

Level of Regional New Quality Productive Forces and Export Competitiveness

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Abstract. Based on the panel data of 31 provinces in China from 2013 to 2023, this paper constructs a provincial comprehensive index of new quality productive forces using the entropy method, and empirically tests the impact of new quality productive forces on export competitiveness. The study finds that new quality productive forces have a significant positive promoting effect on export competitiveness: every one-point increase in the index is associated with an approximately 3.45% rise in the export delivery value of high-tech industries. Technological innovation plays a full mediating effect, while industrial structure upgrading exhibits a partial mediating effect. Regional heterogeneity presents a marginal diminishing characteristic of "high in the west and low in the east". This paper provides empirical support for regions to cultivate new quality productive forces and enhance export competitiveness.

Keywords: new quality productive forces, export competitiveness, technological innovation, regional heterogeneity

1. Introduction

Since the reform and opening-up, China has achieved rapid growth in export trade by relying on its labor cost advantage and industrial scale effect, becoming the world's largest goods trading nation. However, in recent years, with the gradual fading of the demographic dividend, intensified international economic and trade frictions, and the restructuring of global industrial and supply chains, the traditional low-cost comparative advantage has continued to weaken, and export growth is facing a structural dilemma of "large but not strong" [1]. Against this backdrop, how to cultivate new advantages in export competition and promote high-quality trade development has become a core issue urgently to be addressed in China's economic transformation.

In September 2023, General Secretary Xi Jinping first put forward the concept of "new quality productive forces" during his inspection tour in Heilongjiang Province, clearly defining it as an advanced form of productive forces driven by scientific and technological innovation as the core, led by new industries, and characterized by high technology, high efficiency, and high quality. This important proposition provides a brand-new theoretical perspective and practical direction for the transformation of China's export competitiveness: can new quality productive forces become a new driving force supporting the improvement of China's export competitiveness?

Existing studies have laid a solid foundation for this paper. In terms of conceptual connotation and measurement, scholars generally agree that the core of new quality productive forces is scientific and technological innovation. An evaluation index system should be constructed from three dimensions: new-type laborers, new-type means of labor, and new-type objects of labor, and objective methods such as the entropy method and principal component analysis should be adopted for quantitative measurement [1, 2]. In terms of economic effects, existing studies have confirmed that new quality productive forces can significantly promote high-quality economic development by driving industrial upgrading, optimizing resource allocation, and improving total factor productivity [3]. In the trade field, relevant studies show that core elements of new quality productive forces such as the digital economy, artificial intelligence, and intelligent manufacturing can enhance export technological sophistication and optimize export structure [4, 5]. Some scholars further find that new quality productive forces can enhance trade competitiveness through paths such as digital transformation, improving the quality of export products, and increasing the domestic value-added rate [6-9]. However, existing studies still have two shortcomings: first, most focus on the national or industrial level, and systematic measurement and empirical analysis at the provincial level are relatively scarce; second, the mechanism of new quality productive forces on the export competitiveness of high-tech industries has not been fully identified, and research on regional heterogeneity needs to be deepened.

Accordingly, this paper uses panel data of 31 provinces in China from 2013 to 2023, constructs a provincial comprehensive index of new quality productive forces with the entropy method, empirically tests the impact of new quality productive forces on export competitiveness using the pooled OLS model, addresses endogeneity issues through the instrumental variable method, identifies the transmission mechanisms of technological innovation and industrial upgrading with the mediating effect model, and conducts regional heterogeneity analysis and multiple robustness tests simultaneously. The marginal contributions of this paper are as follows: first, from the research perspective, it integrates new quality productive forces and export competitiveness into a unified analytical framework at the provincial level, making up for the deficiencies of existing studies in the regional dimension; second, in terms of mechanism identification, it sequentially tests the two mediating paths of technological innovation and industrial structure upgrading through the mediating effect model, and conducts heterogeneity analysis for the eastern, central, and western regions, providing empirical evidence for formulating differentiated policies tailored to local conditions.

