

Article

Impact of Operating Scale on Factor Inputs in Grassland Animal Husbandry—Intermediary Effects Based on Market Risk

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Abstract: The Chinese government has made the realization of sustainable development in grassland animal husbandry an important policy objective, and achieving a reasonable input of production factors is the key to realizing that goal. Based on the assumption of “rational economic man”, this study measures the economically optimal inputs and actual input bias of production factors, and constructs an econometric model focusing on analyzing the impact of operation scale on the factor input bias. The results indicate that herdsman deviate from the economically optimal production input levels in forage, labor, and machinery, with the degree of bias decreasing as the livestock size or pasture size expands. Furthermore, it is established that market risk plays a role in mediating the impact of operation scale on the bias of variable production factors. Overall, large-scale herding households have a smaller bias in factor inputs, and should be promoted to operate on an appropriate scale, while paying attention to the prevention of market risk and the enhancement of information symmetry between herders and factor markets.

Keywords: operation scale; factor input bias; market risk



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1. Introduction

China is one of the world’s key centers of agricultural origin, and starting from the primitive period (about 9000 BC), the ancient Chinese began domesticating wild animals, and primitive livestock rearing emerged; by the Eastern Zhou Dynasty (770–476 BC), professional animal husbandry management had begun to develop [1]. In modern times, especially after the reform and opening-up (1978), China’s grassland animal husbandry has flourished. Grassland animal husbandry is a human activity that consumes natural resources [2]. However, grassland degradation has occurred on a wide scale and to varying degrees, due to climate change and human activities [3,4]. According to published statistics, the area of degraded usable natural grassland in China is approximately 90% and continues to expand at a rate of 2 million hectares per year [5]. For this reason, the Chinese government has successively implemented a series of grassland ecological protection policies such as grazing bans and grazing moratoria, which have further exacerbated the grass resource constraints in grassland livestock production; in addition, the sustainable development of grassland animal husbandry is facing a major challenge, which urgently requires that grassland animal husbandry be gradually transformed and upgraded from operating under the traditional free-range mode to adopting a modern approach.

However, the current level of modernized management of China’s grassland animal husbandry still needs to be improved. Currently, ordinary family-based herding households are still the mainstay of grassland livestock production, accounting for more than 90% of total production. The livestock with the highest degree of scale is dairy cattle, reaching 67.2%, while sheep and beef cattle are below 50% [6]. The penetration rate of mechanization in the livestock sector is only 35.79%, much lower than that in the plantation sector; the mechanization level of dairy farming is generally over 60%, while that of sheep and beef cattle is generally below 30% [7]. Restricted by factors such as the level of breeding and natural

resources, grassland livestock production capacity has grown slowly, with average yields of cattle and sheep respectively increasing by only 9.3% and 15% between 2000 and 2020.

Furthermore, the forage gap is widening: the dependence on feed grain imports is increasing, the production and processing system is weak, the quality is inconsistent, and the feed conversion rate is lower than that in advanced countries; for example, the feed conversion rate of dairy cows in advanced countries has reached 1.5:1, while China's is 1.2:1 [6]. Additionally, China's forage grass mainly comes from natural grassland, which is declining and has a large supply gap [8]; according to the State Forestry and Grassland Bureau data, in 2021, the total output of natural grassland fresh grass was just under 600 million tonnes, equivalent to 190 million tonnes of hay, a decrease of about 39.4% compared with 2014; at the same time, the degree of standardization of the forage industry, commoditization, industrialization, marketization, and intelligence is not sufficient; there are large losses in forage processing storage, and the ability to maintain a high-quality forage supply is limited.

Meanwhile, with the rising consumption levels and the transformation of meat consumption habits in China, consumer demand for livestock products, such as meat, milk, and eggs, is increasing [9]. The per capita consumption of beef and mutton in 2022 increased by 78.71% compared with that in 2000 [10]. This shows that the contradiction between the increasing demand for livestock products and the lower modernization level and limited forage supply capacity is a key issue affecting the sustainable development of grassland livestock husbandry. Studies have shown that the supply of high-quality forage and the mechanization of animal husbandry have a significant positive impact on improving livestock production and increasing livestock output [11–15]. Therefore, improving the mechanization level of livestock rearing as well as increasing the supply of high-quality forage is considered an important way to solve this key issue. In this context, grassland livestock production factor inputs have become a topic worthy of study.

The input of production factors is the most basic link, and is also the centralized manifestation of the transformation of the production and management mode [16]. The process of transformation from traditional grassland animal husbandry to modern grassland animal husbandry will be accompanied by the adjustment of production factors, which is manifested in the replacement of limited natural forage by artificial forage, the effective replacement of the labor force by machinery and equipment, and the upgrading of the factor allocation structure from the abundance of labor force factors to the abundance of technical factors [17]. Many factors affect production factor inputs, including the aging, feminization, and part-time employment status of the labor force [18–20], the level of capital [21], factor substitution [22], climate change [23,24], and policy factors [25].

Operation scale has also been recognized as an important factor influencing factor inputs. The adjustment of the scale of operations affects changes in the proportions and combinations of factor inputs, in essence achieving an optimal combination of factor inputs [26]. It is well documented that, as the scale of operation increases, the capital and technology factors that are accumulated increase [26–28]. Faced with higher labor costs than small-scale operators, large-scale operators are more willing to use machines or mechanized services in production [29,30], and small-scale operators tend to have relatively high transaction costs for the use of machinery, which is one of the main constraints on mechanization [31,32]. In a study of China's beef cattle industry for the period from 2013 to 2019, Ma et al. (2021) found that the proportion of forage inputs and labor inputs was decreasing, while the proportion of livestock input and other material inputs was increasing with the expansion of operation scale [33]. In addition, numerous scholars have studied the relationship between operation scale and fertilizer application and found that the two show a positive [34], negative [29], U-shaped relationship [35], inverted U-shaped relationship [36], or N-shaped relationship [37]. Some studies have been conducted from the perspective of operation scale and the rationality of production factor inputs. For example, Liu Xiaoyan et al. (2020) found that not only ordinary farmers but also grain-scale

households have the problem of excessive fertilizer application, but the degree of excess is significantly lower than that of ordinary households [38].

In summary, research results on the relationship between the scale of operation and factor inputs are abundant, but there are still the following shortcomings: First, the existing literature focuses on the impact of the scale of operation on the number of factor inputs, but there is little research on judging whether the factor inputs are reasonable or not, and the research results are mainly concentrated in the field of agriculture. In addition, the kind of effect that the scale of operation has on the bias of factor inputs in grassland animal husbandry remains to be studied. Second, most of the existing studies have explored the impact of operation scale on a single factor of production, and lacked research from a multi-factor perspective, thus failing to draw conclusions about the broader and more regular relationship between operation scale and factor inputs. Third, the intrinsic mechanism of the impact of business scale on factor input bias in the grassland livestock industry has not yet been explored in the existing literature. In view of this, this paper intends to use the research data of 282 households (from a 2023 survey) in five pastoral areas, namely, Keshketeng Banner, Bahraini Right Banner, Bahraini Left Banner, Wengniuote Banner, and Arukolqin Banner, in the southern foothills of the Great Hingganling Mountains of Inner Mongolia, to try to answer the following questions: Is the input of factors of production in grassland animal husbandry at the present stage reasonable? How will the expansion of operation scale affect the rationality of production factor inputs, and is there a linear or non-linear relationship between the two? What is the path through which this causal effect is generated, and is there heterogeneity for different types of production factors? This research is therefore intended to inform relevant policymaking.

