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The Impact of Government and Enterprise Management Modes on the Sustainable Development of the China Construction Industry: The Mediating Role of Innovation and the Moderating Role of Economic Development

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Abstract. Over the past several years, following its attainment of peak performance, China's construction industry has exhibited a notable trend of deceleration and decline in its developmental momentum. Simultaneously, the sustainable development (SD) of this sector has emerged as a pivotal area of concern for numerous nations and industries alike. Consequently, it becomes imperative to conduct a comprehensive analysis of the factors influencing SD within the construction industry from a business management lens, with the aim of elucidating strategies to uphold and augment its SD amidst industry downturns. Given China's vast territorial expanse and the pronounced regional disparities in economic, cultural, and policy contexts, the sustainable development of its construction industry shaped by these multifarious factors, holds substantial merit for rigorous exploration. This study meticulously selects data from esteemed Chinese databases and employs regression analysis to scrutinize the ramifications of China's recent policies and corporate management paradigms on the SD of the construction industry, whilst, it integrates an examination of the mediatory function of industry innovation and the moderating influence of economic conditions within the impact pathway.

Keywords. Sustainable development; Construction Industry; Policies; Management; Innovation; Economic development; Regression analysis

1. Introduction

Sustainable development (SD) was formally introduced and defined in the 1987 report titled 'Our Common Future' by the World Commission on Environment and Development as development that satisfies the current needs without jeopardizing the capacity of future generations to fulfill their own requirements. (Chichilnisky, 1999) [1]. SD is a comprehensive and multifaceted concept that encompasses diverse domains such as economics, society, environment, and technology (Parris and Kates, 2003) [2]. Within the construction industry, SD manifests in three intricate dimensions, each with its unique focus and implications: environmental protection, social well-being and economic prosperity (Tan et al., 2011) [3].

These three aspects, while independent, are also complementary. Economic development hinges on the exploitation and utilization of natural resources; however, overexploitation can result in environmental degradation and ecological imbalance (Wei et al., 2021) [4]. Meanwhile, social factors dictate the trajectory of economic progress and the rigor of environmental management, exhibiting a mutually restraining dynamic (Bornmann, 2013) [5], by employing effective social steering to adopt eco-friendly technologies and enhance resource efficiency, it becomes feasible to foster economic growth while safeguarding the environment. Moreover, a favorable ecological environment has the potential to attract investments (Baumgärtner et al., 2002) [6] and talents, thereby further propelling economic development and underscoring their synergistic relationship. In the intricate interplay of long-term dynamics, accompanied by the ongoing urbanization across numerous regions (Tan et al., 2016) [7], the SD of the construction sector stands to be influenced by a variety of factors, encompassing market demand, economic growth (Bon and Hutchinson, 2000) [8], cost management, demographic shifts, regulatory frameworks (Raynsford, 2000) [9], among others. The policies and managerial practices of both governments and corporations assume a crucial role in steering and blueprinting this development. From the vantage point of governmental policy, macroeconomic adjustments and guidance have the capacity to institute economic incentives and policy backing (Zaghini, 2001) [10], fostering and nurturing market demands, elevating the technological proficiency and accumulating expertise in SD, while concurrently augmenting societal recognition and embrace of sustainability principles. Shifting to the lens of industry administration, strategic planning and decision-making exert a determinant influence on cultivating corporate social responsibility ideologies (Sitnikov and Bocean, 2017) [11] and investing in green research and development endeavors. Meanwhile, project management and its practical execution are pivotal in dictating the efficiency of implementation, thereby impacting the efficacy of SD throughout the entire lifecycle of buildings (Hwang and Tan, 2012) [12]. Under the synergistic influence of collaboration between the government and enterprises, the specification of shared objectives and interest aspirations can foster cooperative endeavors aimed at realizing SD within the construction sector. The government's macro-control authority and the market operational prowess of enterprises can serve to complement one another's resources (Sun et al., 2022) [13], thereby facilitating optimal resource allocation and efficient utilization in pursuit of SD. From a systems theory vantage point, enterprises and governments emerge as pivotal constituents of the socio-economic system, with their intricate interactions weaving an indispensable thread through the system's fabric (Adelman, 2000; Balabanis et al., 1998) [14][15], the effective collaboration between these entities is paramount to fostering the robust development of enterprises. Meanwhile, innovation stands as a pivotal force propelling scientific advancement, and within the realm of construction industry's SD, it has facilitated remarkable progress (Zhang et al., 2020) [16]. Through the implementation of automation, intelligent construction practices, modularization, and prefabrication techniques, construction efficiency has been bolstered (Akintoye et al., 2012) [17], these contributions underscore the importance of technological innovation in fostering SD. While regional economic development (Amin, 2004) [18], shaped by a multitude of factors and not entirely within the purview of governments and corporations, still serves as a cornerstone for the growth and innovation within the construction industry (Sui et al., 2019) [19]. It further molds market demands for living spaces, thereby furnishing a supportive platform for SD's advancement. When delving into the intricate factors influencing SD in the construction industry, the aforementioned elements of governance, corporate management, technological innovation, and regional economic development consistently emerge as pivotal. Given the vast scale of China's construction sector and the current trajectory of decline from its post-pandemic peak (Nan, 2021) [20], it becomes imperative to explore how these diverse factors will interplay and impact SD. To this end, the following questions are posed and addressed within this paper:

Q1: Amidst the present market landscape of China's construction industry, have government policies and corporate management strategies exerted a notably positive influence on SD?

Q2: In their roles as mediating and moderating variables, what specific impacts will technological development and regional economic growth exert on SD within the construction sector?

Existing research has explored SD in construction and management practices but overlooked their impact of policies and management frameworks on SD in this sector, particularly within the unique context of China, by investing reputable Chinese database, this study constructs regression models to analyze these relationships, considering technological innovation's mediation and economic development's moderation. It contributes by: (1) Distinct from isolated studies, this research elucidating the interconnectedness of SD, government policies, and management practices (2) Incorporating technological innovation and economic development into the analytical framework (3) offering pertinent insights within the context of China's urbanization drive, thereby providing valuable experience and filling gaps for the advancement of management science and the construction industry.

2. Literature review and hypothesis development

The aim of this section is to provide a review and introduction to each hypothesis that will undergo testing in the logistic regression analysis, figure 1 depicts the conceptual framework in which each of these hypotheses is embedded (Kim et al., 2023) [21].

