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The Role of New-Quality Productivity in the Sustainable Development of the Economic–Social–Environmental System: Evidence from 67 Ethnic Counties in Sichuan Province

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Abstract

Fostering and steering New-Quality Productivity (NQP) to underwrite the sustainable development of the Economic–Social–Environmental System (ESES) in ethnic-minority regions is both an intrinsic requirement and a strategic fulcrum for advancing modernization at the sub-national level. Despite growing policy attention, county-level evidence on how NQP translates into sustainability outcomes—and through which mechanisms—remains insufficient. Embedding NQP within a region-specific sustainability framework, this study first articulates the theoretical channels through which NQP can transform and sustain ethnic areas. It then exploits panel data covering 67 ethnic counties in Sichuan Province from 2005 to 2024 and applies benchmark regressions, multiple-mediator models, and spatial Durbin specifications to identify the mechanisms and impact footprints of NQP. Three core findings emerge: (1) NQP exerts a robust, positive effect on ESE sustainability that varies across geography, development stages, and sectoral structures. (2) Technological innovation, industrial upgrading, and optimized resource allocation all transmit NQP's influence, with industrial upgrading displaying the strongest mediating power. (3) NQP generates positive spatial spillovers that extend its sustainability dividends to neighboring ethnic counties. These results sharpen the academic understanding of the NQP–sustainability nexus in ethnic contexts, expand NQP assessment frameworks, and furnish county-level policymakers with evidence to design differentiated strategies that align NQP cultivation with broader goals of regionally inclusive and sustainable development.

Keywords: new-quality productivity; ethnic areas; economic–social–environmental system; sustainable development

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1. Introduction

Ethnic areas, as an important part of a country, hold unique positions and values in the economy, culture, ecology, and other aspects. Their sustainable development is of great significance to the overall development of the country [1]. The sustainable development of the Economic–Social–Environmental System (SDESES) emphasizes that the interconnection and coordinated development among the economy, society, and environment are key to achieving sustainable development. This concept is particularly important in ethnic areas, which often face issues such as relatively lagging economic development, complex social structures, and fragile ecological environments. Sichuan Province, as one of the

important representatives of China's ethnic areas, boasts rich ethnic resources and a unique geographical environment. Due to the wide distribution of ethnic minorities, uneven economic development levels, diverse and complex social structures, and unique ecological characteristics in Sichuan, it is representative not only in China but also in the global context of ethnic areas. From an international perspective, the sustainable development practices in China's ethnic areas provide valuable experience and reference for other multi-ethnic countries and regions around the world [2].

However, a critical review of existing literature reveals three key gaps that limit the understanding of the sustainable development of the Economic–Social–Environmental System (ESES) in ethnic regions. First, most studies focus on macro scales or developed regions [3,4], with insufficient spatial focus on county-level ethnic areas—these micro-units bear the most direct pressure of balancing economic growth, social stability, and ecological protection, yet their specific characteristics are often overlooked. Second, existing research on New-Quality Productivity (NQP) mainly links it to industrial upgrading or economic efficiency [5], lacking exploration of its mediating mechanisms in the ESES. Third, limited studies have addressed regional differentiation in ethnic areas; most adopt a uniform analytical framework, failing to account for varied development stages and resource endowments across different ethnic counties. These gaps highlight the need for targeted research on county-level ethnic regions to enrich the sustainable development literature.

To lay a solid theoretical foundation for this study and clarify the analytical framework, this paper will elaborate in depth from the conceptual and theoretical perspectives. First, the understanding of NQP must be rooted in existing theoretical contexts. NQP is not an isolated concept; it is essentially the integration and deepening of theories such as the innovation-driven development theory, the total factor productivity framework, and the green growth theory in the new era [6]. Its "newness" lies in taking scientific and technological innovation as the core driver, and its "quality" lies in pursuing high efficiency, high quality, and sustainability of development. This goes beyond the traditional classical productivity paradigm that mainly relies on factor input, representing an advanced form of productivity evolution [7]. Second, this paper examines NQP within the overall framework of the ESES, rather than treating it merely as a measurement indicator. We focus on exploring the dynamic interaction between NQP and the three subsystems of ESE, especially the synergistic effects and trade-offs it generates [8,9]. For instance, industrial upgrading oriented by NQP may not only promote economic growth but also bring challenges such as resource pressure or social structure adjustment in the short term [8]. Recognizing and analyzing these inherent complexities will enable this study to avoid the limitations of linear narratives and better align with the dialectical viewpoints of sustainable development theory regarding system coupling and contradiction transformation, thereby constructing a solid theoretical analytical framework that connects NQP with the sustainable and coordinated development of ESES (Figure 1).

Many countries and regions also face similar development challenges, such as unbalanced economic development and the integration of multicultural societies [10]. The exploration and practice of China's ethnic areas in the sustainable development of the Economic–Social–Environmental System can provide useful references for other countries and regions and promote the achievement of global sustainable development goals [11].

In addition, the sustainable development of China's ethnic areas is highly consistent with the United Nations Sustainable Development Goals (SDGs). The SDGs emphasize multiple aspects, including eradicating poverty, reducing inequality, promoting economic growth, and protecting the ecological environment. In January 2021, the Chinese government officially established the National Rural Revitalization Agency [12], which marked

the full implementation of the Rural Revitalization Strategy. This initiative is a concrete practice of the SDGs. Therefore, taking the ethnic areas of Sichuan Province as a research sample to explore the relationship between NQP and ESEs at the county level not only contributes to the sustainable development of urban and rural areas in China but also provides empirical support and policy recommendations for the achievement of global sustainable development goals.



Figure 1. Conceptual framework of this study.

Against the above research gaps, this study's novelty lies in three distinctive designs. First, it narrows the spatial focus to the county level—specifically 67 ethnic counties in Sichuan—to address the lack of micro-scale research in existing literature, as county governments are the primary implementers of sustainable development policies in ethnic areas. Second, it constructs a multi-dimensional analytical framework that integrates NQP with the ESE system, rather than single economic or environmental dimensions, to clarify the mediating mechanisms (technological innovation, industrial upgrading, resource allocation optimization) linking NQP to coordinated ESE development. Third, it emphasizes regional differentiation by analyzing heterogeneous effects of NQP across counties with different development stages, filling the gap of uniform analysis in prior studies.

The potential marginal contributions of this paper include the following:

(1) **Filling the spatial and dimensional gaps in the literature:** By incorporating NQP into the sustainable development framework of the county-level ESEs in ethnic areas, it expands the existing theoretical system beyond macro scales and single dimensions. This new perspective clarifies how NQP empowers ESE coordination in regions with complex social structures and fragile ecosystems, addressing the lack of micro-scale and multi-dimensional research.

(2) **Complementing the missing mediating mechanisms:** It systematically explores the multi-path mechanisms (technological innovation, industrial upgrading, resource allocation optimization) through which NQP affects ESEs' sustainable development. This clarifies the complex interaction between NQP and sustainable growth, filling the gap of insufficient mechanism analysis in prior studies.

(3) **Addressing the limited regional differentiation:** The findings guide county-level governments to formulate differentiated strategies based on local development stages. By clarifying the heterogeneous effects of NQP, it helps narrow the gap between ethnic and developed regions, addressing the uniform analytical framework in existing research, and promoting balanced regional development.

2. Theoretical Analysis and Research Hypothesis

Under the context of globalization and the knowledge economy, the relationship between productivity, technological innovation, and sustainable development has become one of the core topics of concern in the international academic community. The neoclassical growth model incorporated technological progress into the core variables of long-term economic growth for the first time, laying the theoretical foundation for subsequent studies [13]. Subsequently, Romer (1990) [14], Aghion & Howitt (1992) [15] further emphasized through the endogenous growth theory that knowledge accumulation and innovation are the key mechanisms driving sustainable growth. In the field of sustainable development, Porter & van der Linde (1995) [16] proposed the concept of "green competitiveness", arguing that environmental regulations can achieve a win-win situation for both the environment and the economy by stimulating corporate innovation. Later, the OECD (2001) [17] incorporated "green total factor productivity" into the sustainable development evaluation system, emphasizing the importance of ecological efficiency and optimal resource allocation. In recent years, with the integration of digital technology and green technology, scholars have begun to focus on the sustainability effects of the NQP. Mazzucato (2018) [18] pointed out that promoting green transformation through mission-oriented innovation policies can realize the coordinated evolution of structural upgrading and ecological governance.

2.1. The Direct Impact of New-Quality Productivity on the Sustainable Development of ESEs

The NQP, as an advanced form of productivity with technological innovation as its core driving force [19], has a far-reaching impact on the ESEs. From an economic perspective, NQP relies on emerging technologies such as digital technology to promote the transformation of traditional industries towards intelligence and green-oriented models [20]. It also gives birth to new industries and business forms, thereby improving production efficiency [21], creating new economic growth points, and fostering sustainable economic growth [22,23]. In the social sphere, the development of NQP can create more high-quality jobs, improve the quality of life for residents, and promote social equity and stability [24]. From an environmental point of view, NQP focuses on green and low-carbon development models, which help to reduce resource consumption and environmental pollution and promote the improvement of the ecological environment [25]. Therefore, in the ethnic areas of Sichuan Province, the introduction of NQP is expected to break through the constraints of the traditional development model on ESEs and achieve sustainable development of the economy, society, and environment.