2. Theoretical Analysis

2.1. Operating Scale and Bias in the Input of Production Factors

With the development of agricultural society, traditional grassland animal husbandry is realized through natural animal husbandry, and focuses more on traditional experience and the use of natural resources in the input of factors of production. In contrast, modern grassland animal husbandry prioritizes technology, science, and sustainability in the input of factors of production, and improves the efficiency of the optimal combinations of factors of production. So, what are the criteria for achieving the optimal input of production factors? Herders are the direct users of production factors in animal husbandry. Neoclassical economist Theodore Schultz posits that small peasant economies in competitive markets, like capitalist firms, adhere to the assumption of “rational economic man” in neoclassical economics. This means that the purpose of the production behavior of herdsmen is to obtain greater economic profit and to maximize profit when the marginal benefit is equal to the marginal cost, and further, considering the factor markets, when the marginal cost and marginal benefit of the factors are equal. When the marginal cost of factors is equal to the factor price, the marginal benefit of factors is the marginal product value, and the marginal product value of each factor input in equilibrium must be equal to the factor price; therefore, the economically optimal input quality is obtained when the marginal product value of each factor is equal to the factor price. As illustrated in Figure 1, when the input levels of all other factors remain constant, an increase in the input level of a specific factor results in a decrease in the marginal product value; here, the factor price is denoted as w , and the optimal input level of the factor at that point is Q^* .

However, herdsmen often lack sufficient knowledge of livestock production information, leading to a discrepancy between the actual input of factors and the optimal input. This discrepancy varies among herdsmen of different scales. Existing studies have shown that large-scale operators tend to have more rational factor inputs because they invest more in costs, and in order to save costs, they follow a certain scientific orientation in the arrangement of factor inputs, e.g., the scientific matching of the amount of forage and other material inputs [33]. Smaller-scale operators face challenges such as low specialization in production, high unit costs, and difficulty in optimizing resource allocation [39]. Expanding

the operational scale can improve feeding technology and animal raising conditions, reduce fodder procurement prices, save on labor costs, and enable the rational allocation of production factors like grassland, capital, and labor. This can help reduce the cost of production inputs and enhance operational efficiency [40–43]. On the other hand, large-scale operators are more open to pursuing new production technologies and production knowledge [44] and, thus, have a relatively high level of awareness of sustainable development, a relatively high level of professional knowledge and factor allocation capacity, and are often better equipped with the resources and conditions to achieve optimal resource allocation [45,46].

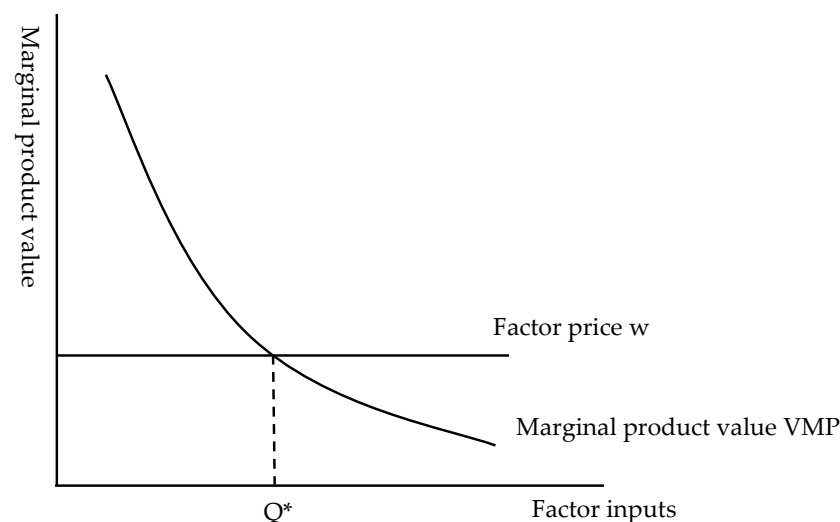


Figure 1. The optimal input of production factors for herdsmen.

Based on these premises, the following hypotheses are posited:

H1. *Herdsmen's factor inputs generally deviate from the optimal economic level, and the bias of factor inputs tends to decrease as the scale of operation increases.*

2.2. The Mediating Role of Market Risk

While large-scale operations lead to a decrease in unit input costs and an increase in expected utility, generally speaking, the larger the scale of operation, the more concentrated the production. This higher concentration increases the risk of being affected by natural disasters and market risks such as rising agricultural input costs and price fluctuations [47,48]. These factors negatively impact herdsmen's production enthusiasm and reduce their risk-bearing capacity [49]. Additionally, larger-scale operations make herdsmen more dependent on agricultural and animal husbandry income, making it challenging to transfer risks through other income sources. This situation enhances their inclination to avoid risks and leads to a more cautious approach in making decisions on inputting production factors [28]. Production factors consist of both variable factors like labor and forage, and fixed factors such as machinery and sheds. In the face of increasing market risk, herdsmen can adjust the quantity of variable inputs in the short term. For example, if the price of a particular feed rises, the economically optimal input amount of that feed will decrease. In this scenario, herdsmen will reduce the purchase of that feed to minimize risks and reduce bias. However, herdsmen are unable to adjust fixed production factors in the short term, showing insensitivity to changes in market risk. See Figure 2.

Based on this, the paper proposes the following hypothesis:

H2. *Market risk increases with the expansion of operating scale, and market risk plays a mediating role in the impact of operating scale on the bias of variable production factor inputs, and there is no mediating role in the effect on the constant factor input bias.*

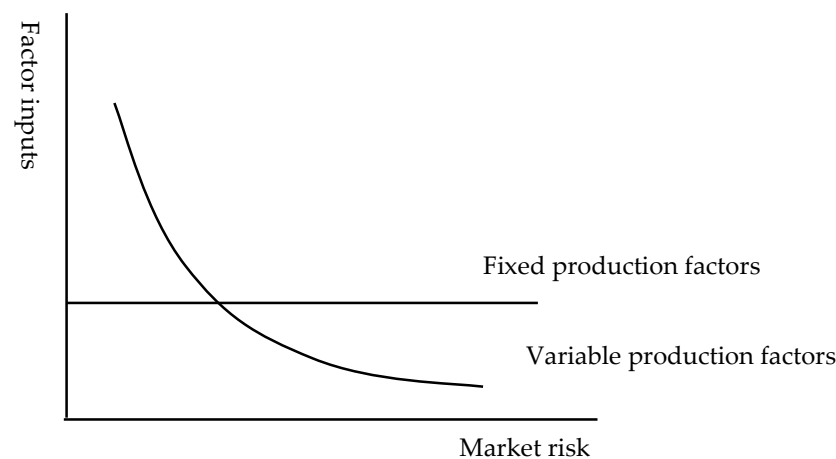


Figure 2. Market risk and short-term production factor adjustment.