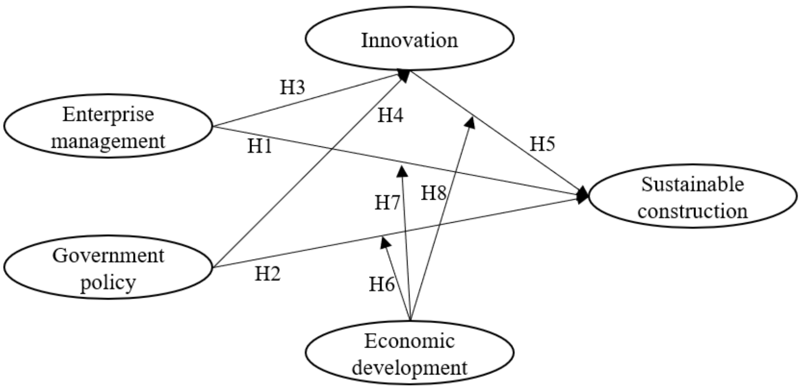

Figure1: The conceptual framework

2.1 Sustainable development of construction industry

Sustainable construction encompasses not only the buildings and spaces themselves, but also the processes and activities employed in their construction, as well as the infrastructural components like waste management, transportation, and utility transmission systems that are implemented to support these built environments (Presley and Meade, 2010) [22]. Zuo et al (2012) [23] pointed out that the construction industry exerts substantial impacts on society, encompassing environmental, economic, and social dimensions. Sustainability has emerged as a pivotal concern, garnering significant attention from both industry practitioners and academic researchers. As an industry with high resource consumption and high emissions, numerous companies are pursuing sustainability due to the identification of significant business value inherent in its implementation (McMullen, 2001) [24], construction industry is currently confronted with the challenge of minimizing energy consumption, carbon emissions, and other adverse environmental impacts, whilst upholding high levels of economic sustainability and social considerations (Zhong and Wu, 2015 [25]; Valdes and Klotz, 2013 [26]). According to the research conducted by Pitt et al. (2009) [27], various factors including financial incentives, building regulations, client awareness and demand, taxes/levies, investment, affordability, and business case understanding have exerted a substantial influence on SD within the construction industry, notably, among these factors, clients and architects have demonstrated the highest level of concern towards sustainable construction, with builders and investors following closely behind. Similarly, Gumusburun and Metinal (2024) [28] also pointed out that the primary factors currently influencing the SD of the construction industry include the shortage of professionals and relevant knowledge, cost considerations, material supply issues, regulatory policies, efficiency requirements, market customer demands, quality control standards, organizational structure, and the need for transformation. It can be inferred from this that the influencing factors of SD in the construction industry originate from multiple dimensions across different groups, and these factors exhibit variations depending on time and space. Consequently, it becomes imperative to conduct thorough research in this regard.

2.2 Government policy and sustainable development of construction industry

Amusan et al (2018) [29] state that appropriate policy controls are of paramount importance to the construction environment, serving as a vital mechanism to mitigate the emergence of further substandard buildings and to facilitate capital and economic growth. Policies introduced by the government will fulfill its regulatory responsibilities, encouraging and promoting the establishment of standards, the implementation of sustainable policies, and ensuring that professionals who commit errors within the construction industry are appropriately penalized (Ogunmakinde and Maund, 2016) [30]. Regarding the practice of sustainable construction, there exist disparities across numerous regions in various aspects. As societal guides, governments ought to support the implementation of sustainable construction practices and energy conservation measures, ensuring minimal policy enforcement while exercising control or providing support to elevate industry standards. However, it is noteworthy that some regions still lack the requisite policies, regulations, or professional committees or institutions necessary to facilitate this transition. (Davies and Davies, 2017 [31]; Akadiri et al., 2012 [32]; Gomes and Maristela, 2005 [33]). Taking China as an example, Liu et al. (2014) [34] demonstrated that due to rapid urbanization, emerging concepts and policies related to sustainable construction have been continuously proposed in recent. Chang et al. (2016) [35] also elaborated on the progressively enhancing regulations and policies pertaining to sustainable construction in China, encompassing the scope of government, developers, builders, suppliers, and designers. Considering that government regulations significantly incentivize or disincentivize the adoption of innovation (Ojo et al., 2014) [36], the impact and degree of influence exerted by recent Chinese government policies remain ambiguous; therefore, we postulate the following hypothesis:

H1: Government policy orientation has a positive and significant impact on the sustainable development of the construction industry.

2.3 Management mode of enterprise and sustainable development of construction industry

Engert et al (2016) [37] elaborate that company environments are rapidly changing due to ecological and social trends, leading to increased interest in corporate sustainability, however, managers rarely consider it in strategic management despite recognizing its importance. As for the construction industry, Sexton and Barrett (2003) [38] expressed in this field, numerous enterprises and subcontractors strive to emphasize cost-effectiveness and offer optimal value to the sector, nonetheless, this typically entails an inability to allocate substantial resources towards sustainable innovation and development endeavors. From the other hand, business growth is fundamentally influenced by the managerial capacity to ensure that resources are efficiently allocated between sustaining current operations and exploring new opportunities. (Packham.G et al., 2003) [39]. Hence, despite the existence of numerous factors that impose constraints on the construction industry to embrace the concept of sustainability in managing projects (Abidin and Pasquire, 2007) [40], implementing high-efficiency management practices can markedly enhance the capacity of a sustainable construction project to be completed within acceptable cost limitations (Robichaud & Anantatmula, 2011) [41]. This offers an explanation for the increasing emphasis placed by enterprises on SD in recent decades. Evidence revealed that construction firms that tend to pursue SD were more inclined to view the introduction of management practices as a necessary step (Packham et al., 2005) [42]. Banihashemi et al. (2017) [43] posited that the construction industry has demonstrated a growing emphasis on SD and management, influenced by a multitude of factors encompassing technical, human development, managerial, political, environmental, social, and economic challenges. In order to assess the influence of construction management modes on SD amidst complex scenarios, we formulate the following hypothesis:

H2：The enterprise management model exerts a positive and significant influence on the sustainable development of the construction industry.

2.4 Government policy orientation and enterprise innovation

Kim et al (2023) [44] state that government support policies will generate positive effect on R&D activities and both new-product and improved-product innovation of corporates. Analogously, Herrera and Nieto (2008) [45] indicate government support for firms' research and development activities serves as a crucial incentive to bolster the innovation performance of these firms. According to the data published by Eurostat, the aggregate research and development (R&D) expenditures of governments across the European Union (EU) member states reached EUR 123.684 billion in 2023, representing a notable 5.3% increase compared to the previous year. This growth underscores the EU's commitment to and sustained investment in R&D activities. In a parallel development, the U.S. Congress enacted the "Chips and Science Act" in 2022 (Peters, 2022) [46], which allocates substantial governmental resources towards semiconductor research, development, manufacturing, and workforce development. This legislative action highlights the intricate interplay and mutual dependence between corporate technological innovation and governmental support. Nevertheless, the investigation into the efficacy of government support policies on corporate product innovation performance, and more specifically, how these policies are moderated by market, financial, and various other uncertain factors, is still in its infancy and lacks maturity. (Schot and Steinmueller, 2018) [47]. High market uncertainty may be seen to give rise to a situation of market failure, which is highly likely to impact on technological development (Hall, 2002) [48]. In the context of China, where the construction industry's development has demonstrated instability in the post-pandemic era

(Wang et al., 2022) [49], and concurrently, governmental policies and support mechanisms are continuously being refined and implemented (Jia et al., 2020) [50], we formulate a hypothesis to systematically examine and elucidate the manner in which government policies exert their influence on technological innovation within the construction industry：

H3: Government policy orientation has a significant positive impact on technological innovation within construction industries.

2.5 Enterprise management and innovation

Corporate innovation is significantly influenced by management governance, particularly the strategic thinking and decision-making processes at the higher management levels (Zhao and Yu, 2021) [51]. In contrast to conventional innovation, sustainable innovation distinguishes itself by embodying two notable externalities: knowledge spillovers and environmental protection. These spillover effects are evident not merely in realms such as technology, knowledge, and managerial know-how, but also in the environmental benefits it yields, which frequently carry the characteristics of public goods. As a result, when viewed from a societal lens, the benefits of sustainable innovation outweigh those realized by individual enterprises or persons (Jaffe et al., 2005 [52]; Silvestre and Diana, 2019 [53]). Moreover, the imperfections within market systems in specific regions, coupled with the inherently high risks associated with innovation endeavors, position sustainable innovation as a strategy of both paramount importance and complexity. The attainment of success in this strategy hinges significantly on the decisions and implementations orchestrated by the top management team, who serve as the principal strategists within corporations (Hambrick and Mason, 1984 [54]; Wang et al., 2022 [55]). Hartmann (2006) [56] put forward that the management of construction firms ought to explicitly champion the notion of innovation, deliberately formulate strategic decisions pertaining to the direction of corporate innovation endeavors, and offer comprehensive, structured support throughout the entirety of the innovation process. Duong et al. (2021) [57] also highlight that the construction industry's pursuit of innovation is not without challenges, notably including inadequate funding and subsequent failures in achieving desired outcomes. With respect to the evolving trends in environmental and innovation management within China's construction sector, we formulate the subsequent hypotheses to delve into their interplay over the recent years:

