



## New Quality Productive Forces and Green Innovation Performance: Evidence from China

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**SUMMARY:** *This article aims to explore the impact and mechanism of creative quality based productive dynamic on corporate sustainability-driven innovation performance. Firstly, taking companies listed on the A-share market as the subject of study, the fixed effects model, mediator model, and interaction effect model are used to empirically investigate the effect of creative quality based productive dynamic on corporate sustainability-driven innovation performance; Then, by introducing digital metamorphosis and government financial subsidies as mediating and moderating variables, the inner workings of the effect of creative quality based productive dynamic on corporate sustainability-driven innovation performance was deeply explored. This article also conducted heterogeneity analysis of regional and corporate nature to comprehensively reveal the effects of creative quality based productive dynamic in different contexts. Research has found that creative quality based productive dynamic substantially enhances the eco-centric solutions performance of enterprises, and digital metamorphosis plays a intervening role in the process of improving the eco-centric solutions performance of enterprises through creative quality based productive dynamic. Government financial subsidies positively regulate the process of improving the eco-centric solutions performance of enterprises through creative quality based productive dynamic. The heterogeneity analysis results show that the contribution of creative quality based productive dynamic to the eco-centric solutions performance of enterprises is more significant in different regions, as well as in state-owned enterprises, which helps to promote the development with cross-sectoral alignment of eco-centric solutions between regions and enterprises.*

**KEYWORDS:** *Creative quality based productive dynamic; Eco-centric solutions performance; Digital metamorphosis; Government financial subsidies*

### 1 Introduction

Ecologically sustainable development is a prerequisite for high-quality economic and social growth. However, China currently faces severe ecological challenges—including high energy utilization and anthropogenic emissions—that damage ecological systems and constrain eco-centric solutions performance, hindering progress toward low-carbon sustainability [1, 2]. The eco-centric solutions process is distinguished by high risk, long cycles, and dual externalities related to knowledge spill over and environmental benefits. These attributes contribute to insufficient motivation for corporate sustainability-driven innovation, resulting in generally unsatisfactory levels of eco-centric solutions performance.

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In September 2023, we proposed the framework of “Creative quality based productive dynamic” on the first occasion. The formation and enhancement of Creative quality based productive dynamic are central to advancing emerging industries of strategic importance and future-oriented sectors through the integration of innovation ecosystem resources [3]. Closely aligned with national policies aimed at economic transformation and sustainable and high-efficiency development, Creative quality based productive dynamic has emerged as a pivotal driver in sustaining healthy economic growth and strengthening comprehensive national power. Against the backdrop of a shifting global industrial landscape and rapid technological progress, conventional productivity models have become inadequate to meet the new demands of socioeconomic development.

This study examines the relationship between creative quality based productive dynamic and eco-centric solutions performance at the micro enterprise level. The research shows that creative quality based productive dynamic markedly enhances the advancement of eco-centric solutions in enterprises, and this relationship effect is mediated by digital metamorphosis. In addition, the study also found that government financial subsidies have a positive regulatory effect on maintaining this intermediary relationship. Heterogeneity analysis reveals that for different regions and industries, creative quality based productive dynamic has diverse effects on the eco-centric solutions performance of enterprises. On this basis, this study proposes policy prescriptions aimed at helping enterprises improve their eco-centric solutions performance in the digital age [4].

In the study of the relationship between creative quality based productive dynamic and eco-centric solutions performance, this research mainly focuses on two aspects: (1) Examining the relationship between creative quality based productive dynamic and eco-centric solutions development performance at the micro enterprise level, providing theoretical support for strengthening the advancement of eco-centric solutions in enterprises; (2) This study integrates digital metamorphosis development, creative quality based productive dynamic, government financial subsidies, and eco-centric solutions performance into a holistic analytical framework, and systematically elucidates the interactions and mechanisms among these factors.

## 2 Literature Review

### 2.1 Factors Influencing Eco-Centric solutions Performance

The literature review indicates that the main factors affecting the advancement of eco-centric solutions in enterprises can be divided into external environmental factors and internal driving factors. Among them, external factors include various key drivers such as institutional theory, market environment, government behavior, and regulations. Related studies have shown that government fiscal and tax incentives can markedly enhance the advancement of eco-centric solutions in enterprises [5]. In addition, studies show that environmental policies and government support also have a positive promoting effect on the eco-centric solutions development of enterprises, and the agglomeration effect of high-tech industries can substantially enhance the degree of eco-centric solutions development of enterprises. Internal driving factors include various key drivers such as organizational resources, executive quality, corporate social responsibility, and strategy [6]. Research has found that sustainable supply chain integration, including both internal eco-integration within the supply chain and external eco-integration with suppliers and customers, can effectively improve the eco-centric solutions development performance of enterprises. The supply chain plays a intervening role in the eco-centric solutions development of enterprises. In addition, absorptive capacity plays an important role in promoting the advancement of eco-centric solutions in enterprises, which can

effectively promote knowledge innovation in enterprises. In addition, corporate sustainability programs can have a beneficial effect on the eco-centric solutions development of enterprises by influencing the strategic decisions of senior management.

## **2.2 Research on the economic consequences of Creative quality based productive dynamic**

Traditionally, research on creative quality based productive dynamic can be analyzed from two perspectives: intrinsic characteristics and intrinsic logic. For example, some studies describe creative quality based productive dynamic as a new form of productivity that deeply integrates technological advancement with emerging industries of strategic importance in the context of social informatization and intelligence. Its characteristics are high efficiency and high quality, which can more efficiently utilize and transform natural resources to obtain more corporate profits [7]. The traditional concept of creative quality based productive dynamic is usually manifested in disruptive innovation, industrial chain restructuring, and improvement of development quality. However, in the current wave of industrial transformation, the new form of creative quality based productive dynamic is digital and eco-centric solutions development, with basic attributes such as reform, consolidation, management, and surpassing.