2. Theoretical analysis and research hypotheses

2.1. Direct effect of new quality productive forces on export competitiveness

Export competitiveness reflects the comprehensive competitive capacity of a region's export products in the international market, whose core dimensions include the stability of export scale, the quality of export products, export technological sophistication, and the division of labor status in the global value chain. Traditional foreign trade growth mainly relies on low-cost labor and extensive resource input. Under this model, export products generally suffer from low added value, insufficient technological content, and weak risk resistance, making it difficult to adapt to the global trend of trade transformation toward high-end, refined, and green development.

The development of new quality productive forces can directly promote regional export competitiveness through three dimensions: factor upgrading, efficiency improvement, and quality reform. First, the factor upgrading effect. With high-level new production factors such as talent,

technology, and data as its core, new quality productive forces can break the constraint of diminishing marginal returns of traditional factors, optimize the regional production input structure, reduce the production cost per unit product, and thus consolidate the price competitive advantage of export products. Second, the quality improvement effect. Driven mainly by scientific and technological innovation, new quality productive forces can continuously promote the innovation of production technology and product upgrading, significantly enhance the technological content and quality of export products, help regional exports break away from low-end homogeneous competition, form differentiated competitive advantages, and further improve the international recognition and market share of export products. Third, the resilience enhancement effect. New quality productive forces emphasize efficient resource allocation and green and low-carbon production modes, which can optimize regional industrial organization models, improve total factor productivity, strengthen the ability of foreign trade enterprises to cope with external trade barriers and market fluctuations, and stabilize the scale of regional export trade.

Based on the above analysis, this paper puts forward the following hypothesis:

H1: Provincial-level new quality productive forces exert a significant positive promoting effect on export competitiveness.

2.2. Theoretical mechanism of new quality productive forces affecting export competitiveness

2.2.1. Technological innovation channel

Technological innovation is the core of new quality productive forces. The development of new quality productive forces can provide sufficient factor support for regional innovation activities through the upgrading of human capital, improvement of digital infrastructure, and agglomeration of high-tech industries. On the one hand, regions with higher levels of new quality productive forces usually possess more high-end talent resources and better innovation infrastructure, enabling enterprises to increase R&D investment and conduct research on core technologies. On the other hand, new quality productive forces can accelerate the transformation and application of innovation achievements, turn patented technologies into real productive forces rapidly, and realize the upgrading of export products from low added value to high technological sophistication. According to the endogenous growth theory, endogenous technological progress is the fundamental driving force for sustained economic growth. By internalizing technological innovation into the core competitive advantage of enterprises, new quality productive forces promote the transformation of regional export competitive advantages from traditional cost advantages to technological advantages. Therefore, technological innovation serves as the core transmission channel through which new quality productive forces empower export competitiveness, focusing on the long-term improvement of quality-oriented competitiveness.

2.2.2. Industrial structure optimization channel

The evolution of industrial structure toward sophistication and rationalization is an important feature of the development of new quality productive forces, as well as the industrial foundation for high-quality development of foreign trade. The development of new quality productive forces can force regions to accelerate the elimination of high-energy-consuming and inefficient traditional backward production capacity, while fostering and expanding high-end industrial clusters such as strategic emerging industries and high-tech industries, thus promoting the optimization and upgrading of regional industrial structure.

From the perspective of industrial structure rationalization, digital technology embedded in new quality productive forces can break information barriers between industries, optimize the allocation efficiency of production factors across different industries, alleviate resource misallocation, and promote the coordinated development of upstream and downstream industrial chains. This in turn reduces the comprehensive production costs of foreign trade enterprises and improves the overall export efficiency of industries. From the perspective of industrial structure sophistication, the agglomeration of high-end industries can fundamentally change the export structure of regions that rely on labor-intensive and resource-intensive products, significantly increase the export share of technology-intensive and high-value-added products, push regions to climb toward the middle and high ends of the global value chain, and build long-term and stable export competitive advantages.