From the perspective of system theory, ESE systems are complex adaptive systems formed by the coupling of economic subsystems, social subsystems, and ecological subsystems. As an external "new driver" of the system, the introduction of NQP not only changes the state of a single subsystem but also reshapes the system structure through nonlinear feedback mechanisms. The integration of digital technology into traditional industries not only improves economic efficiency (economic subsystem) but also achieves the coordinated evolution among subsystems by creating new jobs (social subsystem) and reducing pollutant emissions (ecological subsystem). Therefore, NQP is not a simple "input–output" relationship, but an order parameter that triggers system leapfrogging.

Based on this, this paper proposes

Hypothesis 1. *NQP has a positive driving effect on the sustainable development of ESEs.*

2.2. Heterogeneous Effects of New-Quality Productivity on Sustainable Development of ESEs

The impact of NQP on the ESEs is not uniform but heterogeneous. In terms of regional development, China faces prominent issues of unbalanced and inadequate

regional development [26]. There are differences in resource endowments, industrial structures, and policy environments across regions, leading to regional variations in the implementation paths and development models of NQP. In the ethnic areas of Sichuan Province, such regional differences may be more pronounced. Disparities in economic development levels, infrastructure, and the ability to accept and apply NQP among different ethnic areas can affect the effectiveness of NQP in driving ESEs. From an industry perspective, different industries may also respond differently to NQP. Emerging industries, such as the digital economy [27], can quickly absorb the achievements of NQP and develop rapidly. In contrast, traditional industries, such as agriculture [28], may need more time to adapt and transform. Moreover, the components of NQP, such as human capital, technological equipment, and industrial forms, also have heterogeneous impacts on ESEs [29].

Complex systems theory states that the response of a system to external shocks is characterized by path dependence and sensitivity to initial conditions. Due to institutional embeddedness, cultural diversity, and differences in resource endowments, ethnic regions exhibit significant variations in their absorption capacity for NQP. For instance, Tibetan-inhabited areas show a lagged response to the diffusion of digital technology, primarily due to barriers in language and digital skills; in contrast, Qiang-inhabited areas, dominated by the tourism industry, are more sensitive to the integration of green technology. Therefore, the sustainable effect of NQP is not evenly distributed, but rather a selective coupling result filtered by the system's initial conditions and institutional environment.

Based on this, this paper proposes

Hypothesis 2. *The impact of NQP on ESEs has regional and structural heterogeneity.*

2.3. Pathways of the Impact of New-Quality Productivity on Sustainable Development of ESEs

The impact of NQP on the ESEs is mainly realized through the following pathways. First, technological innovation, as the core driving force of NQP, can promote technological progress and innovative applications. This enhances production efficiency and reduces production costs, thereby fostering sustainable economic development [30]. At the same time, technological innovation also provides new means to solve social and environmental problems, such as intelligent transportation systems and clean energy technologies, which help to improve social welfare and the ecological environment. Second, industrial upgrading is an important way for NQP to promote the sustainable development of ESEs. NQP can optimize the industrial structure; reduce dependence on traditional resource-based industries; and develop high-value-added, low-pollution emerging industries. This can achieve the optimization and upgrading of the economic structure, and also help to relieve social employment and environmental pressures. Finally, NQP can improve the efficiency of resource utilization and reduce resource waste by optimizing the allocation of resource factors [31], thus promoting the sustainable development of the economy, society, and environment. In the ethnic areas of Sichuan Province, the specific implementation of these pathways may vary from region to region and needs to be combined with the local situation to develop targeted strategies.

Systems theory holds that external driving forces must be transmitted through internal "mediating variables" of the system. In ethnic regions, NQP cannot act directly on ESEs; instead, it needs to rely on the following three types of mediating mechanisms: (1) technological innovation → enhancing the system's "information processing efficiency" (e.g., digital platforms reducing transaction costs); (2) industrial upgrading → reconstructing the system's "structural coupling mode" (e.g., eco-tourism replacing high-pollution industries); (3) resource allocation → optimizing the system's "energy flow path" (e.g., intelligent water

resource scheduling reducing waste). These three mechanisms together form an "internal system converter," which transforms NQP into "negative entropy flow" for the sustainable system, thereby delaying system collapse.

Based on this, this paper proposes

Hypothesis 3. *NQP affects the sustainable development of ESEs through three channels: technological innovation, industrial upgrading, and optimization of resource allocation.*

2.4. The Spatial Spillover Effect of New-Quality Productivity on the Sustainable Development of ESEs

Ethnic regions are not isolated systems, but form a "regional system network" with surrounding areas through population migration, trade flow, and institutional learning. The NQP not only affects local ESEs but may also influence the ESEs of surrounding areas through spatial spillover effects. On the one hand, the development of NQP can attract the agglomeration of factors such as talent, capital, and technology, thereby driving the economic development and social progress of surrounding areas. On the other hand, the innovative achievements and advanced experiences of NQP can promote industrial upgrading and technological innovation in surrounding areas and improve the regional ecological environment through technology spillover, industrial linkages, and market diffusion. In addition, the development of NQP can also strengthen economic ties and cooperation between regions, promote regional integration, and thus achieve sustainable regional economic, social, and environmental development. In the ethnic areas of Sichuan Province, this spatial spillover effect may be of great significance for promoting regional sustainable development and helping narrow the development gap between different ethnic areas.

Based on this, this paper proposes

Hypothesis 4. *NQP has a spatial spillover effect on the sustainable development of ESEs.*

3. Materials and Methods

3.1. Study Area and Data Source

3.1.1. Study Area

The study area is the 67 ethnic county-level administrative units in Sichuan Province (Figure 2), mainly in the western Sichuan Plateau and basin-surrounding mountains, including Garze, Aba, and Liangshan Prefectures, where Tibetans, Yi, Qiang, and Miao live. These regions have complex terrain, diverse ecosystems, rich natural resources, but low economic development with an agriculture- and animal husbandry-based industrial structure. Although there has been progress in infrastructure and characteristic industries in recent years, they still face challenges like inconvenient transportation, a single-industry structure, and talent shortage. Socially and culturally, each ethnic group has unique languages, clothing, and customs, and there are rich tourism resources. However, social undertakings such as education and medical care lag far behind other regions.

In recent years, the central and local governments have introduced policies like increasing financial transfer payments, strengthening infrastructure, and promoting characteristic industries [32], which have effectively improved education and medical conditions in these areas. The 67 ethnic county-level administrative units in Sichuan Province are unique due to their complex geography, rich ethnic culture, and weak economic foundation. When studying the impact of NQP on ESEs, the region's particularity must be considered, and innovative paths for ethnic areas should be explored. This study is significant for promoting coordinated development in ethnic areas and achieving sustainable economic, social, and

environmental development. It can offer a scientific basis for ethnic area policymaking and promote high-quality development in these regions.

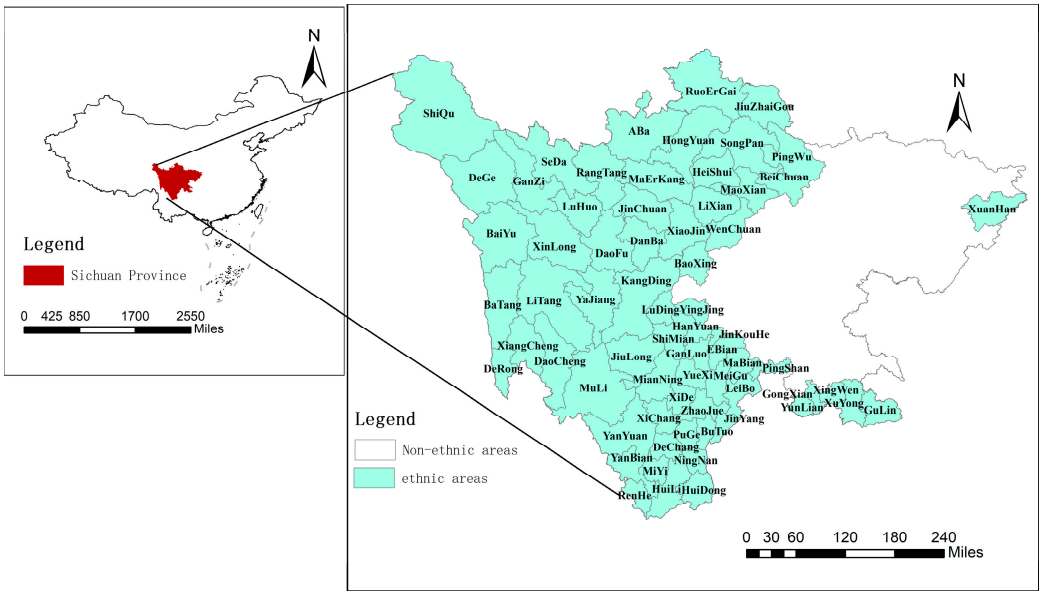


Figure 2. Location of the study area in China (mapping based on the ArcGIS10.8 software can be obtained from the following link, https://desktop.arcgis.com, accessed on 5 September 2025).

3.1.2. Data Source

The research data used in this paper mainly include two aspects: to evaluate the development level of NQP (Table A1) and to measure the SDESEI (Table A2). Based on the principle of data availability, this paper selects panel data from various sources, such as the county-level statistical yearbooks, national economic and social development statistical bulletins, ecological and environmental bulletins, and the China Statistical Yearbook from 2005 to 2024. To ensure temporal consistency, the research period is defined as 2004 to 2023, as data published in Chinese statistical yearbooks typically pertain to the preceding year.

