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Impact of Rangeland Degradation on Farm Performance and Household Welfare in the Case of Mongolia

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In this paper we utilize a nationwide dataset on plot-level rangeland health, which has not been used in previous studies on the economic impact of rangeland degradation in Mongolia. Taking account of typical reverse causality between grass condition and pastoralists' activities, we adopt a 2SLS instrumental variable approach to identify the impact of rangeland degradation on pastoralists' farm performance and welfare. We find that rangeland degradation causes a significant decrease in livestock product sales, farm income, and total paid-out costs. But we do not observe a significant decrease in farm profit and total income of the households.

Key words: pastoralism, rangeland degradation, farm performance

1. Introduction

The degradation of rangeland is an important factor determining pastoralists' wellbeing since their main economic activity, livestock rearing, is tied to rangeland conditions. Mongolia is one of such countries that have a considerable number of pastoralists. A 2014 report states that 65% of Mongolia's rangeland is in a poor condition relative to their ecological potential (NAMEM and MEGDT, 2015).

There have been various studies on rangeland degradation in Mongolia using satellite image data to calculate the change in biomass as a proxy for rangeland degradation, and the consensus is that overgrazing, rainfall and surface temperature are significant factors for rangeland degradation, although the magnitude of their impact varies with studies (Sainnemekh *et al*., 2022). However, the consequences of the rangeland degradation have seldom been analyzed, particularly quantitative analyses on herders' livelihood are scarce. Therefore, the primal objective of this paper is to fill this gap in literature.

One of the reasons for the literature gap is the availability of nation-wide, quantitative data. Due to the lack of data, most existing studies depend on satellite image as mentioned above. However, a study comparing satellite image data and ground data to map ecosystems across the Gobi region of Mongolia finds that satellite image has only an overall 65% of accuracy in terms of distribution of plant communities and major vegetation types (Heiner *et al*., 2015). In this regard, Mongolian government through National Agency for Meteorology and the Environmental Monitoring (hereinafter referred to as NAMEM) measured the rangeland condition with a set of core indicators including foliar canopy cover, species composition, basal gaps of perennial plants, and plant height including biomass and made the data publicly available (NAMEM and MEGDT, 2015). To the best of our knowledge, this study is the first one that utilizes this nation-wide ground data to analyze the impact of rangeland degradation on pastoralists' livelihood.

We hypothesize as follows: (i) rangeland degradation decreases the livestock productivity resulting in lower livestock and its product sales per head; (ii) rangeland degradation increases the costs for feed and fodder per head; and as a result (iii) rangeland degradation decreases livestock income and profit per head and household income per capita. Our hypotheses are not so special but logically postulated from qualitative studies such as Fernández-Giménez *et al*. (2018) and ADB (2014). Rather, our novelty is to confirm those hypotheses quantitatively using the newly available ground data of rangeland condition.

The remainder is organized as follows. Section 2 describes the data sources and the current state of rangeland degradation in Mongolia. Section 3 presents our econometric framework to assess the impact of the rangeland degradation on various indicators of farm performance and livelihood. Section 4 provides the results of the econometric analyses, and we conclude in Section 5.

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2. Data Sources and the State of Rangeland

1) Data sources

In this study we utilize three different data: household survey data, extensive rangeland site monitoring data, and climate data at soum (district) level.

First, we use the Household Socio-Economic Survey (HSES) for the year 2014 collected by the National Statistics Office of Mongolia (NSO) in 2015, which is publicly available. Two-stage stratified random sampling method is adopted to select households: the first stage randomly selects primary sampling units (PSUs) within each stratum[1] with the probability proportional to its population, and the second stage randomly selects households from the administrative list at each PSU. The survey is implemented on a rolling basis, with one twelfth of the sample households are interviewed in each month regarding the activities for the previous 12 months.[2] For the objective of this study, we only keep observations of households from rural PSUs engaging in livestock production.

Second, we use nationwide rangeland monitoring data covering 1450 plots representing all baghs[3] in Mongolia published in NAMEM and MEGDT (2015).[4]

Third, we obtain climate data from NAMEM, containing total annual precipitation and average annual temperature for each of the 138 weather stations and 179 watch posts across Mongolia in 2013 and 2014.

The household survey does not identify exact coordinates of each household, but soum to which each household belongs is recorded. Thus, we match each household in the household survey data with the rangeland monitoring data and climate data at the soum level.[5] Therefore, we construct soum level average of rangeland condition and climate, based on the exact coordinates of monitoring plots and stations.