H4：Corporate management model has a significant positive impact on corporate innovation

2.6 Innovative and sustainable development of construction industry

Innovation and technological advancements can serve as crucial pillars in supporting the sustainable growth of enterprises (Smith et al., 2010) [58], which considered an important element of policies for SD (Nill and Kemp, 2009) [59]. Ahmad et al (2023) [60], Van et al (2021) [61] outlined which in a society characterized by pervasive uncertainties, it is imperative to undertake measures aimed at establishing mechanisms for SD. This constitutes a fundamental prerequisite for augmenting the likelihood of survival for both organizations and society at large, in the face of unforeseen and uncontrollable shifts. Sustainability-oriented innovation emerges as a pivotal strategy, capable of ensuring sustainable progress even as market demands escalate and policy prerequisites undergo constant renewal. However, due to the inherent risks associated with innovation, some enterprises have doubts about its effectiveness. Lazaretti et al (2020) [62] remarked in the study that as they become more socially and environmentally sustainable, their costs will correspondingly rise which can adversely affect their competitiveness and fail to yield immediate financial gains. Wuni and Mahmud (2022) [63] highlighted that the construction industry, due to its inherent characteristics, faces various risks such as inaccurate cost estimation, diseconomies of scale with prolonged durations, modular design complexity, inefficient scheduling, and elevated initial capital costs. These factors collectively contribute to an implicit augmentation of potential threats to the growth and development of enterprises within this sector. Amidst the backdrop of a global economic slowdown and taking into account the present state of development in China's construction industry, we formulate the ensuing hypothesis to examine whether innovation serves as an opportunity or a burden for enterprises.

H5：Enterprise innovation has a positive impact on the sustainable development of construction industry.

2.7 Economic development with innovation and sustainable development of construction industry

Zhuang et al. (2009) [64], Peng et al. (2018) [65] pointed out that the economic status of a region is closely intertwined with its societal development, and the economy, to a significant extent, impacts the operational and management practices of most enterprises, forging intricate associations with their overall development. Economic development drives the adoption of larger and newer technological processes, as well as the optimized allocation of resources and investments towards innovation. (Dabla et al., 2012) [66]. Sylla et al. (2006) [67] formulate this is primarily due to the fact that financial development stimulates innovation, which is contingent upon various factors, including the size of the economy, the nature of industries, and the institutional framework in place. Verdier et al (2010) [68] underscore the significance of innovation for corporate performance and the enhancement of enterprise productivity. Furthermore, they establish the pivotal role of the financial system in influencing enterprise productivity, positing that within a more robust financial framework, enterprises are able to optimize and fully leverage the impact of their innovative endeavors. From an alternative vantage point, the facilitation of innovation by economic development is contingent upon the economic system and its distribution mechanisms. Aristizábal et al. (2015) [69] contend in their study that, owing to divergent national and regional policies coupled with disparate economic magnitudes, the support for corporate innovation encounters challenges of imbalance and inadequacy. The innovation within various modules of an enterprise is subject to influences from both internal and external factors that extend beyond macroeconomic development (Zennouche and Wang, 2014 [70]; Pinto and Fernández, 2023 [71]). Consequently, the interplay between economic development and enterprise innovation cannot be straightforwardly characterized as a linear relationship. Similarly, economic development has a comparable impact on sustainability. Ndubisi et al. (2021) [72] have elucidated the influential role of the economy on SD, emphasizing their inseparable relationship, they have the potential to either reinforce each other synergistically or exist in a state of incompatibility (Clark, 1995) [73]. Yet, the ultimate consequences of this impact are also shaped by various other factors. A complicating factor is that sustainability outcomes are not conventionally assessed using economic development indicators, which makes evaluating success in this domain particularly challenging (Brinkmann, 2018) [74]. Given that the impact of economic development at the macro level does not directly intervene between the explanatory and dependent variables, we regard it as a moderating variable. Consequently, we propose the following hypothesis to elucidate its role and relationship:

H6: Economic development exerts a positive moderating effect on the relationship between technological innovation and sustainable development within the construction industry.

2.8 Economic development and management mode of government and enterprises

The significance of economic development in dictating government policy formulation and corporate management strategy planning cannot be overlooked, as the reciprocal adjustments made by both governments and enterprises subsequently influence economic progress (Lin and Zhou, 2022) [75]. This, in turn, affects various aspects such as businesses' operational profits, efficiency, and product innovation, which ultimately find their reflection in the data pertaining to urban economic development. Zhong and Chen (2023) [76] emphasize that the management practices adopted by governments and enterprises wield considerable influence over contemporary economic systems. Chugunov et al (2021) [77] elaborate when the economic landscape undergoes transformations, it exerts a significant impact on established policies, thereby necessitating corresponding adjustments in the government's economic management framework. In response to the evolving environment, monetary and fiscal policies are fine-tuned accordingly. The financial strategy presents a range of scenarios tailored to the preparation and execution of regulatory measures, taking into account macroeconomic trends and objectives at the appropriate juncture of social development.

Furthermore, for businesses, shifts in the economic situation exert a pronounced influence on various management models, the transformation of economic conditions has a notable impact on diverse corporate management approaches. Bernanke (1983) [78] documented that the inherent uncertainty and irreversibility associated with investments can induce firms to extend their waiting options, consequently leading to a reduction or deferment of investment activities. Dixit et al. (1994) [79] find that under high uncertainty, the benefit of waiting for more information becomes more valuable, and thus managers tend to defer investment with high sunk costs. In short, by deferring investment and keeping the option alive, firms can avoid costly mistakes and wait for additional information about an uncertain future (Atanassov et al., 2015) [80]. Bhattacharya et al. (2017) [81], and Biggerstaff and Goldie (2019) [82] illustrate that a robust economic environment fosters market confidence, propels corporate investment strategies, streamlines resource allocation, and stimulates innovative endeavors, ultimately bolstering economic efficiency. In contrast, an adverse economic climate may induce risk-averse policies within corporations. The escalation of investment costs, heightened uncertainty surrounding investments, and diminished market demand can result in a prevailing conservative management approach, characterized by heightened caution in decision-making and a curtailment of innovation investments (Cui et al., 2021 [83]; Xu 2020 [84]). Moreover, as a result of the influence exerted by policies and corporate entities, economic trends eventually converge with the SD of pertinent industries (Hudon and Huybrechts, 2017 [85]), thereby exerting an implicit influence on their developmental trajectory. Consequently, taking into account the development of the construction industry in China, we formulate the following hypothesis:

H7：Economic development positively regulates the interplay between government management modes and the sustainable development of the construction industry.

H8: Economic development plays a positive role in regulating the relationship between enterprise management mode and sustainable development of construction industry.