3.2. Methods

In this study, first, the entropy weight method was used to measure the level of NQP and the SDESEI for each county from 2004 to 2023. Prior to the entropy weight calculation, a Pearson correlation analysis was conducted to examine multicollinearity among indicators, and highly correlated variables ($|r| > 0.8$) were excluded to ensure robustness [33]. All remaining indicator data were then normalized to eliminate dimensional differences [1]. For cases of missing data within the time series, linear interpolation was applied to ensure dataset completeness. Finally, a sensitivity analysis was performed to validate the stability of the derived entropy weights. Then, the following methods were comprehensively employed to conduct further research. The software used in this paper mainly included Stata 18, ArcGIS 10.8, and Origin (https://www.originlab.com, accessed on 8 September 2025).

3.2.1. Benchmark Regression Model

To measure the impact of NQP in ethnic county areas on the sustainable development level of the ESEs and to mitigate the bias caused by multicollinearity, a multivariate regression method was applied to the panel data. This approach examines the role of technological innovation (TI), industrial upgrading (IU), and resource allocation (RE) in the

relationship between NQP and the sustainable development of ESEs. For Hypothesis 1, the following panel benchmark regression model was established:

$$SDESEI_{it} = \alpha_0 + \alpha_1 NQP_{it} + \gamma control_{it} + \mu_{it} + \lambda_{it} + \varepsilon_{it} \quad (1)$$

In Equation (1), $SDESEI_{it}$ and NQP_{it} represent the Sustainable Development of the Economic–Social–Environmental System Index and the level of New-Quality Productivity for County i in year t, respectively. *control* is the set of control variables that affect the sustainable development of ESEs. α_0 is the constant term. α_1 represents the coefficient of the impact of NQP on the sustainable development of ESEs, while γ represents the coefficients of the impact of the control variables on the sustainable development of ESEs. μ is the regional fixed effect, λ is the time fixed effect, and ε is the random disturbance term.

3.2.2. Multiple Mediator Effect Model

Based on the aforementioned theoretical analysis, NQP may promote the sustainable development of the ESEs through three pathways: technological innovation, industrial upgrading, and resource allocation. To test this hypothesis, a multiple mediator effect model is constructed to examine the impact of NQP on the sustainable development level of ESEs (Figure 3).

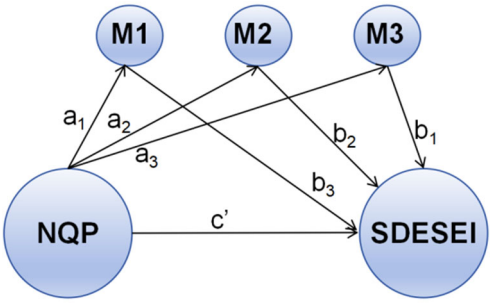


Figure 3. Schematic diagram of multiple mediator effects [34]. Note: M1, M2, and M3 represent the three mediator variables of technological innovation, industrial upgrading, and resource allocation, respectively.

In this model, the mediator effects can be described as follows:

1. Specific Path Mediator Effects: These include the mediator effects of technological innovation (a_1b_1), industrial upgrading (a_2b_2), and resource allocation (a_3b_3). The mechanism analysis indicates that the mediator effect of technological innovation is mainly reflected in the capital crowding-out effect. The mediator effect of industrial upgrading is manifested in the process where NQP promotes the shift in ethnic areas from low-technology, low-value-added industries to high-technology, high-value-added industries, along with changes in the scale, quality, and sustainability of the economy. The mediator effect of resource allocation is primarily reflected in the improvement of resource allocation efficiency and the enhancement of resource utilization efficiency.

2. Comparative Mediator Effects: a_1b_1–a_2b_2, a_1b_1–a_3b_3, a_2b_2–a_3b_3, respectively, represent the differences between the abovementioned three types of mediator effects.

3. Overall Mediator Effect: The development level of NQP acts on the sustainable development level of the ESE system through the three mediator variables of technological innovation, industrial upgrading, and resource allocation, forming the overall mediator effect ($a_1b_1 + a_2b_2 + a_3b_3$). This effect reflects the comprehensive promoting effect of NQP on the sustainable development of the ESE system, which is not only dependent on a single path but also achieved through the synergistic action of multiple paths.

In addition to the abovementioned mediator effects, NQP also has a direct effect on the sustainable development of the ESE system, namely c′ in Figure 3. Based on the above analysis, the following multiple mediator effect model was constructed:

$$TI_{it} = \beta_{01} + \beta_{11} NQP_{it} + \beta_{21} control_{it} + \varepsilon_{it} \quad (2)$$

$$IU_{it} = \beta_{02} + \beta_{12} NQP_{it} + \beta_{22} control_{it} + \varepsilon_{it} \quad (3)$$

$$RE_{it} = \beta_{03} + \beta_{13} NQP_{it} + \beta_{23} control_{it} + \varepsilon_{it} \quad (4)$$

$$SDESEI_{it} = \gamma_0 + \gamma_1 NQP_{it} + \gamma_2 TI_{it} + \gamma_3 IU_{it} + \gamma_4 RE_{it} + \gamma_5 control_{it} + \mu_{it} + \lambda_{it} + \varepsilon_{it} \quad (5)$$

where TI, IU, and RE represent the variables of technological innovation, industrial upgrading, and resource allocation, respectively. β_{01}, β_{02}, β_{03}, and γ_0 are all constant terms, while β_{11}, β_{12}, β_{13}, and $\gamma_1, \cdots, \gamma_5$ are the coefficients corresponding to each variable. When the coefficient α_1 in model (1) is significant, it indicates that NQP has an impact on the sustainable development of the ESEs. When the coefficient β_{11}, β_{12}, β_{13} is significant, it suggests that NQP affects the mediator variables. Based on this, when the coefficient γ_2 is significant and γ_1 is not significant or has a coefficient smaller than α_1, it indicates the presence of a mediator effect.

3.2.3. Spatial Durbin Models

To further verify the spatial spillover effect of NQP on the sustainable development of the ESEs, the spatial Durbin model is constructed:

$$\begin{aligned} SDESEI_{it} &= \rho_0 + \rho_1 \omega SDESEI_{it} + \rho_2 \omega NQP_{it} + \rho_3 NQP_{it} \\ &+ \rho_4 \omega control_{it} + \rho_5 control_{it} + \mu_{it} + \lambda_{it} + \varepsilon_{it} \end{aligned} \quad (6)$$

where ρ_1 is the spatial autoregressive coefficient. ρ_2, ρ_4 are the elasticity coefficients of the spatial interaction terms for the core explanatory variable and control variables, respectively. ρ_3, ρ_5 represent the coefficients of the corresponding variables. ω is the spatial weight matrix, the calculation method of which is based on the latest research by Du et al. (2025) [1].

3.3. Variable Measurement and Description

3.3.1. Dependent Variable: SDESEI

In this study, the dependent variable is the Sustainable Development Index of the Economic–Social–Environmental System (SDESEI) in ethnic areas. The SDESEI is a comprehensive indicator that measures the sustainable development of the three subsystems—economy, society, and environment—in ethnic areas and can fully reflect the overall sustainable development capacity of these regions. Guided by the SDGs, we constructed a comprehensive measurement index system (Table A1). To scientifically and objectively calculate the SDESEI, we employed the entropy weight method. The entropy weight method is a multi-attribute decision-making analysis approach based on information entropy. It can determine the weights of various indicators according to their degree of dispersion, avoiding the interference of subjective factors in the weight allocation and thus more accurately reflecting the importance of each indicator in the system's sustainable development. For the specific calculation process of this method, we refer to the study by Tai et al. (2020) [35].

Before applying the entropy weight method, considering the differences in the dimensions of the index system, we standardized the raw data following the approach of Yang et al. (2024) [36].

3.3.2. Explanatory Variable: NQP

New-Quality Productivity, as an advanced form of productivity with innovation as its core driving force, is mainly characterized by high technology, high efficiency, and high quality. It focuses on the structural optimization and synergistic enhancement of human capital, means of production, and objects of labor. Its development logic originates from production technology innovation, reorganization of production factors, and industrial upgrading. Based on previous studies [37,38], this paper constructs a multi-level, multi-dimensional index system for evaluating the level of NQP from four aspects: new-type laborers, new-type labor tools, new-type objects of labor, and the optimized combination of production factors (Table A2). The entropy weight method is employed to measure the level of NQP.

3.3.3. Mediator and Control Variables

The mediator variables include technological innovation (TI), industrial upgrading (IU), and resource element allocation (RE). Technological innovation is represented by the number of patent applications per capita. Industrial upgrading is measured using the index of industrial structure upgrading, which depicts the evolution of the industrial structure from the primary stage to the advanced stage. Resource allocation is indicated by the efficiency of factor allocation.

To more effectively conduct the effect analysis of NQP empowering the sustainable development of ESEs, this study selects population density (POP), government fiscal expenditure (GFE), and the number of large-scale industrial enterprises (LIEs) as control variables. Among them, government fiscal expenditure is represented by the proportion of local government fiscal expenditure in GDP. Table 1 reports the descriptive statistical analysis results of all variables.

Table 1. Descriptive statistical analysis of variables.

