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Research on the Coupling and Coordination of New Quality Productivity Factors and Language Skill Development Empirical Analysis Based on Grey Relational Degree Model

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ABSTRACT Against the background of a new technological revolution and accelerated industrial transformation, new quality productivity, characterized by technological innovation, digital technology, human capital, data elements, and green development, has a deeply coupled relationship with language skill development. Language skills function not only as tools for communication but also as carriers for cross-cultural technical exchange, knowledge dissemination, standard coordination, and engineering collaboration. Based on coupling coordination theory and grey system theory, this study constructs a binary analytical framework of "new quality productivity elements-language skill development". National-level panel data from 2013 to 2022 are selected, the grey relational model is used to calculate the correlation strength among core elements, the entropy-weight coupling coordination model is applied to measure coordinated development, and regression analysis is used to verify key influencing factors. The results reveal that digital language skills and professional language skills have the strongest association with new quality productivity. The framework is also applicable to advanced engineering fields, including electromagnetic standards, antenna-related technical communication, and international collaboration in electromagnetic-wave technologies. The study provides empirical evidence and policy references for improving language capability under high-quality industrial transformation.

INDEX TERMS new quality productivity, language skills, grey relational model, engineering communication, electromagnetic standards

I. INTRODUCTION

A. RESEARCH BACKGROUND

CURRENTLY, new quality productivity has become the core driving force for promoting high-quality economic development and reshaping the global competitive landscape. With technological innovation as the core engine, digital technology and data elements as important support, human capital as the key carrier, and green development as the inherent requirement, it is profoundly changing the allocation of production factors and the form of industrial development [1,2]. Language, as a tool for human communication, a medium for knowledge

dissemination, and a bridge for cultural integration, not only affects individual development opportunities, but also influences the integration ability of regions and even countries towards high-quality global resources, the efficiency of transforming scientific and technological innovation achievements, and the depth and breadth of cross-cultural cooperation. Against the backdrop of accelerated development of new quality productivity, language skills are no longer simply communication tools, but have become an important link connecting technological innovation, digital technology application, human capital upgrading, and data element circulation. The degree of coupling and coordination with the core elements of new quality productivity directly determines the quality and speed of its development.

B. RESEARCH CONTENT AND TECHNICAL ROUTE

The main research content of this article includes:

1. Theoretical basis and coupling mechanism analysis: Sort out relevant theories such as new quality productivity, language skill development, and coupling coordination theory, define the core elements of new quality productivity and the core dimensions of language skill development, and reveal the coupling mechanism and coordination path between the two.

2. Construction of evaluation index system: Based on theoretical analysis, a coupled and coordinated evaluation

index system for the development of new quality productivity elements and language skills is constructed, covering three levels: target layer, criterion layer, and indicator layer.

3. Empirical analysis:

(1) Data collection and preprocessing: Collect national level relevant indicator data from 2013 to 2022 and standardize it; To address the temporal logic of "new quality productivity"—a concept formally intensified in recent years—this study adopts a retrospective analytical approach. It treats the 2013–2022 period as the "incubation and acceleration phase" of these elements, accounting for the lag effect between technological emergence and theoretical formalization.

(2) Grey correlation analysis: Using the grey correlation model, measure the correlation strength between the core elements of new quality productivity and various dimensions of language skill development;

(3) Calculation of coupling coordination degree: using entropy weight method to determine indicator weights, based on the coupling coordination degree model, calculate the coupling coordination level between the two, and analyze their spatiotemporal evolution characteristics;

(4) Analysis of influencing factors: Construct a regression model to empirically test the impact of factors such as education investment, digital infrastructure construction, level of opening up to the outside world, and industrial structure upgrading on the degree of coupling and coordination.

4. Policy recommendations: Based on empirical analysis results, propose policy recommendations to promote the coupling and coordination of new quality productivity factors and language skills development. The technical route of this article is as follows:

1. Literature research stage: Sort out the research results in related fields such as new quality productivity, language skills development, and coupling coordination theory, clarify the research status, shortcomings, and entry points.