3. Empirical analysis

3.1 Data source and processing

Considering that China's construction industry is one of the nation's key pillar industries which possesses substantial research significance (Zhang et al., 2023)[86], this study meticulously selected a sample of 45 listed construction enterprises spanning 10 provinces in China, these companies embody a diverse range of scales and business domains within the industry, mirroring the development landscape of the construction sector across different regions, the selection ensures the data's comprehensiveness and representativeness. Additionally, panel data from the period of 2017 to 2021 were chosen for analysis, the data pertaining to corporate green transformation was extracted through a rigorous text analysis of corporate annual reports. Meanwhile, other pertinent data were sourced from esteemed databases such as the CSMAR & Wind Database, and the Chinese Research Data Services Platform. These databases hold prominent positions in the realms of finance, economics, and academic research, offering users an abundance of data resources along with convenient data query services. In the initial phase of gathering and processing data, we conducted rigorous data screening (Corrales et al., 2018) [87] to ensure the utmost accuracy and reliability of our analysis, the criteria stipulated that the targeted enterprises must possess comprehensive financial reports, unambiguous green transformation strategies, and uninterrupted operational data, to align with the research requirements, we systematically processed the data as follows: Firstly, excluded construction entities (specifically ST and *ST enterprises) exhibiting abnormal financial statuses or other irregularities; secondly, eliminated redundant data entries and omitted enterprises with substantial missing data or those listed after the year 2017; thirdly, for individual construction companies with missing values, employed linear interpolation to fill in the gaps; and lastly, we thoroughly cleaned the dataset to remove any outliers, prior to conducting the moderation effect analysis, we centered the three key variables—economic development, government policy orientation, and corporate management mode—to mitigate multicollinearity issues within the model. Subsequently, our sample data underwent both the F-test and the Hausman test, with the results rejecting the null hypotheses, this indicated that neither the mixed-effects model nor the random-effects model was appropriate for our analysis. Consequently, we opted for the fixed-effects model. Within this model, i denotes individual enterprises, t signifies time, while τ_it and year represent the fixed effects for individual enterprises and years, respectively.

3.2 Variables

In the course of this research, the selection of variables was grounded in an exhaustive analysis and theoretical examination of the factors that impact SD within the construction sector. As a benchmark for measurement, we adopted the total number of green patents acquired by the construction industry (Chen et al., 2023) [88], which encompasses counts of both independently and jointly obtained green inventions and utility model patents. To gain a comprehensive understanding, we took into account multiple facets such as government policy direction (Zi, 2024) [89], corporate management strategies (Ling and Xiao, 2022; Kuo et al., 2022) [90][91], and technological innovation capabilities of enterprises (Yu et al., 2017) [92]. The objective was to elucidate how these crucial elements interact to drive green transformation and foster SD in the construction industry. Furthermore, to precisely delineate the relationships between explanatory and explained variables, we incorporated a range of control variables (Huan, 2022) [93]. These included enterprise size, ownership concentration, agency costs, employee count, management shareholding ratio, and the proportion of fixed assets held by the enterprise. This holistic approach allowed us to gain deeper insights into the intricate dynamics at play within the construction sector.

Definition and explanation of variables

Variable name	variable symbol	variable description
Sustainable development of construction industry	SD	Green patent acquisition in construction industry
Government policy orientation	GPO	Logarithmic frequency of environmental protection words of local governments
Enterprise management mode	EMM	Assign values to the disclosed company management concepts, policies, organizational structure, circular economy and green development.
Enterprise's technological innovation ability	II	Ratio of R&D investment to operating income
Urban economic development	ED	Logarithm of urban GDP
Enterprise scale	SIZE	Natural logarithm of total assets
Ownership concentration	OC	The sum of squares of the shareholding ratios of the top five major shareholders.
Enterprise agency cost	AC	Capital occupation of major shareholders/agency cost of enterprises
Number of employees in enterprises	EMP	Natural logarithm of enterprise employees
Management shareholding ratio	ES	Proportion of shares held by senior management in the company
Proportion of fixed assets of enterprises	FIX	Ratio of fixed assets to total assets

3.3 Regression analysis

This research employs SPSS 16.0 as its analytical instrument, with any individual missing values being filled using the linear interpolation method. Upon conducting both the F-test and Hausman test on the sample data, the results led to the rejection of the null hypothesis for both tests, prompting the adoption of the fixed-effects model. Given the panel data structure and the inherent heterogeneity of the research sample, a fixed-effects multiple linear regression approach was deemed appropriate for the analysis. Furthermore, the model was developed and the data processing was executed by leveraging insights and model designs from existing research.

3.3.1. H1: Government policy orientation has a positive impact on the sustainable development of the construction industry and is more significant

Jing et al (2024) [94] exploring the interplay between fiscal and taxation support, enterprise innovation, and the high-quality advancement of private enterprises. formulated a series of hypotheses concerning the influence of governmental policies on corporate growth. By constructing a regression model, they demonstrated that both tax incentives and government subsidies notably contribute to the elevated development of private enterprises. Following their research methodology, we have devised the subsequent model:

$$lnSB_{it} = \alpha_0 + \alpha_1 lnGPO_{it} + \alpha_2 control_{it} + \pi_I + \vartheta_I + \tau_{it}$$

3.3.1.1 Descriptive statistical analysis

Table 1 Descriptive Statistics of Hypothesis 1

variable	N	mean	p50	sd	min	max
lnSB	225	1.879	1.792	1.539	0	6.054
lnGPO	225	3.112	3.091	0.403	1.386	3.714
FIX	225	0.0740	0.0740	0.0200	0.0250	0.122
OC	225	0.556	0.564	0.148	0.199	0.892
AC	225	0.0310	0.0200	0.0330	0	0.202

From the descriptive statistics presented in Table 1, it is evident that the average score for SD in the construction industry, serving as the explained variable, stands at 1.879, accompanied by a standard deviation of 1.539. This reveals that a substantial portion of listed construction enterprises are lacking in SD capabilities, with some even experiencing a decline in this area. Additionally, the wide range between the maximum value of 6.054 and the minimum value of 0 in SD capabilities among these enterprises underscores the significant disparities that exist within the sample. Turning to the explanatory variable, government policy orientation, it becomes clear that the influence of governmental policies on listed construction enterprises varies across different provinces. This is manifested in differences in tax policies, fiscal policies, monetary policies, and the corresponding support measures provided. Regarding the control variables, the notable disparity between the maximum and minimum values of the proportion of fixed assets to total assets highlights the varying degrees of emphasis placed on fixed assets by listed construction enterprises. Some enterprises prioritize fixed assets, while others focus more on intangible assets, leading to a lower proportion of fixed assets in the latter case. Furthermore, the descriptive analysis of ownership concentration reveals that a "dominant shareholder" phenomenon is present in some of the listed construction enterprises within the sample, which may result in situations where major shareholders infringe upon the interests of minority shareholders (Xiao，2021) [95]. Lastly, the control variable of corporate agency cost, represented by the proportion of funds occupied by major shareholders as the second type of agency cost, exhibits relatively stable data within the sample. There are no obvious outliers, and the mean and standard deviation are closely aligned, indicating that the differences in supervision costs, restraint costs, and residual costs related to corporate fixed assets and asset proportions among the various listed companies in the sample are not significant.

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3.3.1.2 Correlation analysis

Table 2 Correlation Analysis of H1

	lnSB	lnGPO	FIX	OC	AC
lnSB	1				
lnGPO	0.159***	1			
FIX	0.217***	-0.0740	1		
OC	0.1620**	0.1360**	-0.1430**	1	
AC	0.290***	0.109	-0.109	0.0330	1

Upon conducting a thorough analysis of variable correlations, several key findings emerge: Firstly, the correlation coefficient for government policy orientation stands at 0.059, exhibiting a notable positive correlation. This underscores that when provincial governments' policy orientations align favorably with the interests of listed construction enterprises, it fosters their SD. Conversely, unfavorable policy orientations can hinder the sustainable growth of these enterprises. Secondly, the correlation coefficient for the proportion of fixed assets held by enterprises is 0.217, also indicating a significant positive correlation. This highlights that a greater volume of assets held by an enterprise tends to be more beneficial for its SD. Furthermore, the correlation coefficient for ownership concentration is 0.1620, demonstrating a positive correlation. However, it is worth noting that excessively high levels of ownership concentration may lead to a decline, suggesting that such high concentrations can adversely affect the SD of enterprises. Lastly, the correlation coefficient for corporate agency cost is 0.290, which is statistically significant. This implies that corporate agency costs also play a role in influencing the SD of listed construction enterprises.