Variables Type	Variable Name	Code	Mean	Std.	Min	Max	Obs.
Dependent Variable	Index of Sustainable Development of the Economic–Social–Environmental System	SDESEI	0.418	0.137	0.117	0.856	1340
Independent Variable	New-Quality Productivity	NQP	0.282	0.131	0.076	0.733	1340
Mediating Variables	Technological Innovation	TI	1.053	1.287	0.054	8.681	1340
	Industrial Upgrading	IU	2.303	0.135	0.108	0.757	1340
	Resource Element Allocation	RE	7.141	5.93	0.647	34.47	1340
Control Variables	Population Density	POP	209.887	715.967	6.711	2047.334	1340
	Government Fiscal Expenditure	GEF	0.186	0.043	0.061	0.343	1340
	Number of Large-Scale Industrial Enterprises	LIE	30	20	0	108	1340

4. Results and Analysis

4.1. Spatial–Temporal Characteristics of NQP and SDESEI

The entropy weight method was used to obtain the measurement results of NQP and SDESEI for the 67 ethnic areas in Sichuan Province from 2004 to 2023. Figure 4 reports the average development trends of these two indicators in the region. As can be seen from the figure, during 2004–2023, the NQP and the SDESEI in the 67 ethnic counties of Sichuan Province showed a trend of co-evolution: (1) NQP increased from 0.205 to 0.426, with an average annual growth rate of 4.12%. (2) SDESEI rose from 0.326 to 0.604, with an average annual growth rate of 3.37%. After 2019, a "catch-up effect" emerged. The growth rate of

SDESEI surpassed that of NQP by 0.8 percentage points during 2020–2023. This reflects that after the ethnic counties were lifted out of poverty, the social–environment subsystems' shortcomings were accelerated to be remedied.

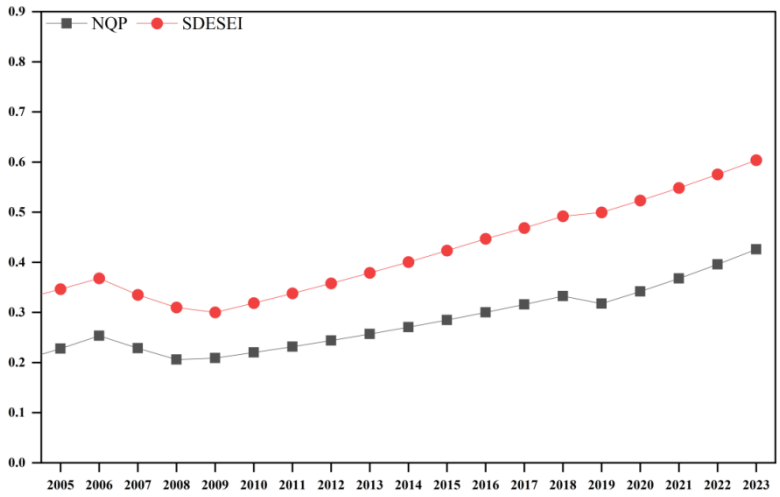


Figure 4. The development trends of NQP and SDESEI in ethnic areas of Sichuan Province from 2005 to 2023 (mapping based on the Origin software can be obtained from the following link: https://www.originlab.com, accessed on 8 September 2025).

To further observe the spatial distribution patterns of NQP and SDESEI, this paper used the natural breaks classification method in ArcGIS 10.8 software to divide NQP and SDESEI into five levels based on their values: very high (0.8–1.0), high (0.6–0.8), medium (0.4–0.6), low (0.2–0.4), and very low (0–0.2). The results for selected years were visualized in ArcGIS 10.8, as shown in Figure 5. Figure 5 reveals that both NQP and SDESEI in the ethnic areas of Sichuan Province have exhibited significant spatiotemporal evolution characteristics over the past two decades.

On the one hand, in 2004, the overall level of NQP in the ethnic areas of Sichuan Province was relatively low, with 91% of counties in the "very low" and "low" categories, and only 9% of counties in the "medium" category. By 2010, with improvements in some regions, especially those near Chengdu, counties with "medium"-level NQP began to emerge, increasing to 22% of the total, while the proportion of counties in the "very low" and "low" categories decreased to 72%. In 2016, the distribution of NQP further improved, with an increase in the number of counties at medium and above-medium levels. The Chengdu Plain and southern Sichuan showed a clear regional agglomeration effect. The proportion of counties at the "medium" level rose to 36%, and counties at the "high" level appeared for the first time, accounting for about 6%. By 2020, the spatial distribution of NQP had become more balanced, with an increase in the number of counties at medium and high levels, indicating the widespread development of NQP in the ethnic areas of Sichuan Province. The number of counties at the "high" level increased significantly, rising to 22%, while those at the "medium" level accounted for 39%. This change may be related to the "Several Policy Measures to Support the Development of New Energy and Intelligent Automobile Industry in Sichuan Province" issued by the Sichuan Provincial People's Government [39], especially the special support for the hydrogen energy and fuel cell automobile industry, which helps promote the development of NQP. By 2023, the distribution of NQP had reached the highest level, with counties at the "very high" level emerging for the first time, mainly concentrated in the Chengdu Plain and southern Sichuan, indicating that NQP in these areas had reached a relatively high level. The proportion of counties at the "high" level rose to 31%, and those at the "very high" level appeared for the first time, accounting for about 6%.

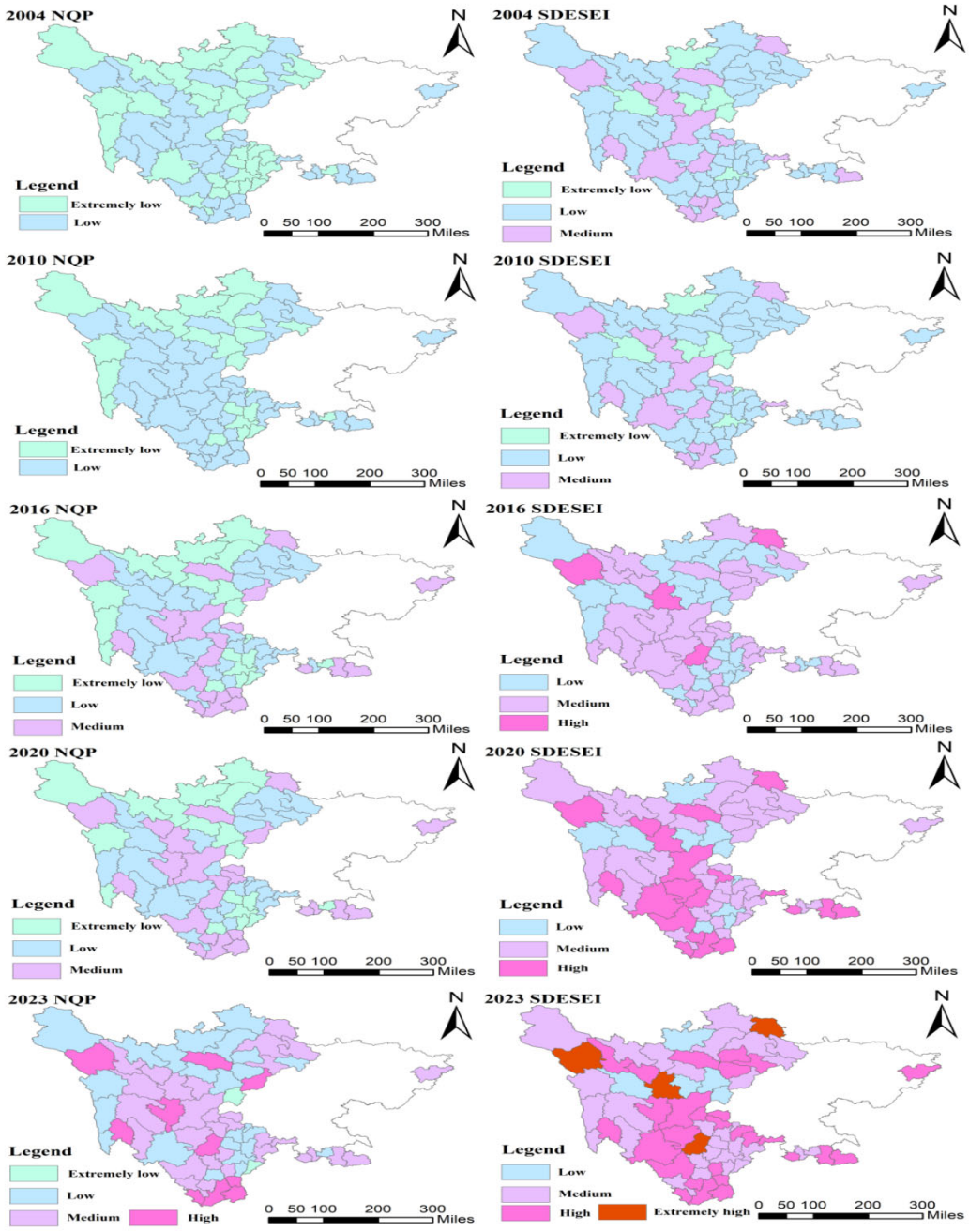


Figure 5. The spatiotemporal evolution trends of NQP and SDESEI in 67 ethnic areas from 2004 to 2023 (mapping based on the ArcGIS10.8 software can be obtained from the following link: https://desktop.arcgis.com accessed on 8 September 2025).

On the other hand, in 2004, the distribution of SDESEI in the ethnic areas of Sichuan Province was relatively balanced overall, with most regions at the "medium" and "low" levels, indicating the initial exploration of sustainable development in these areas. Among them, 82% of counties were at the "low" level, and only 18% of counties were at the "medium" level. By 2010, the distribution of SDESEI had slightly improved, with an increase in the number of counties at medium and above-medium levels, especially in the Chengdu Plain and southern Sichuan, where the improvement in the sustainable development index was more evident. The proportion of counties at the "medium" level rose to 36%, while those at the "low" level decreased to 58%. In 2016, the distribution of SDESEI was further optimized, with an increase in the number of high-level counties, especially in the Chengdu Plain, showing in-depth development of sustainable development in these areas.