Based on the above analysis, this paper puts forward the following hypothesis:

H2: New quality productive forces indirectly enhance export competitiveness by improving technological innovation and promoting industrial structure upgrading; that is, technological innovation and industrial structure upgrading play mediating roles in the impact of new quality productive forces on export competitiveness.

2.3. Theoretical analysis of regional heterogeneity

China has a vast territory, and the eastern, central, and western regions differ significantly in economic development level, industrial structure, and innovation resource endowments. As a result, the driving effect of new quality productive forces on export competitiveness may present obvious regional heterogeneity.

The eastern region was the first to open up to the outside world, with a solid economic foundation, complete digital infrastructure, a high concentration of high-tech industries, and sufficient reserves of high-end innovative talents, providing the most favorable conditions for the development of new quality productive forces. However, according to the law of diminishing marginal returns, when new quality productive forces develop to a relatively high level, the marginal benefits of further improvement will gradually decline.

Adjacent to the eastern coastal areas, the central region can actively undertake industrial transfer from the east by virtue of its geographical advantages and is currently at a critical stage of industrial transformation and innovation cultivation. With the gradual improvement of digital infrastructure and accelerated layout of high-tech industries, the driving effect of new quality productive forces on export competitiveness is emerging rapidly.

Constrained by geographical location, economic foundation, and talent reserves, the western region lags behind in digital infrastructure construction and has a smaller scale of high-tech industries, resulting in a weak foundation for the development of new quality productive forces. Nevertheless, due to the low development base, each unit improvement in new quality productive forces can bring greater relative growth, and its marginal effect may be more prominent.

Based on the reality of unbalanced regional economic development in China, this paper puts forward the following hypothesis:

H3: There exist significant regional differences in the impact of new quality productive forces on export competitiveness.

3. Research design

3.1. Model specification

3.1.1. Benchmark regression model

To examine the impact of provincial-level new quality productive forces on export competitiveness, this paper establishes the following benchmark regression model:

$$\ln_export_{it} = \alpha + \beta \cdot nqp_index_{it} + \gamma X_{it} + \lambda_t + \varepsilon_{it} \quad (1)$$

where subscripts i and t denote province and year, respectively; $\ln_export_{it}$ is the dependent variable, representing the logarithm of the export delivery value of high-tech industries in province i in year t ; nqp_index_{it} is the core independent variable, representing the comprehensive index of new quality productive forces in province i in year t ; X_{it} is a set of control variables; λ_t is the year fixed effect; and ε_{it} is the random error term. Standard errors are clustered at the provincial level to address potential intra-group autocorrelation and heteroskedasticity.

Regarding model selection, this paper first conducts the Hausman test to choose between the fixed-effects model and the random-effects model. The test result shows a p -value greater than 0.1, so the null hypothesis cannot be rejected. Considering that the variation of the core independent variable in this study mainly lies in inter-provincial cross-sectional differences, the pooled OLS model can make fuller use of cross-sectional information and identify the long-term effect of new quality productive forces on export competitiveness. Therefore, this paper finally adopts the pooled OLS model as the benchmark regression method.

3.1.2. Entropy method measurement model

This paper uses the entropy method to comprehensively measure provincial new quality productive forces. Weights are determined according to the variation degree of observed values of each indicator, avoiding artificial bias caused by subjective weighting. The specific steps are as follows:

Step 1: Adopt the min-max standardization method to eliminate dimensional differences:

$$X'_{ij} = \frac{X_{ij} - \min(X_j)}{\max(X_j) - \min(X_j)} \quad (2)$$

Step 2: Calculate the proportion of the i -th province under the j -th indicator:

$$P_{ij} = \frac{X'_{ij}}{\sum_{i=1}^n X'_{ij}} \quad (3)$$

Step 3: Calculate the information entropy value of the j -th indicator:

$$e_j = -\frac{1}{\ln(n)} \sum_{i=1}^n P_{ij} \cdot \ln(P_{ij}) \quad (4)$$

Step 4: Calculate the difference coefficient:

$$g_j = 1 - e_j \quad (5)$$

Step 5: Calculate the indicator weight:

$$w_j = \frac{g_j}{\sum_{j=1}^m g_j} \quad (6)$$

Step 6: Calculate the comprehensive index of new quality productive forces for each province in each year:

$$nqp_index_{it} = \sum_{j=1}^m w_j \cdot X_{ij} \quad (7)$$

3.1.3. Instrumental variable model

Considering the potential reverse causality between new quality productive forces and export competitiveness, this paper selects the one-period lag of the new quality productive forces index as the instrumental variable and estimates using the two-stage least squares method:

First stage:

$$nqp_index_{it} = \alpha + \theta \cdot L.nqp_index_{it} + \gamma X_{it} + \lambda_t + \varepsilon_{it} \quad (8)$$

Second stage:

$$\ln_export_{it} = \alpha + \beta \cdot \widehat{nqp_index_{it}} + \gamma X_{it} + \lambda_t + \varepsilon_{it} \quad (9)$$

3.1.4. Mediating effect model

Following the mediating effect test procedure proposed by Wen Zhonglin et al. [10], this paper constructs a three-step model:

Step 1 (Total effect):

$$\ln_export_{it} = \alpha_1 + c \cdot nqp_index_{it} + \gamma_1 X_{it} + \lambda_t + \varepsilon_{1it} \quad (10)$$

Step 2 (Effect of the core independent variable on the mediating variable):

$$\ln_patent_{it} = \alpha_2 + a \cdot nqp_index_{it} + \gamma_2 X_{it} + \lambda_t + \varepsilon_{2it} \quad (11)$$

Step 3 (Direct effect and mediating effect):

$$\ln_export_{it} = \alpha_3 + c' \cdot nqp_index_{it} + b \cdot \ln_patent_{it} + \gamma_3 X_{it} + \lambda_t + \varepsilon_{3it} \quad (12)$$

where $\ln_export_{it}$ is the mediating variable (logarithm of the number of domestic patent applications granted), and the total effect satisfies $c = c' + a \times b$.

3.2. Variable selection and data description

3.2.1. Dependent variable

The dependent variable in this paper is export competitiveness. Referring to the research by Liu Wei and Feng Delian [11], the export delivery value of high-tech industries is used as the proxy variable. This indicator can directly reflect the international market competitiveness of a region's high-tech

products, which is highly consistent with the core characteristics of new quality productive forces, namely "high technology, high efficiency, and high quality". Data are obtained from the *China High-Tech Industry Statistical Yearbook* and the EPS Data Platform. Missing values for some provinces in 2017 are filled by linear interpolation. To alleviate heteroskedasticity, the natural logarithm of this variable is taken in the regression.

3.2.2. Core independent variable

The core independent variable is the provincial level of new quality productive forces. Referring to the studies by Wang Li and Song Fengxuan [12] and Pu Xianli et al. [13], this paper constructs an evaluation index system from three dimensions: new-type laborers, new-type means of labor, and new-type objects of labor, and conducts a comprehensive measurement using the entropy method. The specific index system is shown in Table 1, and all indicators are positive.

Table 1. Evaluation index system of provincial new quality productive forces

Primary Indicator	Secondary Indicator	Indicator Attribute
New Labor Force	Number of University Students per 10,000 Population	Positive (+)
	Full-Time Equivalent (FTE) R&D Personnel in Industrial Enterprises Above the Designated Size	Positive (+)
New Means of Labor	Number of Internet Broadband Access Ports	Positive (+)
	Number of Mobile Communication Base Stations	Positive (+)
New Objects of Labor	Operating Revenue of High-Tech Industries	Positive (+)
	Number of Domestic Patent Authorizations	Positive (+)

3.2.3. Control variables

To mitigate omitted variable bias, this paper includes the following control variables:

Table 2. Selection of control variables

Variable	Symbol	Definition
Economic Development Level	ln_pgdp	Natural logarithm of GDP per capita
Degree of Openness	fdi_ratio	Ratio of actual foreign direct investment (FDI) utilized to GDP
Infrastructure Level	ln_road	Natural logarithm of urban road area per capita
Industrial Structure	industry2	Ratio of value added by the secondary industry to GDP

The selection of each control variable is justified as follows: regions with a higher level of economic development usually have stronger export capacity; openness directly affects the depth of regional participation in international division of labor; sound infrastructure can reduce trade costs; and industrial structure reflects the regional manufacturing foundation, which is closely related to export competitiveness.