2. Theoretical construction stage: Define core concepts and dimensions, construct a coupling and coordination theoretical framework of "new quality productivity elements language skills development", and reveal the coupling mechanism.

3. Indicator system construction stage: Based on the theoretical framework, construct a coupled and coordinated evaluation indicator system, clarify the connotation of indicators and data sources.

4. Empirical analysis stage:

(1) Data collection and preprocessing: Collect panel data and standardize it;

(2) Grey correlation degree calculation: using the grey correlation degree model to analyze the strength of correlation between elements;

(3) Calculation of coupling coordination degree: using entropy weight method to determine weights, measuring coupling coordination level and analyzing spatiotemporal characteristics;

(4) Regression analysis of influencing factors: Construct a regression model to identify key influencing factors.

5. Conclusion and Suggestion Stage: Summarize the research results, propose policy recommendations, point out research limitations and future research directions.

II. THEORETICAL BASIS AND COUPLING MECHANISM ANALYSIS

A. DEFINITION OF CORE CONCEPTS

1) Core Elements of New Quality Productivity

Based on existing research and the connotation characteristics of new quality productivity, this article defines the core elements of new quality productivity as the following five dimensions:

Technological innovation elements: Refers to various scientific research and technological innovation activities that promote the development of productivity, and are the core engine of new quality productivity, mainly reflected in research and development investment, patent output, and technological achievement transformation [3];

Digital technology elements: Refers to digital technologies and their applications represented by big data, artificial intelligence, cloud computing, the Internet of Things, etc., which are important supports for new quality productivity, mainly reflected in the construction of digital infrastructure, the depth of digital technology applications, and the scale of digital economy;

Human capital elements: Refers to high-quality labor force with innovative ability, digital skills, and professional knowledge, which is a key carrier of new quality productivity, mainly reflected in the education level of labor force, the number of skilled talents, and the reserve of high-level talents;

Data elements: Refers to various types of data resources with value density, liquidity, and reusability, which are new production factors of new quality productivity, mainly reflected in data output, data infrastructure, and data element market development;

Green development elements: Refers to a sustainable development model that balances economic and ecological benefits, which is an inherent requirement of new quality productivity, mainly reflected in green technology research and development, energy utilization efficiency, pollutant reduction, and other aspects [4,5].

2) Core Dimensions of Language Skill Development

Based on the demand for language skills in the development of new quality productivity, this article defines language skill development as the following four core dimensions:

Basic language skills: Refers to the ability to listen, speak, read, and write basic language skills, which are the foundation of language skills, mainly reflected in the national average language level, the quality of language education in the basic education stage, and other aspects;

Professional language skills: refers to the ability to apply professional language that is suitable for specific industries or fields, such as technology language, business language, legal language, etc., mainly reflected in the number of professional language talents, the scale of professional language education, and other aspects;

Cross cultural communication skills: refers to the ability to effectively communicate and resolve cultural conflicts using language in cross-cultural contexts, mainly reflected in the frequency of cross-cultural communication, language adaptation for cross-border cooperation, and other aspects;

Digital language skills: refers to the ability to use digital technology for language learning, language application, and language data processing, mainly reflected in the utilization rate of digital language learning tools, cross language data processing ability, and other aspects [6,7].

B. THEORETICAL BASIS

The theory of human capital holds that human capital is an intangible asset such as knowledge, skills, and experience embodied in workers, and is a key factor in promoting economic growth and productivity development. Language skills, as an important component of human capital, can enhance workers' information acquisition ability, cross-cultural cooperation ability, and innovation achievement transformation ability, thereby enhancing the overall quality of human capital. In the context of the development of new quality productivity, workers with high-level language skills can better adapt to the needs of digital technology applications, technological innovation, and cross-border cooperation, becoming the core talent support for the development of new quality productivity [8,9].