3.3.1.3 Multiple collinearity analysis

Table 3 Multicollinearity Test of Variables for Hypothesis 1

Variable	VIF	1/VIF
AC	1.003	0.977
FIX	1.018	0.98
lnGPO	1.017	0.983
OC	1.003	0.996
Mean	VIF	1.006

The results are shown in Table 2. The average VIF of the sample data in all models is within the interval of (1,10), indicating that there is no multicollinearity in the variables in this sample.

3.3.1.4 Regression analysis

Table 4 Regression Analysis Results of H1

	(1) lnSB
lnGPO	0.806^{***}
	(3.34)
FIX	23.53^{***}
	(4.87)
OC	0.224^{*}

	(0.34)
AC	4.129
	(1.38)
_cons	-2.633**
	(-2.84)
N	225
R^2	0.136
adj. R^2	0.120

t statistics in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

* Indicates significance at the 10% level, ** indicates significance at the 5% level, *** indicates significance at the 1% level.

The explanatory variable, government policy orientation, exhibits a notable correlation coefficient of 3.34 at the 1% significance level, signifying a robust positive association with the SD of listed construction enterprises. Specifically, a one-unit increment in government policy orientation corresponds to a 0.806-unit enhancement in these enterprises' SD. By directing corporate behavior, furnishing resource support, and refining the developmental milieu, the government can augment the SD capacities of enterprises. Additionally, government policy orientation catalyzes green transformation, technological innovation, and social responsibility, thereby facilitating the realization of enterprises' SD objectives. Among the control variables, the proportion of fixed assets demonstrates a pronounced correlation coefficient of 4.87 at the 1% significance level, indicating a strong positive relationship with the SD of listed construction enterprises. A one-unit increase in fixed asset proportion translates to a substantial 23.58-unit boost in their SD. As a crucial indicator of an enterprise's asset structure and operational status, the proportion of fixed assets exerts multifaceted influences on its SD. Consequently, enterprises must judiciously allocate the ratio of fixed assets to current assets, taking into account their unique circumstances and market environment, to ensure stable operations and sustainable growth. Moreover, ownership concentration reveals a significant correlation coefficient of 0.34 at the 10% significance level, highlighting a positive link with the SD of listed construction enterprises. A one-unit rise in ownership concentration corresponds to a 0.224-unit increase in their SD. In pursuit of SD, listed construction enterprises can benefit from maintaining a moderate level of ownership concentration. However, an excessively high concentration may lead to overly conservative management practices, potentially impeding the SD capabilities of these enterprises. Therefore, it is imperative for listed construction enterprises to strike a balance and align the degree of ownership concentration with their scale and other pertinent factors.

3.3.1.5 Robustness test

To ensure the objectivity and precision of the research findings pertaining to this model, a robustness check was undertaken by means of reducing the sample size. Specifically, owing to the pandemic incident that occurred at the end of 2020, the samples from 2021 were omitted, and the analysis was confined to the samples spanning from 2017 to 2020. The outcomes of this test revealed that the significance of the explanatory variable, namely government policy orientation, remained unaltered. While some control variables did exhibit a degree of variation in their significance levels, the positive or negative influence on enterprise innovation stayed consistent, and no other notable changes were observed in the results. This

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serves as evidence that the research outcomes of the model are characterized by a high degree of objectivity, thereby attesting to the robustness of the model.

Table 5 Robustness Test Results of Hypothesis 1

	(1) lnSB
lnGPO	0.862***
	(3.47)
FIX	19.38***
	(3.44)
OC	0.235
	(0.33)
AC	3.456
	(1.07)
_cons	-2.590**
	(-2.64)
N	180
R^2	0.119
adj. R^2	0.099

statistics in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

3.3.2 H2：Enterprise management model has a positive impact on the sustainable development of construction industry and is more significant.

Refer to the research methodology introduced by Ma et al (2023) [96] of the impact of ESG on corporate development which used data from listed companies and employed linear regression models, as well as regarding the research conducted by Shen et al., (2022) [97] on the relationship between corporate sustainability performance and managerial confidence，we conduct the following analysis：

$$lnSB_{it} = \beta_0 + \beta_1 EMM_{it} + \beta_2 control_{it} + \pi_I + \vartheta_I + \tau_{it}$$

3.3.2.1 Descriptive statistical analysis

Table 6 Descriptive Statistics of Hypothesis 2

variab	N	mean	p50	sd	min	max
lnSB	225	1.879	1.792	1.539	0	6.054
EMM	225	0.600	1	0.491	0	1
SIZE	225	23.32	23.02	1.541	20.58	26.43
OC	225	0.556	0.564	0.148	0.199	0.892
AC	225	0.0310	0.0200	0.0330	0	0.202

As depicted in Table 6's descriptive statistics, the mean value for the dependent variable, the construction industry, stands at 1.879, accompanied by a standard deviation of 1.539.

Regarding the explanatory variable, enterprise management mode, it is evaluated in this sample through an assignment system grounded in companies' environmental management practices. With a mean of 0.6 and a standard deviation of 0.491, this indicates that a vast majority of listed construction firms in this sample have deliberately taken into account their unique circumstances and developmental requirements when crafting their management models. These models are aimed at fostering long-term, stable, and sustainable growth momentum for their enterprises. Shifting focus to the control variables, the standard deviation for enterprise size, at 1.542, reflects a relatively consistent distribution, highlighting the stability in the sizes of enterprises included in this sample. The analysis of equity concentration reveals marked disparities between the extreme values, suggesting that in some listed construction enterprises within this sample, there exist notable differences in interests between majority and minority shareholders. Lastly, when examining enterprise agency costs, the data portrays a stable landscape, with no conspicuous outliers and closely aligned mean and standard deviation values. This underscores the minimal variations in agency costs across the listed companies encompassed in this sample.

3.2.2.2 Correlation analysis

Table 7 Correlation Analysis of H2

	lnSB	EMM	SIZE	OC	AC
lnSB	1				
EMM	0.251***	1			
SIZE	0.732***	0.136**	1		
OC	0.0190	-0.191***	-0.00400	1	
AC	0.0780	0.0200	0.176***	0.0330	1

The correlation coefficient for enterprise management mode stands at 0.251, highlighting a notable positive correlation. This underscores that a management mode tailored to the specific development needs of a listed construction company favors its sustainable growth. Conversely, a misaligned management mode can hinder such SD, ultimately affecting the company's long-term prospects. Regarding enterprise size, the correlation coefficient of 0.732 indicates a strong positive relationship. Initially, when a company is nascent and relatively small, its focus tends to be on expansion rather than SD goals, which are often prioritized by larger enterprises. However, as the company grows, it becomes increasingly inclined to assess whether each business endeavor contributes to profitability and sustainability. Nevertheless, attaining a critical size also necessitates deeper contemplation of the company's own sustainability to avoid potential drawbacks.

As for the control variables, both equity concentration and enterprise agency costs exhibit negligible impacts on the SD of listed construction companies in this model, with correlation coefficients of 0.019 and 0.078, respectively.

3.2.2.3 Multiple collinearity test

Table 8 Hypothesis 2 multicollinearity

Variable	VIF	1/VIF
EMM	1.060	0.945
SIZE	1.050	0.951
OC	1.040	0.962
AC	1.030	0.968
Mean	VIF	1.050

Upon conducting the multicollinearity test for the variables in this model, as outlined in Table 8, it becomes evident that the mean Variance Inflation Factor (VIF) values are confined within the acceptable range of 1 to 10. Similarly, the VIF of each individual variable also remains within this bracket, conclusively demonstrating the absence of multicollinearity among the predictors. This affirms the suitability of proceeding with the regression analysis.