The existing research on creative quality based productive dynamic mainly relies on macro level exploration, focusing on the relationship between creative quality based productive dynamic and key drivers such as tax policies, digital economy, green development, and digital finance inclusive. For example, some studies suggest that tax fairness plays an important role in promoting creative quality based productive dynamic, while pointing out that taxation can serve as both a favorable and unfavorable factor for creative quality based productive dynamic [8]. Some studies suggest that the digital economy can promote technological advancement in enterprises through digital metamorphosis, mainly manifested in the use of optimized data resource allocation to improve enterprise productivity. In addition, the integration of the digital economy and the real economy can effectively improve the industrial structure, and through the synergistic effect of the value chain, it can stimulate conventional productivity to achieve new improvements. The improvement of digital infrastructure can also provide basic support for the advancement of creative quality based productive dynamic, thereby providing new impetus for enterprise innovation and development. For example, some studies suggest that creative quality based productive dynamic can effectively promote the advancement of eco-centric solutions in enterprises based on spatial externalities on adjacent regions. In addition, digital finance inclusive can effectively promote the advancement of creative quality based productive dynamic, but this promotion relationship will be constrained by the law of diminishing marginal returns.

## **2.3 Literature Review**

In traditional research, the relationship between creative quality based productive dynamic and eco-centric solutions development of enterprises has been mainly explored from a macro perspective. Studies show that creative quality based productive dynamic has a significant promoting effect on the eco-centric solutions development of enterprises in the region [9]. At present, there are relatively few research results exploring the relationship and mechanism between creative quality based productive dynamic and eco-centric solutions development of enterprises at the micro level. This study selects listed companies from 2011 to 2023 as subject of study, and analyzes and explores the causal mechanism of creative quality based productive dynamic on the performance of eco-centric solutions development of enterprises from a micro level.

Figure 1 shows the theoretical framework of this study.

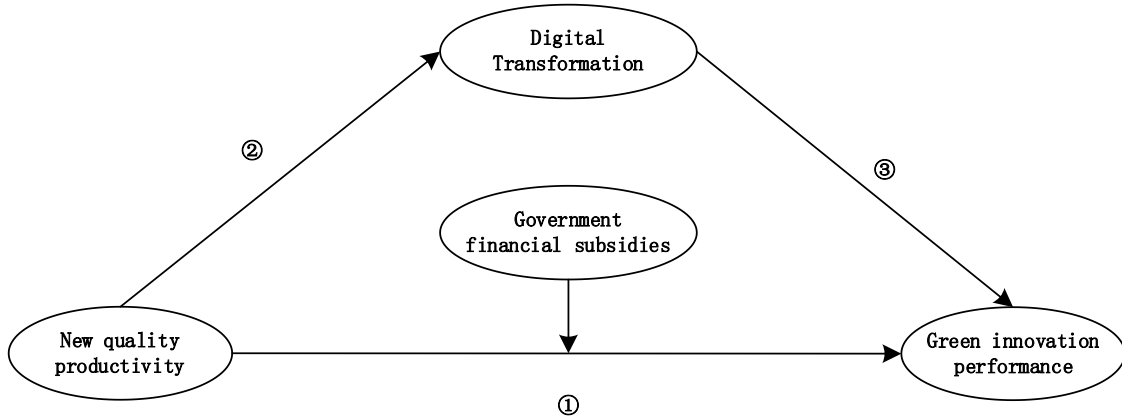


Figure 1: Theoretical framework diagram

### 3 Theoretical Basis and Research Hypotheses

#### 3.1 Creative quality based productive dynamic and Eco-centric solutions Performance

The main characteristics of creative quality based productive dynamic are guided by green development and driven by technological advancement. It is a new form of productivity that can promote the transformation of traditional production methods towards greener and more environmentally friendly directions, including three elements: new high-quality labor, advanced production tools, and new labor objects [10]. Among them, the improvement of labor quality as a reserve of talent skills can provide sustained impetus for the eco-centric solutions development of enterprises; Advanced production tools, as technological reserves, can provide technical support for the eco-centric solutions and development of enterprises; The new labor force as a material resource reserve can provide material support for the eco-centric solutions and development of enterprises. The emergence of creative quality based productive dynamic can effectively promote technological advancement in production equipment, solve the constraints of high energy utilization and pollution that hinder the advancement of eco-centric solutions in enterprises, and thus promote the green transformation of traditional manufacturing enterprises [11]. In addition, creative quality based productive dynamic can also promote the transformation and upgrading of green industries in enterprises, enabling them to break through traditional industry barriers and achieve new eco-centric solutions development performance. Ultimately, by applying commercial green environmental protection technologies, enterprises can continuously enhance their overall competitiveness and achieve sustainable and high-efficiency development. On this basis, the following hypotheses can be proposed:

H1: Creative quality based productive dynamic can effectively enhance the eco-centric solutions development performance of enterprises.

#### 3.2 The intervening role of digital metamorphosis

As a new engine driving economic and social development, creative quality based productive dynamic can effectively enhance the technological and market competitiveness of enterprise products and services. By implementing creative quality based productive dynamic, enterprises can effectively acquire and integrate external knowledge and technology, thereby rapidly

promoting their digital metamorphosis and obtaining more efficient and intelligent operating models.

