The Functions and Effects of New Quality Productive Forces in Promoting Green Development

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Abstract. Based on panel data collected from 30 provinces across China spanning 2012 to 2021, this paper utilizes a two-way fixed effects methodology to thoroughly evaluate the impact of novel quality-oriented productive forces on promoting sustainable and high-level green economic growth.The findings from the analysis reveal that innovative, quality-driven productive forces, primarily by optimizing the allocation of production factors and enhancing green technological innovation, significantly contribute to the progress of the green economy. This positive impact is especially evident in eastern regions, non-resource-based areas, and provinces with more developed green finance, whereas the effects are less pronounced in central and western regions, resource-dependent areas, and regions where green finance is less advanced. These findings highlight the importance of further cultivating new quality productive forces through strengthened technological innovation and human capital development, promoting the improvement of green financial systems to provide sustained support for green industrial transformation, and formulating regionally adaptive strategies to accelerate green transition and achieve coordinated regional development.

Keywords: New Quality Productive Force; Green Development; Green Technological Innovation.

1. Introduction

Amid intensifying ecological pressures driven by global climate change, green development has become a critical priority for countries seeking to reconcile economic growth with environmental sustainability. Since the Paris Agreement, national commitments to carbon peaking and carbon neutrality have been strengthened, as the largest developing nation globally, China has established bold objectives to reach its carbon emission peak by 2030 and to realize carbon neutrality by 2060. This transition from a high-carbon to a low-carbon, green, and high-quality development paradigm underscores the urgent need to enhance productivity while minimizing environmental impacts, placing green transformation at the core of China's economic agenda[1].

In this context, new quality productive forces have emerged as a key driver for green transformation and the realization of dual-carbon targets[2]. Defined by the qualitative upgrading of production factors—including a digitally skilled and green-oriented labor force, advanced green technologies and intelligent equipment, and the integration of low-carbon energy and materials—these forces optimize production processes and resource allocation. Through technological and institutional innovation, new quality productive forces enable reductions in carbon emissions, support the circular economy, and foster synergies between ecological protection and economic development, thereby laying the foundation for a harmonious relationship between humans and nature[3].

Against this background, this research thoroughly investigates how emerging quality-oriented productive forces facilitate and influence the advancement of green development within China. The research clarifies the theoretical linkages the linkage between emerging quality-oriented productive forces and sustainable green advancement, explores their heterogeneous impacts across sectors and regions, and quantitatively assesses these effects using empirical models. In light of the results, specific policy suggestions are put forward to strengthen the cultivation of innovative quality-driven productive forces and to foster sustainable, high-standard green development.[4].

2. Theoretical Analysis

New quality productive forces, serving as a fundamental engine for green growth, play a pivotal role by promoting innovation and optimization across multiple dimensions. Foremost, green technological innovation is central to this paradigm; the integration of intelligent energy management systems and clean energy technologies substantially enhances energy efficiency and reduces reliance on conventional fossil fuels. This shift not only optimizes and greenifies the energy structure but also provides foundational support for sustainable development. In addition, advancements in green production tools, enabled by smart manufacturing and automation, have increased productivity while minimizing both energy utilization and emissions within industrial procedures[5]. This transformation facilitates the shift away from conventional modes characterized by heavy pollution and excessive energy usage models to low-carbon, environmentally friendly production systems[6].

The pervasive use of novel green materials and renewable energy further accelerates the substitution of conventional high-energy production inputs, promoting resource recycling and the restructuring of production systems along greener lines. These changes reinforce the foundation for comprehensive green transformation. Moreover, by comprehensively optimizing production processes, new quality productive forces are gradually steering energy-intensive, high-emission industries, such as manufacturing, toward green development[7]. The deployment of green technologies and practices within these sectors has significantly reduced their ecological footprint and advanced the green upgrading of industrial value chains[8].

By enhancing total factor productivity, innovative productive capacities contribute to the optimized and lasting distribution of both resources and energy, reducing environmental burdens associated with production and enabling economic growth to decouple from traditional resource- and carbon-intensive pathways[9]. Therefore, advanced productive forces with a focus on quality serve to directly enhance the process of green development through technological and production tool innovation, but further facilitate the sustainable transformation of whole industrial systems by optimizing the allocation of productive elements, thereby underpinning the progress of green and high-quality economic development. Drawing from this theoretical basis, this paper formulates the subsequent hypothesis:

H: New quality productive forces can effectively promote green development.