2) The state of Mongolia's rangelands

The rangeland data evaluates the health of rangelands by the estimated number of seasons required to recover to reference level,[6] or degradation class. It ranges from Class I to Class V: Class I (near reference level, requires 1-3 growing seasons from minor changes), Class II (requires 3-5 growing seasons with favorable climatic conditions or a change in management), Class III (requires 5-10 growing season with changed management), Class IV (unlikely to recover for over a decade or requires many decades without intensive intervention), and Class V (true desertification, unlikely to recover). NAMEM and MEGDT (2015) states that 52% of the points are in Class I; 25% in Class II; 15% in Class III; and 7% in Class IV, and 0% in Class V[7] (See Figure 1).

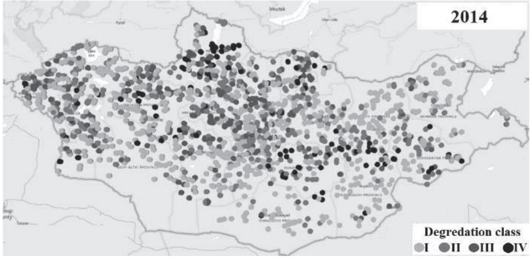

Figure 1. Rangeland degradation class of Mongolia

Source: NAMEM and MEGDT (2015).

3. Empirical Strategy

1) The instrumental variable model

We are interested in the causal effect of rangeland degredation on farm performance and livilihood of pastoralist households. To that end we use the following equation (1).

$$Y_{is} = \beta_0 + \beta_1 W_s + \gamma X_{is} + \delta E_a + \theta M_i + \epsilon_{is} \quad (1)$$

Let Y_{is} be the outcome of interest for household i in soum s. And let W_s be the state of rangeland degradation or the degredation class in soum s. X_{is} is a vector of household i's specific characteristics such as household head age, gender and household size in order to control for innate ability of the household head as well as household's labor supply and food

1) Four strata are considered in the HSES: urban, consisting of aimag (province) capital cities and national capital; and rural, divided into soum (district) capital and soum countryside.

2) Birthing and slaughtering take place in specific months of a year. In general birthing is from February to May, and slaughtering is from September to November although it depends on animal type and region. Thus, survey month determines which year's birthing and which year's slaughtering to cover in the survey that took place in 2014. For example, a survey in August 2014 covers slaughtering in 2013 and birthing in 2014.

3) Bagh is the lowest administrative units under soum (district).

4) Plot location data are obtained from Rangeland Research Programs of New Mexico University website. https://jornada.nmsu.edu/esd/international/mongolia/recovery-classes-interactive-map (accessed on October 16, 2020).

5) An important assumption in this study is that pastoralist households would move within a soum in a transhumance. This is largely valid recently since pastoralists tend to settle in a soum and long-distance movements have become infrequent (Ahearn, 2018).

6) Note that the reference level is not simply measured by the volume of biomass but takes into account the composition of plant species.

7) Although no plots are classified as Class V, researchers state that desertified plots do exist.

demand. The equation also includes aimag fixed effects E_a that control for time-invariant characteristics fixed to the aimag, controlling for innate market characteristics since major markets are in aimag centers. M_i is a vector of binary variables of the month in which the household i was surveyed to control for the coverage of birthing and slaughtering (refer to footnote 2). The last term in the equation, ϵ_{is}, is the error term. However, the estimation of impact of rangeland degradation is challenged by an endogeneity problem due to potential reverse causality (i.e., farm performance and household welfare can influence degradation, particularly through household herd size and grazing decisions) as well as omitted variables that affect both rangeland degradation and pastoralism outcome. We address this issue by employing an instrumental variable (IV) approach, specified as equation (2) given below.

$$W_s = \omega_0 + \omega_1 Temp_{s,2014} + \omega_2 Temp_{s,2013} + \omega_3 Perc_{s,2014} + \omega_4 Perc_{s,2013} + \mu X_{is} + \rho E_a + \varphi M_i + \varepsilon_{is} \quad (2)$$

where rangeland degradation is instrumented by the annual mean temperature (*Temp*) and total precipitation (*Perc*) in the soum for years 2013 and 2014.[8)] The selection of IVs can be justified by our assumptions that soum level climate (total precipitation and average temperature) can affect pastoralist households' farm performance and livelihood only through its influence on rangeland condition. Also, this paper formally tests the validity of IVs by weak identification test and Hansen J test.

Standard errors are clustered at the month and PSU level as they are the sampling unit. In addition, since we have a relatively large number of outcome variables, we adopt multiple hypotheses testing for significant variables, following Benjamini and Hochberg (1995) and Benjamini *et al.* (2006), abbreviated as BH1995 and BKY 2006, respectively.