With the advancement of digital technology, people are increasingly concerned about its application in internal innovation and development of enterprises, including new digital technology applications such as artificial intelligence, big data, cloud computing, blockchain, etc. Different mechanisms of action and digital metamorphosis models have varying impacts on the performance of eco-centric solutions development in enterprises [12]. Digital platforms further assist enterprises in effectively identifying and utilizing opportunities for innovative development, thereby generating new solutions for eco-centric solutions development in enterprises. In addition, by strengthening the technological advancement capabilities of enterprises, digital metamorphosis can effectively enhance their eco-centric solutions level and inject new vitality into their sustainable eco-centric solutions development. On this basis, the following hypotheses can be proposed:

H2: Creative quality based productive dynamic can improve the eco-centric solutions development performance of enterprises by promoting their digital metamorphosis

### 3.3 The Regulatory Role of Government Financial Subsidies

Government subsidies are an important tool used by government departments to regulate the market and play a crucial role in shaping the competitive development advantages of enterprises. In the new economic situation, government subsidies, as a fiscal policy, mainly focus on fixed capital and human capital, which can substantially enhance the eco-centric solutions development performance of enterprises and effectively promote the innovative development of new high-quality productivity in enterprises. Among them, in terms of human capital subsidies, it helps enterprises attract more eco-centric solutions development talents and overcome technological bottlenecks; In terms of fixed capital subsidies, it enables enterprises to acquire advanced equipment and technology, providing a material foundation for their eco-centric solutions and development.

Government subsidies send a positive signal that eco-centric solutions development has enormous potential and can receive strong support from government departments. In addition, government subsidies can significantly broaden the financing channels for enterprises, inject stronger impetus into their eco-centric solutions development, and lay a solid foundation for achieving high-quality economic and social development [13]. On this basis, the following hypotheses can be proposed:

H3: Government financial subsidies play a moderating role between new-quality productivity and eco-centric solutions performance.

## 4 Data Selection and Model Design

### 4.1 Sample Selection

This paper selects listed companies from 2011 to 2023 as the subject of study. After removing ST, \*ST, and delisted companies, as well as missing value samples, there are 3,890 sample companies, and the total sample data is 24,145 [14]. The research variables in this paper are Creative quality based productive dynamic level, eco-centric solutions performance, digital metamorphosis level, government financial subsidies, and other financial indicators. The data on Creative quality based productive dynamic, number of green patents, and government financial subsidies are from CSMAR and the Wind database. Other economic data comes from the China Research Data Service Platform (CNRDS) financial statements.

## 4.2 Variable Measurement

### 4.2.1 Explained Variables

Eco-centric solutions Performance (GRP). Drawing on the practice take the logarithm of the green patent application plus 1 to measure eco-centric solutions performance. Green patent refers to the performance of an enterprise's green technology and environmental protection, and also better reflects the degree of enterprise eco-centric solutions.

### 4.2.2 Explanatory variables

Creative quality based productive dynamic (NQP). Drawing on the practice, starting from the three-core level 1 indicators of NQP, NQP objects, and NQP materials, further refine and determine the corresponding secondary and tertiary indicators, construct the evaluation index system as shown in Table 1, and use the entropy weight method to obtain the NQP indicators.

Table 1: Creative quality based productive dynamic Evaluation Indicator System

Level 1 indicators	Secondary indicators	Tertiary indicators	Calculation method	Weights
New Quality Workers (NQW)	Quality of employees (in ideological education)	Percentage of R&D staff	$(\text{Number of R\&D personnel}/\text{number of employees}) \times 100$	12.985
		Percentage of highly educated personnel	$(\text{Number of graduate students and above}/\text{number of employees}) \times 100$	8.855
	Management quality	Executive Green Perceptions	$\ln(\text{Keyword frequency of green development in annual reports}+1)$	6.320
		Management's overseas background	The value of 1 for executives with an overseas background, 0 otherwise.	6.617
New object of labor	Ecological environment	Environmental governance score	The E indicator of CSI's ESG rating, with each of the 9 levels assigned a value from 1 to 9.	7.929
	Future development	Fixed assets as a percentage	$(\text{Fixed assets}/\text{total assets}) \times 100$	2.732
		Rate of capital accumulation	$(\text{Increase in owners' equity for the year}/\text{owners' equity at the beginning of the year}) \times 100$	1.124
New material for labor	Scientific and technical labor information	Innovation level	$\ln(\text{Number of patents granted}+1)$	21.81
	Digital labor information	Degree of digitization	$\ln(\text{Word frequency of digitized keywords in annual reports}+1)$	4.62
		Intangible assets as a percentage	$(\text{Intangible assets}/\text{total assets}) \times 100$	4.10
	Green labor information	Level of green technology	$\ln(\text{Number of green patents granted} + 1)$	9.96
Percentage of Green Patents		$(\text{Number of green patents granted}/\text{number of patents granted}) \times 100$	12.95	

### 4.2.3 Mediator variable

Digitalization transformation (DIG). Text analysis was employed to examine the word frequency of corporate annual reports related to digitization [15]. The annual reports of all A-share listed enterprises were collected and organized by using the Python crawler function. All text content was extracted using the Java PDFBox library. Keywords were extracted according to the two levels of “underlying technology application” and “practical application of technology” to form a feature word map. The keywords are extracted based on two levels: “underlying technology utilization” and “technology practice application” to create a feature word map. By searching, matching, and counting the word frequencies of feature words, the word frequencies of key technology directions are categorized and summarized. Finally, the total word frequency is established, enabling the construction of an index system for enterprise digital metamorphosis.

### 4.2.4 Moderating Variables

Government Financial Subsidy (SUB). Currently, the indicators reflecting government subsidies in the literature primarily include the ratio of government financial subsidies to total assets, the ratio of government financial subsidies to operating income, and the natural logarithm of government financial subsidies. In this paper, we build on the work and utilize the ratio of the current year's government subsidies to total assets to measure the degree of government financial subsidies to the enterprise [16].

### 4.2.5 Control Variables

In this paper, enterprise size (Size), gearing ratio (Lev), net interest rate on total assets (ROA), total asset turnover (ATO), total asset growth rate (AssetGrowth), independent director ratio (IndDirectorRatio), and two positions in one (Dual) are selected as control variables. They are measured as shown in Table 2.