C. COUPLING MECHANISM BETWEEN NEW QUALITY PRODUCTIVITY FACTORS AND LANGUAGE SKILL DEVELOPMENT

The coupling and coordination between the elements of new quality productivity and the development of language skills is a multidimensional and multi-level dynamic process. The two interact and support each other to form an inherent logic of collaborative development. This interaction functions through a bidirectional causal loop: primarily, the advancement of new quality productivity acts as a 'demand-pull' force, necessitating an upgrade in digital and professional language skills to manage complex data and global innovation cycles. Conversely, improved language skills serve as an 'efficiency-driver,' reducing information asymmetry and accelerating the transformation of scientific achievements [10]. By identifying these distinct driving directions, the model transitions from a static correlation to a dynamic analysis of mutual reinforcement: Technological innovation can also promote the development of language skills: the new industries and technologies generated by technological innovation require corresponding professional language system support, which promotes the upgrading of professional language skills; The application of innovative achievements such as digital technology and artificial intelligence in language education can improve the efficiency and accuracy of language skill development [11].

On the contrary, language skills are an important support for the application of digital technology and the development of the digital economy. The creation and dissemination of cross linguistic digital content require high-level language skills, and the cross linguistic governance and utilization of digital data also depend on language skills; The international promotion and cooperation of digital technology require language skills as a communication bridge to promote the global flow of digital technology [12,13].

Language skills are an important dimension for upgrading the quality of human capital: high-level language skills can enhance workers' information acquisition ability, cross-cultural cooperation ability, and professional competitiveness, and enhance the overall value of human capital; In the context of the development of new quality productivity, composite talents with "language skills+professional skills+digital skills" have become the core component of human capital. On the contrary, the upgrading of human capital will also promote the development of language skills: high-quality workers have a more urgent demand for language skills, which can promote the optimization of language education resources; High level talents in human capital can participate in language education reform and professional language system construction, improving the quality of language skills training [14-17].

The circulation and utilization of data elements cannot be separated from the support of language skills: the collection, cleaning, analysis, and application of cross linguistic data require language skills as the foundation, which can enhance the value density and circulation range of data elements; The international development of the data factor market requires language skills to resolve language barriers in data transactions and promote cross-border data flow [18]. On the contrary, the development of language skills will also promote the optimized allocation of data elements: language skills can promote the integration and sharing of multilingual data resources, enriching the sources of data elements; The improvement of digital language skills can enhance the efficiency and accuracy of cross linguistic data processing, and improve the utilization efficiency of data elements [19-21].

The internationalization process of green development requires the support of language skills. Specifically, the 'green barrier' in global trade necessitates high-level professional language skills to interpret complex international environmental regulations and ESG (Environmental, Social, and Governance) reporting standards. The international dissemination of green technologies, cross-border docking of green standards, and the development of international green cooperation all require language skills as a communication bridge[22]. Furthermore, the promotion of green development fosters new linguistic domains, such as 'green terminology,' which enriches the professional dimension of language skills and enables workers to participate in global climate governance. On the contrary, the development of language skills can promote the implementation of green development: spreading green concepts and knowledge through language skills, and enhancing public awareness of green; Professional language skills can support the research and development of green technologies and green industries, and promote the improvement of green productivity [23-25].

III. CONSTRUCTION OF COUPLING COORDINATION EVALUATION INDEX SYSTEM

A. PRINCIPLES FOR CONSTRUCTING INDICATOR SYSTEM

To ensure the scientificity, rationality, and operability of the evaluation index system, this article follows the following construction principles:

1. Principle of scientificity: The selection of indicators is based on relevant theories and research results, and can accurately reflect the core connotation and coupling relationship between new quality productivity factors and language skill development;
2. Systematic principle: The indicator system covers various core dimensions of the development of new quality productivity elements and language skills, comprehensively reflecting the level of coordinated development between the two;
3. Principle of operability: The indicator data is easy to obtain and mainly comes from official statistical yearbooks, authoritative reports, and public databases to ensure the feasibility of empirical analysis;
4. Principle of dynamism: The indicator system balances stability and dynamism, adapts to the characteristics of the era of new quality productivity and language skills development, and facilitates long-term tracking and research;
5. Principle of comparability: The selection of indicators focuses on the comparability of horizontal (inter regional) and vertical (time series) indicators, using a combination of relative and absolute indicators to enhance the objectivity of evaluation results [26-28].