3.2.2.4 Regression analysis

Table 9 Regression Analysis Results of H2

	(1) lnSB
EMM	0.517^{***}
	(3.61)
SIZE	0.719^{***}
	(15.78)
OC	0.577
	(1.22)
AC	-2.549
	(-1.20)
_cons	-15.43^{***}
	(-14.32)
N	225
R^2	0.565
adj. R^2	0.557

t statistics in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Drawing upon the regression analysis results outlined in Table 9, we arrive at the following conclusions: The explanatory variable, namely corporate management mode, exhibits a robust correlation coefficient of 3.61 at the 1% significance level, underscoring a pronounced positive association with the SD of listed construction enterprises. This implies that a one-unit enhancement in corporate management mode corresponds to a 0.517-unit increase in the SD of these enterprises. The influence of corporate management mode on SD is substantial, as it directly governs how enterprises strategize and leverage resources for sustainable endeavors. An efficient management mode ensures that enterprises formulate strategies tailored to their unique circumstances and market demands, while also facilitating effective monitoring and adjustments during implementation. This enables enterprises to capitalize on market opportunities, navigate challenges, and ultimately attain SD objectives. A superior management mode bolsters an enterprise's competitiveness and market standing, thereby generating greater economic returns. Consequently, for an enterprise to thrive in sustainability, it must continuously learn from and adopt advanced management philosophies and practices, refining and optimizing its management mode to adapt to the dynamic market environment and competitive landscape. Regarding the control variables, corporate size demonstrates a strong correlation coefficient of 15.78 at the 1% significance level, highlighting a significant positive relationship with the SD of listed construction enterprises. A one-unit increase in corporate size translates to a 0.719-unit boost in SD. Larger enterprises, owing to their robust financial strength and extensive resource networks, can more easily access crucial resources such as capital, technology, and talent, thereby providing substantial support for their SD. A larger scale also grants enterprises a competitive edge in the market, enabling them to withstand external pressures and foster long-term stability. Moreover, these enterprises often invest more in research and development, possessing greater R&D capabilities to introduce innovative products and technologies that meet market demands and sustain competitive advantages. However, it is important to note that an excessively large corporate size does not necessarily equate to enhanced SD capability, as it may lead to increased management complexity and elevated internal communication costs.

3.2.2.5 Robustness test

To ensure the precision and reliability of the research outcomes derived from this model, a rigorous robustness test was performed by strategically reducing the sample size. Specifically, the samples from the year 2021 were omitted, and the analysis concentrated on the dataset spanning from 2017 to 2020. The results of this test revealed that the significance of the explanatory variable, namely corporate management mode, remained consistent and unaltered. Likewise, there were no discernible shifts in the significance levels of the control variables. Upon reviewing the robustness test result table, it was observed that while the correlation coefficients experienced some variations, the other findings remained notably stable and did not undergo any substantial changes. Consequently, this attests to the high degree of objectivity inherent in the research results and confirms the robustness of the model employed.

Table 10 Robustness Test of H2

	(1)
	lnSB
EMM	0.534^{***}
	(3.48)
SIZE	0.713^{***}
	(14.39)
OC	0.395
	(0.78)
AC	-2.913
	(-1.30)
_cons	-15.28^{***}
	(-13.20)
N	180
R^2	0.577
adj. R^2	0.567

t statistics in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

3.3.3 H3：Government policy orientation has a significant positive impact on enterprise technological innovation

Hu et al (2023) [98] conducted a study on the impact of government subsidies on manufacturing innovation and showed that government financial support plays a crucial role in promoting technological innovation efficiency. The researchers employed a panel threshold regression model to assess how subsidies influence innovation, according to its research method, we propose the following model:

$$lnII_{it} = \gamma_0 + \gamma_1 lnGPO_{it} + \gamma_2 control_{it} + \pi_I + \vartheta_I + \tau_{it}$$

Table 11 Regression Analysis Results of H3

	(1)
	lnII
lnGPO	0.276*
	(2.16)
FIX	3.716
	(1.45)
SIZE	0.0916**
	(2.69)
AC	-8.606***
	(-5.40)
_cons	3.878***
	(4.62)
N	225
R^2	0.176
adj. R^2	0.161

t statistics in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Based on the regression analysis results outlined in Table 11, it is evident that the explanatory variable, government policy orientation, exhibits a significant positive correlation with enterprise technological innovation, with a correlation coefficient of 2.16 at the 10% level. This suggests that a one-unit increase in government policy orientation corresponds to a 0.276-unit increase in enterprise technological innovation. By offering financial assistance, policy support tailored to enterprises, guiding them towards policy-incentivized development paths, fostering an innovative environment, and nurturing and attracting scientific and technological talents, the government can substantially bolster enterprises' technological innovation activities, thereby enhancing their innovation capabilities and competitiveness. The implementation of these government-guided policies is instrumental in promoting the sustainable growth of enterprises. Regarding the control variables, the proportion of fixed assets held by enterprises shows no correlation with their technological innovation in this model. Conversely, enterprise size demonstrates a significant positive correlation with technological innovation, with a correlation coefficient of 2.69 at the 5% level. This indicates that a one-unit increase in enterprise size leads to a 0.0916-unit increase in technological innovation. According to the product life cycle theory, smaller enterprises tend to invest less in product innovation than mature, larger ones, and they may also do so at a later stage. As enterprises grow larger, their investment in innovation tends to increase. However, once they reach a certain size, this may impact their innovation efforts. This suggests that manufacturing enterprises, from their inception, have prioritized innovation. By appropriately expanding their size, they can provide a solid foundation for their innovation endeavors. Lastly, the control variable, enterprise agency cost, exhibits a significant negative correlation with technological innovation, with a correlation coefficient of -5.40 at the 1% level. This means that a one-unit increase in agency cost corresponds to a 0.276-unit decrease in technological innovation. Enterprise agency costs encompass monitoring costs, constraint costs, and residual losses. High monitoring costs may hinder shareholders' ability to effectively oversee managers' actions, potentially leading managers to invest resources in non-innovative, low-risk projects to safeguard their personal

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positions and interests, rather than pursuing long-term technological innovation and development. As for constraint costs, given that all samples in this study are listed construction enterprises, they are likely to impose constraints on managers' behavior through strict internal control systems and equity incentive plans. However, the implementation of these measures also incurs costs and may impact enterprise technological innovation. Residual losses may manifest as failures or delays in technological innovation projects, ultimately affecting enterprise innovation. In conclusion, this model aligns with Hypothesis 3, and Hypothesis 3 is thereby verified.