The proportion of counties at the "medium" level rose to 52%, and those at the "high" level accounted for about 15%. By 2020, the spatial distribution of SDESEI had become more balanced, with a further increase in the number of high-level counties, indicating the widespread development of sustainable development in the ethnic areas of Sichuan Province. The number of counties at the "high" level increased significantly, rising to 33%, while those at the "medium" level accounted for 46%. This change is consistent with Sichuan Province's efforts to respond to the national "dual-carbon" goals and promote a comprehensive green transition in economic and social development [40].

By 2023, the distribution of SDESEI had reached the highest level, with a significant increase in the number of counties at the "very high" level, especially in the Chengdu Plain and southern Sichuan, indicating that sustainable development in these areas had reached a relatively high level. The proportion of counties at the "high" level rose to 46%, and those at the "very high" level accounted for about 9%.

These changes indicate that the ethnic areas of Sichuan Province have made significant progress in both NQP and sustainable development. Regional development has become more balanced. These findings provide important spatial information and a theoretical basis for further research on the economic development and sustainable development of the ethnic areas in Sichuan Province.

4.2. The Direct Effect of NQP on SDESEI

Regarding endogeneity concerns, we conducted a Hausman test to compare fixed-effects and random-effects models. The results indicated that the fixed-effects model was the more appropriate choice for addressing endogeneity. So the two-way fixed-effects model was used to examine the impact of NQP on the SDESEI in ethnic areas. According to the benchmark regression results (Table 2), the coefficient of NQP is positive and significant at the 1% significance level across all models, with specific coefficients of 0.609, 0.711, 0.749, and 1.017, respectively. This supports Hypothesis 1, namely that NQP has a significantly positive impact on the SDESEI. This finding highlights the crucial role of NQP in promoting the sustainable development of the economic–social–environmental system and provides a solid theoretical basis for relevant policymaking.

Table 2. Benchmark regression results.

Variable	(1)	(2)	(3)	(4)
NQP	0.609 *** (0.186)	0.711 *** (0.178)	0.749 *** (0.102)	1.017 *** (0.119)
POP		−0.418 *** (0.083)	−0.430 *** (0.078)	−0.317 *** (0.076)
GFE			−0.255 *** (0.056)	0.102 ** (0.046)
LIE				−0.471 *** (0.071)
constant	0.942 *** (0.066)	1.282 *** (0.085)	1.362 *** (0.083)	1.218 *** (0.080)
R^2	0.592	0.526	0.571	0.576
Estimator	FE	FE	FE	FE
Hausman χ^2 (p)	36.84 *** (0.031)	41.92 *** (0.066)	39.75 *** (0.047)	45.03 *** (0.028)
Obs.	1340	1340	1340	1340

Note: *** and ** indicate significance at the 1% and 5% levels, respectively. Standard errors are in parentheses. The Hausman test, which assumes 'consistent and valid random effects,' rejected the null hypothesis for all four columns at the 1% significance level, thus favoring fixed effects.

Regarding the control variables, population density (POP) and the number of large-scale industrial enterprises (LIEs) both show negative impacts on sustainable development, significant at the 1% significance level. This may be related to the resource strain and increased environmental pressure caused by higher population density, as well as the potential environmental stress brought about by an increase in the number of industrial enterprises. These findings suggest that policymakers should pay attention to the potential

environmental impacts of population management and industrial development while promoting the development of NQP. The impact of government fiscal expenditure (GFE) is more complex. It shows a negative impact in model (3) but a positive impact in model (4), although only significant at the 5% significance level. This result indicates that the role of government fiscal expenditure in the sustainable development of ESEs may require more detailed analysis and policy design.

From a theoretical perspective, the above research enriches the understanding of driving mechanisms and constraint conditions for sustainable development in ethnic areas under the ESE system theory. First, the NQP has a significantly positive impact on the SDESEI, confirming the core role of targeted policy intervention in addressing market failures in ethnic area sustainable development, aligning with the "institutional coordination" in sustainable development theory. Second, the POP and LIE have a negative impact, verifying the "carrying capacity constraints" in ecological economics. In ethnic areas, excessive population and industrial expansion may exceed the environmental threshold, echoing the initial stage of the Environmental Kuznets Curve (EKC) in underdeveloped regions. Finally, the GFE has a fluctuating impact, reflecting the complexity of public financial intervention in the ESE system. Its role depends on its "structural orientation". These findings supplement the existing public finance theory, emphasizing that the effectiveness of fiscal tools in sustainable development is context-dependent, especially in ethnic areas.

4.3. Heterogeneous Effects of NQP on SDESEI

4.3.1. Regional Heterogeneity

To explore the regional heterogeneity effect of NQP on the SDESEI, this study adopted a regional classification framework based on geographical location and ethnic distribution characteristics. The 67 county-level administrative units in Sichuan Province were divided into three representative main regions: the Northwest Sichuan Plateau Tibetan Area (NWPTA, 30 sample units), the Panxi Region (PR, 20 sample units), and the Southwest Sichuan Mountainous Area (SSMA, 17 sample units).

The NWPTA, as the main settlement area for Tibetans and Qiang people, is not only unique in its sociocultural aspects but also distinct in its economic development model. The PR is renowned for its abundant mineral resources and rapid industrialization. This area plays a significant role in Sichuan Province's industrial development and urbanization process. In comparison, the SSMA is primarily agriculture-oriented and rich in natural resources and biodiversity, making it a key region for Sichuan Province's ecological protection and green development strategy.

The results of the regional heterogeneity test (Table 3) show that NQP has a significantly positive impact on SDESEI in the NWPTA, PR, and SSMA, but there are obvious differences in the degree of impact and significance level. The NQP coefficient is highest in the NWPTA (0.614 ***), followed by the PR (0.307 ***), and relatively lower in the SSMA (0.538 *). This result indicates that NQP has heterogeneous impacts on the sustainable development of different geographical regions in Sichuan Province, and such impacts are moderated by region-specific factors. In addition, the significance and directionality of the control variables also vary across different regions, further confirming the existence of regional heterogeneity. For example, POP has a significantly negative impact on SDESEI in the SSMA, while it is not significant in the other two regions. GFE has a significantly negative impact on SDESEI in the PR, while it shows a positive impact in the NWPTA. These findings emphasize the need to consider regional characteristics and the role of specific factors when formulating regional sustainable development policies.

Table 3. Grouped regression results based on different geographical locations.

Variable	NWPTA	PR	SSMA
NQP	0.614 *** (0.029)	0.307 *** (0.080)	0.538 * (0.306)
POP	0.114 (0.108)	−0.107 (0.124)	−0.189 ** (0.089)
GFE	0.109 ** (0.070)	−0.337 *** (0.131)	0.088 (0.124)
LIE	−0.117 (0.160)	0.141 (0.266)	−0.625 (0.356)
constant	1.503 *** (0.152)	1.162 *** (0.271)	1.103 *** (0.245)
Obs.	600	400	340
R^2	0.671	0.663	0.476
County fix	Yes	Yes	Yes
Year fix	Yes	Yes	Yes

Note: ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively. Standard errors are in parentheses.

The underlying reasons for the regional structural heterogeneity mentioned above can be further analyzed from three aspects:

Firstly, the average altitude of the NWPTA region exceeds 3000 m. The ecosystem is fragile but highly sensitive to policies. The national ecological compensation and transfer payments for ethnic areas in this region are significantly higher than those in other areas, resulting in a greater marginal effect of the same amount of NQP funds in this area. At the same time, the population density in the pastoral areas is low, and the negative crowding-out effect of POP on SDESEI has not yet manifested.

Secondly, the PR relies on vanadium–titanium magnetite and rare earth resources to form a "resource-smelting heavy chemical industry" lock-in structure. For every additional unit of GFE, high-energy-consuming production capacity expands rapidly, significantly offsetting the benefits of green development. Therefore, GFE shows a significant negative trend. In addition, rapid industrialization attracts an external population, but public services lag behind, and POP and SDESEI show a weak negative correlation.

Finally, the mountainous area in SSMA is located in the core area of the ecological barrier in the upper reaches of the Yangtze River. Its main functional area positioning is to restrict development. NQP funds are mainly used for biodiversity protection and high-altitude characteristic agriculture, with a limited project scale, resulting in a smaller coefficient and a significant decrease in significance. Moreover, the combined effect of population pressure and scarce arable land, POP has a strong negative effect on the ecosystem. Therefore, the negative effect of POP is the strongest.

In conclusion, regional heterogeneity is not simply a difference in regression coefficients, but is the result of the interaction of the "nature–economy–institution" triple gradient. Future policy design should implement more spatially targeted combination schemes in terms of fund allocation, industry access, and population control.

4.3.2. Structural Heterogeneity

Starting from the perspective of structural heterogeneity is conducive to a more comprehensive understanding of the complex role mechanism of NQP in achieving sustainable coordinated development of the ESE system in ethnic areas. This paper analyzes the driving forces of SDESEI in ethnic areas from the four structural dimensions of NQP (namely new-type laborer, new-type labor tools, new-type labor subjects, and optimization of component generation combinations). As shown in Table 4, all structural dimensions of NQP have a significant impact on the SDESEI, but the intensity and direction of the impact vary significantly. Specifically, new-type labor tools and new-type labor subjects have a particularly significant positive impact on ESEs, with coefficients of 1.341 and 2.419, respectively, both significant at the 1% significance level. This may be because new labor tools are directly related to technological innovation, such as the application of intelligent equipment, which can significantly improve

the efficiency of resource development and productivity in the production process. The impact of new-type labor subjects may be constrained by multiple factors such as technology, capital, and market, but their positive effect on ESEs should not be overlooked.

Table 4. Results of grouped regression based on different structures.

