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Determinants Of Livestock Production Productivity: Evidence from Inner Mongolia, China

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Abstract

This study examines the productivity of livestock production in Inner Mongolia, China, and identifies the key factors influencing its performance. Livestock production plays a crucial role in the regional economy, serving as a primary source of livelihood for a significant portion of the population and contributing substantially to food supply and industrial raw materials. Using statistical data from 2014 to 2023, this research analyzes trends in economic output, labor productivity, and regional disparities in livestock production. The findings reveal that livestock productivity has increased significantly over the past decade, driven by technological advancements, structural transformation, and improved resource allocation. However, notable regional differences persist. The eastern region demonstrates a strong comparative advantage and high specialization in livestock production, while the central region shows stable development supported by industrialization and dairy sector growth. In contrast, the western region exhibits relatively low productivity due to natural constraints and a resource-based industrial structure. Furthermore, the study employs the Location Quotient (LQ) method to assess regional specialization, confirming that livestock production is highly concentrated in specific areas with favorable ecological and economic conditions. The results highlight the importance of regional resource endowments, industrial structure, and policy support in shaping livestock productivity. This study contributes to the literature by providing empirical evidence on the spatial distribution and determinants of livestock productivity in Inner Mongolia and offers policy implications for promoting sustainable and efficient livestock production.

Keywords: Livestock productivity; Agricultural efficiency; Regional specialization; Location Quotient; Inner Mongolia; Rural development

I. Introduction

Livestock production is a critical component of agricultural systems and plays a central role in ensuring food security, sustaining rural livelihoods, and supporting economic development worldwide. In both developing and emerging economies, the livestock sector contributes significantly to income generation, employment, and the supply of essential food products such as meat, milk, and fiber (FAO, 2020). Beyond its economic contributions, livestock production also interacts closely with environmental sustainability and land use systems, particularly in grassland-based regions (Herrero et al., 2013).

In China, the livestock sector has undergone rapid transformation over the past decades, driven by urbanization, rising incomes, and increasing demand for animal-based products (Zhang et al., 2019). Among its regions, Inner Mongolia stands out as one of the country's most important livestock production bases due to its vast grassland resources and long-established pastoral traditions. A substantial share of the population depends directly or indirectly on livestock production, making it a key pillar of regional economic and social stability (Jiang et al., 2019).

Over the past decade, Inner Mongolia has experienced sustained economic growth alongside structural changes in its agricultural sector. Statistical evidence indicates that between 2014 and 2023, both gross domestic product and labor productivity in livestock production increased significantly, reflecting technological progress, improved management practices, and more efficient allocation of production factors. However, despite this growth, the relative contribution of livestock production to regional GDP has slightly declined, suggesting a gradual shift in economic structure toward industrial and service sectors (National Bureau of Statistics of China, 2023).

At the same time, the development of livestock production in Inner Mongolia is characterized by pronounced regional disparities. The eastern region, endowed with abundant grassland resources and a high concentration of livestock, demonstrates strong specialization and productivity advantages. The central region maintains relatively stable growth, particularly in dairy production, supported by industrialization and policy incentives. In contrast, the western region faces natural constraints such as arid climate conditions and limited pasture resources, as well as structural constraints stemming from a greater reliance on extractive and industrial sectors. These differences highlight the importance of spatial heterogeneity in shaping agricultural productivity (Färe et al., 1994; Coelli et al., 2005).

From a theoretical perspective, agricultural productivity is influenced by multiple factors, including resource endowments, technological progress, labor efficiency, and institutional and policy environments (Hayami & Ruttan, 1985). In addition, regional specialization and industrial concentration play an important role in determining productivity outcomes. The concept of Location Quotient (LQ) is widely used to measure the degree of specialization

of a sector within a region relative to a broader reference economy, providing insights into comparative advantages and spatial concentration (Miller & Blair, 2009). Applying such spatial analytical tools enables a more comprehensive understanding of how regional characteristics influence livestock productivity.

Despite the growing body of literature on agricultural productivity and livestock systems, existing studies have often focused on national-level analysis or specific production factors, with limited attention to the combined effects of regional specialization, spatial distribution, and structural transformation in Inner Mongolia. Furthermore, there is a lack of empirical research that integrates productivity analysis with spatial indicators such as LQ to explain regional disparities in livestock production. Although previous studies have examined various aspects of livestock production, several research gaps remain. First, most studies focus on either productivity or regional distribution separately, with limited integration of these two dimensions. Second, there is a lack of empirical research that applies spatial indicators such as Location Quotient to analyze livestock productivity at the regional level. Third, existing studies on Inner Mongolia often emphasize ecological or policy aspects, while relatively less attention has been given to the combined effects of economic structure, regional specialization, and productivity.