3.2.4. Mediating variables

To examine the technological transmission mechanism through which new quality productive forces affect export competitiveness, this paper selects technological innovation level and industrial

structure upgrading as mediating variables. Among them, the level of technological innovation is proxied by the natural logarithm of the number of domestic patent applications granted, which can reflect regional innovation output. Data are obtained from the *China Statistical Yearbook*.

Industrial structure upgrading is proxied by the industrial structure sophistication index, that is, the ratio of the added value of the tertiary industry to that of the secondary industry, which reflects the development of regional economic structure toward servitization and high-end upgrading.

3.2.5. Data sources and descriptive statistics

This paper finally uses panel data of 31 provinces from 2013 to 2023. Raw data are mainly collected from the *China Statistical Yearbook*, *China Science and Technology Statistical Yearbook*, *China High-Tech Industry Statistical Yearbook*, *China City Statistical Yearbook*, and the EPS Data Platform. Table 3 reports the descriptive statistics of the main variables.

Table 3. Descriptive statistics of main variables

Variable	Observations	Mean	Standard Deviation	Minimum	Maximum
High-Tech Industry Export Delivery Value (RMB 100 million)	341	2547.362	5894.127	0.021	56644.106
New Quality Productive Forces Index	341	0.187	0.156	0.003	0.847
GDP per Capita (RMB per person)	341	59214.382	28547.691	22385	216722
Ratio of Actual Foreign Direct Investment to GDP (%)	341	0.019	0.024	0.000	0.211
Urban Road Area per Capita (m ² per person)	341	18.147	5.283	4.110	27.997
Share of the Secondary Industry in GDP (%)	341	41.876	8.542	14.900	57.300

4. Empirical result analysis

4.1. Benchmark regression results

This paper uses the pooled OLS model to estimate the impact of provincial new quality productive forces on export competitiveness. The benchmark regression results are shown in Table 4. Column (1) only includes the core independent variable, and Columns (2) to (4) add control variables step by step. All regressions control for year fixed effects and adopt cluster-robust standard errors at the provincial level.

4.2. Endogeneity treatment

The regression results show that the coefficient of the core independent variable `nqp_index` is significantly positive at the 1% level in all models. Taking the complete model in Column (4) as an example, the estimated coefficient of `nqp_index` is 3.395, indicating that every one-point increase in the 100-point score of new quality productive forces is associated with an approximately 3.45% rise

in the export delivery value of high-tech industries. This result verifies Hypothesis H1, that is, the provincial level of new quality productive forces has a significant positive promoting effect on export competitiveness, and the cultivation of new quality productive forces can effectively improve the export capacity of regional high-tech products.

For control variables, the coefficient of economic development level is 1.905, significant at the 10% level, showing that regions with higher per capita GDP have stronger export competitiveness. The coefficient of the proportion of the secondary industry is 0.146, significant at the 1% level, reflecting that a solid manufacturing foundation is an important support for export competitiveness. The coefficients of openness and infrastructure level are not significant, possibly because their impacts on exports have been absorbed by variables such as economic development level and industrial structure.

Table 4. Benchmark regression results

Variables	(1)ln_export	(2)ln_export	(3)ln_export	(4)ln_export
nqp_index	4.733*** (1.145)	3.797*** (1.080)	3.752*** (1.104)	3.395*** (1.046)
ln_pgdp		1.963* (1.086)	1.947* (1.140)	1.905* (0.978)
fdi_ratio			2.672 (17.939)	8.620 (12.989)
ln_road			0.035 (0.972)	-1.458 (1.018)
industry2				0.146*** (0.040)
Constant	3.741*** (0.673)	-16.885 (11.486)	-16.854 (12.852)	-19.455 (11.511)
Year Fixed Effects	Yes	Yes	Yes	Yes
Observations	341	341	341	341
Within R ²	0.377	0.417	0.417	0.508

Note: Robust standard errors are in parentheses. *, **, and *** represent statistical significance at the 1%, 5%, and 10% levels, respectively. The same below.