3. Methodology and Data

3.1. Study Area

The data used in this article were derived from the 2023 survey of the pastoral areas in Kezuoqian Banner, Balin Right Banner, Balin Left Banner, Wengniute Banner, and Alukeerqin Banner, in Inner Mongolia, China. After excluding samples with recording errors, missing data, and abnormal numerical values, we obtained a valid sample with 282 observations. Data collection followed a stratified random sampling procedure. The research area selected was the agro-pastoral transitional zone, where both crop farming and animal husbandry coexist. Compared with pure grassland pastoral areas, herders in this region, as independent production decision makers, had a strong correlation with and displayed high substitutability between crop farming and animal husbandry. Herders relied heavily on self-produced feed in their animal husbandry production input. However, the per capita land and pasture area of herders were relatively small, production resources were scarce, and poverty was widespread. Therefore, using this region as a sample for studying production input is more meaningful (Table 1).

Table 1. Distribution of survey samples.

County	Sample Size
Aluqorqin Banner	84
Bahrain Left Banner	39
Right Banner of Bahrain	79
Wengniute Banner	47
Keshketeng Banner	33

3.2. Methods

3.2.1. Cost Contribution Model

This study utilizes a contribution model to assess the impact of each cost component on the change in total costs. Originally used to analyze economic benefits, expressed by the ratio of product output to resource consumption, the contribution model has evolved to analyze the factors influencing the development process of entities [50]. Based on previous research, the model is presented as follows:

$$\ln C_i = \beta_1 \ln \text{Forage}_i + \beta_2 \ln \text{Mating}_i + \beta_3 \ln \text{Medical}_i + \beta_4 \ln \text{Fuel}_i + \beta_5 \ln \text{Mac}_i + \beta_6 \ln \text{Insure}_i + \beta_7 \ln \text{Labor}_i + \mu_i \quad (1)$$

The contribution of the cost is

$$Rc_j = c_j / C_j \times \beta_j \times 100\% \quad (2)$$

where C_j is the total cost of animal husbandry, c_j denotes the input cost of each sub-item, and β_j stands for the elasticity coefficient of the input cost. Forage_i , Mating_i , Medical_i , Fuel_i , Mac_i , Insure_i , and Labor_i denote forage inputs, allotment costs, medical and vaccination costs, fuel and power costs, machinery inputs, insurance costs, and labor inputs, respectively (Table 2).

Table 2. Input and output of production factors in grassland animal husbandry (per hundred sheep units).

Variables	Definitions	Mean	Std. Dev.	Min	Max
Hay_i	Annual hay input costs (CNY)	56,344.52	89,828.63	130.00	725,000.00
Corn_i	Annual corn input costs (CNY)	139,728.30	203,319.70	1040.00	1,562,400.00
Feed_i	Annual other feed inputs (CNY)	11,723.69	23,325.81	0.00	256,747.40
Labor_i	The direct labor and hired workers of the family (CNY)	59,987.65	33,266.03	15,500.00	326,000.00
Mac_i	Depreciation of fixed assets (CNY)	12,742.22	13,280.53	800.00	89,381.00
Mating_i	Actual costs incurred for breeding through natural mating, artificial insemination, and embryo transfer, etc. (CNY)	3827.81	6518.11	0.00	43,000.00
Medical_i	Medical and epidemic prevention fees (CNY)	6154.73	8237.24	0.00	70,000.00
Fuel_i	Expenditure on coal, fuel, electricity, lubricants, and other power consumed (CNY)	13,458.98	38,137.40	300.00	353,000.00
Insure_i	Insurance expenses (CNY)	1575.08	3161.46	0.00	30,000.00
C_i	Total costs of grassland animal husbandry (CNY)	338,422.20	321,320.00	57,697.25	2,391,281.00
Output_i	Output value of all livestock products sold and retained (CNY)	758,086.60	637,816.90	62,700.00	4,042,500.00

3.2.2. Cobb–Douglas Production Function Model

The Cobb–Douglas production function was originally created by the American mathematician C.W. Cobb and economist Paul H. Douglas when they jointly explored the relationship between inputs and outputs, and it is one of the most widely used forms of production function in economics. Although the form of the transcendental logarithmic function is relatively flexible and is not limited by constant returns to scale, it is not possible to solve the optimal input of shares of factors for the transcendental logarithmic function [51]; therefore, this paper adopts the Cobb–Douglas production function model, combined with the actual situation of the production, to establish the C–D production function as follows:

$$\text{Output}_i = A \text{Hay}_i^{\alpha_1} \text{Corn}_i^{\alpha_2} \text{Feed}_i^{\alpha_3} \text{Labor}_i^{\alpha_4} \text{Mac}_i^{\alpha_5} \text{Else}_i^{\alpha_6} \quad (3)$$

In the C–D function, the dependent variable represents the total output value of animal husbandry for the i th herdsman (10,000 CNY); Hay_i and Corn_i refer to the expenses of hay and corn for the i th herdsman, respectively (CNY) (Since the largest share of forage cost for herders is corn (59.25%) and hay (24.01%), corn inputs and hay inputs were selected to represent forage inputs for the study); Feed_i refers to the sum of all forage costs incurred by the herdsman other than corn and hay (CNY); Else_i refers to the additional costs incurred in livestock production besides forage, labor, and mechanical inputs, including mating fees, fuel and power costs, medical and epidemic prevention fees, insurance premiums,

maintenance and care fees, etc. (CNY) (Table 2); α_1 – α_6 represent the output elasticities of hay, corn, other forages, labor, machinery, and other production inputs, respectively, and A is the sum of the effects of other influences in addition to the above. Taking both sides of the C–D production function in logarithmic form yields the Cobb–Douglas production function in logarithmic form as follows:

$$\ln \text{Output}_i = \lambda + \alpha_1 \ln \text{Hay}_i + \alpha_2 \ln \text{Corn}_i + \alpha_3 \ln \text{Feed}_i + \alpha_4 \ln \text{Labor}_i + \alpha_5 \ln \text{Mac}_i + \alpha_6 \ln \text{Else}_i + \beta_1 \text{Age}_i + \beta_2 \text{Education}_i + \beta_3 \text{Pasture}_i + \mu_i \quad (4)$$

Considering that other factors may have an impact on the output elasticity of the various factor inputs in production, the three variables Age_i , Education_i , and Pasture_i are added to Equation (4) to denote the age of the head of household, the level of education, and the size of the pasture, respectively. Age_i and Education_i can be used to represent the experience and skills in grassland animal husbandry, and Pasture_i can indicate the availability of grassland resources to pastoralists. See Table 3.

Table 3. Descriptive statistics for characteristics of household head, family, and operational features.