2) Descriptive statistics

Table 1 displays descriptive statistics of sample households. Farm product consumption is computed by summing the value of products consumed by the household based on the market price.[9)] Livestock sales value is defined

Table 1. Descriptive statistics[1)]

	Mean	Std. Dev.	min	max
Panel A: Household (HH) characteristics (household level)				
Household size	3.87	1.65	1	12
Age of household head	45.37	13.94	18	94
Male household head	0.88	0.33	0	1
Herd size (sheep unit)	361.88	307.66	0	2,046.6
Panel B: Dependent variables (household level)				
Farm product consumption (10^3 MNT/sheep unit)	18.23	14.88	0	252.53
Livestock sales value (10^3 MNT/sheep unit)	5.39	8.44	0	208.33
Livestock product sales value (10^3 MNT/sheep unit)	5.7	6.88	0	135.56
Farm income (10^3 MNT/sheep unit)	26.37	17.03	-111.37	243.37
Farm profit (10^3 MNT/sheep unit)	15.44	23.84	-493.27	243.37
Total farm cost (paid out) (10^3 MNT/sheep unit)	2.95	6.62	0	169.38
Feed and fodder cost (10^3 MNT/sheep unit)	1.33	2.96	0	36.67
Household income (10^3 MNT/per capita)	3,999.86	3,045.44	312.78	51,646.2
Panel C: Endogenous variable (soum level)				
Degradation class	1.81	0.62	1	4
Panel D: Instrumental variables (soum level)				
Total annual precipitation 2013 (millimeters)	223.61	120.7	0	580.9
Total annual precipitation 2014 (millimeters)	182.33	90.06	0.2	411.5
Average annual temperature 2013 (degrees Celsius)	0.36	2.67	-6.49	10.03
Average annual temperature 2014 (degrees Celsius)	0.53	2.78	-6.96	9.4

Note: 1) Sample size is 2,827 households in 515 primary sampling units in 242 soums in 19 aimags. MNT stands for Mongolian currency, the Tugrug. In 2014, one thousand MNT was equivalent to 0.53 USD.

8) Some monthly temperature data (115 monthly observations of 25 soums out of total 10,584 observations of 294 soums) are missing. We use linear time-series interpolation to estimate missing temperature. Precipitation data have no missing values.

9) Price of livestock depends on the sex, age, weight of the livestock. Since we lack this information, we use the sales data from households in the case of livestock sale and we use the mean price of the oldest male livestock in the soum in the case of self-consumption.

as payment received from selling of livestock in the market.

Livestock product sales value is the payment received from selling of products such as processed and unprocessed wool and cashmere, skin and hide, and milk. We see that on average livestock product sales value brings higher or almost the same amount into the family as livestock sales. Majority of livestock product sales come from the sale of wool and cashmere while skin and hide sale inevitably connected to livestock sale. Milk sales are not so high in comparison.

Farm income is defined as the sum of consumption and sales less paid-out cost for feed, fodder, veterinary, hired labor, transportation, and others. Then, farm profit is obtained by subtracting imputed costs of family labor[10)] from the farm income. Paid-out cost of feed and fodder does not include hay from the rangelands, which most Mongolian pastoralists prepare by themselves, but its cost is imputed as part of family labor. To compare monetary variables by unit we use per sheep unit (hereinafter mentioned as SU) values.[11)]

Finally, household total income is calculated as the sum of flows received including livestock related revenue, crop revenue, business revenue, salary income, and other income such as sales/rental of non-livestock assets, withdrawal of bank savings, state benefit like pension, aid from government, private gifts, etc. Since this variable is used as an indicator of household welfare, the unit is MNT per capita.

Our endogenous variable is soum level average of degradation class. Its mean value is 1.8 indicating that rangeland of most of the soums in our dataset is degraded but can be rapidly recovered at most 5 growing seasons with changes in management.

4. Results

Table 2 presents 2SLS estimates of the impact of rangeland degradation on farm performance and total income (full results are given in Appendix Table). About the relevance of IVs, weak identification test shows that the IVs as a set are sufficiently correlated with the endogenous variable. As for the exogeneity of IVs, Hansen J statistics is small enough indicating that IVs are exogenous except for feed and fodder cost (column (7)). Thus, we consider that IVs are generally valid to manage the endogeneity problems.

Results suggest that livestock product sales per sheep unit and farm income per sheep unit would decrease signicantly as rangeland degrades (columns (3) and (4)). They are robust for multiple hypotheses testing confirming that sales of products such as milk, wool and cashmere, skin and hide and other decreased as rangeland became degradated. We consider that the results are due to decreasing livestock productivity caused by less nutritious types of grass prevalent in degraded rangeland.

