual Property Office (SIPO) of the People's Republic of China [51]. Considering the applicable period and coverage of each ESG rating, SNSI ESG ratings were used as the proxy variable of enterprise ESG ratings. The SNSI ESG ratings have been used to evaluate the ESG performance of securities issuers such as A-shares and bond issuers since 2009. Currently, it covers all A-share listed companies, and the index is widely recognized by industry and academia. Stata17 was used to regress the data, and in order to eliminate the influence of outliers on the empirical results, the Winsorize command was used to shrink the data, resulting in 151 samples.

4. Results and Discussion

4.1. Descriptive Statistical Analysis

The study conducted descriptive statistical analysis on the key variables, and the results are presented in Table 3. The maximum values of Lngpl and Rep, measuring the green transition indicators of construction industry enterprises, are 6.026 and 1, respectively, with standard deviations of 1.117 and 0.166. These values indicate substantial fluctuations in innovations related to green patents. The standard deviation of government subsidies is 2.718, signifying a diverse range of government subsidies received by enterprises. As control variables, enterprise size and enterprise value demonstrate significant variability, whereas the variances of the other control variables are all less than 1.

Table 3. Descriptive statistics of variables.

Variable	Obs	Mean	Std. Dev.	Min	Max
Lngpl	1510	0.659	1.117	0	6.026
Rep	1510	0.080	0.166	0	1
ESG	1510	4.409	1.232	0	7
Sub	1510	5.653	2.718	0	11.411
Lev	1510	0.660	0.176	0.028	1.347
Size	1510	14.218	1.373	10.085	18.805
Roa	1510	0.024	0.537	−13.476	0.524
Q	1509	3.035	1.735	−1.241	13.41
Bsize	1510	2.147	0.190	1.386	2.708
Id	1510	0.376	0.055	0.250	0.667
Property	1510	0.596	0.491	0	1

Guided by the theoretical analysis, a multiple regression model was established, opting for fixed-effects models based on the outcomes of the Hausman test, and the results of the test are presented in Table 4. Analyzing the test results, the Hausman test statistics are 82.33 and 63.43, respectively, with a p-value less than 0.01. This leads to the rejection of the null hypothesis and suggests strong evidence in favor of fixed effects. Consequently, a fixed-effects model is employed in this analysis. Drawing on the work of Xia et al. (2022) [52] and Shao (2022) [53], a fixed-effect model is formulated.

Table 4. Hausman test.

Variable	Lngpl	ESG
Sub	0.0270 ***	0.000279
	(0.0103)	(0.0117)
Observations	1510	1510
R-squared	0.135	0.078
Hausman	82.33 ***	63.43 ***
p-value	0	0

Standard errors in parentheses. *** $p < 0.01$.

4.2. Correlation Analysis

Table 5 presents the correlation analysis of the paper's dependent variables and independent variables. The correlation coefficients between dependent and independent variables are 0.358, 0.239, and 0.062, showing significant correlations at the 1% and 5% levels. This suggests that government subsidies have a notable impact on green transition, providing initial support for the hypothesis of this research. Moreover, from Table 6, the 1/VIF values are more than 0.1, indicating that there is no serious collinearity.

Table 5. Correlation analysis.

Variable	Sub	Lngpl	Rep	ESG
Sub	1			
Lngpl	0.358 ***	1		
Rep	0.239 ***	0.620 ***	1	
ESG	0.062 **	−0.113 ***	−0.074 ***	1

** $p < 0.05$, *** $p < 0.01$.

Table 6. Multicollinearity test.

Variable	VIF	1/VIF
size	1.870	0.535
lev	1.580	0.634
Bsize	1.530	0.653
Id	1.500	0.668
Sub	1.380	0.723
q	1.250	0.799
roa	1.090	0.916
Property	1.050	0.952
Mean	VIF	1.410

4.3. Tests of Group Differences

The complete sample was divided into groups with and without government subsidies, and the results of group mean differences are presented in Table 7. Mean difference tests were performed on the two indicators of the dependent variable. The results reveal that the mean values for samples with government subsidies are 0.7319 and 0.0878, significantly surpassing the mean values of 0.0302 and 0.0070, respectively, for samples without government subsidies. This implies that the degree of green transition in samples with government subsidies is markedly higher than that in samples without government subsidies.

Table 7. Mean difference test.