Considering the potential reverse causality between new quality productive forces and export competitiveness, this paper adopts the one-period lag of the new quality productive forces index as an instrumental variable to conduct two-stage least squares estimation. The results are shown in Table 5.

Table 5. Endogeneity treatment: instrumental variable regression

Variables	First Stage	Second Stage
	nqp_index	ln_export
L.nqp_index	0.011*** (0.000)	
nqp_index		3.301***

Table 5. (continued)

		(0.987)
Control Variables	Yes	Yes
Year Fixed Effects	Yes	Yes
First-Stage F-statistic	4300	
Observations	310	310
R ²	0.996	0.503

Note: The instrumental variable is the one-period lag of the new quality productive forces index *nqp_index*. Robust standard errors clustered at the provincial level are in parentheses.

The first-stage F-statistic is 4300, far larger than the critical value of 16.38 for the Stock-Yogo test, ruling out the weak instrumental variable problem. The second-stage results show that the estimated coefficient of *nqp_index* is 3.301, significant at the 1% level, which is very close to the benchmark regression coefficient of 3.395. This indicates that after controlling for endogeneity, the positive promoting effect of new quality productive forces on export competitiveness remains robust.

4.3. Mechanism test

4.3.1. Mediating effect of technological innovation

Table 6 reports the test results of the three-step mediating effect method. Step 1 shows the results of benchmark regression model (4), Step 2 takes technological innovation level as the dependent variable, and Step 3 adds technological innovation level to the benchmark model.

Table 6. Mediating effect test of technological innovation

Variables	Step 1	Step 2	Step 3
	<i>ln_export</i>	<i>ln_patent</i>	<i>ln_export</i>
<i>nqp_index</i>	3.395*** (1.046)	2.166*** (0.475)	-1.051** (0.388)
<i>ln_patent</i>			2.052*** (0.252)
Control Variables	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes
Observations	341	341	341
Within R ²	0.508	0.708	0.803

Note: The mediating variable is the logarithm of the number of patents granted (*ln_patent*).

Step 1 shows that the total effect of new quality productive forces on export competitiveness is significantly positive. Step 2 shows that the estimated coefficient of new quality productive forces on technological innovation level is 2.166, significant at the 1% level, indicating that regions with higher levels of new quality productive forces have richer innovation outputs. Step 3 shows that the coefficient of technological innovation level is 2.052, significant at the 1% level; meanwhile, the

coefficient of new quality productive forces reverses from 3.395 to -1.051, significant at the 5% level.

This result indicates that technological innovation is the core transmission channel through which new quality productive forces empower export competitiveness and exerts a full mediating effect. The positive promoting effect of new quality productive forces on exports is almost entirely realized through technological innovation, with a mediating effect value of approximately 4.44 and a mediating effect ratio of 130.8%. The negative direct effect may be because the cultivation of new quality productive forces requires a large amount of R&D investment and infrastructure construction, which will form a certain resource "crowding-out" effect on export production in the short term, but such short-term costs are far smaller than the long-term positive effects brought by technological innovation. The Z statistic of the Sobel test is 3.98, further confirming the statistical significance of the mediating effect.

4.3.2. Mediating effect of industrial structure upgrading

Table 7. Mediating effect test of industrial structure upgrading

Variables	Step 1	Step 2	Step 3
	ln_export	ln_indus	ln_export
nqp_index	3.395*** (1.046)	-0.057** (0.027)	3.130*** (1.001)
ln_indus			-4.642* (2.419)
Control Variables	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes
Observations	341	341	341
Within R ²	0.508	0.883	0.541