Variable	New-Type Laborer	New-Type Labor Tools	New-Type Labor Subjects	Component Generation
NQP	−0.612 (0.711)	1.341 *** (0.205)	2.419 *** (0.479)	1.724 ** (0.722)
POP	0.128 *** (0.112)	0.169 (0.132)	−0.438 *** (0.149)	0.098 (0.190)
GFE	−0.112 (0.107)	−0.312 *** (0.126)	0.436 ** (0.177)	−0.711 ** (0.315)
LIE	0.117 (0.231)	−0.621 *** (0.107)	1.178 ** (0.445)	−0.397 ** (0.176)
constant	0.775 *** (0.252)	0.833 *** (0.113)	0.722 *** (0.279)	0.811 *** (0.308)
Obs.	1340	1340	1340	1340
R^2	0.473	0.702	0.601	0.403
County fix	Yes	Yes	Yes	Yes
Year fix	Yes	Yes	Yes	Yes

Note: *** and ** indicate significance at the 1% and 5% levels, respectively. Standard errors are in parentheses.

In comparison, the optimization of component generation combinations also shows a significant positive impact, but its coefficient (1.724) is lower than that of new-type labor subjects. This indicates that at the current stage, innovation in direct production tools and objects may more rapidly enhance ESEs than the optimization of factor combinations. The impact of the new-type laborer dimension is not significant. This may be related to the relatively low quality requirements for labor in traditional industries. Meanwhile, urban education and training systems struggle to quickly adapt to the talent demands of emerging industries and lack competitiveness in attracting external talent.

Moreover, the significance and directionality of the control variables also vary across different models, further confirming the heterogeneity of the impact of New-Quality Productivity. For example, GFE has a significantly negative impact on ESEs in the dimensions of new-type labor tools and optimization of component generation combinations, but a significantly positive impact in the dimension of new-type labor subjects. This may reflect the complexity of the role of government expenditure under different structural dimensions. Thus, this study confirms Hypothesis 2, that is, New-Quality Productivity has both regional and structural heterogeneity effects on the sustainable development of ESEs.

The significant differences among the four structural dimensions can be explained by three aspects: the technological penetration path, the elasticity of factor substitution, and the degree of institutional matching.

First, the coefficient of "new-type labor tools" is as high as 1.341, which stems from the high sensitivity of resource-based industries in ethnic regions to intelligent equipment: for instance, the selection of vanadium–titanium ores and the full mechanization of high-altitude grassland management have seen a significant increase in marginal output once intelligent sensors or unmanned equipment are integrated. However, GFE is significantly negative in this dimension, reflecting that local finances still tend to subsidize traditional energy-consuming equipment, resulting in an "alternative inhibition" effect.

Second, the coefficient of "new-type labor subjects" is the highest (2.419), as it directly corresponds to the "Fourth Industry of Ecological Products"—such as highland carbon sinks and local medicinal herbs in the Yi ethnic area. These new raw materials can achieve value multiplication through blockchain traceability, and the marginal return on capital is much higher than that of traditional agriculture and animal husbandry. At this point, GFE becomes significantly positive, indicating that fiscal interest subsidies or government procurement can effectively reduce the initial market trial costs of new raw materials.

Third, the coefficient of "new-type laborer" is not significant. The fundamental reason is that the proportion of high school and above education in ethnic regions is only 58% of the provincial average, and the "bilingual + digital skills" integrated training system has not yet been formed, leading to a "structural mismatch" between human capital and emerging positions. The significant positive coefficient of POP indicates that the surplus labor force can still rely on traditional family operations to maintain their livelihoods and has not yet negatively crowded out productivity. Fourth, the coefficient of "component generation" is lower than that of "new-type labor subjects", because the ecologically fragile area in the highlands faces the tripartite competition of "carbon sink–grazing–cultivation", and the reconfiguration of factors is limited by the national land space red line. In the short term, it is difficult to provide benefits through large-scale land transfer, as in plain areas. LIE is significantly negative in the "component generation" dimension, revealing that industrial electricity subsidies have instead solidified high-energy-consuming paths and inhibited the reorganization of green factors.

In conclusion, structural heterogeneity is not simply a difference in regression coefficients, but a necessary result of the interaction and coupling of technological maturity, factor endowment, and institutional incentives; in the future, the promotion of new quality productive forces should be implemented with precise irrigation based on the "technology–factor–institution" three-dimensional framework, rather than the replication of a single policy.

4.4. Pathways of NQP Effects on SDESEI

To explore whether TI, IU, and RE act as mediators through which NQP affects the sustainable development of ESEs, this paper employs a causal stepwise regression model to construct a multiple mediator effect model for in-depth analysis. The results are shown in Table 5. The results show that NQP has a significantly positive impact on TI (coefficient of 1.301 ***), and TI also has a significantly positive impact on SDESEI (coefficient of 0.077 **), indicating that TI plays a partial mediating role in the impact of NQP on the sustainable development of ESEs. IU is also significantly positively affected by NQP (coefficient of 0.718 ***), and IU has a significant impact on SDESEI (coefficient of 0.314 ***), indicating that IU is an important mediating variable in the impact of NQP on the sustainable development of ESEs. RE is significantly positively affected by NQP (coefficient of 1.818 ***), and its impact on SDESEI is also significant (coefficient of 0.101 **), which further confirms the mediating role of RE in this process.

These outcomes are deeply rooted in the socio-economic context of ethnic regions. On one hand, compared to technological innovation and resource allocation, industrial restructuring often receives more direct and concentrated policy support in these areas (such as the characteristic industry cultivation policies implemented by the Aba Prefecture government), making its transmission path smoother. On the other hand, the IU typically involves fixed asset investment and industrial chain restructuring, with large-scale economic effects and high visibility, exerting more direct and significant driving effects on county-level development. In contrast, pathways like technological innovation may be constrained by bottlenecks in factors such as talent and capital, resulting in longer benefit realization cycles.

Among the control variables, POP has a significantly negative impact on SDESEI in all models, which may be related to the resource strain and increased environmental pressure caused by higher population density. The impact of GFE is more complex, with different directions and significance levels in various models, indicating that the role of GFE may be moderated by the structural dimensions of NQP. LIE has a significantly negative impact on SDESEI in all models, which may reflect that an increase in the number of

industrial enterprises may bring environmental pressure and thus have a negative impact on sustainable development.

Table 5. Intermediary mechanism test results.

Variable	TI	IU	RE	SDESEI
NQP	1.301 *** (0.102)	0.718 *** (0.155)	1.818 *** (0.103)	1.334 *** (0.255)
TI				0.077 ** (0.034)
IU				0.314 *** (0.046)
RE				0.101 ** (0.133)
POP	0.083 (0.064)	0.092 * (0.051)	−0.314 *** (0.081)	−0.299 *** (0.177)
GFE	0.430 ** (0.072)	−0.143 *** (0.045)	0.141 *** (0.041)	−0.153 * (0169)
LIE	−0.298 *** (0.082)	−0.012 (0.062)	−0.122 *** (0.047)	−0.484 *** (0.107)
Obs.	−0.136 *** (0.026)	0.232 *** (0.074)	−0.252 *** (0.049)	1.307 *** (0.107)
R^2	0.591	0.418	0.563	0.557
County fix	Yes	Yes	Yes	Yes
Year fix	Yes	Yes	Yes	Yes

Note: ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively. Standard errors are in parentheses.

Obviously, the stepwise regression method has the disadvantage of weak power. Therefore, this study employs the Bootstrap sampling method with 1000 replications to test the mediating effects. The results show that the mediating effects of TI, IU, and RE are consistent with the direction and significance of the coefficients (Table 6). The 95% confidence intervals do not include 0, indicating that the mediating effects of the three factors remain valid after testing. Thus, Hypothesis 3 is confirmed.

Table 6. Results of the mediation effect test.

Pathways	Value of Intermediate Effect	Std.	95% Confidence Interval
TI	0.618 ***	0.108	[0.351, 1.163]
IU	1.166 ***	0.209	[0.811, 1.412]
RE	0.331 ***	0.077	[0.093, 0.396]

Note: *** indicate significance at the 1% levels. Standard errors are in parentheses.

4.5. Spatial Spillover Effect of NQP on SDESEI

4.5.1. Test for Spatial Autocorrelation

NQP is characterized by high innovativeness and strong penetration. However, its spatial distribution effect on the sustainable development of the ESE system is not yet fully clear. To this end, this study uses the global spatial autocorrelation test method to analyze the spatial correlation of NQP and SDESEI, aiming to reveal their agglomeration and equilibrium characteristics in the spatial dimension. Due to space limitations, the calculation formula of the global Moran's I index refers to the study of Yang et al. (2024) [41]. As shown in Table 7, the global Moran's I indices are all positive and pass the significance test, indicating significant spatial agglomeration characteristics of NQP and SDESEI. This shows that it is feasible to conduct spatial Durbin regression analysis in the following sections of this paper.

Table 7. SDESEI global correlations.

Year	Moran's I_NQP	*p*_Value	Moran's I_SDESEI	*p*_Value
2004	0.048	0.091	0.012	0.020
2005	0.093	0.061	0.024	0.078

Table 7. *Cont.*

Year	Moran's I_NQP	*p*_Value	Moran's I_SDESEI	*p*_Value
2006	0.220	0.000	0.068	0.000
2007	0.180	0.000	0.070	0.000
2008	0.085	0.081	0.055	0.004
2009	0.186	0.000	0.087	0.001
2010	0.210	0.000	0.071	0.000
2011	0.093	0.062	0.023	0.020
2012	0.168	0.001	0.045	0.021
2013	0.002	0.082	0.002	0.080
2014	0.081	0.099	0.064	0.000
2015	0.070	0.015	0.027	0.014
2016	0.064	0.018	0.031	0.099
2017	0.054	0.024	0.053	0.006
2018	0.033	0.035	0.029	0.011
2019	0.146	0.004	0.049	0.010
2020	0.165	0.001	0.141	0.000
2021	0.060	0.083	0.098	0.041
2022	0.065	0.012	0.086	0.067
2023	0.111	0.045	0.080	0.089

4.5.2. Results of Spatial Durbin Regression

After the LM, LR, and Wald tests, the spatial Durbin model (SDM) was confirmed to be the optimal choice. Based on this, the spatial Durbin model combining the contiguity-based spatial weight matrix and fixed effects was used to explore the spatial impact of NQP on the SDESEI. The regression results are presented below (Table 8).