Table 2: Measurement of key research variables

Variable name	Measurement Method
Eco-centric solutions performance	$\ln(\text{Green Patent Applications} + 1)$
Digital metamorphosis	Crawler digitized word frequency.
Government financial subsidies	$\text{Government financial subsidy} = \frac{\text{government subsidy}}{\text{operating income}}$
Enterprise size( <i>Size</i> )	Natural logarithm of annual assets
<i>gearing(Lev)</i>	$\frac{\text{Total liabilities at year-end}}{\text{total assets at year-end}}$
Net interest rate on total assets( <i>ROA</i> )	$\frac{\text{Net profit}}{\text{average balance of total assets}}$
Total asset turnover( <i>ATO</i> )	$\frac{\text{Operating income}}{\text{average total assets}}$
Total asset growth rate( <i>AssetGrowth</i> )	$\frac{\text{Total assets for the current year}}{\text{total assets for the previous year-1}}$
Proportion of independent directors( <i>IndDirectorRatio</i> )	$\frac{\text{Number of independent directors}}{\text{directors}}$
Two jobs in one( <i>Dual</i> )	The chairman of the board of directors and the general manager are the same person, is 1; otherwise, it is 0

### 4.3 Model design

#### 4.3.1 Baseline regression model

The calculation form of the baseline regression model is as follows [17]:

$$GRP_{i,t} = \beta_0 + \beta_1 NQP_{i,t} + \beta_2 Control_{i,t} + \delta_i + \lambda_t + \varepsilon_{i,t} \quad (1)$$

where, subscripts  $i$  and  $t$  represent years and firms, respectively.  $\beta_0$  represents the constant coefficient,  $\beta_1$  represents the coefficient of the effect of Creative quality based productive dynamic and eco-centric solutions performance,  $\beta_2$  represents the coefficient of the effect of the control variable and eco-centric solutions performance,  $\delta_i$  represents the time fixed effect,  $\lambda_t$  represents the individual fixed effect, and  $\varepsilon_{i,t}$  represents the error term; GRP denotes eco-centric solutions performance, NQP denotes Creative quality based productive dynamic level, and Control denotes control variables.

#### 4.3.2 Mediating effects model

The calculation form of the mediator model is as follows [18]:

$$DIG_{i,t} = \eta_0 + \eta_1 NQP_{i,t} + \eta_2 Control_{i,t} + \varepsilon_{i,t} \quad (2)$$

$$GRP_{i,t} = \lambda_0 + \lambda_1 NQP_{i,t} + \lambda_2 DIG_{i,t} + \lambda_3 Control_{i,t} + \varepsilon_{i,t} \quad (3)$$

where, DIG denotes digital metamorphosis and is the mediating variable..

#### 4.3.3 Moderating effects model

The calculation form of the interaction effect model is as follows [19]:

$$GRP_{i,t} = \alpha_0 + \alpha_1 NQP_{i,t} + \alpha_2 SUB_{i,t} + \alpha_3 NQP_{i,t} \times SUB_{i,t} + \alpha_4 Control_{i,t} + \varepsilon_{i,t} \quad (4)$$

where, SUB denotes government financial subsidies, which is the moderating variable of NQP on eco-centric solutions performance.  $NQP \times SUB$  denotes the cross-multiplier term, which measures whether government financial subsidies moderate the process of NQP to improve eco-centric solutions performance.

## 5 Empirical analyses

### 5.1 Descriptive statistics

Table 3 presents the descriptive statistics of the key variables. The eco-centric solutions performance variable has a minimum value of 0.000, a maximum of 6.848, and a mean of 0.453, indicating a generally low level of eco-centric solutions among listed companies in China, with some firms yet to achieve any eco-centric solutions. The Creative quality based productive dynamic variable ranges from 1.504 to 16.355, with a mean of 5.723, reflecting an uneven development level across firms and a relatively low average.

*Table 3: Descriptive Statistics*

Variable name	Observations	Mean	standard deviation	Min	Median	Max
GRP	25418	0.453	0.878	0.000	0.000	6.848
NQP	25418	5.723	2.971	1.504	4.957	16.355
Size	25418	22.333	1.271	19.653	22.127	26.444
Lev	25418	0.408	0.193	0.032	0.402	0.898
ROE	25416	0.056	0.137	-0.926	0.069	0.437
ATO	25414	0.631	0.452	-0.055	0.546	11.975
AssetGrowth	25416	0.156	0.325	-0.384	0.084	4.600
IndDirectorRatio	25416	37.907	5.415	28.570	36.360	60.000
Dual	25418	0.321	0.467	0.000	0.000	1.000

## 5.2 Baseline regression analysis

Hausman as well as individual and time effect tests were conducted on the above models, and the results of the tests are shown in Table 4, indicating that the two-way fixed effect model applies to all four models.

*Table 4: Hausman, individual, and time effect tests*

Variable name	(1)	(2)	(3)	(4)
Hausmantest	10.87	24.14	10.83	10.87
time effect tests	11.06	24.98	11.01	11.06
individual effect tests	10.87	24.14	10.83	10.87

The results of the benchmark regression are shown in Table 5, column (1), controlling for time and individuals, without control variables, the regression coefficient of Creative quality based productive dynamic on eco-centric solutions performance is 0.025, which is significant at the 1% level. Column (2) controls for time and individuals, and adding control variables, the regression coefficient of Creative quality based productive dynamic on eco-centric solutions performance is 0.025, which is significant at 1% level, indicating that enterprises can improve the degree of Creative quality based productive dynamic to promote eco-centric solutions performance. Creative quality based productive dynamic itself is green productivity, due to the addition of a new quality labor force and new quality labor materials. Enterprises have eco-centric solutions talents, as well as eco-centric solutions materials, which can carry out eco-centric solutions activities, thereby improving eco-centric solutions performance. Therefore, hypothesis 1 is verified.