Table 2. 2SLS results of impact of rangeland degradation on farm performance and total income[1)]

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Dependent variable	Farm product consumption	Livestock sales	Livestock product sales	Farm income	Farm profit	Total farm costs (paid out)	Feed and fodder cost	Total income
Degradation class	-2.36	0.55	-6.30***	-6.42***	-4.16	-1.68**	-0.15	-268.78
	(1.68)	(1.21)	(1.38)	(2.38)	(3.49)	(0.74)	(0.27)	(408.71)
	[0.16]	[0.65]	[0.00]	[0.01]	[0.23]	[0.02]	[0.58]	[0.51]
Control variables[2)]	yes	yes	yes	yes	yes	Yes	yes	Yes
# of observations	2,827	2,827	2,827	2,827	2,827	2,827	2,827	2,827
Hansen J statistics	1.09	0.21	1.66	1.64	0.73	5.30	17.82***	2.66
BKY 2006[3)] p-value	0.32	0.65	0.00	0.03	0.37	0.06	0.65	0.65
BH 1995[3)] p-value	0.25	0.48	0.00	0.03	0.31	0.05	0.48	0.48

Note: 1) *** p<0.01, ** p<0.05, * p<0.1. Robust standard errors clustered at month and PSU are in parentheses. Unadjusted p-values are given in square brackets. The unit of each dependent variable is the same as shown in Table 1. Kleibergen-Paap rk Wald F statistic of weak identification test is 6.31, rejecting the null of weak instrumental variables with 30% maximal IV relative bias at 5% significance level. Therefore, the instruments as a set are sufficiently correlated with the endogenous variable (degradation class).

2) We control for household characteristics shown in Table 1 as well as total herd size in sheep unit at the beginning of survey year (in the case of monetary dependent variables), aimag fixed effects, and survey month fixed effects.

3) BKY 2006 and BH 1995 are adjusted p-values calculated based on Benjamini *et al.* (2006) and Benjamini and Hochberg (1995) respectively.

10) Family labor costs are computed using the annual minimum wage rate in Mongolia during that year.

11) Sheep unit is calculated by using the following equivalence: cattle=6, horse=7, camel=5, sheep=1, goat=0.9.

In addition, column (6) shows that total paid-out costs per sheep unit significantly decrease at 5% level. The decrease in total costs may suggest that farm cost reduced because of decreasing livestock production. But since the impact of rangeland degradation on feed and fodder cost is insignificant as shown in column (7), the decrease in total cost must be from other costs such as breeding, transportation, veterinary services and so on. As for farm profit per sheep unit, it is not significantly affected by rangeland degradation (column (5)), meaning that household labor reduced to adjust the decreased livestock production.

Finally, our analysis indicates that rangeland degradation does not significantly decrease household welfare proxied by total income of household per capita (column (8)).

5. Conclusion

Various studies have used aboveground biomass observed from satellite as a proxy for rangeland health and have found that overstocking of livestock in the area and climate factors are influential to rangeland health. However extensive quantitative analyses of the effect of rangeland health on farm performance and pastoralists' livelihood have yet to be conducted. In this paper we use field data covering all of Mongolia as a proxy for long-term regeneration potential of rangelands and estimate the impact of rangeland degradation on farm performance (e.g., farm product consumption, sales, income, profit and costs per sheep unit) and household welfare (total income per capita). We employ a 2SLS approach to handle the endogeneity of rangeland degradation using total annual precipitation and annual average temperature in the soum as IVs.

Results show that rangeland degradation has generally a negative impact on pastoralists' farm productivity. Probably due to the decreased livestock production and paid-out. As a result, rangeland degradation does not have a significant negative impact on production efficiency (i.e. profit) and pastoralists' livelihood (i.e. income).

However, we are not confident that this situation will continue. The data for degradation class was updated by NAMEM in 2018 and it is reported that rangeland degradation was intensified. Therefore, there is a need for further research incorporating the changes of rangeland degradation in the recent years to confirm our findings. Looking ahead, we believe keeping resilient livestock breeds, better management of common rangelands, and development better forage and product markets will help pastoralists to buffer the risks that come with rangeland degradation.