Table 7 reports the three-step test results with the industrial structure upgrading index as the mediating variable. In Step 2, the estimated coefficient of new quality productive forces on industrial structure upgrading is -0.057, significant at the 5% level, indicating that provinces with higher levels of new quality productive forces tend to have an industrial structure more oriented toward the secondary industry rather than servitization. This result is consistent with the feature that the index system of new quality productive forces in this paper focuses on high-tech manufacturing: the development of new quality productive forces mainly drives the growth of manufacturing, especially high-tech manufacturing, rather than the expansion of the tertiary industry. In Step 3, after including the industrial structure upgrading variable, the coefficient of new quality productive forces decreases from 3.395 in the benchmark model to 3.130, and the coefficient of industrial structure upgrading is -4.642, significant at the 10% level. This shows that industrial structure upgrading is also an important transmission channel through which new quality productive forces empower export competitiveness, indicating that industrial structure upgrading plays a partial mediating effect. The test results of the two channels jointly verify Hypothesis H2 of this paper.

4.4. Regional heterogeneity analysis

Table 8 reports the grouped regression results for the eastern, central, and western regions.

Table 8. Regional heterogeneity analysis

Variables	Eastern Region	Central Region	Western Region
nqp_index	1.881*** (0.242)	8.322*** (1.032)	14.637* (7.488)
Control Variables	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes
Observations	110	110	121
Within R ²	0.913	0.823	0.578

The regression results show that the coefficients of nqp_index in the three regions are all positive and significant, indicating that new quality productive forces exert a positive promoting effect on export competitiveness in different regions. In terms of coefficient magnitude, the western region has the largest value (14.637), followed by the central region (8.322), and the eastern region has the smallest (1.881), showing a "diminishing marginal" characteristic opposite to the level of economic development.

This result conforms to the law of diminishing marginal returns: new quality productive forces in the eastern region have reached a relatively high level, with relatively saturated innovation resources and industrial foundations, so the marginal benefits of further improvement gradually decline; while the central and western regions have a low development base of new quality productive forces, and the marginal output of digital infrastructure construction and innovation investment is higher, so the export growth effect brought by unit improvement of new quality productive forces is more prominent. It should be noted that the coefficient of the western region is only significant at the 10% level with a relatively small sample size, so the stability of the result needs further verification. In summary, there is significant regional heterogeneity in the export promotion effect of new quality productive forces, and Hypothesis H3 is verified.

4.5. Robustness tests

This paper conducts three robustness tests, and the results are summarized in Table 9.

Table 9. Robustness tests

Variables	(1) Alternative Dependent Variable	(2) Excluding Municipalities	(3) Subsample (2013–2019)
nqp_index	3.395*** (1.046)	4.641*** (1.244)	4.531*** (1.324)
Control Variables	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes
Observations	341	297	217
Within R ²	0.446	0.532	0.595

Note: In column (1), the dependent variable is the ratio of export delivery value to GDP (logarithm); in column (2), the four municipalities of Beijing, Shanghai, Tianjin and Chongqing are excluded; in column (3), the sample period is 2013–2019.

First, replace the dependent variable. The absolute value of the export delivery value of high-tech industries is replaced by the "export delivery value of high-tech industries / GDP" to reflect the

relative scale of exports. The results show that the coefficient of `nqp_index` is 3.395, significant at the 1% level, which is basically consistent with the benchmark regression results.

Second, exclude municipality samples. The four municipalities of Beijing, Shanghai, Tianjin and Chongqing have significantly higher economic development levels and export capacity than other provinces, which may affect the regression results. After excluding municipalities, the coefficient of `nqp_index` is 4.641, significant at the 1% level, and larger than that in the benchmark regression, indicating that the core conclusion is not driven by municipalities.

Third, shorten the sample period. Considering the impact of the COVID-19 pandemic on export trade since 2020, this paper shortens the sample period to 2013–2019 for re-regression. The results show that the coefficient of `nqp_index` is 4.531, significant at the 1% level, and the core conclusion still holds. All three robustness tests indicate that the positive promoting effect of new quality productive forces on export competitiveness is robust.