Table 5: Base regression analysis

	(1)	(2)
	<i>GRP</i>	<i>GRP</i>
<i>NQP</i>	0.025***	0.025***
	(0.002)	(0.002)
<i>Size</i>		0.064***
		(0.012)
<i>Lev</i>		0.030
		(0.044)
<i>ROE</i>		0.047
		(0.034)
<i>ATO</i>		0.050***
		(0.018)
<i>AssetGrowth</i>		-0.032***
		(0.012)
<i>IndDirectorRatio</i>		0.001
		(0.001)
<i>Dual</i>		-0.011
		(0.012)
<i>Constant</i>	0.314***	-1.200***
	(0.013)	(0.259)
<i>Fixed time</i>	YES	YES
<i>Fixed Individual</i>	YES	YES
<i>Observations</i>	24,145	24,145
<i>R</i> <sup>2</sup>	0.752	0.753

Standard errors in parentheses,\*\*\*p<0.01,\*\*p<0.05,\*p<0.1

### 5.3 Robustness Tests

#### 5.3.1 Replacement variable measurement

In this paper, we choose the ratio of green patent applications to the total number of patent applications to represent eco-centric solutions performance. The regression results are shown in column (1) of Table 6. After replacing the variable measures, the regression coefficient of Creative quality based productive dynamic on eco-centric solutions performance is 0.018, which is significant at the 1% level and consistent with the benchmark regression results, indicating that the model is robust.

Table 6: Robustness check

	(1)	(2)	(3)
	<i>T-GRP</i>	<i>GRP</i>	<i>GRP</i>
<i>NQP</i>	0.018***	0.024***	0.027***
	(0.002)	(0.002)	(0.003)
<i>Size</i>	-0.015	0.056***	0.059***
	(0.010)	(0.012)	(0.013)
<i>Lev</i>	0.077**	0.035	0.051
	(0.037)	(0.045)	(0.049)
<i>ROE</i>	-0.014	0.022	0.014
	(0.032)	(0.036)	(0.040)
<i>ATO</i>	-0.012	0.050**	0.079***
	(0.020)	(0.023)	(0.022)
<i>AssetGrowth</i>	-0.015	-0.027**	-0.048***
	(0.011)	(0.013)	(0.014)
<i>IndDirectorRatio</i>	0.002**	0.001	0.000
	(0.001)	(0.001)	(0.001)
<i>Dual</i>	-0.014	-0.009	-0.017
	(0.010)	(0.012)	(0.014)
<i>Constant</i>	0.346	-1.012***	-1.083***
	(0.226)	(0.265)	(0.300)
<i>Fixed time</i>	YES	YES	YES
<i>Fixed individual</i>	YES	YES	YES
<i>Observations</i>	15,122	22,033	19,165
<i>R-squared</i>	0.613	0.737	0.753

Standard errors in parentheses,\*\*\*p<0.01,\*\*p<0.05,\*p<0.1

### 5.3.2 Removal of special variables

In this paper, we exclude samples of municipalities directly under the central government, as well as first-tier and second-tier cities, to conduct the robustness test. Municipalities directly under the central government, first- and second-tier cities have higher levels of economic development and faster technological turnover, and the results of the study are more generalizable after excluding these samples. The results are shown in column (2) of Table 6. The regression results show that the regression coefficient of Creative quality based productive dynamic on eco-centric solutions performance is 0.028, which is significant at the 1% level and consistent with the baseline regression results, indicating that the model is robust after excluding the special sample variables.

### 5.3.3 Limit the sample to the industrial sector

This paper restricts the sample to industrial sector firms to conduct the robustness test. Industrial industry enterprises are the key industries of green transformation, so choosing industrial enterprises can see more intuitive observation. The results are shown in Table 6, paragraph (3), and the regression results show that the regression coefficient of Creative quality based productive dynamic on eco-centric solutions performance is 0.027, and it is significant at the 1% level, which is consistent with the benchmark regression results, indicating that the model is robust.

### 5.3.4 Endogeneity test

The third power of the difference between the new productivity level of an enterprise and the average of the new productivity of enterprises in the same industry in the same year is used as the instrumental variable of “new productivity”. Since the new productivity level of the enterprise and the new productivity level of other enterprises in the same industry have a certain correlation, but the advancement of the new productivity of other enterprises in the same industry will not have a direct impact on the organizational resilience of the enterprise. Therefore, this instrumental variable satisfies the requirements of relevance and exogeneity.

The regression results are shown in Table 7. Column (1) presents the regression results of the first stage, where the regression coefficient of the instrumental variables with endogenous explanatory variables is 0.009, which is significant at the 1% level, indicating that the instrumental variables are significantly correlated with the endogenous explanatory variables. The first stage F-value = 1534.69 > 10 indicates that the weak instrumental variables test is passed. The Kleibergen-Paap rk LM statistic has a p-value of 0.000 < 0.1 and rejects the original hypothesis that the instrumental variables are under-identified. The Cragg-Donald Wald F-statistic has an F-value of 20461.24, which is greater than 16.38. The result indicates a strong correlation between the instrumental variables and the endogenous explanatory variables; therefore, the original hypothesis of weak instrumental variables is rejected. Column (2) presents the results of the second-stage regression, where the regression coefficient between the explanatory variable and the dependent variable is 0.013, which is significant at the 1% level. This indicates that there is endogeneity in the explanatory variable, and the instrumental variable mitigates this endogeneity.