Variables	Definitions	Mean	Std. Dev.	Min	Max
Hay input bias	Calculated from Equations (4)–(6), and taken to absolute values (tonne)	12.58	14.60	0.02	175.84
Corn input bias	Calculated from Equations (4)–(6), and taken to absolute values (tonne)	10.21	14.48	0.01	116.74
Labor input bias	Calculated from Equations (4)–(6), and taken to absolute values (days)	141.30	100.70	0.31	526.85
Mechanical inputs bias	Calculated from Equations (4)–(6), and taken to absolute values (CNY)	2164.77	2591.18	0.15	23,656.65
Livestock size	Number of stocked livestock at the end of the year before survey (sheep units) ¹	337.54	232.48	50.00	1550.00
Pasture size	Pasture size = Own pasture size + Transferred – in pasture size – Transferred – out pasture size (mu) ²	1042.71	1161.82	0.00	8157.00
Gender	Male = 1; female = 2	1.03	0.17	1.00	2.00
Age	Age of household head (years)	48.43	9.04	22.00	70.00
Educational level	Schooling years of household head (years)	9.26	3.00	0.00	16.00
Family size	Number of family members	3.77	1.33	1.00	9.00
Political status	Whether the head of the household is a village cadre or not (Yes = 1; Otherwise = 0)	0.23	0.42	0.00	1.00
Transportation conditions	Distance from county government (kilometer)	59.66	25.75	1.10	126.00
Animal husbandry income	Income from sale of live animals and livestock products (CNY 10,000) ³	1.99	2.99	200.00	31.05
Proportion of hay	The proportion of hay cost to total costs (%)	10.08	8.63	0.01	40.53
Proportion of corn	The proportion of corn cost to total costs (%)	22.04	10.85	0.69	46.36
Proportion of other feeds	The proportion of other feeds costs to total costs (%)	9.81	11.26	0.00	77.49

Table 3. Cont.

Variables	Definitions	Mean	Std. Dev.	Min	Max
Participation in cooperatives	Whether they intend to join the cooperative or not (Yes = 1; Otherwise = 0)	0.13	0.33	0.00	1.00
Technological training	Whether they participated in technical training (never participated = 0; occasional participation = 1; Regular participation = 2)	0.93	0.77	0.00	2.00
Pasture quality	Quality deterioration = 0; quality unchanged = 1; better quality = 2	0.41	0.70	0.00	2.00

¹ Since herders usually cultivate multiple types of animals, sheep units were used to calculate aggregated livestock numbers. 1 sheep = 1 goat = 1 sheep unit; 1 cattle = 5 sheep units; 1 horse = 6 sheep units; 1 camel = 7 sheep units. ² 1 mu = 1/15 ha. ³ 1 USD = 6.7261 CNY in 2022.

Next, the economically optimal input levels of production factors for herdsmen are calculated. Economic optimality implies that marginal revenue equals marginal cost, and the price of production factors equals the marginal product value. Referring to prior research [38], the optimal input levels of production factors per hundred sheep units are as follows:

$$Q^* = \alpha_j \times y/w \quad (5)$$

α_j is the output elasticity of each production factor, y is the output value of animal husbandry per one hundred sheep units, and w is the price of each production factor. The price of mechanical input is represented by the depreciation rate [52]; the price of labor input is represented by the wage labor price in CNY/day; and the prices of forage are represented by the market prices of hay and corn in CNY/tonne.

Finally, the factor input bias is calculated by subtracting the optimal quantity from the actual quantity of production factors. In this equation, D_i represents the bias of input factors, Q_i is the actual input quantity of production factors, and Q_i^* is the optimal input quantity of production factors. When $D_i > 0$, a larger value indicates a greater positive bias in the input of production factors; when $D_i < 0$, a smaller value indicates a greater negative bias in the input of production factors; and when $D_i = 0$, it signifies no bias in the actual input quantity of production factors.

$$D_i = Q_i - Q_i^* \quad (6)$$

3.2.3. Multiple Linear Regression Model

We employ multiple regression analysis to explore the relationship between the operation scale and the bias of input factors in pastoral households. The model is as follows:

$$D_i = \gamma_0 + \sum_{j=1}^3 \gamma_j \text{Scale}_{ij} + \gamma_4 \text{Personal}_i + \gamma_5 \text{Family}_i + \gamma_6 \text{Operational}_i + \mu_i \quad (7)$$

Model (6) is utilized to investigate the impact of operation scale on the bias of production factor inputs. Here, D_i represents the bias of hay, corn, labor, and machinery inputs. Since production factor inputs may have a positive or negative bias, we select the absolute values of hay, corn, labor, and machinery input bias as the dependent variables in the regression analysis. When the absolute value of the bias approaches 0, it indicates that the positive or negative bias is smaller. Operation scale (Scale_i) is the primary explanatory variable in this study, reflecting the influence of different operation scales of herdsmen on the bias of production factor inputs. Generally, operation scale refers to the quantity of various production factors invested by herdsmen in the process of livestock breeding [53]. Building on the research of relevant scholars, we consider livestock size (Livestock_i) and pasture size (Pasture_i) as representative indicators of herdsmen's operation scale. Specifi-

cally, livestock size is indicated by the number of livestock at the end of the year in standard sheep units; pasture size is represented by the actual contracted pasture area of herdsmen's families plus the area of transferred-in pastures minus the area of transferred-out pastures. Based on the "Compilation of National Agricultural Products Costs and Returns" division criteria, combined with the overall situation of the research samples, the livestock size groups are categorized into four groups, namely, below 100 sheep units, 100–300 sheep units, 300–500 sheep units, and 500 sheep units, and above, with below 100 sheep units as the reference group. The pasture size groups are divided into four groups, namely, below 250 mu, 250–900 mu, 900–1550 mu, and 1550 mu and above, with below 250 mu as the reference group. "1" represents the scale group to which the herdsmen belong, and "0" represents other groups.

The characteristics of herdsmen (Personal_i) include the age of the household head, gender, and educational level; the family characteristics (Family_i) include the family size, political status of the household head, and transportation conditions; and operational characteristics (Operational_i) include the total livestock income, proportion of production input costs to total costs, participation in cooperatives, technical training, and pasture quality. μ_i represents a random disturbance term. See Table 3.

3.2.4. Mediation Effect Model

We utilize a mediation effect model to investigate the impact pathway of operational scale on the bias of production factors among herdsmen. The specific model is as follows:

$$\text{Risk}_i = \delta_0 + \delta_1 \text{Scale}_i + \delta_2 \text{Personal}_i + \delta_3 \text{Family}_i + \delta_4 \text{Operational}_i + \mu_i \quad (8)$$

$$D_i = \varphi_0 + \sum_{j=1}^3 \varphi_j \text{Scale}_{ij} + \varphi_4 \text{Risk}_i + \varphi_5 \text{Personal}_i + \varphi_6 \text{Family}_i + \varphi_7 \text{Operational}_i + \mu_i \quad (9)$$

When herdsmen encounter market risk, they mitigate it by adjusting their input of production factors [54], which subsequently impacts the bias degree of factor input. Building on prior research, market risk indicators (Risk_i) are chosen to analyze their influence on the bias degree of factor input. Market risk in terms of hay, corn, labor, and machinery input is assessed through the ratios of livestock selling price to hay price, livestock selling price to corn price, livestock selling price to labor price, and livestock selling price to machinery price, respectively. A lower ratio signifies lower breeding profit, higher market risk, and vice versa [55].

4. Empirical Study

4.1. Analysis of the Cost Contribution

We employ the least squares method to perform linear regression analysis on cross-sectional data, and the corresponding results obtained through regression are presented in Table 4, which indicates a high goodness of fit for the regression analysis model, with a favorable regression effect. The coefficients of the variables in the table represent elasticity coefficients, showing the extent of changes in production costs in response to variable changes. The results of the regression analysis reveal a positive correlation between various production costs and total production costs, with varying elasticities of different production factor input costs. The highest elasticity is observed for forage (0.66) and labor (0.26).