Variable	With Subsidies		Without Subsidies		*t*-Test	
	Observation	Mean	Observation	Mean	Mean Difference	T Value
Lngpl	1336	0.7319	174	0.0302	−0.7017	−20.1675 ***
Rep	1336	0.0878	174	0.0070	−0.0808	−13.7847 ***

*** $p < 0.01$.

4.4. Baseline Results

Table 8 presents the baseline regression results investigating the impact of government subsidies on green transition. All regressions control for fixed-year effects. In the first column, the Lngpl coefficient is 0.032, significant at the 1% level. This suggests that an increase in subsidies received by enterprises results in an average increase of approximately 3.2% in the number of invention patent applications. This aligns with theoretical Hypothesis H1 and supports the findings of Shao (2022) [53].

Table 8. Baseline regression results.

Variable	**(1)** **Lngpl**	**(2)** **ESG**	**(3)** **Lngpl**
Sub	0.032 ***	−0.007	
	(3.21)	(−0.60)	
ESG*Sub			0.004 **
			(0.002)
Lev	0.124	−1.749 ***	−0.245
	(0.65)	(−8.35)	(0.190)
Size	0.110 ***	0.414 ***	0.345 ***
	(3.00)	(10.59)	(0.032)
Roa	0.230 **	0.132	0.150
	(2.32)	(1.17)	(0.096)
Q	−0.046 **	0.058 ***	−0.033 *
	(−2.42)	(2.73)	(0.019)
Bsize	−0.185	0.538 **	−0.487 **
	(−0.95)	(2.53)	(0.207)
Id	−0.495	3.938 ***	−1.070
	(−0.77)	(5.56)	(0.690)
Property	0.092	0.326 ***	0.000
	(0.72)	(2.71)	(.)
Constant	−0.772	−2.991 ***	−2.661 ***
	(−1.15)	(−4.12)	(0.728)
Observations	1510	1510	1510
Year	YES	YES	YES

z-statistics in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

In the second column, after replacing the explanatory variable with the ESG rating, the coefficient is negative and statistically insignificant. The results suggest that the impact of government subsidies on the green transition of enterprises mainly originates from innovation, with a negative effect on ESG ratings. Government subsidies, as observed, do not have a noticeable impact on the ESG ratings of construction enterprises. Unlike the direct impact on green technology innovation, the influence of government subsidies on ESG ratings is indirect. Consequently, this paper introduces an interaction term between government subsidies and ESG rating, investigating the moderating effect of the ESG rating on the relationship between government subsidies and enterprise green transition. The third column of Table 8 reveals that the coefficient of the interaction term between government subsidies and ESG rating is 0.004, significantly positive at the 5% level. This suggests that ESG rating positively strengthens the relationship between government subsidies and enterprise green transition, providing support for H2.

Regarding the controlled variables, the coefficients of enterprise size and profitability (Roa) are significantly positive, indicating a favorable impact on the number of green patent applications. This suggests that larger-scale and more profitable construction industry enterprises exhibit greater innovation output. For green transition, which demands prolonged investment, enterprise profitability facilitates successful green innovation (Banerjee et al., 2020) [54]. The asset liability ratio (Lev) shows a positive impact on the number of green patent applications, but lacks statistical significance. There is a significant negative impact on ESG ratings, implying that a higher asset risk unfavorably affects companies in raising funds and increasing investment in ESG. The Tobin Q coefficient significantly influences green transition, but has opposing effects on green technology innovation and ESG. Enhanced enterprise performance stimulates more active ESG investment, resulting in a crowding-out effect on innovation investment, and is not conducive to improving innovation levels.

4.5. Heterogeneity Analysis

4.5.1. Nature of Property Right, Government Subsidies, and Green Transition of Construction Enterprises

There exists a substantial disparity between state-owned enterprises (SOEs) and private enterprises in the construction industry concerning resources, technology, and financial strength. SOEs, having an advantage in terms of supporting the green transition, are generally established earlier and benefit more from policy preferences. This prompts an exploration into whether government subsidies exhibit varying effects on construction enterprises with different property rights during their green transition. The results in Table 9 reveal that government subsidies significantly and positively impact the green technology innovation of SOEs. However, their impact on private and other enterprises is positive, but not statistically significant. This suggests that government subsidies have a stronger incentive effect on SOEs' green transition, while private businesses try to "drift green" in order to obtain government funding. Due to their restrictions on project selection, private businesses frequently and consistently reduce their earnings in order to compete with SOEs. This raises the likelihood that there are insufficient subsidies in place to make up for the profit difference.

Table 9. Government subsidies and green transition: SOEs vs. non-SOEs.