Table 7: Endogeneity test

	(1)	(2)
	NQP	GRP
<i>NQP</i>		0.013***
		(0.004)
<i>Size</i>	0.274***	0.067***
	(0.043)	(0.017)
<i>Lev</i>	-0.581***	0.020
	(0.150)	(0.052)
<i>ROE</i>	-0.120	0.043
	(0.104)	(0.036)
<i>ATO</i>	-0.064	0.048**
	(0.055)	(0.020)
<i>AssetGrowth</i>	0.446***	-0.019
	(0.056)	(0.013)
<i>IndDirectorRatio</i>	-0.002	0.001
	(0.003)	(0.001)
<i>Dual</i>	-0.030	-0.012
	(0.036)	(0.013)
<i>VI</i>	0.009***	
	(0.000)	
<i>F</i>	1534.69***	
<i>Kleibergen-Paapr kLMstatistic</i>	0.000***	
<i>Cragg-DonaldWaldFstatistic</i>	20461.24	
<i>Fixed time</i>	YES	YES
<i>Fixed individual</i>	YEA	YES
<i>Observations</i>	24,133	24,133
<i>R<sup>2</sup></i>		0.007

Standard errors in parentheses, \*\*\*p<0.01, \*\*p<0.05, \*p<0.1

## 5.4 Mechanism Tests

### 5.4.1 Mediated effects test

In this paper, the degree of digital metamorphosis is used as a mediating variable, and the regression results are shown in Table 8. In column (2), the regression results of Creative quality based productive dynamic and digital metamorphosis, the regression coefficient of Creative quality based productive dynamic on digital metamorphosis is 0.008, and it is significant at the 1% level, indicating that enterprises that improve the degree of Creative quality based productive dynamic can markedly enhance digital metamorphosis. In column (3), the regression coefficient of digital metamorphosis on eco-centric solutions is 0.018, which is also significant at the 1% level, while the regression coefficient of Creative quality based productive dynamic on eco-centric solutions performance is 0.025, which is significant at the 1% level, indicating that the enterprise's Creative quality based productive dynamic not only directly affects the eco-centric solutions performance, but also indirectly promotes the improvement of the eco-centric solutions performance by improving the degree of digital metamorphosis. Among them, the mediating effect value is 58.11%, and the results of both the Sobel test and Bootstrap test prove the existence of the mediating effect of digital metamorphosis. Creative quality based productive dynamic can enhance technical content, encourage talent training and industrial upgrading, and facilitate digital metamorphosis and upgrading. Under the guidance of Creative quality based productive dynamic, digital, and intelligent technology, empowered enterprises can improve economic efficiency. Digital metamorphosis introduces digital technology for enterprises, which promotes eco-centric solutions activities by improving technological advancement capacity, and then improves eco-centric solutions performance. Therefore, hypothesis 2 is verified.

Table 8: Mediation effect test

	(1)	(2)	(3)
	<i>GRP</i>	<i>DIG</i>	<i>GRP</i>
<i>NQP</i>	0.025***	0.008***	0.025***
	(0.002)	(0.003)	(0.002)
<i>DIG</i>			0.018***
			(0.006)
<i>Size</i>	0.064***	0.211***	0.060***
	(0.012)	(0.014)	(0.012)
<i>Lev</i>	0.030	-0.016	0.031
	(0.044)	(0.054)	(0.044)
<i>ROE</i>	0.047	0.061	0.046
	(0.034)	(0.043)	(0.034)
<i>ATO</i>	0.050***	0.050**	0.049***
	(0.018)	(0.023)	(0.018)
<i>AssetGrowth</i>	-0.032***	-0.017	-0.032***
	(0.012)	(0.015)	(0.012)
<i>IndDirectorRatio</i>	0.001	-0.005***	0.001
	(0.001)	(0.001)	(0.001)
<i>Dual</i>	-0.011	0.019	-0.012
	(0.012)	(0.015)	(0.012)
<i>Constant</i>	-1.200***	-2.819***	-1.150***
	(0.259)	(0.323)	(0.259)
<i>Fixed time</i>	YES	YES	YES
<i>Fixed individual</i>	YES	YES	YES
<i>Observations</i>	24,145	24,145	24,145
<i>R<sup>2</sup></i>	0.753	0.853	0.753
<i>value of the intermediary effect</i>			58.11%
<i>Sobel test</i>			31.2***
<i>Bootstrap test</i>			[0.04490.0515]

Standard errors in parentheses, \*\*\*p<0.01, \*\*p<0.05, \*p<0.1

### 5.4.2 Moderating effects test

The regression results with government financial subsidy as the moderating variable are shown in Table 9. The first column is the regression of Creative quality based productive dynamic and eco-centric solutions performance, and the regression coefficient is 0.025 and is significant at the 1% level. Column (3) is the regression of NQP, government financial subsidy and its interaction term with eco-centric solutions performance, and the regression coefficient of NQP is 0.027, which is significant at the 1% level, the regression coefficient of government financial subsidy is 0.037, which is significant at the 10% level, and the regression coefficient of its interaction term is 0.498, which is significant at the 5% level. The coefficient of NQP in Model 1 is significant, and the coefficient of the cross-multiplier term in Model 3 is significant, indicating that the moderating effect of government financial subsidies is significant. The government financial subsidy adopts the double subsidy of human capital and fixed capital to provide support for enterprises to develop Creative quality based productive dynamic. The synergistic effect of these two aspects not only accelerates the R&D and application of enterprises' eco-centric solutions technology but also substantially enhances their eco-centric solutions performance. Therefore, hypothesis 3 is valid.