By combining the elasticity coefficients from Table 4 with Formula (2), the contributions of various input factors to total production costs can be calculated. According to Table 5, the top three contributors to costs are forage input (41.27%), labor input (6.41%), and machinery input (0.22%), while the cost contributions of other production factors are all below 0.10%. Therefore, we focused on analyzing the bias in the inputs of forage (corn and hay), labor, and machinery, which are the major contributors to production costs.

Table 4. Estimation results for the elasticity of production factor input costs.

Variables	Coefficients	Std. Dev.
ln Forage _i	0.6640 ***	0.0118
ln Mating _i	0.0028	0.0022
ln Medical _i	0.0062 *	0.0032
ln fuel _i	0.0118 ***	0.0026
ln Mac _i	0.0517 ***	0.0112
ln Insure _i	0.0017	0.0022
ln Labor _i	0.2580 ***	0.0190
Constant	1.0930 ***	0.2010
R-squared		0.963
F-test		1041.174

***, $p < 0.01$; *, $p < 0.1$.**Table 5.** Contribution of factor input to total costs of animal husbandry (%).

Factors	Contribution
Forage _i	41.2645
Stud _i	0.0034
Medical _i	0.0129
fuel _i	0.0478
Mac _i	0.2161
Insure _i	0.0008
Labor _i	6.4107

4.2. Analysis of the Bias of Production Factors Input from the Economic Optimal Result

The least squares method is utilized to estimate the production function model (4). It is evident that the regression estimates are relatively significant. Regarding input factors for production, hay, corn, other feed, labor, and machinery inputs, all have a significantly positive impact on output: a 1% increase in the cost of hay, corn, labor, and machinery inputs results in an approximate increase of 0.09%, 0.12%, 0.21%, and 0.30%, respectively, in the output of the livestock industry. Among other control variables, the educational level of the household head positively influences output, possibly indicating that the educational level reflects breeding technology to some extent; a higher education level corresponds to a higher technical level; however, the age of the household head does not significantly affect output. Pasture size is significant at the 1% level, although the coefficient is very small, suggesting that the impact of pasture size on grassland animal husbandry production is diminishing amidst the transition from traditional grazing to stall-feeding practices.

According to Table 6, the output elasticity of hay, corn, labor, and machinery inputs on the output value of animal husbandry is 0.09, 0.12, 0.21, and 0.30, respectively. Labor and machinery inputs exhibit higher output elasticity, while forage input shows lower output elasticity. This suggests that all input factors contribute to the increase in output value. Although an increasing forage input has a smaller impact on the output value, it remains essential in the production of grassland animal husbandry, which relies heavily on forage. The increase in labor input has a significant effect on boosting output value, highlighting the labor-intensive nature of grassland animal husbandry. Machinery input demonstrates the highest output elasticity, indicating its crucial role in the production process as a labor-saving technology. Despite the rising costs of forage and labor, machinery remains pivotal for the sustainable development of grassland animal husbandry.

Table 6. Estimation results of production function model.

Variables	Coefficients	Std. Dev.
ln Hay _i	0.0905 ***	0.0254
ln Corn _i	0.1150 ***	0.0326
ln Feed _i	0.0160 *	0.0084
ln Labor _i	0.2110 ***	0.0793
ln Mac _i	0.2970 ***	0.0458
ln Else	0.0802 **	0.0357
Age _i	−0.0011	0.0039
Edu _i	0.0522 ***	0.0121
Grass _i	0.0001 ***	3.15×10^{-5}
Constant	4.6020 ***	0.8750
R-squared		0.530
F-test		34.430

***, $p < 0.01$; **, $p < 0.05$; *, $p < 0.1$.

Combining the input–output elasticities with Equations (5) and (6) yields the economically optimal factor inputs and factor input bias. Table 7 illustrates the bias in factor inputs for pastoral households. In terms of production factor inputs, the bias of hay, corn, labor, and machinery inputs was −3.11 tonnes, 5.67 tonnes, −109.65 man-days, and USD 486.70, respectively, indicating that there was a negative bias for hay and labor inputs as a whole, and a positive bias for corn and machinery inputs as a whole. The degree of bias of factor inputs (in descending order) is labor (0.59), machinery (0.69), hay (0.82), and maize (1.39), which indicates that all factor inputs deviate from the economic optimum to varying degrees, and that maize inputs have the greatest degree of bias and labor inputs have the least degree of bias. From the distribution of herding households, 65.96% of the herding households had a bias of hay input higher than 0.50, 64.89% of the herding households had a bias of corn input higher than 0.50, 65.6% of the herding households had a bias of labor input higher than 0.50, and 55.67% of the herding households had a bias of machinery input lower than 0.50, from which it can be deduced that most of the herding households had a large bias of hay, corn, and labor inputs, and a small bias of machinery input.

Table 7. Bias of production factor input for different operation scales (per hundred sheep units).

Types of Production Factor	Factor Input Bias	Degree of Factor Input Bias ¹	Percentage of Bias in Factor Inputs for Herders (%)				
			Small (<0.25)	Smaller (0.25–0.50)	Comparatively Large (0.50–0.75)	Large (0.75–1.00)	Big (>1.00)
Hay input	−3.11 (tonne)	0.82	14.89	19.15	29.43	24.47	12.06
Corn input	5.67 (tonne)	1.39	16.31	18.79	19.86	14.18	30.85
Labor input	−109.65 (days)	0.59	15.25	19.15	38.65	23.05	3.90
Mechanical input	486.70 (CNY)	0.69	31.56	24.11	18.44	9.93	15.96

¹ The degree of factor input bias is the absolute value of the ratio between factor input deviation and the economically optimal amount of input.

4.3. Analysis of the Impact of Operating Scale on the Bias of Production Factors

4.3.1. Regression Results Analysis

Table 8 presents the regression results of the impact of livestock size on the bias of production factors after controlling for household head, family, and operational characteristics variables. The model specifically examines the significance of livestock size dummy variables. The coefficients for the three different livestock size dummy variables are all negative, using the reference category of less than 100 sheep units.

Table 8. Regression results of livestock size and bias of production factors input.