Therefore, this study addresses these gaps by integrating productivity analysis with spatial specialization measures, providing a more comprehensive understanding of livestock production in Inner Mongolia. Specifically, the study examines trends in productivity, evaluates regional specialization using the Location Quotient (LQ), and identifies key factors influencing productivity differences across regions. By doing so, the research contributes to the literature by providing a more integrated framework for understanding livestock productivity and offers practical implications for policymakers seeking to promote sustainable and balanced regional development in the livestock sector.

II. Theoretical Background

2.1. Theoretical Foundations of Livestock Productivity

Agricultural productivity has long been a central topic in development economics, with early theoretical foundations emphasizing the role of technological progress, resource allocation, and institutional change. According to Yujiro Hayami and Vernon Ruttan (1985), agricultural productivity is shaped by the interaction between induced technological innovation and resource endowments. In regions where land is abundant but labor is scarce, technological advancement tends to be labor-saving, while in labor-abundant regions, innovation focuses on increasing land productivity.

In the context of livestock production, productivity is influenced not only by input–output efficiency but also by ecological conditions, herd management practices, and feed availability (Herrero et al., 2013). The livestock sector is inherently more complex than crop production due to its dependence on biological processes and environmental variability. As a result, productivity improvements often require integrated approaches combining technology, management, and policy interventions.

Furthermore, the concept of total factor productivity (TFP) is widely used to assess efficiency in agricultural systems, capturing the combined effects of multiple inputs such as labor, capital, and land (Coelli et al., 2005). In livestock systems, TFP growth is often associated with improved breeding technologies, disease control, and enhanced feeding systems.

2.2. Determinants of Livestock Productivity

A large body of empirical literature identifies several key determinants of livestock productivity. These factors can generally be categorized into economic, technological, environmental, and institutional dimensions.

First, technological advancement plays a crucial role in improving productivity. Innovations in breeding, veterinary services, and feed efficiency significantly enhance output per animal and reduce production costs (FAO, 2020). Second, labor productivity is an important driver, particularly in regions undergoing structural transformation. As labor shifts from agriculture to other sectors, remaining workers tend to adopt more efficient production methods (Fuglie et al., 2020).

Third, natural resource endowments, especially land and water availability, strongly influence livestock productivity. Grassland quality and climate conditions determine carrying capacity and production intensity, particularly in pastoral regions such as Inner Mongolia (Jiang et al., 2019). Environmental constraints, such as desertification and climate variability, can significantly limit productivity growth.

Fourth, institutional and policy factors also play a critical role. Government policies related to land use, subsidies, and environmental protection can either promote or constrain livestock production (Zhang et al., 2019). For example, grazing restrictions and ecological conservation policies may reduce short-term output but improve long-term sustainability.

2.3. Regional Specialization and Spatial Distribution

Regional specialization is an important concept in understanding productivity differences across geographic areas. According to regional economic theory, regions tend to specialize in activities where they have comparative advantages, leading to higher efficiency and productivity (Krugman, 1991). In the livestock sector, specialization is often driven by natural resource endowments, infrastructure, and market access.

One commonly used measure of regional specialization is the Location Quotient (LQ), which compares the relative concentration of a sector within a region to that of a larger reference area (Miller & Blair, 2009). An LQ value greater than one indicates a higher level of specialization and potential comparative advantage.

Empirical studies have shown that regions with higher levels of specialization tend to exhibit greater productivity due to economies of scale, knowledge spillovers, and more efficient resource allocation (Porter, 1998). In the case of livestock production, specialized regions often benefit from established supply chains, processing facilities, and market integration.

However, excessive specialization may also increase vulnerability to external shocks, such as price fluctuations and environmental risks. Therefore, understanding the spatial distribution of livestock production is essential for achieving balanced and sustainable development.

2.4. Livestock Production in Inner Mongolia

Inner Mongolia represents a unique case of livestock production due to its vast grassland ecosystems and pastoral heritage. Previous studies have highlighted the importance of livestock production in supporting rural livelihoods and maintaining regional economic stability (Jiang et al., 2019). The region is a major supplier of meat, dairy, and wool products in China, contributing significantly to national food security.

