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# Can changing breeding structure serve as a climate adaptation strategy? Evidence from a comparative study of China and Mongolia

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**Keywords:** Climate change; Breeding structure; NDVI; Grassland quality; Mongolian Plateau.

**Abstract.** Under the influence of climate change, the vulnerability of grassland ecosystems in the Mongolian Plateau has increased. Correspondingly, herdsmen need to adopt more livelihood adaptation strategies to cope with changes in climate and grassland environment. The purpose of this study is to analyze the impact of breeding structure on grassland quality in Mongolian plateau. We select 20 border provinces/banners of Mongolia and Inner Mongolia Autonomous Region for research, and combined statistical data with remote sensing data of 2007-2016. The Normalized Difference Vegetation Index (NDVI) is used to quantify the grassland vegetation quality. Results show that there are differences in livestock dynamics and grassland quality between Mongolia and Inner Mongolia, and higher sheep proportion leads to grassland degradation, and the impact varied in regions with different livestock carrying capacity. The initial grassland conditions could alleviate the negative impact of the sheep proportion on the grassland quality. The results of the mediation effect show that the primary industry GDP has a masking effect, i.e., the primary industry GDP can alleviate the negative influence of sheep proportion on grassland quality. The results of heterogeneity analysis showed that there were differences in the effect of sheep proportion on grassland quality under different livestock carrying capacity. In addition, after distinguishing countries, Mongolia did not show significant results due to its relatively stable breeding structure. While the breeding structure of Inner Mongolia had a greater negative impact on the grassland quality, which further indicated that the decline of sheep proportion has played a stronger ecological benefit.

## Introduction

The grassland ecosystem is among the largest ecosystems in the world, covering 25% of the global land area and 70% of agricultural area (Shi et al. 2021). The Mongolian Plateau (henceforth, MP) is located in the arid and semi-arid area in the hinterland of the Asian continent, and is one of the three major areas of grassland livestock production in the world, raising about 120 million livestock of all kinds and maintaining the livelihood of about 10 million low-income population (Neely and Bunning 2009; Bao et al. 2014). However, the ecosystem of MP is relatively fragile, in recent decades, due to the dual impact of climate change and human activities, a series of ecological and environmental problems such as grassland degradation and desert expansion have seriously affected the regional ecological environment and economic development (Tong et al. 2018; Wei and Zhen 2020).

Grassland vegetation change is mainly affected by natural and human factors. Breeding structure is an important aspect of livestock husbandry production. The previous research in the field of natural sciences proved that the breeding structure has an impact on the grassland through grazing experiment methods, mainly due to the differences in the herbivorous way and the degree of hoof trampling between cattle and sheep, while sheep will cause greater damage to vegetation (Chang et al. 2018; Jordon 2021). In addition, previous studies claimed changing breeding structure may be an important livelihood adaptation strategy (Wang et al. 2013; Zhao et al. 2019). However, as far as we know, there is no study to analyze the causality between breeding structure and grassland quality by long panel socio-economic data. Therefore, through the combination of socio-economic data and remote sensing data, we empirically analyze the impact of breeding structure on grassland quality, and explores the mechanism from an economic perspective.

The MP is mainly composed of Mongolia (henceforth, M) and China's Inner Mongolia Autonomous Region (henceforth, IM). These two regions have similar climate, ecology environment and traditional grazing culture, but under different regimes, there are differences in economy, politics and culture (Guo,

et al., 2021). However, few studies have focused on the border areas of M and IM. The livestock and people were separated by a national boundary, but climate change, natural disasters, grassland pests and rodents do not recognize it, so the ecosystem of MP is inherently consistent (Fernández-Giménez et al. 2012; Wei and Zhen 2020). Therefore, we selected 20 regions adjacent to M and IM for research, which can not only compare the dynamics of breeding structure and grassland quality in the past few years, but also further prove the robustness of the impact of breeding structure on grassland quality.

## Methods and Study Areas

The MP is located in the inland region of East Asia and is one of the largest areas of continuous arid rangeland in the world. We select 20 border provinces/banners of M and IM for research, and combined statistical data with remote sensing data of 2007-2016. The Normalized Difference Vegetation Index (NDVI) is used to quantify the grassland vegetation quality. Fixed effect model is used as benchmark to analyze the impact of breeding structure on grassland quality, and the heterogeneity analysis was conducted based on country and livestock carrying capacity. Then, the mediation effect model is used to identify the influence mechanism of breeding structure and economic benefit on grassland quality.