	SOEs		**Non-SOEs**	
	Lgpl	**ESG**	**Lgpl**	**ESG**
Sub	0.032 **	−0.018	0.015	0.016
	(0.013)	(0.014)	(0.016)	(0.019)
Lev	−0.033	−2.602 ***	−0.448 *	−0.102
	(0.274)	(0.291)	(0.260)	(0.310)
Size	0.322 ***	0.406 ***	0.338 ***	−0.073
	(0.043)	(0.045)	(0.048)	(0.057)
Roa	0.548 ***	0.180	−0.044	0.260 *
	(0.158)	(0.168)	(0.120)	(0.143)
Q	−0.003	−0.024	−0.084 ***	−0.005
	(0.024)	(0.026)	(0.032)	(0.038)
Bsize	−0.410	0.798 ***	−0.672 **	1.517 ***
	(0.266)	(0.283)	(0.331)	(0.395)
Id	−0.326	3.589 ***	−2.405 **	7.157 ***
	(0.866)	(0.920)	(1.135)	(1.354)
_cons	−3.069 ***	−2.400 **	−1.406	−0.645
	(0.951)	(1.010)	(1.131)	(1.349)
Year	YES	YES	YES	YES
N	900.000	900.000	610.000	610.000
r2	0.140	0.162	0.154	0.062
r2_a	0.037	0.062	0.049	−0.054

Standard errors in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Government subsidies show limited impact on ESG ratings. Given ESG's comprehensive nature, government subsidies are less likely to significantly influence social responsibility among construction companies. It is notable that government subsidies negatively impact the ESG ratings of SOEs, while a positive impact is observed for the ESG ratings of private and other enterprises. This indicates weaker governance capacity in non-state-owned enterprises compared to state-owned enterprises. Due to the limited ability of external investors to fully grasp internal enterprise information, non-state-owned enterprises face poor financing capabilities. Consequently, government subsidies play a more significant role in alleviating their financing constraints, leading to improved ESG performance. In summary, government subsidies play a stronger role in promoting ESG performance in non-state-owned enterprises.

4.5.2. Enterprise Value, Government Subsidies, and Green Transition of Construction Enterprises

The attitude towards green transition may vary based on enterprises' value when receiving government subsidies. High-value enterprises, owing to their market strength, brand influence, financial stability, and technological advancements, are more likely to proactively embrace government policies on green transition, adopting social responsibility measures and implementing actions to mitigate negative environmental impacts. These enterprises, with greater economic strength and larger market share, can enhance competitiveness through technological innovation and environmentally sustainable production methods. In contrast, low-value enterprises may face operational constraints and financial difficulties, leading them to prioritize short-term benefits and economic gain over long-term sustainable development when receiving government subsidies. These enterprises might utilize subsidies to address immediate business challenges or expand production capacity, rather than investing in green transition or environmental initiatives. However, even low-value enterprises may recognize the importance of green transition and take voluntary measures to mitigate environmental impacts. Government subsidies can act as a driving force for these enterprises to pursue green transition.

To examine the impact of government subsidies on the green transition of enterprises with varying values, this study divided the entire sample into high-value and low-value enterprises based on the median of TobinQ, a commonly used indicator to assess a company's worth. Table 10 displays the regression results. The findings indicate that, for both high-value and low-value enterprises, the regression coefficients of the logarithm of government subsidies are significantly positive. This suggests that government subsidies play a crucial role in encouraging green technology innovation in enterprises. However, government subsidies show no discernible effect on the ESG ratings of enterprises.

Table 10. Government subsidies and green transition: High vs. low value.

	High-Value		**Low-Value**	
	Lngpl	**ESG**	**Lngpl**	**ESG**
Sub	0.020 *	−0.010	0.046 **	−0.016
	(0.012)	(0.015)	(0.020)	(0.022)
Lev	−0.681 ***	−0.381	−0.255	−2.251 ***
	(0.224)	(0.282)	(0.361)	(0.394)
Size	0.278 ***	0.231 ***	0.422 ***	0.236 ***
	(0.053)	(0.067)	(0.047)	(0.051)
Roa	0.124	0.108	0.315 **	0.216
	(0.126)	(0.158)	(0.145)	(0.159)
Q	−0.049 *	0.064 *	0.001	−0.141 **
	(0.030)	(0.037)	(0.053)	(0.058)
Bsize	−0.148	1.705 ***	−1.040 ***	0.350
	(0.287)	(0.361)	(0.323)	(0.353)
Id	−0.615	6.634 ***	−1.255	3.836 ***
	(1.006)	(1.265)	(1.010)	(1.103)
Property	0.000	0.000	0.000	0.000
	(.)	(.)	(.)	(.)
_cons	−2.475 **	−4.893 ***	−2.536 **	0.653
	(1.156)	(1.455)	(1.058)	(1.156)
Year	YES	YES	YES	YES
N	755.000	755.000	755.000	755.000
r2	0.080	0.071	0.205	0.099
r2_a	−0.101	−0.112	0.053	−0.073