3. Research Design

3.1. Variable Selection and Description

3.1.1 Dependent Variable

In this study, the Super-SBM-GML analytical framework, utilizing the slack-based measure and the global Malmquist-Luenberger index method, which incorporates resource consumption, environmental outputs, and undesirable outputs, is employed to measure green economic efficiency (GP). This metric is subsequently used to appraise the level of environmentally friendly development regionally (GED). Specifically, capital input is measured by the total fixed asset investment; labor input is measured by the number of employed persons at year-end; and energy input is measured by electricity consumption, water consumption, and gas consumption. The desired output is represented by regional GDP, while the undesirable output is proxied by the values of "three industrial wastes" calculated using the entropy weight method[10].

3.1.2 Independent Variable

Drawing upon the conceptual foundation of emerging quality-oriented productive forces, an evaluation system is constructed in this research, measuring new quality productive forces across three categories: skilled laborers, upgraded labor objects, and advanced production means. The entropy weight method is adopted to assign weights to each indicator, thereby avoiding subjective bias and ensuring the rationality and validity of the measurement associated with novel quality-

oriented production capabilities. The SBM (Slack-Based Measure) method is then employed to assess the degree of novel quality productive forces (NQP).

3.1.3 Control Variables and Mechanism Variables

To further remove confounding factors and pinpoint the pure influence of new quality productive forces regarding green development, this study additionally controls for the following variables: regional level of industrialization (LOI), stage of economic progress (LED), level of social consumption (LSC), level of infrastructure (LI), level of marketization (LM), and level of innovation (IN). Specifically, the level of industrialization is measured as the logarithm of industrial added value; the level of economic development is represented by per capita GDP; the stage of economic development is reflected through per-person GDP figures.; the level of infrastructure is measured as the logarithm of total freight volume; the level of marketization is measured by the total score of the marketization index; while the degree of innovation is evaluated using the logarithmic value of patent applications in the current year. In Table 1, the descriptive values for all metrics are presented.

Table 1. Indicator Summary Statistics

Variable	N	Mean	Std. Dev.	Min	Max
GED	300	0.377	0.212	0.167	1.085
NQP	300	0.137	0.063	0.042	0.477
LOI	300	0.316	0.079	0.101	0.523
LED	300	12769.65	8145.207	5422.97	48075
LSC	300	0.384	0.069	0.222	0.538
LI	300	11.64	0.833	9.501	12.981
LM	300	8.138	1.882	3.359	12.39
IN	300	9.705	1.365	5.697	12.399

3.2. Model Specification

To accurately identify the role of novel productive forces in promoting green development,the analysis utilizes a model with fixed effects in both dimensions. Such an approach enables the control of hidden factors that are time-invariant within entities and entity-invariant over time, thereby addressing their potential interference with the dependent variable. The model is specified below:

$$ged_{i,t}=\alpha+\beta nqp_{i,t}+\gamma Control_{i,t}+\mu_i+\theta_t+\varepsilon_{i,t} \quad (1)$$

where $ged_{i,t}$ indicates the extent of green development observed in province *i* during period *t*; $nqp_{i,t}$corresponds to the value of new quality productive forces for province *i* at point *t* in time; the coefficients to be estimated are denoted by the relevant parameters. $\mathrm{Control}_{i,t}$ is comprised of various control variables; μ_i and θ_t denote the individual fixed effects and fixed effects corresponding to each time period; and $\varepsilon_{i,t}$ represents the random disturbance term.

3.3. Data Sources

Relying on provincial panel data from China between 2012 and 2021, this study examines the relationship between new quality productive forces and green development. Data on green patents are obtained from the CNRDS database, while the remaining data utilized in this study come from the China Statistical Yearbook and the statistical publications of each province.

4. Empirical Analysis

4.1. Baseline Regression

Grounded in the model specification and variable selection described above, this section empirically examines Model (1) is utilized to analyze how new quality productive forces influence

green economic efficiency, with Table 2 displaying the results of the regression analysis.The results in columns (1)–(3) show that, regardless of adding time fixed effects, individual fixed effects, or control factors, the effect of new quality productive forces on green economic efficiency is stably and significantly positive at the 1% level. These results further confirm Hypothesis 1, indicating that green economic efficiency is greatly boosted by advanced quality-driven productive forces. This finding not only provides empirical support for the theoretical expectation that advanced quality-oriented productive forces are an important impetus for the advancement of green economic development, but also offers important policy implications—namely, that the sustained promotion of the development of new quality-oriented productive forces plays a vital role in promoting ecological transformation and high-quality economic progress.

Table 2. Baseline Regression Results

Variable	(1) *GED*	(2) *GED*	(3) *GED*
NQP	2.0912***	1.9802***	1.9472***
	(0.105)	(0.549)	(0.580)
Control Variables	Yes	Yes	Yes
Constant	0.0906**	0.1230*	-0.2417
	(0.036)	(0.062)	(0.627)
Observations	300	300	300
R^2	0.0674	0.6242	0.6298
fe	No	Yes	Yes
year	No	Yes	Yes

Note: Robust standard errors, adjusted for clustering within provinces, are given in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Notes for subsequent tables are identical.