Table 8. Spatial effects' decomposition results.

Variable	Direct Effect	Indirect Effect	Total Effect
NQP	1.468 *** (0. 194)	1.649 *** (0.233)	3.117 *** (0.374)
POP	−0.409 *** (0.076)	0.425 *** (0.062)	0.016 (0.634)
GFE	−0.237 * (0.075)	−0.819 (1.288)	−1.056 (1.203)
LIE	−0.452 *** (0.059)	−0.700 * (0.305)	−1.152 *** (0.174)

Note: *** and * indicate significance at the 1% and 10% levels, respectively. Standard errors are in parentheses.

First, the direct impact coefficient of NQP on SDESEI is 1.468, significant at the 1% significance level. This means that a 1% increase in NQP will directly boost the local ESE system's sustainable development level by 1.468%. In addition, NQP also affects the SDESEI of neighboring areas through spatial spillover effects, with an indirect effect coefficient of 1.649, significant at the 1% significance level. This means that the improvement of NQP not only directly promotes local sustainable development but also generates positive externalities for neighboring areas through spatial linkages. Overall, the total effect of NQP on SDESEI is 3.117, significant at the 1% significance level, further confirming the important driving role of NQP in the sustainable development of the ESE system.

For the control variables, the direct impact coefficient of population density (POP) is −0.409, significant at the 1% significance level. This means that an increase in population density may inhibit local sustainable development. However, its indirect effect coefficient is 0.425, significant at the 1% significance level, indicating that an increase in population density may have a positive impact on the sustainable development of neighboring areas through spatial linkages. Overall, the total effect of population density on SDESEI is 0.016, but it is not significant, indicating that its net effect on sustainable development may be relatively small. The direct impact coefficient of government fiscal expenditure (GFE)

is −0.237, significant at the 10% significance level, and the indirect effect coefficient is −0.819, but it is not significant. This suggests that GFE may have a certain inhibitory effect on local sustainable development, but its impact on neighboring areas is not statistically significant. Overall, the total effect of GFE on SDESEI is −1.056, but it is not significant. The direct impact coefficient of the number of large-scale industrial enterprises (LIE) is −0.452, significant at the 5% significance level, and the indirect effect coefficient is −0.700, significant at the 10% significance level. This indicates that an increase in the number of industrial enterprises may have a negative impact on the sustainable development of both the local area and neighboring areas. Overall, the total effect of LIE on SDESEI is −1.152, significant at the 5% significance level.

In summary, Hypothesis 4 proposed in this paper is confirmed. This indicates that (1) regional development initiatives in ethnic regions (such as the Western Development Program and the Border Enrichment Initiative) often create coordinated implementation across geographically adjacent areas, driving synchronized evolution of development strategies. (2) The concentration of labor in high-growth zones and the subsequent influx of supporting capital strengthen the central county's radiating influence on surrounding areas. (3) Neighboring counties tend to form complementary industrial chain divisions. For instance, the industrial upgrading in Mutuo County has stimulated demand for raw materials and supporting services from neighboring counties, creating positive spillover effects.

4.6. Robustness Test

To ensure the reliability of the regression results, the following robustness tests were conducted: First, data winsorization was performed. To eliminate the impact of outliers in the sample on regression analysis, all variables were subjected to 1% bilateral winsorization, and the regression analysis was conducted again. Second, the instrumental variable method was used for endogeneity tests. The lagged value of NQP by one period can affect the current-period NQP, meeting the strong relevance condition for instrumental variable selection. Meanwhile, the lagged value of NQP by one period does not directly affect the level of high-quality development, satisfying the strict exogeneity condition of the endogenous variable. Based on this, the lagged value of NQP by one period was selected as an instrumental variable for IV–2SLS regression to eliminate biases caused by endogeneity issues. As shown in Table 9, the results of the robustness tests are consistent with the benchmark regression results.

Table 9. Robustness test results.

Variable	Winsorization	IV-2SLS
NQP	0.488 ** (0.224)	1.373 *** (0.185)
POP	−0.324 *** (0.082)	−0.318 *** (0.076)
GFE	−0.147 ** (0.072)	−0.031 (0.067)
LIE	−0.503 *** (0.087)	−0.404 *** (0.079)
constant	1.310 *** (0.093)	1.225 *** (0.079)
R^2	0.516	0.667
County fix	Yes	Yes
Year fix	Yes	Yes

Note: *** and ** indicate significance at the 1%, and 5% levels, respectively. Standard errors are in parentheses.

5. Main Conclusions and Policy Recommendations

5.1. Main Conclusions

This study employs panel data from 67 ethnic counties in Sichuan Province over the period 2004–2023 to empirically examine the impact of New-Quality Productivity on the

sustainable development of the Economic–Social–Environmental System in ethnic regions. The following main conclusions are drawn:

(1) New-uality Productivity has a significant positive impact on the sustainable development of the Economic–Social–Environmental System in ethnic regions: New-quality productivity enhances production efficiency, optimizes industrial structure, and improves resource utilization efficiency, thereby providing important support for sustainable development in ethnic regions. The study finds that an increase in the level of New-Quality Productivity significantly promotes the improvement of the Sustainable Development Index of the Economic–Social–Environmental System in ethnic regions, thus verifying the important driving role of new-quality productivity in the sustainable development of ethnic regions.

(2) The impact of New-Quality Productivity exhibits regional and structural heterogeneity: From a regional perspective, the driving effect of New-Quality Productivity on sustainable development is most pronounced in the Tibetan Plateau area of northwest Sichuan, followed by the Panxi region, while the southwest mountainous area of Sichuan is relatively weaker. This indicates that differences in resource endowment, industrial structure, and policy environment among different regions lead to significant variations in the effectiveness of New-Quality Productivity. From a structural perspective, different dimensions of New-Quality Productivity also have varying impacts on sustainable development. Among them, new types of labor tools and new types of labor objects have a more pronounced positive impact on sustainable development, while the optimization of factor combination and the driving effect of new types of laborers are relatively weaker.

(3) New-Quality Productivity affects the sustainable development of the Economic–Social–Environmental System in ethnic regions through three pathways: scientific and technological innovation, industrial upgrading, and resource factor allocation. Scientific and technological innovation provides technological support for sustainable development in ethnic regions, industrial upgrading optimizes the industrial structure of ethnic regions, and resource factor allocation improves resource utilization efficiency. These three pathways work together to promote the coordinated development of the economy, society, and environment in ethnic regions. Among them, the mediating effect of industrial upgrading is the most significant, indicating that the optimization and upgrading of industrial structure is an important way for new-quality productivity to drive sustainable development in ethnic regions.

(4) New-Quality Productivity has a positive spatial spillover effect on the sustainable development of the Economic–Social–Environmental System in ethnic regions: The development of New-Quality Productivity not only promotes local sustainable development but also drives sustainable development in neighboring regions through technology diffusion, industrial linkages, and market expansion. This spatial spillover effect helps to narrow the gap in sustainable development among ethnic regions and promotes coordinated regional development.

5.2. Policy Recommendations

Given the significant regional heterogeneity in the impact of NQP on sustainable development in ethnic regions, policy design should not only reflect differentiation but also align with broader national strategies while addressing local institutional constraints. The following recommendations are proposed:

First, development strategies at the county level should be closely integrated with ongoing national initiatives such as the Rural Revitalization Strategy and Western Development Plan. For instance, Aba County could leverage its hydropower and mineral

resources to advance green, low-carbon industrialization under the framework of the Dual-Carbon Targets, while developing eco-tourism and ethnic cultural industries to promote integrated economic and social development. Similarly, Batang County could utilize its geographical advantages to foster specialty agriculture and eco-tourism, aligning with the national emphasis on ecological conservation and high-quality growth. Baiyu County may focus on sustainable forestry and water resource management, contributing to regional ecological security.

Second, while increasing investment in scientific and technological innovation is essential, it is also crucial to overcome institutional barriers that hinder technology absorption and industrial upgrading in ethnic regions. Local governments should establish special innovation funds to support university–enterprise–research collaboration, but also simplify approval procedures and strengthen intellectual property protection to encourage the adoption of digital and green technologies in traditional industries. Moreover, the development of high-tech industries should be linked to local resource advantages—for example, supporting the deep processing of mineral products and clean energy utilization—rather than pursuing generic industrial models.

Third, in optimizing resource allocation, market-based mechanisms such as resource trading platforms and differential pricing policies can be introduced. However, these measures must be adapted to local conditions. For instance, differentiated resource taxes and environmental subsidies could be piloted in key ecological functional areas to guide resources toward high-efficiency, low-pollution sectors. At the same time, cross-regional cooperation mechanisms should be strengthened under the spatial spillover effects identified in this study, promoting the flow of factors such as talent, capital, and technology between core and peripheral counties to avoid inefficient duplication of construction.