Variables	Hay Input Bias	Corn Input Bias	Labor Input Bias	Mechanical Input Bias
Livestock ₁	−1.5428 (3.2996)	−5.6045 * (3.3501)	−104.4684 *** (22.7794)	−1103.1360 * (612.0238)
Livestock ₂	−4.0643 (3.5977)	−10.1026 *** (3.6675)	−88.9249 *** (25.1258)	−998.2799 (672.1068)
Livestock ₃	−7.6267 * (4.5214)	−14.3610 *** (4.1781)	−86.4160 *** (28.7748)	−914.1912 (765.7775)
Sex _i	1.3869 (5.0497)	4.3712 (4.5678)	−13.0690 (31.5602)	1076.4790 (840.4974)
Age _i	0.1216 (0.1000)	0.0920 (0.0912)	0.5259 (0.6265)	3.5045 (16.7866)
Education _i	0.6642 ** (0.3050)	−0.4106 (0.2770)	1.7117 (1.9008)	−11.7560 (50.9572)
Members _i	−0.7406 (0.6493)	0.4252 (0.5910)	0.7667 (4.0589)	45.0315 (108.7228)
Identity _i	−1.8084 (2.0498)	−2.5675 (1.8747)	0.7375 (12.8439)	−582.9056 * (346.8293)
Traffic _i	−0.0158 (0.0340)	0.0110 (0.0311)	−0.0600 (0.2070)	9.1519* (5.5170)
ln Income _i	2.0876 ** (0.8875)	2.2932 *** (0.8203)	25.8903 *** (5.7060)	97.7681 (150.8521)
Proportion _i	58.6947 *** (10.0320)	65.2936 *** (7.2922)	−132.8810 *** (30.0200)	15709.9430 *** (1831.3950)
Cooperate _i	5.0618 ** (2.5306)	0.8848 (2.2990)	43.1544 *** (15.7260)	718.2626 * (423.0583)
Train _i	1.3065 (1.1420)	0.2224 (1.0431)	12.8988 * (7.1267)	223.3172 (190.8137)
Quality _i	−1.4965 (1.2228)	0.1802 (1.1179)	6.7683 (7.6502)	15.1886 (205.6527)
Constant	−24.9933 * (12.7060)	−29.8188 ** (11.7147)	−63.4700 (84.6908)	−1561.8390 (2143.2530)
N	282	282	282	282
R-squared	0.163	0.293	0.309	0.253
F-test	3.700	7.892	8.532	6.451

***, $p < 0.01$; **, $p < 0.05$; *, $p < 0.1$. Standard errors are presented in parentheses.

The bias of hay input in the size group Livestock₃ (500 sheep units and above) is statistically significant at the 10% level. Additionally, the bias of corn input and labor input in the size groups Livestock₁ (100–300 sheep units), Livestock₂ (300–500 sheep units), and Livestock₃ (500 sheep units and above) all show statistical significance. The bias of machinery input in the size group Livestock₁ (100–300 sheep units) also passes the 10% significance test. From this, it can be judged that hay, corn, labor, and machinery input bias all show a decreasing trend with the increase in livestock size.

Table 9 presents the regression results for the relationship between pasture size and bias in input factors for livestock production. The coefficients for the different pasture size dummy variables are predominantly negative. The bias in hay input for size groups Pasture₁ (250–900 mu), Pasture₂ (900–1550 mu), and Pasture₃ (1550 mu and above) is found to be statistically significant at the 1% level. The bias in corn input for size group Pasture₂ (900–1550 mu) is significant at the 5% level. Labor input bias is significant at the 10% level, while machinery input bias is significant at the 1% level. These results suggest that

bias in input factors decreases as pasture size increases. Although the regression results of either the livestock size dummy variable or the pasture size dummy variable are not fully significant, only the two production factor biases, corn and labor, show a significant downward trend in the all-livestock size groups, and while the hay input bias shows significance in the all-pasture size groups, the coefficients of the production factors are basically negative in the other size groups. Therefore, we can still conclude that overall, as the scale of operation expands, the smaller the input bias of production factors is, the closer the actual input quantity is to the economically optimal level. Hypothesis 1 is therefore largely tested.

Table 9. Regression results of pasture size and bias of production factors input.

Variables	Hay Input Bias	Corn Input Bias	Labor Input Bias	Mechanical Input Bias
Pasture ₁	−9.1427 *** (2.3035)	1.6472 (2.1799)	−20.4669 (14.7470)	−439.1651 (394.8024)
Pasture ₂	−9.8401 *** (2.7829)	−5.3867 ** (2.6348)	−34.0066 * (18.5248)	−1246.5790 *** (476.3681)
Pasture ₃	−9.4308 *** (2.7032)	−1.1282 (2.5531)	−17.2847 (18.0267)	−376.0524 (458.0566)
Sex _i	0.7085 (4.9126)	4.1197 (4.6444)	−13.7316 (32.7394)	935.1094 (839.9993)
Age _i	0.1721 * (0.0970)	0.1120 (0.0919)	0.5495 (0.6461)	3.9856 (16.6153)
Education _i	0.7033 ** (0.2971)	−0.4184 (0.2806)	1.3419 (1.9708)	−11.3133 (50.7079)
Members _i	−0.7799 (0.6293)	0.4538 (0.5959)	−0.4878 (4.1874)	40.8911 (107.7220)
Identity _i	−2.0145 (1.9928)	−4.0023 ** (1.8893)	−2.7105 (13.2443)	−661.6979 * (343.4713)
Traffic _i	0.0004 (0.0340)	0.0307 (0.0322)	−0.1221 (0.2223)	8.7723 (5.7213)
ln Income _i	1.4582 ** (0.7115)	0.4712 (0.6756)	23.6150 *** (4.9816)	85.3129 (121.9534)
Proportion _i	57.3402 *** (9.9025)	63.6836 *** (7.4087)	−134.3908 *** (31.6791)	15393.4900 *** (1814.4190)
Cooperate _i	3.7729 (2.4438)	−0.1618 (2.3168)	42.0696 ** (16.2472)	678.9699 * (419.0419)
Train _i	1.3134 (1.0982)	−0.1470 (1.0419)	16.8823 ** (7.3035)	267.5041 (187.5166)
Quality _i	−1.4478 (1.2068)	0.9371 (1.1453)	8.5891 (8.0226)	91.76384 (206.9793)
Constant	−15.6702 (11.7371)	−17.5086 (11.1971)	−101.4175 (84.5396)	−1760.8070 (2015.7770)
N	282	282	282	282
R-squared	0.206	0.278	0.261	0.263
F-test	4.962	7.348	6.752	6.822

***, $p < 0.01$; **, $p < 0.05$; *, $p < 0.1$. Standard errors are presented in parentheses.

Furthermore, when considering Tables 8 and 9 collectively, it is evident that the total livestock income significantly influences the bias of various production factors. This can be attributed to the fact that higher income levels among herdsmen enhance their ability to withstand risks, providing them with more flexibility in adjusting production factor inputs, thus making them more likely to deviate from the economic optimum. Costs such as hay, corn, and machinery exhibit a notable positive impact on the bias, whereas labor cost shows a significant negative impact. This could be due to the tendency of herdsmen to exceed the optimal levels of hay, corn, and machinery inputs, while falling below the optimal level in terms of labor input. One possible reason for joining a cooperative is the substantial positive effect on the bias of labor and machinery inputs caused by an increase in the negative bias. Cooperation membership enables herdsmen to free up labor, access machinery, and technical services more conveniently, reduce production costs, and ultimately achieve significant economic gains with less labor and machinery inputs.

4.3.2. Mediation Effect Analysis

Table 10 demonstrates that in model (8), livestock size has a significant positive impact on herders' market risk in hay, corn, labor, and machinery inputs, indicating that as the livestock size increases, herders face higher market risk. Model (9) indicates that with each unit increase in the market risk level, herders' input bias in hay input decreases by 0.98 tonnes, with a decrease in corn input bias by 2.71 tonnes, and a decrease in labor input bias by 2.68 days. Livestock size significantly influences herders' bias in hay, corn, and labor inputs through mediating variables, with the estimated values of livestock size having the same sign but larger coefficients compared to model (7). It is evident that market risk serves as the transmission mechanism through which livestock size impacts bias in variable production inputs. However, the impact of market risk on bias of machinery input is not significant. This is due to machinery input being a fixed production factor, where herders cannot adjust the quantity in the short term despite facing significant market risk. Consequently, machinery bias is not sensitive to changes in market risk, indicating that market risk does not mediate bias of fixed production input in the short term. Market risk does not have a mediating effect on the effect of livestock size on constant factor input bias.