B. DESIGN OF COUPLING COORDINATION EVALUATION INDEX SYSTEM

Based on the above principles and core dimensions, this article constructs a binary coupled and coordinated evaluation index system for "new quality productivity elements language skills development", covering three levels: target layer, criterion layer, and indicator layer. The specific indicators are as follows:

1) Target Layer

Coupling and coordination of new quality productivity elements and language skill development: comprehensively reflecting the level of collaborative development between new quality productivity elements and language skill development [29].

2) Criteria layer

The criteria layer includes two first level criteria layers: "New Quality Productivity Elements" and "Language Skill Development". Each first level criteria layer is divided into several second level criteria layers: The first level of criteria for new quality productivity elements includes five second level criteria: scientific and technological innovation, digital technology, human capital, data elements, and green development; The first level criteria layer for language skill development includes four secondary criteria layers: basic language skills, professional language skills, cross-cultural communication skills, and digital language skills[30].

IV. RESEARCH METHODS AND DATA SOURCES

This article uses the entropy weight method to determine the weights of indicators, avoiding the onesidedness of subjective weighting. Combined with the coupling coordination degree model, the coupling coordination level between new quality productivity elements and language skill development is calculated. To isolate the specific impact of new quality productivity from broader economic trends, 'General Economic Development' (measured by GDP per capita) is introduced as a control variable in the regression analysis. This ensures that the measured coupling coordination reflects the intrinsic synergy of new productivity factors rather than a general byproduct of national economic expansion. To ensure the robustness of the quantified results, a sensitivity analysis was performed by perturbing the weights of core indicators (e.g., R&D expenditure and digital economy value) by $\pm 10\%$. The resulting coupling coordination scores remained within a stable range (variance < 0.05), confirming that the model effectively captures the structural relationship between productivity factors and language skills rather than being skewed by specific weight distributions. The coupling coordination degree is divided into the following five levels:

V. EMPIRICAL ANALYSIS RESULTS

A. RESULTS OF GREY CORRELATION ANALYSIS

Utilizing standardized 2013–2022 panel data, the grey relational model assessed the nexus between the four language skill dimensions and the five core elements of new quality productivity. The results are as follows:

From Table 2, it can be seen that:

The average correlation between the factors of new quality productivity and the development of language skills is 0.78, indicating a significant positive correlation between the two, which verifies the theoretical hypothesis of coupling and coordination;

From the perspective of language skill development, the average correlation between digital language skills and new quality productivity factors is the highest (0.81), followed by professional language skills (0.80), and the average correlation between basic language skills is the lowest (0.76). This indicates that digital language

TABLE 1. Classification Criteria for Coupling Coordination Degree

Coupling Coordination Degree D	Coordination Level	Development Status
[0,0.2)	Extreme Imbalance	Severe imbalance in development, mutual restriction
[0.2,0.4)	Severe Imbalance	Poor coordination in development, obvious restrictions
[0.4,0.6)	Near Imbalance	Basic coordination in development, but with certain shortcomings
[0.6,0.8)	Primary Coordination	Coordinated development, initial emergence of synergistic effects
[0,0.2)	Extreme Imbalance	Severe imbalance in development, mutual restriction

TABLE 2. Grey Relational Degree Matrix Between New Productive Force Elements and Language Skill Development Dimensions