3.3.4 H4：Enterprise management mode has a significant positive impact on technological innovation.

Wang et al (2021) [99] investigates how internal control mechanisms affect corporate technological innovation, it using a panel data regression model with control variables and emphasizes that effective internal control systems can enhance innovation by reducing financial constraints and improving R&D investment, with reference to its research methods, we make the following analysis.

$$lnII_{it} = \delta_0 + \delta_1 EMM_{it} + \delta_2 control_{it} + \pi_I + \vartheta_I + \tau_{it}$$

Table 12 Regression Analysis Results of H4

	(1)
	lnII
EMM	0.495***
	(4.86)
SIZE	0.0973**
	(3.01)
OC	0.767*
	(2.28)
AC	-8.699***
	(-5.75)
_cons	4.427***
	(5.78)
N	225
R^2	0.241
adj. R^2	0.227

t statistics in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Based on the regression analysis results presented in Table 12, it is evident that the explanatory variable, corporate management mode, exhibits a significant positive correlation with enterprise technological innovation, with a correlation coefficient of 4.86 at the 1% level. This suggests that a one-unit increase in corporate management mode corresponds to a 0.495-unit increase in enterprise technological innovation. Given that enterprises frequently need to invest considerable resources in innovation projects, a corporate management mode that can adeptly adjust resource allocation to ensure essential support for these projects can effectively propel technological innovation activities. The corporate management mode dictates the quality of corporate decision-making, and innovation activities, being inherently risky, demand scientific decision-making methods and precise decision-making foundations. Moreover, innovation activities necessitate the presence of high-quality research and development teams and talent pools within enterprises. By emphasizing talent development and recruitment, as well as implementing appropriate innovation mechanisms for employee innovation activities, the corporate management mode can continuously enhance the enterprise's technological innovation capabilities. Regarding the control variables, firm size demonstrates a significant positive correlation with enterprise technological innovation, with a correlation coefficient of 3.01 at the 10% level. This indicates that a one-unit increase in firm size leads to a corresponding 0.0973-unit increase in enterprise technological innovation. Similarly, ownership concentration shows a significant positive correlation, with a correlation coefficient of 2.28 at the 50% level, implying that a one-unit increase in ownership concentration results in a 0.495-unit increase in enterprise technological innovation. For listed construction companies, maintaining an appropriate level of ownership concentration can provide valuable support for implementing and initiating new innovation activities. However, excessively high ownership concentration may lead to conservative management practices, diminishing the motivation for substantial innovation and potentially compromising innovation quality. Therefore, listed construction companies should strike a balance between ownership concentration and enterprise innovation. Lastly, corporate agency costs exhibit a significant negative correlation with enterprise technological innovation, with a correlation coefficient of -5.75 at the 1% level, indicating that a one-unit increase in corporate agency costs corresponds to a 0.495-unit decrease in enterprise technological innovation, thereby confirming Hypothesis 4.

3.3.5 H5: Enterprise technological innovation has a positive impact on the sustainable development of construction industry.

On the basis of previous study analyzed listed companies which found that green innovation significantly enhances corporate SD in China (Liao et al, 2022) [100], drawing on its regression model, we have carried out the following analysis.

$$InSB_{it} = \varepsilon_0 + \varepsilon_1 lnII_{it} + \varepsilon_2 control_{it} + \pi_I + \vartheta_I + \tau_{it}$$

Table 13 Regression Analysis Results of H5

	(1) lnSB
lnII	0.188*
	(2.17)
SIZE	0.739***
	(14.20)
OC	0.187
	(0.39)
ES	-0.00220
	(-0.52)
_cons	-15.92***
	(-12.25)
N	225
R^2	0.547
adj. R^2	0.538

t statistics in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

From the data presented in the table, it is evident that enterprise technological innovation exhibits a significant positive correlation with the SD of the construction industry, with a correlation coefficient of 2.17 at the 10% level. This indicates that a one-unit increase in enterprise technological innovation corresponds to a 0.188-unit increase in the SD of the construction industry. Indeed, enterprise technological innovation is pivotal for maintaining competitive advantages and achieving sustainable growth. It not only bolsters enterprises' competitiveness in the market but also establishes a solid foundation for their long-term development. Moreover, by enhancing their sensitivity to market changes, technological innovation empowers enterprises to better navigate and mitigate various uncertain risks, thereby ensuring their continuous operation and progress. Furthermore, the table reveals that enterprise scale has a notable positive correlation with enterprise technological innovation, with a correlation coefficient of 14.20 at the 1% level. This signifies that a one-unit increase in enterprise scale leads to a corresponding 0.739-unit increase in enterprise technological innovation. Consequently, Hypothesis 5 has been validated.

3.3.6 H6: Economic development plays a positive role in regulating the relationship between technological innovation of enterprises and sustainable development of construction industry

The study issued by Jiang et al (2023) [101] focused on how fiscal policies and economic development interact with green innovation to promote SD. Drawing upon the research content presented in the article and integrating insights from the model developed by Cao et al (2019) [102], which examines the interplay between economic growth, environmental regulations, and corporate innovation, we proceed to conduct the following analysis.

$$BS_{it} = \theta_0 + \theta_1 II_{it} + \theta_2 IIED_{it} + \theta_3 control_{it} + \pi_I + \vartheta_I + \tau_{it}$$

Table 14 Regression Analysis Results of H6

	(1) SB	(2) SB
II	1.011*	0.818*
	(2.49)	(1.79)
ED	48.52**	45.10*
	(2.74)	(2.49)
IIED		2.102*
		(0.93)
ES	-0.903***	-0.894***
	(-4.17)	(-4.13)
OC	40.89	43.95
	(1.40)	(1.50)
_cons	-362.7*	-339.6*
	(-2.52)	(-2.33)
N	225	225
R^2	0.136	0.140
adj. R^2	0.119	0.119

t statistics in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

In this model, the variable IIED embodies the interaction between enterprise technological innovation (II) and economic development (ED). Before delving into the regression analysis of the second model, it is imperative to address the issue of potential multicollinearity arising from the direct product of these variables forming the IIED interaction term. To mitigate this and ensure accurate interpretation of the interaction effect, both the enterprise II and ED variables were centered, thereby reducing their covariance and minimizing multicollinearity within the model.

The analysis outcomes of models (1) and (2) reveal that the IIED interaction term holds a significant positive correlation with the SD of the construction industry at the 10% level, with a notable correlation coefficient of 2.49. Furthermore, technological innovation, as the core explanatory variable, demonstrates a significant positive association with the SD of the construction industry. This underscores the positive moderating role of economic development in the relationship between enterprise technological innovation and the SD of the construction sector, thereby validating Hypothesis 6.

3.3.7 H7: Economic development plays a positive role in regulating the relationship between government policy orientation and sustainable development of construction industry

Drawing inspiration from the investigation of Luo et al (2024) [103] into the efficacy of government financial support in enhancing corporate sustainability, particularly its role in nurturing green innovation, as well as Ozili (2024)'s [104] exploration of the function of economic policies in bolstering government-driven sustainability ventures and promoting corporate innovation and sustainability, we embark on our analysis using the following approach.

$$SB_{it} = \sigma_0 + \gamma_1 ED_{it} + \gamma_2 FIX_{it} + \gamma_3 EDlnGPO + \gamma_4 control_{it} + \pi_I + \vartheta_I + \tau_{it}$$

Table 15 Regression Analysis Results of H7

	(1)	(2)
	SB	SB
ED	48.47**	53.11**
	(2.93)	(3.20)
lnGPO	23.34*	27.81**
	(2.38)	(2.78)
EDlnGPO		92.90*
		(2.01)
AC	-10.91***	-11.32***
	(-3.44)	(-3.59)
OC	26.84	28.79
	(0.99)	(1.06)
_cons	-643.1***	-708.9***
	(-3.67)	(-4.00)
N	225	225
R^2	0.110	0.126
adj. R^2	0.090	0.102

t statistics in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Within this particular model, the variable EDlnGPO signifies the interaction between economic development (ED) and the logarithm of government policy orientation (lnGPO). To address potential multicollinearity issues in the model, both ED and lnGPO variables were centered before proceeding with the regression analysis for the second model. The outcomes of the regression analysis for models (1) and (2) indicate that the EDlnGPO interaction term exhibits a significant positive correlation with SD in the construction industry at the 10% level, with a notable correlation coefficient of 2.01. Furthermore, government policy orientation, serving as the core explanatory variable, demonstrates a significant positive association with SD in the construction sector at the 5% level, with a correlation coefficient of 2.78. Notably, economic development plays a positive moderating role in the relationship between government policy orientation and SD in the construction industry. Consequently, Hypothesis 7 has been validated.