Standard errors in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

4.6. Robustness Tests

4.6.1. Replacement of the Dependent Variable

The dependent variable was substituted with the percentage of green patent applications (Rep). Table 11 presents the regression results, with columns (1) to (6) controlling for other relevant variables. The coefficient symbols and significance levels of the main explanatory and control variables have remained consistent, indicating the robustness of the econometric model's results to changes in the sample.

Table 11. Regression results of robustness test (1).

	(1) Rep	(2) Rep	(3) Rep	(4) Rep	(5) Rep	(6) Rep
Sub	0.010 ***	0.010 ***	0.007 ***	0.007 ***	0.007 ***	0.007 ***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Lev		0.003	−0.055	−0.074 *	−0.079 **	−0.080 **
		(0.035)	(0.037)	(0.038)	(0.038)	(0.039)
Size			0.025 ***	0.026 ***	0.025 ***	0.025 ***
			(0.006)	(0.006)	(0.006)	(0.006)
Roa				−0.042 **	−0.039 **	−0.039 **
				(0.019)	(0.019)	(0.020)
Q					−0.005	−0.005
					(0.004)	(0.004)
Bsize						0.008
						(0.042)
Id						−0.043
						(0.141)
Property						0.000
						(.)
_cons	0.020 *	0.018	−0.282 ***	−0.277 ***	−0.241 ***	−0.245 *
	(0.011)	(0.024)	(0.080)	(0.079)	(0.084)	(0.148)
Year	YES	YES	YES	YES	YES	YES
N	1510.000	1510.000	1510.000	1510.000	1510.000	1510.000
r2	0.021	0.021	0.033	0.036	0.037	0.037
r2_a	−0.087	−0.088	−0.077	−0.074	−0.073	−0.074

Standard errors in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

4.6.2. Independent Variables Lagged One and Two Periods

In light of the previous regression results highlighting the significant role of government incentives in promoting environmentally friendly practices among construction companies, it is plausible that an organization's success in transitioning to a greener business model contributes to its eligibility for government subsidies. This suggests a potential bilateral causality. The independent variables in this research include government subsidies lagged by one and two periods. Table 12 presents the findings, indicating that government subsidies effectively promote the green transition of construction industry enterprises. Furthermore, the regression results for the current period remain significant at the 1% level, suggesting that government subsidies are primarily granted to construction businesses based on their achievements in green technology, rather than in anticipation of them.

Table 12. Regression results of robustness test (2).

	Lngpl	One-Period Lag	Two-Period Lag
Sub	0.027 ***	−0.008	0.007
	(0.010)	(0.011)	(0.011)
Lev	−0.275	−0.290	−0.255
	(0.189)	(0.207)	(0.233)
Size	0.341 ***	0.368 ***	0.331 ***
	(0.032)	(0.036)	(0.044)

Table 12. *Cont.*

	Lngpl	One-Period Lag	Two-Period Lag
Roa	0.155	0.180 *	0.176 *
	(0.096)	(0.099)	(0.103)
Q	−0.031	−0.046 **	−0.048 **
	(0.019)	(0.021)	(0.024)
Bsize	−0.468 **	−0.306	−0.298
	(0.207)	(0.233)	(0.273)
Id	−0.965	−0.802	−0.747
	(0.690)	(0.756)	(0.853)
Property	0.000	0.000	0.000
	(.)	(.)	(.)
_cons	−2.708 ***	−3.253 ***	−2.827 ***
	(0.724)	(0.819)	(0.956)
Year	YES	YES	YES
N	1510	1359	1208
r2	0.135	0.111	0.087
r2_a	0.034	−0.005	−0.049