Language Skill Development Dimension	Technological Innovation	Digital Technology	Human Capital	Data Elements	Green Development	Average Relational Degree
Basic Language Skills	0.75	0.79	0.82	0.73	0.71	0.76
Professional Language Skills	0.81	0.84	0.83	0.78	0.76	0.80
Cross-Cultural Communication Skills	0.77	0.82	0.80	0.75	0.74	0.78
Digital Language Skills	0.79	0.85	0.81	0.83	0.77	0.81
Average Relational Degree	0.78	0.83	0.81	0.77	0.75	0.78

skills and professional language skills are better suited to the needs of the development of new quality productivity, and are the core link for their coupling and coordination;

3. In terms of specific correlation strength, the correlation between digital technology elements and digital language skills is the highest (0.85), the correlation between human capital elements and basic language skills is the highest (0.82), the correlation between technological innovation elements and professional language skills is the highest (0.81), the correlation between data elements and digital language skills is the highest (0.83), and the correlation between green development elements and professional language skills is the highest (0.76). This result reflects the differences in the coupling focus between different elements and skill dimensions.

B. CALCULATION RESULTS OF COUPLING COORDINATION DEGREE

1) Determination of Indicator Weights

The entropy weight method was used to calculate the weights of 30 evaluation indicators, and the results are as follows (only the weights of the top 10 indicators are listed):

TABLE 3. Weights of Key Evaluation Indicators

Indicator Name	Weight	Indicator Name	Weight
Proportion of core digital economy added value in GDP (%)	0.068	Proportion of skilled talents in employed population (%)	0.052
Internet penetration rate (%)	0.062	Enrollment of language majors in colleges and universities (10,000 people)	0.048
Number of invention patents granted per 10,000 people (pieces)	0.058	Number of cross-border e-commerce language service talents (10,000 people)	0.045
R&D expenditure as a proportion of GDP (%)	0.056	Number of users of digital language learning platforms (10,000 people)	0.043
Average years of education for population aged 15 and above (years)	0.054	Number of international conferences held (times)	0.041

From the weight results, we can see that the added value of the core industries of the digital economy accounts for a high proportion of GDP, the Internet penetration rate, the number of invention patents granted per 10000 people, the proportion of R&D investment in GDP, and the proportion of skilled personnel in employment. This indicates that these indicators are the core factors that affect the coupling and coordination between the elements of new quality productivity and the development of language skills, which is consistent with the characteristics of new quality productivity with scientific and technological innovation, digital technology, and human capital as the core.

2) Calculation of Comprehensive Development Level

Based on indicator weights and standardized data, calculate the comprehensive development level of new quality productivity factors and language skills from 2013 to 2022. The results are as follows:

TABLE 4. Comprehensive Development Levels of New Productive Force Elements and Language Skill Development (2013-2022)

Year	New Productive Force Elements (U1)	Language Skill Development (U2)
2013	0.321	0.287
2014	0.358	0.312
2015	0.396	0.345
2016	0.432	0.378
2017	0.475	0.413
2018	0.521	0.456
2019	0.568	0.492
2020	0.605	0.534
2021	0.652	0.578
2022	0.703	0.625

From Table 4, it can be seen that the comprehensive development level of new quality productivity factors and language skills in China has shown a steady upward trend from 2013 to 2022. While "new quality productivity" is a contemporary theoretical construct, the empirical results suggest that its constitutive elements (such as digital economy value and R&D intensity) were already undergoing a process of "latent coupling" during the last decade. The steady growth reflects the evolving definition of productivity, where the early years (2013–2017) represent the foundational accumulation of digital and innovative factors that eventually culminated in the current high-quality development paradigm.

The comprehensive development level of language skills has increased from 0.287 in 2013 to 0.625 in 2022, with an average annual growth rate of 8.5%, reflecting the improvement of the quality of language education, the growth of professional language talents, and the popularization of digital language skills in China; Overall, the comprehensive development level of new quality productivity factors is slightly higher than that of language skills development, and the gap has shown a widening trend from 2013 to 2018, and a narrowing trend after 2019, indicating that the adaptability of language skills development to new quality productivity has been improved in recent years.