Table 9: Moderating effects test

	(1)	(2)	(3)
	<i>GRP</i>	<i>GRP</i>	<i>GRP</i>
<i>NQP</i>	0.025***	0.025***	0.027***
	(0.002)	(0.002)	(0.002)
<i>SUB</i>		0.003	0.037*
		(0.010)	(0.020)
<i>NQP*SUB</i>			0.498**
			(0.253)
<i>Size</i>	0.064***	0.064***	0.064***
	(0.012)	(0.012)	(0.012)
<i>Lev</i>	0.030	0.030	0.030
	(0.044)	(0.044)	(0.044)
<i>ROE</i>	0.047	0.047	0.048
	(0.034)	(0.034)	(0.034)
<i>ATO</i>	0.050***	0.050***	0.050***
	(0.018)	(0.018)	(0.018)
<i>AssetGrowth</i>	-0.032***	-0.032***	-0.032***
	(0.012)	(0.012)	(0.012)
<i>IndDirectorRatio</i>	0.001	0.001	0.001
	(0.001)	(0.001)	(0.001)
<i>Dual</i>	-0.011	-0.011	-0.011
	(0.012)	(0.012)	(0.012)
<i>Constant</i>	-1.200***	-1.200***	-1.215***
	(0.259)	(0.259)	(0.259)
<i>Fixed time</i>	YES	YES	YES
<i>Fixed individual</i>	YES	YES	YES
<i>Observations</i>	24,145	24,145	24,145
<i>R</i> <sup>2</sup>	0.753	0.753	0.753

Standard errors in parentheses, \*\*\*p<0.01, \*\*p<0.05, \*p<0.1

## 5.5 Heterogeneity Analysis

### 5.5.1 Analysis of regional heterogeneity

China has a vast territory and uneven regional development. The eastern region benefits from its advantageous geographical location, strong economic foundation, abundant resource endowment, and favorable business environment. Enterprises have inherent advantages in obtaining advanced technological support; The western region, on the other hand, faces relatively lagging economic development, infrastructure, and transportation infrastructure, and enterprises are at a disadvantage in obtaining advanced technological support; The central region has a developed transportation network, lower logistics costs, and sufficient human resources, allowing enterprises to obtain relatively more development resources; Although the development speed in Northeast China is relatively slow, it is rich in resources and has a strong industrial foundation. Traditional enterprises can receive more support in accelerating their green development transformation. Emerging industries such as new energy and high-end equipment manufacturing are also rapidly expanding, and eco-centric solutions development of enterprises can obtain more new and old growth drivers. Due to these regional disparities, the advancement of new-quality productivity and its impact on eco-centric solutions performance vary across enterprises. This paper, therefore, analyses heterogeneity based on enterprise location.

The results of the regional heterogeneity analysis are shown in Table 10. Column (1) presents the regression result for the eastern region, with a regression coefficient of 0.029, which is significant at the 1% level. Column (2) presents the regression results for the central region, with a regression coefficient of 0.026, significant at the 1% level. No. (3) is listed as the regression result for the Western region, and the regression result is not significant. Column (4) is listed as the regression result for the Northeast region, and the regression coefficient is 0.020, which is significant at the 5% level. In summary, the contribution of Creative quality based productive dynamic to eco-centric solutions performance is most significant in the eastern region, followed by the central region, and finally the northeaster region. Benefiting from a superior geographical location, the eastern region outperforms the central region with its stronger economic foundation and greater resource abundance.

Table 10: Analysis of regional heterogeneity

	(1)	(2)	(3)	(4)
	<i>East Region</i>	<i>Central Region</i>	<i>Western region</i>	<i>Northeastern part of China</i>
	<i>Ldgi</i>	<i>Ldgi</i>	<i>Ldgi</i>	<i>Ldgi</i>
<i>NQP</i>	0.029*** (0.003)	0.026*** (0.006)	0.005 (0.006)	0.020** (0.010)
<i>Size</i>	0.075*** (0.014)	0.034 (0.031)	0.065* (0.036)	-0.037 (0.053)
<i>Lev</i>	0.009 (0.052)	0.123 (0.119)	0.122 (0.132)	-0.173 (0.205)
<i>ROE</i>	0.039 (0.041)	0.052 (0.093)	0.104 (0.106)	0.107 (0.142)
<i>ATO</i>	0.053** (0.021)	0.022 (0.052)	0.123* (0.067)	-0.081 (0.096)
<i>AssetGrowth</i>	-0.045*** (0.015)	0.028 (0.034)	-0.019 (0.041)	-0.035 (0.050)
<i>IndDirectorRatio</i>	0.001 (0.001)	0.001 (0.003)	-0.001 (0.003)	0.005 (0.005)
<i>Dual</i>	-0.002 (0.014)	-0.037 (0.035)	-0.062 (0.040)	0.014 (0.057)
Constant	-1.448*** (0.315)	-0.506 (0.700)	-1.193 (0.802)	0.934 (1.196)
Fixed time	YES	YES	YES	YES
Fixed individual	YES	YES	YES	YES
Observations	17,226	3,337	2,728	831
R <sup>2</sup>	0.761	0.760	0.693	0.688

Standard errors in parentheses, \*\*\*p<0.01, \*\*p<0.05, \*p<0.1

### 5.5.2 Heterogeneity Analysis of Enterprise Nature

The results of the heterogeneity analysis of enterprise ownership are shown in Table 11. Column (1) is the regression result of state-owned enterprises, and the regression coefficient is 0.030; it is significant at the 1% level. Column (2) shows the regression results for non-state-owned enterprises with a regression coefficient of 0.022, also significant at the 1% level. This shows that the contribution of Creative quality based productive dynamic to eco-centric solutions performance is more significant in state-owned enterprises. State-owned enterprises, as entities directly overseen by government bodies, enjoy distinct advantages over non-state-owned enterprises in financial backing and policy responsiveness. This institutional feature allows State-owned enterprises to swiftly align with policy directives and adjust their development strategies to unlock significant growth potential. Their proactive stance also serves as a guide for non-state-owned enterprises, prompting them to similarly respond to policy requirements, optimize strategic development, enhance eco-centric solutions performance, and actively cultivate new-quality productive forces.