Table 10. Testing the mediating effect of market risk.

Variables	Model (7)	Model (8)	Model (9)	Model (7)	Model (8)	Model (9)
	Hay Input Bias	Market Risk	Hay Input Bias	Corn Input Bias	Market Risk	Corn Input Bias
Livestock		−0.0009 * (0.0005)			−0.0005 *** (0.0002)	
Livestock ₁	−1.5428 (3.2996)		−0.4353 (3.3544)	−5.6045 * (3.3501)		−3.9520 (3.4468)
Livestock ₂	−4.0643 (3.5977)		−2.6355 (3.6858)	−10.1026 *** (3.6675)		−8.1325 ** (3.7960)
Livestock ₃	−7.6267 * (4.5214)		−6.0582 * (4.6027)	−14.3610 *** (4.1781)		−11.7417 *** (4.3830)
Risk _i			0.9766 * (0.5835)			2.7105 * (1.4344)
Whether to control variables	Yes	Yes	Yes	Yes	Yes	Yes
Constant	−24.9933 * (12.7060)	−5.0939 *** (1.3321)	−20.2112 (12.9817)	−29.8188 ** (11.7147)	−2.2030 *** (0.5052)	−23.6797 * (12.1029)
N	282	282	282	282	282	282

Table 10. Cont.

Variables	Model (7)	Model (8)	Model (9)	Model (7)	Model (8)	Model (9)
	Labor Input Bias	Market Risk	Labor Input Bias	Mechanical Input Bias	Market Risk	Mechanical Input Bias
Livestock		−0.0081 *** (0.0028)			−0.0894 *** (0.0299)	
Livestock ₁	−104.4684 *** (22.7794)		−80.3726 *** (22.8083)	−1103.1360 * (612.0238)		−1266.7620 ** (628.1)
Livestock ₂	−88.9249 *** (25.1258)		−59.9043 ** (25.3074)	−998.2799 (672.1068)		−1194.7623 * (693.2303)
Livestock ₃	−86.4160 *** (28.7748)		−49.3434 * (29.2407)	−914.1912 (765.7775)		−1175.5871 (798.5683)
Risk _i			2.6752 *** (0.6311)			−1.8445 (1.6089)
Whether to control variables	Yes	Yes	Yes	Yes	Yes	Yes
Constant	−63.4700 (84.6908)	−29.2697 *** (8.0633)	13.9678 (84.1296)	−1561.8390 (2143.2530)	−313.1594 *** (81.7493)	−2137.0913 (2199.9780)
N	282	282	282	282	282	282

***, $p < 0.01$; **, $p < 0.05$; *, $p < 0.1$. Standard errors are presented in parentheses.

To further investigate the mediating effect of market risk on the bias of production factor input in relation to operational scale, this study replaces livestock size with pasture size. The estimation results of the mediating effect are robust and reliable, as presented in Table 11. Pasture scale has a significant positive impact on market risk, indicating that as pasture scale expands, herdsmen are exposed to increased market risk. With each unit increase in market risk level, the bias of hay input for herdsmen decreases by 0.98 tonnes, the corn input bias decreases by 3.55 tonnes, and the labor input bias decreases by 3.03 days. Pasture scale significantly influences the bias of hay, corn, and labor inputs for herdsmen through the mediating effect. The effect of market risk on the bias of machinery input is not significant, suggesting that market risk does not mediate the impact of pasture scale on the bias of fixed production input.

Table 11. Robustness test estimates of mediation effects.

Variables	Model (7)	Model (8)	Model (9)	Model (7)	Model (8)	Model (9)
	Hay Input Bias	Market Risk	Hay Input Bias	Corn Input Bias	Market Risk	Corn input Bias
Pasture		−0.0002 ** (0.0001)			−0.0001 * (0.00003)	
Pasture ₁	−9.1427 *** (2.3035)		−9.1316 *** (2.2945)	1.6472 (2.1799)		1.2907 (2.162)
Pasture ₂	−9.8401 *** (2.7829)		−9.4877 *** (2.7792)	−5.3867 ** (2.6348)		−5.1452 ** (2.6094)
Pasture ₃	−9.4308 *** (2.7032)		−8.9715 *** (2.7052)	−1.1282 (2.5531)		−0.7730 (2.5306)
Risk _i			0.9813 * (0.5566)			3.5425 ** (1.3816)
Whether to control variables	Yes	Yes	Yes	Yes	Yes	Yes
Constant	−15.6702 (11.7371)	−4.6307 *** (1.2797)	−11.1871 (11.9643)	−17.5086 (11.1971)	−1.8612 *** (0.4912)	−10.9072 (11.3772)
N	282	282	282	282	282	282

Table 11. Cont.

Variables	Model (7)	Model (8)	Model (9)	Model (7)	Model (8)	Model (9)
	Labor Input Bias	Market Risk	Labor Input Bias	Mechanical Input Bias	Market Risk	Mechanical Input Bias
Pasture		−0.0008 * (0.0005)			−0.0088 * (0.0050)	
Pasture ₁	−20.4669 (14.7470)		−17.1540 (15.3425)	−439.1651 (394.8024)		−427.1717 (395.1142)
Pasture ₂	−34.0066 * (18.5248)		−29.2058 * (17.8141)	−1246.5790 *** (476.3681)		−1273.9150 *** (477.3973)
Pasture ₃	−17.2847 (18.0267)		−11.4536 (17.3500)	−376.0524 (458.0566)		−409.6087 (459.5948)
Risk _i			3.0269 *** (0.6228)			−1.4385 (1.5481)
Whether to control variables	Yes	Yes	Yes	Yes	Yes	Yes
Constant	−101.4175 (84.5396)	−25.0709 *** (7.9864)	−26.4338 (82.6246)	−1760.8070 (2015.7770)	−257.9842 *** (79.6469)	−2134.0330 (2055.9110)
N	282	282	282	282	282	282

***, $p < 0.01$; **, $p < 0.05$; *, $p < 0.1$. Standard errors are presented in parentheses.

Through the above analysis, it can be seen that market risk has a mediating role in either herd size or pasture size on variable factor inputs such as hay, corn, and labor. Since herd size and pasture size are representative indicators of operation scale, it can be deduced that market risk has a mediating role in the effect of operation scale on variable factor input bias, and does not have a mediating role in the effect of constant factor input bias. Hypothesis 2 is therefore fully tested and gives better test results.