Standard errors in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

4.7. Discussion

Subsidy policies play a crucial role in driving green transition, but the construction industry has been underexplored in existing research, particularly in terms of corporate social responsibility. This study utilizes panel data from 151 listed Chinese construction companies spanning 2012 to 2021 to investigate the influence of government subsidies on enterprise green transition, alongside the significant role of ESG ratings. The findings reveal that government subsidies significantly induce green innovation (Table 8), especially for SOEs (Table 9). This provides additional empirical evidence that public support can promote technological innovation. Due to the special market situation of China's transitional economy, state-owned enterprises and private enterprises have coexisted in the market for a long time. SOEs are characterized by a large amount of assets and stricter government control [55], which leads to differences in government communication efficiency, investment behavior, and research and development efficiency between state-owned enterprises and private enterprises, affecting the effectiveness of public support for the green transition of enterprises. Although a large number of scholars are interested in the interaction between government subsidies and enterprises innovation [56–58], few quantitative evaluations of the effectiveness of public subsidy policies on different forms of ownership have been researched [49]. The results have enlightening significance for the green transition of the construction industry in other transition economies.

Yet, the empirical evidence on the impact of government subsidies on ESG ratings of construction industry enterprises is quite weak. The coefficient of ESG rating in the regression model (Table 8) is negative and not significant. Subsidies have a negative impact on ESG ratings, which is consistent with a study by Zhang et al. (2023) that companies often improve their ESG performance after environmental subsidies are interrupted [59]. However, there is still a lack of strong evidence that subsidies stimulate construction enterprises to undergo more comprehensive green transition. The study also found that the ESG rating positively strengthens the relationship between subsidies and enterprise green transition. This indicates that companies actively participating in ESG ratings exhibit behavioral additionality, which means that ESG ratings can affect the behavior of external investors [60,61]. Enterprises participating in ESG ratings will release positive signals, affecting the government's public support attitude. The interaction between subsidies and ESG ratings is complex and requires further exploration of their impact effects in different contexts.

5. Conclusions, Implications, and Limitations

5.1. Conclusions

In this study, using panel data sets during the period of 2012–2021 in China, we applied the fixed-effect model to investigate the causality between government subsidies and construction enterprises' green transition. The empirical analysis yielded the following conclusions:

(1) Government subsidies significantly induce the green transition of construction enterprises. In other words, a 1% increase in the subsidies will boost the number of green patent applications by 3.2%. This conclusion remains robust even after controlling for other variables, including time fixed effects. The results of the analysis support the hypothesis that government subsidies can induce the green transition of construction enterprises (H1).

(2) When the ESG ratings are used as the dependent variable, the results are not significant. However, introducing the interaction term between enterprise ESG ratings and government subsidies renders a significant effect on green transition, which supports Hypothesis 2. Overall, the impact of subsidies on enterprise green innovation is direct, while the impact on ESG ratings is not evident.

(3) In terms of enterprise heterogeneity, government subsidies exert a more pronounced pushing effect on the green transition of SOEs compared to private enterprises and other types of enterprises. The impact of government subsidies on businesses' efforts to go green appears unrelated to their financial value.

This research, based on data from listed companies in China's construction industry and the number of green patent applications, provides robust empirical evidence supporting the aforementioned theoretical assumptions, thereby validating the main findings of this paper. It offers a unique insight into understanding the effect of government subsidy policies as an infrastructure powerhouse.

5.2. Implications

Drawing from the findings of the aforementioned research, there are several implications, as follows: (1) Enterprises' investment in green innovation is highly dependent on government subsidies. In order to promote a green transition of the construction industry, governments at all levels should increase subsidies and the types of subsidy policies. (2) For enterprises, although green innovation can reflect the participation of enterprises in environmental governance, they should pay more attention to social responsibility, which realizes the value of stakeholders and improves the quality of people's work and life. The research in this paper shows that subsidies have a stronger role in promoting the green innovation of state-owned enterprises. Managers of SOEs should further apply government subsidies to social responsibility activities and create a sustainable green competitive advantage. (3) The development of ESG in China is still in its initial stage, but its future development is unstoppable. Construction enterprises should also actively participate in ESG certification. The government can subsidize this based on ESG ratings or incorporate ESG certification into the bank credit system as a supplementary measure for government subsidies.

5.3. Limitations

This study has two main limitations. First, as it is limited by the different policies of local governments, there is no distinction between the specific types of subsidy policies. The data are derived from the listed firms in their annual reports. It is necessary for us to further study which kinds of subsidy methods, such as direct reward, tax relief, or loan discount, are more effective for driving a green transition. Second, although this study includes the ESG ratings as a dependent variable, it is a comprehensive indicator that includes three pillars. Further research could explore the impact of subsidies on the environment, society and governance separately.

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