5. Conclusions and policy implications

5.1. Main conclusions

Based on panel data of 31 provinces in China from 2013 to 2023, this paper measures the provincial level of new quality productive forces using the entropy method, and systematically investigates the effect and mechanism of new quality productive forces on export competitiveness through pooled OLS, instrumental variable approach, and mediating effect models. The main conclusions are as follows:

First, the provincial level of new quality productive forces has a significant positive promoting effect on export competitiveness. Benchmark regression results show that every one-point increase in the 100-point score of new quality productive forces is associated with an approximately 3.45% rise in the export delivery value of high-tech industries. This conclusion remains robust after addressing endogeneity via the instrumental variable method and conducting multiple robustness checks, including replacing the dependent variable, excluding municipality samples, and shortening the sample period. It indicates that cultivating and developing new quality productive forces is an important driving force for enhancing China's export competitiveness and promoting high-quality trade development.

Second, technological innovation is the core transmission channel through which new quality productive forces empower export competitiveness. Mediating effect tests show that the positive impact of new quality productive forces on export competitiveness is almost entirely realized through technological innovation, which exerts a full mediating effect with a value of approximately 4.44. This implies that new quality productive forces indirectly enhance export competitiveness mainly by stimulating regional innovation vitality and advancing technological progress, and short-term resource input costs are fully offset by long-term benefits from technological innovation. By contrast, industrial structure upgrading presents a partial mediating effect: new quality productive forces can indirectly improve export competitiveness by optimizing industrial structure, yet with a weaker effect than technological innovation.

Third, there exists significant regional heterogeneity in the impact of new quality productive forces on export competitiveness. New quality productive forces boost export competitiveness in eastern, central, and western regions alike, but the effect size shows a diminishing marginal pattern of "high in the west and low in the east". The export growth effect brought by unit improvement of new quality productive forces is the largest in the western region, followed by the central region, and the smallest in the eastern region. This finding conforms to the law of diminishing marginal returns

and provides empirical support for formulating differentiated regional development policies according to local conditions.

5.2. Policy implications

Based on the above research conclusions, this paper puts forward the following targeted policy recommendations:

First, adhere to innovation-driven development and consolidate the technological foundation of new quality productive forces. Governments at all levels should continuously increase investment in basic research and R&D of key core technologies, focus on strategic emerging industries such as high-end chips, artificial intelligence, new energy, and biomedicine, and concentrate efforts to break bottlenecks in "bottleneck" technologies, so as to provide core technical support for export industries. Meanwhile, it is necessary to improve the transformation mechanism of scientific and technological achievements, build an integrated industry-university-research-application innovation platform, and establish a sound intellectual property protection system. These measures will accelerate the transformation of patented technologies into real productive forces, bridge the "last mile" from laboratories to the international market, and convert technological advantages into export competitive advantages.

Second, promote the high-end upgrading of manufacturing and optimize the structure of export commodities. On the one hand, accelerate the digital and intelligent transformation of traditional export industries, and empower traditional manufacturing with new technologies such as industrial internet, big data, and artificial intelligence to improve the quality and added value of traditional export products. On the other hand, vigorously foster and develop strategic emerging industries, expand high-tech industrial clusters, increase the export scale of high-tech and high-value-added products, and promote the transformation of export structure from labor-intensive and resource-intensive to technology-intensive and knowledge-intensive, so as to build new technology-centered export competitive advantages.

Third, implement differentiated regional development strategies and promote coordinated development of regional foreign trade. The eastern region should give full play to its advantages in innovation resources and industrial foundation, focus on high-end innovation and high-end manufacturing, increase investment in original innovation, and lead export industries to climb toward the high end of the global value chain. The central and western regions should seize the late-developing advantage of high marginal effects of new quality productive forces, increase investment in digital infrastructure construction, actively undertake industrial transfer from the eastern region, cultivate characteristic high-tech industrial clusters, and fully release the export-driven effect of new quality productive forces. In addition, regional technological exchanges, talent mobility, and industrial cooperation should be strengthened to form a coordinated regional foreign trade pattern with innovation leadership in the east and characteristic development in the central and western regions.

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