3) Calculation of Coupling Coordination Degree and Analysis of Spatiotemporal Characteristics

Based on the calculation of comprehensive development level, the coupling degree and coupling coordination between new quality productivity factors and language skills development from 2013 to 2022 were calculated. The results are as follows:

TABLE 5. Coupling Degree and Coupling Coordination Degree of New Productive Force Elements and Language Skill Development

(2013–2022)

Year	Coupling Degree (C)	Coupling Coordination Degree (D)	Coordination Level	Development Status
2013	0.982	0.423	Near Imbalance	Basic coordination, with shortcomings
2014	0.985	0.447	Near Imbalance	Basic coordination, with shortcomings
2015	0.987	0.472	Near Imbalance	Basic coordination, with shortcomings
2016	0.989	0.496	Near Imbalance	Basic coordination, with shortcomings
2017	0.991	0.523	Near Imbalance	Basic coordination, shortcomings improved
2018	0.992	0.557	Near Imbalance	Basic coordination, shortcomings improved
2019	0.993	0.589	Near Imbalance	Close to primary coordination
2020	0.994	0.621	Primary Coordination	Initial emergence of synergistic effects
2021	0.995	0.658	Primary Coordination	Enhanced synergistic effects
2022	0.996	0.687	Primary Coordination	Significant synergistic effects

From Table 5, it can be seen that:

1. Coupling degree analysis: From 2013 to 2022, the coupling degree was above 0.98 and showed a steady upward trend, indicating that the interaction and mutual influence between new quality productivity factors and language skill development are very close, and the coupling degree is extremely high;

2. Stage feature analysis:

(1) 2013-2016: The coupling coordination degree was between 0.423-0.496, in the early stage of the “near imbalance” level. At this time, the development of new quality productivity and language skills were at a relatively low level, and the shortcomings of coordinated development were more obvious;

(2) From 2017 to 2019, the coupling coordination degree was between 0.523-0.589, in the later stage of the “near imbalance” level. The development speed of new quality productivity and language skills accelerated, and the shortcomings of coordinated development gradually improved, approaching the “primary coordination” level.

VI. RESEARCH CONCLUSIONS AND POLICY RECOMMENDATIONS

A. RESEARCH CONCLUSION

This article is based on panel data at the national level from 2013 to 2022. Using the grey correlation model, entropy weight coupling coordination model, and regression analysis, it systematically explores the coupling and coordination relationship between new quality productivity elements and language skill development. The following core conclusions are drawn:

There is a significant positive coupling relationship between the elements of new quality productivity and the development of language skills, with an average grey correlation degree of 0.78. Among them, the correlation between digital technology elements and language skill development is the closest (correlation degree 0.83), followed by human capital elements (0.81); The correlation between digital language skills and new quality productivity factors is the closest (0.81), followed by professional language skills (0.80), indicating that digital technology and human capital are the core driving forces for the coupling of the two, and digital language skills and professional language skills are the core link for the coupling of the two.

There are obvious stage characteristics and dimensional differences in the coupling and coordination between the elements of new quality productivity and the development of language skills: 2020 is a key node for the two to enter “primary coordination” from “near imbalance”; The coupling focus of different elements and skill dimensions varies, with the highest coupling strength between digital technology and digital language skills, human capital and basic language skills, and technological innovation and professional language skills.

B. POLICY SUGGESTIONS

The empirical evidence from the Grey Relational Matrix (Table 2) shows that digital language skills have the highest correlation (0.85) with digital technology. This direct numerical link necessitates the following actionable strategies:

1) Optimize the Language Education System and Strengthen Talent Support

1. Strengthen the connection between basic language education and the demand for new quality productivity, integrate the cultivation of digital language skills and cross-cultural communication skills in the basic education stage, and enhance the overall language literacy of the nation; Specifically, the transition from ‘near imbalance’ to ‘primary coordination’ observed in 2020 suggests that policy interventions should prioritize the digitalization of language curricula.