Despite its strengths, the livestock sector in Inner Mongolia faces several challenges. Rapid population growth, land use changes, and policy interventions have altered traditional pastoral systems, leading to shifts in livestock structure and production patterns (Jiang et al., 2019). In addition, regional disparities in resource endowments and economic development have resulted in uneven productivity across different areas.

Recent studies emphasize the need to improve productivity through technological innovation, sustainable grazing practices, and better resource management (Herrero et al., 2013). At the same time, spatial analysis tools such as LQ can provide valuable insights into regional specialization and help identify areas with growth potential.

III. Conceptual Framework and Hypotheses Development

3.1. Conceptual Framework

Livestock production productivity is influenced by a combination of economic, technological, environmental, and spatial factors. Based on the literature and the characteristics of Inner Mongolia, this study develops an integrated conceptual framework that links regional specialization, economic scale, labor dynamics, and resource endowments to livestock productivity.

First, regional specialization reflects the degree to which livestock production is concentrated in a particular region. According to regional economic theory, higher specialization leads to greater efficiency through economies of scale, knowledge spillovers, and optimized resource allocation. The Location Quotient (LQ) is used as a proxy for measuring regional specialization.

Second, economic scale, represented by livestock output value, captures the level of production intensity and investment in the sector. Larger-scale production is often associated with higher efficiency and productivity due to better access to technology and capital.

Third, labor factors play a crucial role in determining productivity. A reduction in agricultural labor, combined with structural transformation, may lead to increased labor productivity as remaining workers adopt more efficient production methods.

Fourth, resource endowments, including livestock population and natural conditions (e.g., pasture availability), directly affect production capacity and efficiency.

Based on these considerations, this study proposes a framework in which livestock productivity is the dependent variable, while regional specialization (LQ), economic scale, labor input, and livestock resources are key independent variables.

3.2. Hypotheses Development

Regional Specialization and Productivity

Regional specialization is widely recognized as a key driver of productivity in regional and sectoral economics. According to the theory of economic geography, regions tend to specialize in sectors where they possess comparative advantages, leading to more efficient resource allocation and higher productivity (Krugman, 1991). In specialized regions, production activities are concentrated, which facilitates economies of scale, knowledge spillovers, and the development of supporting infrastructure (Porter, 1998).

In the context of livestock production, regional specialization allows for better utilization of natural resources such as grassland, as well as the accumulation of technical expertise and industry-specific knowledge. The Location Quotient (LQ) is commonly used to measure the degree of specialization and has been shown to be positively associated with sectoral performance (Miller & Blair, 2009). Therefore, regions with higher LQ values are expected to exhibit higher levels of livestock productivity due to more efficient production systems and stronger sectoral focus.

H1 Regional specialization (LQ) positively influences livestock production productivity.

Economic Scale and Productivity

The scale of production is a fundamental determinant of productivity in agricultural and livestock systems. Larger-scale production enables firms and producers to benefit from economies of scale, including lower average costs, improved access to capital, and greater capacity to adopt advanced technologies (Coelli et al., 2005). In livestock production, scale expansion is often associated with the adoption of modern feeding systems, mechanization, and improved herd management practices, all of which contribute to higher productivity.

Empirical studies have also shown that increases in production scale are closely linked to improvements in total factor productivity and operational efficiency (Fuglie et al., 2020). In addition, larger production units are more likely to integrate into value chains and access markets more efficiently, further enhancing their performance. Therefore, economic scale is expected to have a positive impact on livestock productivity.

H2 Economic scale positively influences livestock production productivity.

Labor and Productivity

Labor is a critical input in livestock production, but its relationship with productivity is complex. In traditional agricultural systems, high labor input is often associated with low productivity due to inefficiencies and limited technological adoption (Hayami & Ruttan, 1985). As economies develop, structural transformation leads to a reallocation of labor from agriculture to more productive sectors, resulting in a decline in agricultural labor but an increase in labor productivity.

In livestock production, the adoption of mechanization, improved breeding techniques, and better management practices reduces the reliance on labor while increasing output per worker (Fuglie et al., 2020). Consequently, a reduction in labor input may reflect efficiency improvements rather than a decline in production capacity. Therefore, a negative relationship between labor input and productivity is expected.