Table 11: Heterogeneity analysis of firm nature

	(1)	(2)
	<i>State-owned enterprise</i>	<i>Non-state-owned enterprises</i>
	<i>Ldgi</i>	<i>Ldgi</i>
<i>NQP</i>	0.030***	0.022***
	(0.004)	(0.003)
<i>Size</i>	0.024	0.080***
	(0.022)	(0.014)
<i>Lev</i>	0.115	0.027
	(0.086)	(0.051)
<i>ROE</i>	0.048	0.044
	(0.063)	(0.041)
<i>ATO</i>	0.059*	0.043*
	(0.033)	(0.022)
<i>AssetGrowth</i>	-0.020	-0.039***
	(0.024)	(0.014)
<i>IndDirectorRatio</i>	0.002	0.000
	(0.002)	(0.001)
<i>Dual</i>	0.008	-0.015
	(0.025)	(0.014)
<i>Constant</i>	-0.357	-1.526***
	(0.500)	(0.304)
<i>Fixed time</i>	YES	YES
<i>Fixed individual</i>	YES	YES
<i>Observations</i>	7,685	16,438
<i>R<sup>2</sup></i>	0.788	0.726

Standard errors in parentheses, \*\*\*p<0.01, \*\*p<0.05, \*p<0.1

## 6 Conclusions and Policy prescriptions

### 6.1 Research Conclusions

China's environmental problems have led to damage to the ecological barrier and the obstruction of eco-centric solutions, making it difficult to realize sustainable development. Eco-centric solutions, as an important driving force for sustainable and high-efficiency development, plays an important role in the sustainable and high-efficiency development of enterprises. Therefore, to improve the eco-centric solutions performance of enterprises, this paper establishes the theoretical framework of Creative quality based productive dynamic, digital metamorphosis and eco-centric solutions performance, selects A-share listed companies as the subject of study, and through the use of the fixed effect model, the mediating effect model and the moderating effect model, this paper empirically analyses the effect of Creative quality based productive dynamic on the eco-centric solutions performance of enterprises and its role mechanism. The research conclusions are as follows: (1) Creative quality based productive dynamic can improve enterprise eco-centric solutions performance. The conclusion still holds after mitigating endogeneity through the instrumental variable method and robustness tests by replacing the explanatory variables and excluding the samples of first- and second-tier cities. (2) Creative quality based productive dynamic can indirectly improve eco-centric solutions performance by increasing the degree of digital metamorphosis. (3) Government financial

subsidies positively regulate the process of Creative quality based productive dynamic to improve firms' eco-centric solutions performance. (4) Creative quality based productive dynamic contributes more significantly to firms' eco-centric solutions performance in the eastern, central, and northeaster regions and in state-owned enterprises.

## 6.2 Policy prescriptions

(1) Promote technological advancement and develop Creative quality based productive dynamic. According to the results of the previous study, it is known that Creative quality based productive dynamic can improve the eco-centric solutions performance of enterprises. To foster this productivity, it is essential to intensify talent cultivation through collaborative government-enterprise efforts in formulating attractive policies that introduce forward-thinking eco-centric solutions talents. This infuses continuous vitality into Creative quality based productive dynamic and drives eco-centric solutions. Additionally, advanced digital technologies must be actively adopted to provide robust scientific support. By integrating with green production materials, digital technology drives efficient and eco-friendly Creative quality based productive dynamic, which not only upgrades production modes but also substantially enhances eco-centric solutions performance, establishing a solid foundation for sustainable corporate development.

(2) Accelerate the digital metamorphosis of enterprises. According to the previous study, it is known that the Creative quality based productive dynamic can indirectly improve the eco-centric solutions performance of enterprises by improving digital metamorphosis. Digital metamorphosis is a long-term and iterative process marked by gradual, spiral progression. The government plays a crucial role in this process and should strengthen its leadership and provide adequate financial support to accelerate enterprises' digital metamorphosis. Local authorities must effectively fulfill their responsibilities by improving policy guidance and enhancing public service systems to create a favorable environment. Furthermore, it is essential to strengthen the protection of intellectual property related to digital technologies, safeguarding the outcomes achieved by enterprises and thereby increasing their awareness and engagement in digital metamorphosis.

(3) The government should improve subsidy policies and increase subsidy amounts. Especially for enterprises that have outstanding performance in eco-centric solutions, environmental technology research and development, and energy conservation and emission reduction, strengthening financial support can significantly alleviate the cost pressure of equipment upgrading, technology development, market expansion, and environmental facilities for such enterprises, effectively stimulating their eco-centric solutions development and industrial optimization and upgrading.

(4) Implementing differentiated policies to optimize the overall development environment. According to the previous study, it can be seen that Creative quality based productive dynamic contributes more significantly to the eco-centric solutions performance of enterprises in the eastern, central, and northeaster regions and state-owned enterprises. Leveraging its solid economic foundation and concentration of innovation resources, the eastern region should strengthen policy support for cutting-edge technology R&D and establish cross-regional platforms for green technology exchange. This will facilitate the spread of advanced technologies and practices to the central, western, and northeaster regions, reinforcing its role as a national leader. Furthermore, state-owned enterprises should take the lead in establishing eco-centric solutions laboratories in collaboration with universities, research institutes, and private enterprises. Such partnerships can enhance the sharing of eco-centric solutions resources and accelerate the dissemination of research outcomes, thereby boosting eco-centric solutions across industries. Simultaneously, state-owned enterprises should open their

technological resources and innovations to non-state-owned enterprises to foster complementary advantages, advance new-quality productivity, and improve eco-centric solutions performance.

## Availability of data and materials

The data sources have been indicated in the text, and all data are available upon request from the authors.

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## Ethics declarations

Ethics approval and consent to participate

Not applicable.

Consent for publication

Consent was given by all the authors.

Competing interests

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## Data Availability Statement

Data can be provided if requested by a journal.

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