3.3.8 H8: Economic development plays a positive role in regulating the relationship between enterprise management mode and sustainable development of construction industry

Follow the research work of Cai et al (2024) [105] which explored the interaction between environmental, social, governance practices and corporate development, showing that economic development significantly influences how corporate governance structures affect sustainability outcomes, the following model and analysis are made:

$$BS_{it} = \varphi_0 + \varphi_1 ED_{it} + \varphi_2 EMM_{it} + \varphi_3 EDEMM_{it} + \varphi_4 control_{it} + \pi_I + \vartheta_I + \tau_{it}$$

Table 16 Regression Analysis Results of Hypothesis 8

	(1) BS	(2) BS
ED	66.62***	59.79*
	(4.16)	(2.26)
EMM	27.85***	27.98***
	(3.50)	(3.51)
EDEMM		10.52*
		(0.32)
OC	33.99	34.71
	(1.31)	(1.33)
AC	688.0***	680.1***
	(5.83)	(5.63)
_cons	-576.7***	-521.3*
	(-4.40)	(-2.42)
N	225	225
R^2	0.203	0.203
adj. R^2	0.188	0.185

t statistics in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

In this model, the variable EDEMM denotes the interactive term between economic development (ED) and enterprise management mode (EMM). Prior to analyzing the second regression model, the ED variable was centered to mitigate potential multicollinearity issues among the variables. Analysis of models (1) and (2) revealed that the EDEMM term is significantly and positively correlated with SD in the construction industry at the 10% level. Furthermore, the EMM is found to be significantly and positively correlated with SD in the industry at the 1% level, with a correlation coefficient of 3.51. These findings indicate that economic development exerts a positive moderating effect on the relationship between enterprise management mode and SD in the construction industry, thereby validating Hypothesis 8.

4. Discussion

Research findings underscore that amidst the present saturation and subsequent decline in China's construction market, government policy orientation exerts a profound influence on the SD of the construction industry. This revelation bolsters the hypothesis that the government, through the formulation and implementation of environmental policies, the provision of incentive measures and other strategic initiatives can effectively propel the construction industry towards a sustainable trajectory. Policy orientation not only shapes corporate behavior but also catalyzes the green transformation of the entire sector by refining the market environment and optimizing resource allocation (Ma et al., 2023) [106]. Consequently, in the context of development planning for the construction industry, it is imperative to account for the multifaceted impact of policies, encompassing taxation, subsidies, regulatory frameworks, and the establishment of a comprehensive certification system, as these elements exert subtle yet significant guiding forces. It is noteworthy that the efficacy of policies may exhibit considerable variation across different regions and types of enterprises. Furthermore, given the industry's susceptibility to market volatility, outdated policies can pose obstacles to industry progress, therefore, it is crucial for policies to be meticulously tailored to the distinct circumstances of various regions and scales within the industry, and for a dynamic mechanism of supervision with feedback to be instituted, ensuring more balanced regulatory outcomes (Aryeetey and Nkechi, 2017) [107]. Furthermore, based on the given circumstances, government ought to implement more aggressive fiscal incentives and regulatory mandates in order to cultivate a fairer competitive landscape which would help mitigate the present scenario wherein the adoption of sustainable building practices entails substantial premium costs. This requires continuous effective communication and collaboration mechanism between enterprises and the government, enabling policies to respond swiftly to market demands and eventually achieve SD. Meanwhile, effective corporate management models exert a profound positive influence on the SD of the construction industry, the management philosophy directly impacts the developmental efficacy of listed construction enterprises; by embracing scientific management principles and methodologies, these enterprises can elevate operational efficiency, bolster market competitiveness (Ojra et al., 2021) [108], and attain SD objectives. Among these models, the green building management approach underscores the achievement of environmental goals throughout the project's lifecycle; the lean construction management model emphasizes process optimization, efficiency enhancement and construction period reduction; the integrated project management model seamlessly integrates various project stages to facilitate information sharing and coordinated efforts; the intelligent management model leverages big data, cloud computing and IoT technologies for real-time monitoring, data analysis, and predictive alerting; and the efficient supply chain management model aims to optimize resource allocation and ensure the timely availability of materials, equipment and labor. Under the overarching management framework, there are also specialized models such as the project management model that prioritizes the project lifecycle, the quality management system that extends product longevity through a robust quality control framework, and the human resource management model that emphasizes employee training, evaluation, and motivation to enhance employee performance. These diverse management models not only pertain to the long-term growth of individual enterprises but also actively contribute to the SD of the entire industry, specifically, they optimize the allocation of human and material resources to minimize waste and enhance work efficiency (Zhu et al., 2018) [109], encourage the revitalization of outdated policies and technologies to boost productivity, adeptly respond to shifts in market and customer demands by adjusting production strategies and service levels, and foster a positive corporate culture that ignites employee loyalty and creativity. Furthermore, research has revealed that technological innovation transcends the actions of individual enterprises; it is the culmination of collaborative efforts within the entire industry ecosystem. This underscores the notion that effective innovation cannot thrive in isolation. Both institutional and technological advancements are bolstered by governmental encouragement through pertinent policies and the enactment of laws that reinforce industry standards and environmental prerequisites, thereby augmenting corporate creativity across multiple dimensions. A comparative analysis of the 2019 and 2014 editions of the "Green Building Evaluation Standards" elucidates China's heightened emphasis on the relationship between humans and nature in defining green buildings for the contemporary era. Additionally, the innovative establishment of a green building materials rating system offers insight into the progressive increase in sustainable indicators within the industry. Analogously, in the realm of management practices, fostering a corporate culture that encourages exploration and embraces failure provides a fertile ground for innovation (Li et al., 2021) [110]. Complemented by rational systems and adequate resource allocation, these practices accelerate the realization of innovative outcomes. Moreover, innovations encompassing advancements in construction technology, the development of environmentally friendly materials, and policy refinements have collectively bolstered the industry's capacity for SD, subsequently enhancing its competitiveness in the market. Ultimately, it must be emphasized that economic development transcends mere GDP growth; it is fundamentally rooted in the optimization and upgrading of the economic structure. This shift fosters an environment conducive to enhancing market demand, guiding governmental adjustments in policies and fiscal measures, and shaping corporate strategies, innovation investments, and levels of market collaboration. Empirical data reveals that regions with robust economic performance tend to experience a concurrent push towards SD across industries. Yet, it is crucial to recognize that SD within the construction sector is a multifaceted concept that cannot be reduced to a single influencing factor. Given the diverse environments across different countries and regions, the factors promoting or hindering SD vary considerably, therefore, addressing specific cases necessitates the application of tailored models for comprehensive analysis.

5. Conclusion

The diverse factors that contribute to SD vary significantly across different industries, this research delves into the key factors influencing the SD of China's construction industry over recent years, emphasizing the pivotal roles of government guidance and corporate management in their respective pathways. Furthermore, it acknowledges the intermediary function of technological innovation and the moderating influence of economic growth; by highlighting the necessity for businesses to actively engage with the government to maintain consistency in their SD strategies, this document serves as a valuable research reference for policymakers. Given China's construction industry's recent downturn following its peak, the document also presents insights for enterprises to embrace green development pathways, nonetheless, the model's construct is not without limitations, primarily due to the exclusion of small and micro-enterprises from the sample selection. Consequently, to enhance the model's comprehensiveness, future research endeavors should broaden the sample base and variables, explore cross-national comparisons, and foster interdisciplinary collaborations. Such endeavors will collectively propel deeper understanding and practical applications aimed at fostering the SD of the construction industry.

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