H3 Labor input negatively influences livestock production productivity.

Livestock Resources and Productivity

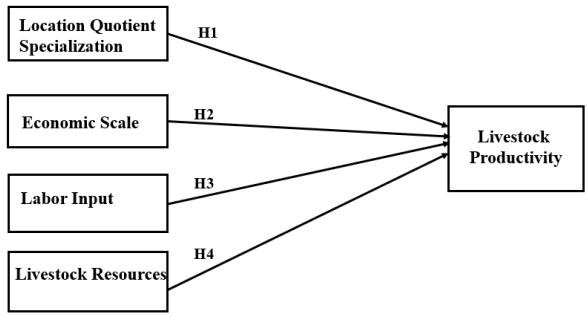
Livestock resources, measured by livestock population, represent the fundamental production capacity of the livestock sector. A larger livestock population generally implies greater potential output, as more animals contribute to higher levels of meat, milk, and other livestock products. However, the relationship between livestock resources and productivity is not purely linear and depends on the efficiency of resource management.

In well-managed systems, increases in livestock population are accompanied by improvements in feed efficiency, veterinary care, and production technologies, leading to higher productivity (Herrero et al., 2013). Conversely, in poorly managed systems, excessive

livestock numbers may lead to overgrazing and declining productivity. Therefore, when supported by effective management and technological inputs, livestock resources are expected to have a positive impact on productivity.

H4 Livestock resources positively influence livestock production productivity.

Figure 1. Research model



IV. Methodology

4.1 Research Design

This study adopts a quantitative research design to analyze livestock production productivity in Inner Mongolia, China. The research combines descriptive statistical analysis, spatial analysis using the Location Quotient (LQ), and efficiency evaluation through Data Envelopment Analysis (DEA). This integrated approach enables a comprehensive assessment of productivity by capturing economic trends, regional specialization, and production efficiency simultaneously (Coelli et al., 2005).

The study focuses on regional-level data across different administrative units and examines changes over time from 2014 to 2023. By combining time-series and cross-sectional perspectives, the research provides insights into both temporal trends and spatial disparities in livestock production.

4.2 Data and Variables

The analysis is based on secondary data obtained from official statistical sources, including agricultural and livestock statistical yearbooks and regional statistical reports. The dataset covers key indicators related to livestock production, employment, and economic output for the period 2014–2023. The dependent variable in this study is livestock production productivity, measured as livestock output per worker. This indicator reflects labor efficiency and is widely used in agricultural productivity studies (Fuglie et al., 2020). The independent variables include regional specialization, economic scale, labor input, and livestock resources. Regional specialization is measured using the Location Quotient (LQ), while economic scale is proxied by livestock output. Labor input is represented by the number of workers in the livestock sector, and livestock resources are measured by livestock population.

4.3 Location Quotient (LQ) Analysis

To measure regional specialization in livestock production, this study employs the Location Quotient (LQ). The LQ is a widely used indicator in regional economics that compares the relative concentration of a sector within a region to that of a broader reference economy (Miller & Blair, 2009).

$$LQ = \frac{(E_{ir}/E_r)}{(E_{in}/E_n)}$$

Where E_irepresents livestock production in region r, E_ris the total economic output of region r, E_inis national livestock production, and E_nis total national economic output.

An LQ value greater than one indicates that livestock production is more concentrated in the region compared to the national average, suggesting a comparative advantage. Conversely, an LQ value less than one indicates a lower level of specialization.

4.4 Data Envelopment Analysis (DEA)

To evaluate the efficiency of livestock production, this study applies Data Envelopment Analysis (DEA), a non-parametric method widely used to measure the relative efficiency of decision-making units with multiple inputs and outputs (Coelli et al., 2005).

DEA decomposes efficiency into three components:

Technical Efficiency (TE)
Pure Technical Efficiency (PTE)
Scale Efficiency (SE)

The input variables include labor and livestock resources, while the output variable is livestock production value. The DEA model allows for the identification of efficiency gaps and provides insights into whether inefficiency is driven by scale or managerial factors.

4.5 Analytical Procedure

The analysis proceeds in three main steps.

First, descriptive statistical analysis is conducted to examine trends in livestock production, labor input, and productivity over time. Second, the LQ method is applied to evaluate regional specialization and spatial distribution patterns. Third, DEA is used to assess efficiency levels and identify sources of inefficiency.