Finally, it is important to recognize that the implementation of the above recommendations may be constrained by path dependencies, such as reliance on traditional industries and insufficient local fiscal capacity. Therefore, we suggest phased policy experiments and dynamic evaluation mechanisms, starting with pilot zones to explore replicable models, and gradually scaling up effective practices.

5.3. Limitations and Prospects

The data for this study were derived from statistical yearbooks and other publicly available sources. Future research would benefit from expanding the scope to include micro-level data on human daily activities, which could provide deeper insights into the relationship between NQP and ESEs. This study assumes that the relationship between NQP and ESEs in ethnic regions remained relatively stable over the study period. However, in reality, this relationship may evolve over time due to factors such as technological advancements and policy changes. Future research could consider incorporating dynamic models to analyze the time-varying characteristics of the relationship between NQP and sustainable development.

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Appendix A

Table A1. SDESEI measurement index system.

Subsystem	Dimension	Indicators	Define	Attribute	Weight	SDGs Target
Economic	Economic Efficiency	Labor productivity of secondary industry (RMB/person)	Reflects the production efficiency of the secondary industry and the productivity level of workers	Positive	0.066	
		Labor productivity of tertiary industry (RBM/person)	Reflects the production efficiency of the tertiary industry and the productivity level of workers	Positive	0.058	
		Per capita GDP (RMB)	Reflects the overall economic development level and the average economic contribution of residents	Positive	0.016	
		Per capita retail sales of consumer goods (RMB)	Reflects the consumption capacity of residents and market activity	Positive	0.014	
	Economic structure	The proportion of the secondary industry to GDP (%)	Reflects the relative scale and importance of the secondary industry in the industrial structure	Neutral	0.010	
		The proportion of the tertiary industry to GDP (%)	Reflects the relative scale and importance of the tertiary industry in the industrial structure	Neutral	0.004	
		Energy consumption per unit GDP (10,000 t/100 million RMB)	Reflects the energy utilization efficiency and energy intensity of economic activities	Negative	0.002	
	Economic growth	GDP growth rate (%)	Reflects the growth trend and vitality of the economy	Positive	0.044	
		per capita disposable income (RMB)	Reflects the economic well-being and living standards of residents	Positive	0.048	
		R&D (10,000 RMB)	Reflects the intensity of investment in scientific and technological innovation and the capacity for innovation	Positive	0.044	

Table A1. *Cont.*

Subsystem	Dimension	Indicators	Define	Attribute	Weight	SDGs Target
Social	Well-being	Green coverage rate of negative built-up areas (%)	Reflects the ecological environment quality and greening level of the city	Positive	0.025	
		Urban road area per capita (m^2)	Reflects the perfection of urban traffic infrastructure	Positive	0.039	
		Number of hospital beds per 100 population (tiers)	Reflects the sufficiency of medical resources and the capacity of medical services	Positive	0.025	
		The proportion of education expenditure in the fiscal budget (%)	Reflects the emphasis on education and the intensity of investment	Positive	0.022	
	Green Living	Per capita carbon emissions (t/person)	Reflects the impact of economic activities on the environment and the intensity of carbon emissions	Negative	0.032	
		Urban sewage discharge (10,000 m^3)	Reflects the pressure on sewage treatment and environmental stress	Negative	0.012	
		Number of public transport vehicles per 10,000 people (vehicles)	Reflects the supply capacity and coverage of public transportation	Positive	0.003	
		Per capita annual public transport trips	Reflects the frequency of public transport use and residents' travel habits	Positive	0.084	
Environmental	Environmental Governance	Industrial wastewater discharge (10,000 t)	Reflects the degree of pollution of water resources by industrial activities	Negative	0.115	
		Sewage treatment capacity (10,000 m^3/day)	Reflects the scale and treatment capacity of sewage treatment facilities	Positive	0.015	
		Centralized treatment rate of sewage treatment plants (%)	Reflects the efficiency and degree of centralized sewage treatment	Positive	0.105	
	Environmental Resources	Forest coverage rate (%)	Reflects the abundance of forest resources and the quality of the ecological environment	Positive	0.035	
		Proportion of renewable energy (%)	Reflects the sustainability of the energy structure and the utilization of clean energy	Positive	0.004	
		Total installed capacity of renewable energy (kilowatts)	Reflects the development scale and power generation capacity of renewable energy	Positive	0.019	

Table A2. NQP measurement index system.

Subsystem	Dimension	Indicators	Define	Attribute	Weight
New-type Laborer	Strategic scientific and technological talents	Number of scientific researchers (persons)	Reflects the quantity of scientific research personnel	Positive	0.039
		Proportion of scientific researchers (%)	Reflects the proportion of scientific research personnel in the total workforce	Positive	0.029
	Applied talents	Employment ratio in manufacturing, information technology services, and scientific research and technical services (%)	Reflects the employment distribution in key industries	Positive	0.026
	Talent structure	Proportion with associate degree or above (%)	Reflects the educational level of the workforce	Positive	0.020
		Proportion with master's degree or above (%)	Reflects the educational structure of the workforce	Positive	0.035
		Proportion of tertiary industry personnel (%)	Reflects the distribution of workforce across different industries	Neutral	0.019
	Talent reserve	Number of higher education students per 100,000 population (persons)	Reflects the scale of higher education enrollment	Positive	0.022
		Ratio of graduates in the year to the permanent population (%)	Reflects the output of educational institutions	Positive	0.023
		Ratio of university students to the permanent population (%)	Reflects the capacity of higher education institutions	Positive	0.022
New-type Labor tools	New production tools	Industrial robot installation density (units/10,000 people)	Reflects the level of automation and technological advancement in manufacturing	Positive	0.029
		Integrated circuit production (ten thousand pieces)	Reflects the capacity and output of the semiconductor industry	Positive	0.034
	New infrastructure	Digital inclusive finance index	Reflects the accessibility and usage of digital financial services	Positive	0.028
		Per capita Internet access port number (ports/person)	Reflects the infrastructure and accessibility of Internet services	Positive	0.029
		Mobile phone number per hundred people (units/person)	Reflects the penetration and usage of mobile communication	Positive	0.022
		Fiber optic cable length per unit area (km/square km)	Reflects the density and coverage of fiber optic infrastructure	Positive	0.033
	Energy consumption level	Waste emissions per unit GDP (tons/ten thousand RMB)	Reflects the environmental impact and waste management efficiency	Negative	0.017
		Water consumption per unit GDP (cubic meters/ten thousand RMB)	Reflects the efficiency of water resource utilization	Negative	0.013
		Electricity consumption per unit GDP (kilowatt-hours/ten thousand RMB)	Reflects the efficiency of energy utilization	Negative	0.023

Table A2. *Cont.*

Subsystem	Dimension	Indicators	Define	Attribute	Weight
New-type Labor subjects	New production factors	Proportion of enterprise e-commerce sales (%)	Reflects the extent to which enterprises use e-commerce platforms for sales	Positive	0.028
		Per capita telecommunications business volume (billion RMB/person)	Reflects the average telecommunications business volume per person	Positive	0.060
		Average mobile internet access traffic per household (GB/household)	Reflects the average mobile internet usage per household	Positive	0.054
	New industries and new business forms	Proportion of high-tech enterprise operating income (%)	Reflects the share of high-tech enterprises in total operating income	Positive	0.036
		Average operating income of high-tech enterprises (billion RMB/enterprise)	Reflects the average operating income of high-tech enterprises	Positive	0.017
		Proportion of high-tech enterprises among all industrial enterprises (%)	Reflects the share of high-tech enterprises in the total number of industrial enterprises	Positive	0.023
	Green development model	Harmless treatment capacity per 10,000 people (tons/day)	Reflects the capacity for harmless treatment of waste per 10,000 people	Positive	0.027
		Proportion of environmental protection expenditure (%)	Reflects the share of environmental protection expenditure in total expenditure	Positive	0.029
		Comprehensive utilization rate of solid waste (%)	Reflects the efficiency of solid waste utilization	Positive	0.025
Optimization of component generation combinations	Technologization	Number of patent grants per 10,000 people (pieces/10,000 people)	Reflects the number of patents granted per 10,000 people	Positive	0.036
		Proportion of technology market transactions (%)	Reflects the share of technology market transactions in total transactions	Positive	0.039
		R&D expenditure intensity (%)	Reflects the proportion of R&D expenditure in total expenditure	Positive	0.025
	Greenification	Proportion of green technology patents in total patents (%)	Reflects the share of green technology patents in total patents	Positive	0.017
		Per capita park green space area (square meters/person)	Reflects the average area of park green space per person	Positive	0.027
		Green coverage rate in urban areas (%)	Reflects the green coverage rate in urban areas	Positive	0.011
	High efficiency	Labor productivity (ten thousand RMB/person)	Reflects the economic output per worker	Positive	0.026
		Capital productivity (%)	Reflects the efficiency of capital utilization	Positive	0.035
		Energy productivity (tons of standard coal/ten thousand RMB)	Reflects the efficiency of energy utilization	Negative	0.023

Table A3. Abbreviation overview.

Full Name	Abbreviation
Economic–Social–Environmental System	ESES
Sustainable Development of the Economic–Social–Environmental System	SDESES
Index of Sustainable Development of the Economic-Social-Environmental System	SDESEI
New-Quality Productivity	NQP
Technological Innovation	TI
Industrial Upgrading	IU
Resource Element Allocation	RE
Population Density	POP
Government Fiscal Expenditure	GFE
Number of Large-scale Industrial Enterprises	LIE
Sustainable Development Goals	SDGs
Northwest Sichuan Plateau Tibetan Area	NWPTA
Panxi Region	PR
Southwest Sichuan Mountainous Area	SMA

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