## Results and Discussion

### *Descriptive analysis*

The variable definitions and summary statistics are shown in Table 1. Our panel dataset includes 20 banner/province during 10 years, amounting to 200 observations (60 in M and 140 in IM of China). The results show that the annual mean temperature of IM (4.76℃) is higher than that of M (2.03℃), and annual cumulative precipitation of IM (237.16 mm) is also higher than that of M (164.48 mm). Similarly, in terms of statistical variables, the area of arable land, Number of rural households, GDP of primary industry and Beef price in IM are significantly higher than M. In particular, primary industry GDP of IM (664.59×106 CNY) far exceed M (79.96×106 CNY). In general, the human activity intensity of IM is much higher than that of M.

**Table 1. Variable definitions and summary statistics.**

| Variables | Variable definition | Units | MP | | M | | IM | |
|---|---|---|---|---|---|---|---|---|
| | | | Mean | S.D. | Mean | S.D. | Mean | S.D. |
| $Y_{it}$ | NDVI of banner/province i in year t [a] | n.a. | 0.15 | 0.07 | 0.13 | 0.05 | 0.15 | 0.07 |
| $S_{it}$ | The proportion of sheep in the five animals of banner/province i in year t [b] | % | 0.65 | 0.16 | 0.53 | 0.11 | 0.70 | 0.15 |
| $T_{it}$ | Annual mean temperature of banner/province i in year t | ℃ | 3.94 | 3.01 | 2.03 | 1.94 | 4.76 | 3.02 |
| $P_{it}$ | Annual cumulative precipitation of banner/province i in year t | mm | 215.36 | 110.96 | 164.48 | 80.31 | 237.16 | 115.29 |
| $A_{it}$ | Area of arable land of banner/province i in year t [c] | $\times 10^3$ha | 28.29 | 47.07 | 4.40 | 10.46 | 38.53 | 52.66 |
| $H_{it}$ | Number of rural households of banner/province i in year t [c] | $\times 10^3$ | 14.06 | 19.65 | 6.40 | 2.48 | 17.34 | 22.67 |
| $PI_{it}$ | GDP of primary industry of banner/province i in year t [d] | $\times 10^6$ CNY | 489.20 | 556.88 | 79.96 | 31.81 | 664.59 | 583.33 |
| $BP_{it-2}$ | Beef price of banner/province i in year t-2 [d e] | CNY/kg | 19.27 | 13.31 | 2.94 | 2.14 | 26.27 | 9.34 |
| No. of observations | | | 200 | | 60 | | 140 | |

### *Effects of livestock structure on grassland quality*

Table 2 reports the results of benchmark models. In models 1-3, breeding structure ($S_{it}$) has a statistically significant negative impact on $Y_{it}$ ($\beta_1$<0, p<0.05), indicating that the higher the proportion of sheep, the worse the quality of grassland. According to Model 2, the interaction term of breeding structure and initial grassland condition ($S_{it} \times D_i$) has a significantly positive effect ($\beta_2$ =0.394, p< 0.01) on grassland quality. This means that the negative impact of sheep proportion on grassland quality will be alleviated by initial grassland quality, i.e. compared with the regions with low initial grassland quality, the increase of sheep proportion has less damage to the grassland quality in the regions with high initial grassland quality.

**Table 2 Benchmark regression: the impact of breeding structure on grassland quality**

| | Model 1 | Model 2 | Model 3 |
|---|---|---|---|
| $S_{it}$ | -0.261**(-2.45) | -0.552***(-5.11) | -0.585***(-5.49) |
| $T_{it}$ | -0.044***(-5.53) | -0.019**(-2.37) | -0.043***(-4.73) |
| $P_{it}$ | 0.003***(12.75) | 0.002***(11.86) | 0.002***(7.20) |
| $S_{it} \times D_i$ | | 0.394***(6.16) | 0.273***(4.18) |
| $A_{it}$ | | | 0.133***(2.75) |
| $H_{it}$ | | | -0.039(-0.86) |
| Year Fixed Effect | Controlled | Controlled | Controlled |
| Country Fixed Effect | Controlled | Controlled | Controlled |
| Constant | 6.969***(73.01) | 6.754***(71.87) | 7.129***(59.70) |
| Observations | 200 | 200 | 200 |
| R-squared | 0.776 | 0.814 | 0.836 |

Note: The figures in parentheses are standard errors. *p < 0.10, **p < 0.05, and ***p < 0.01.