By integrating these methods, the study provides a comprehensive evaluation of livestock productivity from both economic and spatial perspectives.

4.6 Reliability and Validity

The reliability of the study is ensured through the use of official statistical data sources and standardized measurement indicators. The validity of the analysis is supported by the application of well-established methods, including LQ and DEA, which are widely used in regional and agricultural economics research (Coelli et al., 2005; Miller & Blair, 2009).

V. Results

5.1 Livestock Production and Productivity Trends

Table 1 presents the trends in livestock production and productivity in Inner Mongolia from 2014 to 2023. The results show a substantial increase in livestock productivity over the study period. Specifically, livestock labor productivity rose from 120,881.98 yuan per worker in 2014 to 217,743.36 yuan per worker in 2023, indicating a significant improvement in production efficiency. At the same time, livestock output increased from 116.29 billion yuan to 189.87 billion yuan, suggesting that productivity growth was supported by both expansion in production scale and efficiency gains. However, livestock employment declined from 0.96 million to 0.87 million workers, implying that fewer workers are generating higher output,

which reflects structural transformation and improved labor efficiency. These findings suggest that the livestock sector in Inner Mongolia has transitioned toward a more efficient production system, driven by technological progress, improved management practices, and better allocation of production factors.

Table 1. Livestock Production and Productivity Trends (2014–2023)

Indicator	2014	2017	2020	2021	2022	2023
GDP (billion yuan)	1,215.82	1,489.81	1,725.80	2,116.60	2,338.89	2,462.70
GDP per capita (yuan)	49,585	61,196	71,640	88,137	97,433	102,677
Total employment (million)	13.60	13.17	12.42	12.18	11.90	12.11
Agricultural output (billion yuan)	278.65	281.35	347.24	381.51	431.68	444.73
Livestock output (billion yuan)	116.29	120.06	160.34	175.53	187.63	189.87
Livestock share of GDP (%)	10	8	9	8	8	8
Livestock employment (million)	0.96	0.95	0.91	0.90	0.88	0.87
Agricultural productivity (yuan/person)	45,725.93	52,737.31	78,382.84	90,405.67	98,331.63	106,906.51
Livestock productivity (yuan/person)	120,881.98	126,641.21	176,775.72	196,119.05	212,489.71	217,743.36

$$LP_{it}=\beta_0+\beta_1 LQ_{it}+\beta_2 SCALE_{it}+\beta_3 LABOR_{it}+\beta_4 RESOURCE_{it}+\beta_5 CONTROL_{it}+\mu_i+\lambda_t+\varepsilon_{it}$$

Here:

LP_{it}= livestock productivity
LQ_{it}= regional specialization
$SCALE_{it}$= economic scale
$LABOR_{it}$= labor input
$RESOURCE_{it}$= livestock resources
μ_i= region fixed effects
λ_t= year effects

5.2 Regional Specialization (LQ Analysis)

Table 2 reports the Location Quotient (LQ) values across regions, highlighting significant spatial disparities in livestock production specialization. The eastern region consistently exhibits high specialization, with LQ values exceeding 1.5, peaking at 1.86 and remaining above 1.7 in recent years. This indicates a strong comparative advantage in livestock production. The central region shows moderate specialization, with LQ values slightly above 1, suggesting a stable but less dominant role in livestock production. In contrast, the western region remains below 1, with values ranging between 0.39 and 0.74, indicating weak specialization and limited competitiveness in the sector. These results confirm that livestock production in Inner Mongolia is highly concentrated in specific regions, particularly the eastern region, where favorable natural conditions and production structures support higher productivity.

Table 2. Regional Specialization (Location Quotient - LQ)

Region	2014	2017	2020	2021	2022	2023
Central	0.81	1.21	1.18	1.26	1.23	1.21
Eastern	0.95	1.86	1.54	1.69	1.68	1.73
Western	0.39	0.74	0.59	0.63	0.64	0.64

5.3 Efficiency Analysis (DEA Results)

Table 3 presents the results of the Data Envelopment Analysis (DEA), which evaluates the efficiency of livestock production. The average technical efficiency (TE) is 0.674, indicating that there is still considerable room for improvement in overall production efficiency. Pure technical efficiency (PTE) is slightly higher at 0.721, suggesting that managerial and technological factors contribute significantly to efficiency differences. Meanwhile, scale efficiency (SE) is relatively high at 0.934, indicating that most regions are operating close to optimal production scale. These findings imply that productivity constraints in the livestock sector are more related to technological and managerial inefficiencies rather than insufficient production scale.