2. Increase investment in language education, increase the proportion of education investment in GDP, improve language education infrastructure, promote intelligent language learning tools, and enhance the efficiency and accuracy of language skill development.

2) Promote the Integration of Digital Technology and Language Skills to Enhance Adaptability

1. Accelerate the construction of digital infrastructure, expand the coverage of the Internet and 5G network, and provide technical support for the training and application of digital language skills;

2. Encourage cooperation between enterprises and universities to develop digital language products such as artificial intelligence translation tools, virtual reality language training systems, and cross language data processing platforms, promoting the deep integration of language skills and digital technology;

3. Enhance the popularization of digital language skills, carry out digital language skills training, and focus on targeting groups such as workers, entrepreneurs, and researchers to enhance their ability to adapt to the development of new quality productivity.

3) Expand Opening Up to the Outside World and Promote Cross-Cultural Exchange

1. Further enhance the level of opening up to the outside world, expand the scale of cross-border trade, international cooperation, and academic exchanges, and provide broad scenarios for the application of language skills;

2. Strengthen international exchange of language talents, attract high-end language talents from overseas to work in China, support Chinese language talents to participate in international affairs, and enhance China’s voice in global language governance.

4) Promote Industrial Structure Upgrading and Strengthen Demand Pull

1. Accelerate the upgrading of industrial structure, vigorously develop new industries and formats such as digital economy, high-end manufacturing, green industry, cross-border e-commerce, etc., and stimulate the demand for professional language skills;

2. Encourage enterprises to participate in the training of language skills talents, enhance the industrial adaptability of language talents through school enterprise cooperation, order based training, and other methods, and promote the precise connection between language skills and new quality productivity factors.

5) Improve the Mechanism for Coordinated Development and Address Regional Imbalances

1. Establish a coordinated development mechanism between new quality productivity elements and language skills development, strengthen the coordination and cooperation among education, science and technology, industry and information technology, commerce and other departments, and form a policy synergy;

2. Increase the tilt towards language education resources in the central and western regions, and narrow the gap in language skills development between regions through teacher training, educational informatization, and targeted support;

3. Develop differentiated language skills development policies based on the industrial characteristics and new quality productivity development priorities of different regions, and enhance the coupling and coordination level between the two at the regional level.

C. RESEARCH LIMITATIONS AND FUTURE PROSPECTS

1) Research Limitations

This study still has certain limitations:

1. Data level and Temporal Logic: The selected indicator data mainly consists of macro-level national data. A notable limitation is the “concept-data lag”; since new quality productivity was formally conceptualized after the study’s primary data range, the retroactive application of this framework may not fully capture the qualitative shifts in productivity definitions that occurred toward the end of the sample period. Future studies should employ more recent post-2023 data to validate these findings;

2. At the methodological level: The grey relational model and the coupling coordination model are mainly used for static and dynamic descriptions, and have not fully revealed the causal relationship and dynamic evolution path of their coupling coordination;

2) Future Outlook

Future research can be conducted in the following directions:

1. Expand the scope of data, collect data at the regional, industrial, and micro levels, conduct regional difference analysis and micro mechanism research, and enhance the pertinence and practicality of research results;

2. Innovative research methods are introduced, including panel vector autoregression (PVAR) model, threshold regression model, spatial econometric model, etc., to reveal the causal relationship, threshold effect, and spatial spillover effect of their coupling and coordination.

AUTHOR CONTRIBUTIONS

Zixian Gong designed, collected and analyzed the data, and drafted the manuscript. Zixian Gong conducted the study, critically revised the manuscript for important intellectual content, and gave final approval of the version to be published. Zixian Gong participated fully in the work, take public responsibility for appropriate portions of the content, and agreed to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

CONFLICTS OF INTEREST

The author declares no conflict of interest.

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