5. Conclusions and Prospects

5.1. Conclusions

This study measured and analyzed the economically optimal inputs of major production factors in grassland animal husbandry as well as the deviations between actual and optimal inputs in five pastoral areas, namely, Keshketeng Banner, Bahraini Right Banner, Bahraini Left Banner, Wengniuote Banner, and Arukolqin Banner, of Chifeng City, in the southern foothills of the Greater Hingganling Mountains of Inner Mongolia; the research area chosen is an agricultural and pastoral zone, and the data are derived from a 2023 survey. Further, the relationship and path of action between the scale of operation and the deviation of production factor inputs are analyzed by using a multiple linear regression model and a mediation effect model, and the policy implications are proposed. Through the analyses, the following basic conclusions can be drawn:

- (1) The study reveals that forage, labor, and machinery costs are the primary factors influencing the total production cost of herdsman, contributing 41.27%, 6.41%, and 0.22%, respectively. Of these, the cost contribution of forage is much higher than that of the other factors of production, accounting for nearly half. Therefore, one of the keys to realizing sustainable development of grassland animal husbandry lies in controlling the cost of forage.
- (2) Various types of production factor inputs have a certain promoting effect on the output value of grassland animal husbandry, and the output elasticity is demonstrated by (in descending order) machinery (0.30), labor (0.21), corn (0.12), and hay (0.09). Machinery has the highest output elasticity but makes a small cost contribution, and the focus should be on improving mechanization in grassland animal husbandry. Labor is also an important contributor to output. However, in the face of the impact of rising labor prices and an aging workforce in today's society, raising labor inputs is clearly not a sustainable approach. The contribution of forage was lower. However, forage cannot

be replaced, as it is an indispensable part of grassland animal husbandry production; therefore, we should start by reducing the price of the forage supply.

- (3) In grassland livestock production, there is a deviation from the economic optimum in the inputs of factors of production, namely, labor, machinery, hay, and corn (in descending order), and the mean values of deviations were −109.65 days, CNY 486.70, −3.11 tonnes, and 5.67 tonnes, respectively. As the livestock size or pasture size increases, factor deviations show a decreasing trend. This decreasing trend makes large-scale herders more competitive than small-scale herders.
- (4) As ranchers' scales of operation increase, the degrees of market risk they face for hay, maize, labor, and machinery inputs gradually increase. Market risk plays a mediating effect in the influence pathway of operational scale on variable factor input bias, but does not play a mediating role in the effect of operation size on invariant factor input bias.

5.2. Policy Implications

Based on the results of this study, the following recommendations are made for the input of production factors and sustainable development of grassland animal husbandry:

- (1) Forage occupies an extremely important position in the production costs of grassland animal husbandry and has a direct impact on the sustainable development of grassland animal husbandry. Therefore, a series of measures should be taken to cope with the pressure of rising forage costs. Firstly, in areas where grass resources are scarce, it is possible to promote the implementation of industrial policies such as the "grain-to-fodder" policy, which replaces part of the demand for forage by planting food crops, thus reducing the pressure on the supply and cost of forage. Secondly, strengthening subsidies for forage planting is another important initiative, whereby the government can promote the planting of forage crops through direct subsidies, tax incentives, or policy support to reduce their planting costs and increase their planting income, thus encouraging farmers to increase the supply of forage, stabilize feed market prices, and reduce the economic pressure on herdsmen. In addition, scientific research institutions and enterprises can be encouraged to increase the level of research and development, and promote forage planting technology; in addition, the introduction of good varieties, improved planting technology, and efficient management modes and other measures can lead to improving the yield and quality of forage crops, reducing the cost of feeding, and increasing the profitability of herdsmen, thus promoting a more stable and sustainable development of grassland animal husbandry.
- (2) Machinery and labor play a crucial role in the development of grassland livestock farming. Labor has a high output elasticity and is critical to livestock production, but faces challenges such as rising labor prices and an aging workforce. These factors have given rise to the demand for mechanized equipment, and mechanization can replace labor to a certain extent, helping to reduce production costs and improve efficiency. Therefore, the government can promote the promotion and utilization of mechanical technology in grassland livestock husbandry by formulating relevant policies. One effective policy is to provide subsidies for the purchase of agricultural machinery and equipment, which can help herders obtain advanced agricultural machinery and equipment at a lower cost and improve production efficiency. In addition, the government can subsidize the construction of pens to improve the conditions of barns and enhance the environment for livestock production, thereby improving the productivity and health of livestock. In short, the government should increase the promotion of grassland livestock production machinery technology, effectively alleviate the impact of labor shortage and aging on livestock production, and lay a more solid foundation for the sustainable development of grassland animal husbandry.
- (3) Although there is a certain degree of deviation in the input of factors of production by large-scale herding households, the degree of deviation is significantly lower rela-

tive to that of small-scale herding households. This shows that scale operation has important practical significance in the development of grassland animal husbandry. Grassland transfer is an important way to realize moderate-scale operation. First, government departments should further improve relevant laws and regulations, provide tax incentives and financial support, set up special funds for pasture integration and transfer, and provide transfer subsidies and incentives to motivate herdsmen to actively participate in pasture transfer and to promote the large-scale development of animal husbandry. Second, government departments should establish a pasture resource trading market to provide a platform with transparent information and convenient transactions to promote the orderly flow of pasture resources. Third, government departments should strengthen the training and technical support for herdsmen to enhance their scale operation and resource management ability, so as to make them more aware of and capable of scaling their operation. It is also possible to encourage herders to transform into family farms or to form new management bodies such as professional cooperatives, so as to realize the integration of production factors and complementary advantages. In conclusion, through a moderate scale of operation, herdsmen can refine the management of forage, labor, and machinery inputs, realize the optimal allocation of production factors, and implement more efficient production methods, which will help the sustainable development of grassland animal husbandry.

- (4) The results of the study show that an increase in the degree of market risk reduces variable factor input bias to a large extent, while the effect on constant factor input bias is not significant. This finding poses the following question: How can we reduce the factor input bias while coping with market risk? Enhancing information symmetry between herders and factor markets is the key. First, a production factor information-sharing platform can be created so that herders can keep abreast of market prices, supply and demand trends regarding forage and labor, and so on; these could be in the form of online platforms, regular information meetings, or local cooperatives. Second, herders should be encouraged to conduct regular market research, which will help them better grasp changes in factors of production and market conditions, avoid blindly expanding or reducing means of production, and be able to better adjust their production plans and input levels. Finally, herding households can be provided with relevant training on market information and production factor allocation, including how to obtain, interpret, and utilize market information and how to optimize production factor allocation. Such training can help them better understand market dynamics and allocate production factors in a scientific and reasonable manner. In summary, it is crucial to enhance the awareness of market information and improve the production decision-making ability of herdsmen, which can effectively reduce the uncertainty in the production process and promote the rational allocation of production factors, thus promoting the sustainable development of grassland animal husbandry.

5.3. Prospects

Compared with that in previous studies, the research vision of this study was further expanded, providing new insights for optimizing the allocation of production factors. We were no longer confined to direct research on factor inputs but could instead focus on the analysis of factor input bias in grassland animal husbandry. We aimed to explore whether operation scale had regular effects on different types of factor input bias and what the influencing mechanisms were. The study was conducted based on three dimensions: forage, labor, and machinery input.

However, there are some limitations in this study. The representativeness of the samples may have been insufficient, making it difficult to fully reflect the overall picture of the research object. Additionally, the different types of grassland areas may have caused sample heterogeneity. As the production method of grassland livestock farming changes or develops, the effective input amounts of production factors may also change, leading

to a lack of scalability in research results. In the next step, we should consider factors such as technological or policy changes and conduct a more comprehensive study on the relationship between operation scale and production factors in different types of grassland areas. This will enhance the accuracy and comprehensiveness of our analysis and provide strong evidence for relevant policymaking.

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