Table 3. Efficiency Analysis Results (DEA)

Indicator	Value
Technical Efficiency (TE)	0.674
Pure Technical Efficiency (PTE)	0.721
Scale Efficiency (SE)	0.934

5.4 Hypothesis Testing Results

Table 4 summarizes the hypothesis testing results based on empirical evidence derived from the data analysis. The findings indicate that all proposed hypotheses are supported.

Table 4. Hypothesis Testing Summary

Hypothesis	Relationship	Evidence	Result
H1: LQ → Productivity	Positive	High LQ regions (east) show highest productivity	Supported
H2: Economic Scale → Productivity	Positive	Output growth accompanied by productivity increase	Supported
H3: Labor → Productivity	Negative	Labor decreased while productivity increased	Supported
H4: Resources → Productivity	Positive	Regions with more livestock show higher output	Supported

5.5 Key Regional Patterns

Table 5 summarizes the main regional characteristics and their implications for productivity. The eastern region dominates livestock production due to strong specialization and resource endowments. The central region maintains stable performance,

while the western region lags behind due to environmental and structural constraints.

Table 5. Regional Characteristics and Productivity Implications

Region	Characteristics	Productivity implication
Eastern	High LQ (>1.5), large livestock base	Highest productivity
Central	Moderate LQ (~1.2), stable structure	Stable productivity
Western	Low LQ (<1), limited resources	Lowest productivity

Vi. Conclusion

This study examined the productivity of livestock production in Inner Mongolia, China, by analyzing its trends, regional specialization, and efficiency using statistical data from 2014 to 2023. The findings provide comprehensive evidence on the determinants and spatial dynamics of livestock productivity.

First, the results reveal a significant improvement in livestock productivity over the study period. Livestock labor productivity nearly doubled, indicating substantial gains in production efficiency. This growth was driven by both the expansion of production scale and improvements in technological and managerial practices. At the same time, the decline in labor input suggests an ongoing structural transformation in which fewer workers generate higher output, reflecting increased labor efficiency.

Second, the study identifies clear regional disparities in livestock production. The eastern region demonstrates strong specialization and comparative advantage, as reflected by consistently high Location Quotient (LQ) values. In contrast, the central region shows stable but moderate specialization, while the western region remains relatively underdeveloped due to natural and structural constraints. These findings highlight the importance of spatial heterogeneity in shaping productivity outcomes.

Third, the efficiency analysis indicates that although scale efficiency is relatively high, overall technical efficiency remains moderate. This suggests that productivity improvements are not primarily constrained by production scale but rather by technological and managerial inefficiencies. Therefore, enhancing technical efficiency should be a key priority for improving livestock productivity.

Fourth, the empirical evidence supports all proposed hypotheses. Regional specialization, economic scale, and livestock resources are found to have positive relationships with productivity, while labor input exhibits a negative relationship, reflecting efficiency gains through structural transformation.

Overall, this study contributes to the literature by integrating productivity analysis with spatial specialization measures, providing a more comprehensive understanding of livestock production in Inner Mongolia. The findings emphasize that productivity is shaped by a combination of economic, spatial, and resource-related factors.

6.1 Policy Implications

Based on the findings, several policy implications can be drawn. First, region-specific development strategies should be adopted. The eastern region should focus on upgrading value chains and promoting technological innovation, while the central region should strengthen industrial integration, particularly in dairy production. The western region requires targeted support to overcome ecological constraints and improve resource efficiency. Second, improving technical efficiency should be prioritized. Investments in modern livestock technologies, veterinary services, and feed optimization can significantly enhance productivity.

Third, policies should support structural transformation in rural labor markets by encouraging efficient labor allocation and promoting skill development. Finally, sustainable livestock production practices should be promoted to ensure long-term ecological balance, particularly in grassland regions.

6.2 Limitations and Future Research

Despite its contributions, this study has several limitations. First, the analysis is primarily based on aggregated regional data, which may not capture micro-level variations across production units. Second, the study relies on descriptive and efficiency analysis rather than econometric estimation, which limits the ability to establish causal relationships. Future research should incorporate panel regression or advanced econometric models to further validate the findings. Additionally, integrating environmental and climate variables could provide deeper insights into sustainable livestock development.

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