***The mediating role of the GDP of the primary industry***

This section tests the mediating effect of the GDP of the primary industry on the causal relationship between breeding structure and grassland quality, and the test results are shown in Table 3. Model 6 shows the influence of breeding structure ($S_{it}$) on grassland quality ($Y_{it}$), corresponding to the first stage of the mediation effect test, i.e. Equation (3). The results of Model 6 are consistent with the benchmark models, $S_{it}$ has a significant negative impact on $Y_{it}$ ($a_1 = -0.252$, p<0.05). Model 7 shows the influence of breeding structure ($S_{it}$) on primary industry GDP ($PI_{it}$), corresponding to the second stage, i.e. Equation (4). The results of Model 7 show that $S_{it}$ has a significant positive effect on $PI_{it}$ ($b_1$ =0.974, p<0.01). The possible explanation is that there are differences in the economic benefits of breeding sheep in pastoral areas. Factors such as production cost, production cycle, value of additional products and technical requirements cause the economic benefits of sheep to be significantly higher than that of cattle (Wei and Zhen 2020). However, in the short term, the herdsmen only enjoy the economic benefits brought by the increase in the number of breeding, and do not bear the negative environmental externalities caused by overgrazing.

Model 8 shows the direct impact of breeding structure ($S_{it}$) on grassland quality ($Y_{it}$) and the indirect impact through primary industry GDP ($PI_{it}$), corresponding to the third stage, i.e., Equation (5). In Model 8, $S_{it}$ ($c_1 = -310$, p<0.01) and $PI_{it}$ ($c_2$ =0.059, p<0.1) have significant negative effect and positive effect on $Y_{it}$ respectively, indicating that the partial mediating effect is confirmed. However, due to the different signs of $b_1 c_2$ and $c_1$, it means that $PI_{it}$ has masking effect, and the ratio of this effect is 0.188 ($|b_1 c_2 / c_1|$). That is to say, sheep proportion has negative influence on grassland quality, but it can be partially mitigated by the positive impact of primary industry GDP. The probable reason is that, with the development of economy and the improvement of income level, herders and local governments will pay more attention to environment protection, and they are motivated to protect the grassland environment and pursue sustainable production, which contributes to the improvement of grassland quality

**Table 3 The results of mediation test**

| | Model 6 | Model 7 | Model 8 |
|---|---|---|---|
| | $Y_{it}$ | $PI_{it}$ | $Y_{it}$ |
| $S_{it}$ | -0.252**(-2.56) | 0.974***(4.80) | -0.310***(-2.99) |
| $PI_{it}$ | | | 0.059* (1.69) |
| Other control variables | Controlled | Controlled | Controlled |
| Constant | 7.153***(77.19) | -1.415**(-7.42) | 7.237***(68.92) |
| Observations | 200 | 200 | 200 |
| R-squared | 0.804 | 0.854 | 0.8073 |
| Indirect effect | | 0.058(0.04) | |
| Direct effect | | -0.310(0.10) | |
| Total effect | | -0.252(0.10) | |

Note: Other control variables $T_{it}$, $P_{it}, A_{it}, H_{it}$. The standard errors are in parentheses. *p < 0.10, **p < 0.05, and ***p < 0.01.

## Conclusions

The results of descriptive analysis showed that there were differences in livestock dynamics between M and IM from 2007 to 2016, and the total livestock showed an overall increasing trend, and the total livestock and growth rate of M were higher than that IM. About grassland quality, the NDVI of M and IM showed an overall increasing trend, and the quality of IM grassland was higher than M. About breeding structure, the proportion of sheep in M has remained stable at 53%, and M has decreased about 9% in ten years, but it is still higher than M. Livestock dynamics in M and IM are influenced by market economies, state policies and natural disasters.The empirical resulted show that the increase in the sheep proportion reduced the grassland quality. After solving the endogeneity problem through instrumental variable, the influence direction and significance of breeding structure are consistent with the benchmark models.
The results of the moderating effect showed that the initial grassland conditions could alleviate the negative impact of the sheep proportion on the grassland quality. The vegetation vulnerability of different grassland types are different, in the regions with higher initial grassland quality, the increases of sheep proportion has less damage to grassland quality. In addition, the results of the mediation effect showed that the primary industry GDP has a masking effect. The increase of sheep proportion can improve the primary industry GDP, and the primary industry GDP has a significant positive impact on the grassland quality, thus alleviating the negative impact of the sheep proportion on the grassland quality.
In the heterogeneity analysis, livestock carrying capacity was considered as a key factor affecting grassland quality. The results showed that under a reasonable livestock carrying capacity, grassland was vulnerable, and increasing the sheep proportion would accelerate grassland degradation. However, when the grassland is degraded to a certain extent due to the excessive carrying capacity of livestock, the disturbance capacity of human activities on the grassland is reduced, so the increase in the proportion of sheep has relatively little effect.
In addition, we compared the similarities and differences between M and IM. M did not show significant results due to its relatively stable breeding structure. Compared with the benchmark models, the breeding structure in IM had a greater negative impact on the grassland environment, which further indicated that the decline of sheep proportion has played a stronger ecological benefit. In the analysis of IM, GECP has been considered, and the result showed that the implementation of the first phase of the policy has significantly improved the grassland quality.

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