4.2. Robustness Checks

For the sake of validating the reliability and robustness of the results, as well as to address potential endogeneity, this study conducts four robustness checks. First, since municipalities have unique administrative and economic characteristics that may influence the outcomes, the four municipalities are excluded from the sample, while the results consistently show significant positive effects at the 1% margin. Second, to minimize potential bias from the measurement of the independent variable, the standard of new quality-based productive capacities is recalculated using principal component analysis, and the effectremains positively associated, achieving significance at the 10% level. Third, to control for the possible influence of the carbon emissions trading pilot policy, which may cause affected regions to differ from others, these regions are excluded from the analysis, and the positive effect remains robust. Fourth, additional control variables—such as government intervention, financial development, and human capital—are included to account for other potential influences on green development. In all cases, as shown in Table 3, the positive implications of new quality-based production factors for green transformation persists, confirming the robustness and reliability of the findings.

Table 3. Robustness Checks

Variable	(1)	(2)	(2)	(3)
NQP	2.2275***	0.4357*	1.9872***	1.7408***
	(0.639)	(0.236)	(0.594)	(0.561)
Control Variables	Yes	Yes	Yes	Yes
Low-Carbon Pilot			-0.0602	
			(0.053)	
Degree of Government Intervention				0.4753*
				(0.271)
Financial Development Level				-0.0830*
				(0.042)
Human Capital Level				-13.7410
				(9.013)
Constant	-0.5026	-0.4790	-0.2877	0.2312
	(0.607)	(0.824)	(0.640)	(0.680)
Observations	260	300	300	300
R^2	0.6891	0.4809	0.6352	0.6644
fe	Yes	Yes	Yes	Yes
year	Yes	Yes	Yes	Yes

4.3. Heterogeneity Analysis

Significant regional differences exist in China's economic development, industrial structure, technological innovation, and green policy implementation. To examine these differences, the analysis divides the sample by region, green finance development, and resource endowment. Regression results in Table 4 show that new quality productive forces have a significantly positive effect on green development in both the eastern and central-western regions, though the impact is more pronounced in the east, likely due to stronger innovation capacity and more mature market mechanisms. Further, in regions with developed green finance, the positive effect is both larger and highly significant, while in non-pilot regions, the effect is not statistically significant, drawing attention to the significance of supportive policies and financial resources. Lastly, in non-resource-based regions, emerging productive forces with improved quality contribute greatly to green development, whereas in resource-based regions, the effect is positive but not significant, possibly due to rigid industrial structures and greater transformation pressures. These findings demonstrate substantial heterogeneity in the contribution of innovative productive forces to the advancement of green development, emphasizing the roles of innovation, finance, and regional characteristics.

Table 4. Heterogeneity Analysis

Variable	(1) Eastern region	(2) Central and Western region	(3) Green Finance	(4) Non-green finance	(5) Resource-based	(6) Non-resource-based
NQP	1.7956***	1.9500**	2.9315***	1.1730	0.7447	1.8806***
	(0.528)	(0.740)	(0.440)	(0.753)	(1.139)	(0.650)
Control Variables	Yes	Yes	Yes	Yes	Yes	Yes
Constant	-0.1495	0.5068	-2.0628**	0.3005	0.0872	-0.2000
	(1.082)	(0.479)	(0.797)	(0.609)	(0.434)	(1.133)
Observations	120	180	70	230	110	190
R^2	0.6911	0.5840	0.9238	0.5486	0.3792	0.6786
fe	Yes	Yes	Yes	Yes	Yes	Yes
year	Yes	Yes	Yes	Yes	Yes	Yes

5. Conclusion and Policy Implications

5.1. Research Conclusions

Drawing on panel data from 30 provinces in China spanning 2012 to 2021, together with a two-way fixed effects approach, results indicate that innovative quality-driven productive forces strongly advance green economic efficiency by optimizing production factor allocation and fostering green technological innovation. Heterogeneity analysis reveals that this effect is more pronounced in eastern, non-resource-based, and green finance-developed regions, while it is weaker in central-western, resource-based, and non-green finance-developed regions. These findings highlight the importance of technological innovation, financial support, and policy environment for green development.

5.2. Policy Recommendations

Based on these results, several policy suggestions are offered. First, efforts should focus on cultivating new quality productive forces to accelerate green industry transformation, especially through talent development and technological innovation. Second, the green finance system should be strengthened to provide financial support for green technologies and industries, expanding tools like green credit and bonds. Third, region-specific strategies should be adopted—particularly in central-western and resource-based regions—by improving infrastructure, encouraging green innovation, and tailoring policies to local conditions to promote coordinated and sustainable green development.

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