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Appendix Table. 2SLS results of impact of rangeland degradation on farm performance and total income[1)]

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Dependent variable	Farm product consumption	Livestock sales	Livestock product sales	Farm income	Farm profit	Total farm costs (paid out)	Feed and fodder cost	Total income
Degradation class	-2.36	0.55	-6.30***	-6.42***	-4.16	-1.68**	-0.15	-268.78
	(1.68)	(1.21)	(1.38)	(2.38)	(3.49)	(0.74)	(0.27)	(408.71)
Household characteristics								
HH size	1.90***	0.34	0.13	2.45***	1.74	-0.08	0.15	-1,980.87***
	(0.58)	(0.41)	(0.25)	(0.90)	(1.16)	(0.64)	(0.15)	(164.68)
HH size sq	-0.15**	-0.03	0.00	-0.19*	-0.14	0.01	-0.02	124.85***
	(0.07)	(0.04)	(0.03)	(0.11)	(0.13)	(0.09)	(0.02)	(16.20)
Age of HH head	0.09	0.15**	0.05	0.16	-0.18	0.14***	0.07***	112.44***
	(0.11)	(0.06)	(0.06)	(0.12)	(0.20)	(0.05)	(0.02)	(19.73)
Age of HH head sq	0.00	-0.00***	-0.00	-0.00	0.00	-0.00**	-0.00**	-0.87***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.20)
Male household head	-3.63***	-0.88	-1.25*	-6.23***	-2.89	0.46	0.19	758.07***
	(1.11)	(0.79)	(0.65)	(1.44)	(2.39)	(0.38)	(0.18)	(147.58)
Herd size (sheep unit)	-0.02***	0.00***	-0.00***	-0.02***	-0.00***	-0.00***	-0.00***	4.24***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.33)
Aimag dummies								
Sukhbaatar	8.78***	-1.03	4.66***	10.32***	18.61***	2.09***	-0.11	1,869.85*
	(2.23)	(1.63)	(1.18)	(2.65)	(3.70)	(0.68)	(0.35)	(408.08)
Khentii	2.66	-1.45	1.83	2.55	3.72	0.49	-0.63***	840.91*
	(1.63)	(1.15)	(1.14)	(2.71)	(6.18)	(0.42)	(0.22)	(437.57)
Tuv	11.14***	-2.72***	7.90***	11.35***	10.91***	4.96***	2.25***	2,544.63*
	(1.78)	(1.03)	(1.92)	(2.51)	(3.33)	(0.85)	(0.57)	(352.54)
Selenge	9.54***	-1.09	5.74***	10.18***	21.97***	4.00***	1.67***	1,044.68*
	(3.44)	(1.40)	(1.38)	(3.76)	(4.60)	(0.78)	(0.52)	(402.06)
Dornogovi	1.94	-5.45***	6.57***	1.12	1.46	1.94***	-0.61**	93.66
	(1.93)	(0.93)	(1.31)	(2.58)	(3.39)	(0.57)	(0.27)	(389.91)
Darkhan-Uul	14.50***	-0.90	7.62***	14.26***	15.95***	6.96***	3.50***	1,954.52*
	(3.45)	(3.02)	(1.60)	(3.37)	(5.21)	(1.55)	(0.97)	(629.62)
Umnugovi	5.21***	-6.73***	11.02***	8.06***	14.07***	1.44**	-0.84***	1,410.42*
	(1.58)	(1.07)	(1.41)	(2.26)	(2.69)	(0.57)	(0.24)	(382.80)
Dundgovi	5.76**	-6.68***	12.94***	8.50**	10.77**	3.51***	-0.57	1,253.84*
	(2.51)	(1.68)	(1.97)	(3.38)	(5.09)	(1.04)	(0.40)	(662.30)
Uvurkhangai	6.38***	-6.28***	3.92***	4.65**	5.45**	-0.63*	-0.71***	228.33
	(1.41)	(0.86)	(0.74)	(1.92)	(2.65)	(0.38)	(0.22)	(263.32)
Bulgan	7.44***	-4.21***	6.40***	6.99***	8.60**	2.65***	0.58	663.25
	(1.98)	(1.27)	(1.30)	(2.69)	(3.77)	(0.67)	(0.38)	(419.50)
Bayankhongor	2.45	-7.58***	12.12***	7.01***	10.59***	-0.02	-1.22***	432.79
	(1.69)	(1.11)	(1.22)	(2.43)	(3.69)	(0.57)	(0.27)	(418.77)
Arkhangai	3.25**	-1.44	6.14***	6.90***	8.38***	1.04*	-0.13	324.71
	(1.61)	(1.14)	(1.24)	(2.35)	(2.99)	(0.54)	(0.26)	(365.16)
Khuvsgul	4.69**	-3.40**	6.40***	6.62**	8.51**	1.06	-0.49	92.52
	(1.97)	(1.69)	(1.29)	(2.79)	(3.81)	(0.71)	(0.31)	(422.62)
Zavkhan	3.78**	-5.91***	4.52***	1.51	2.45	0.89*	-0.96***	-383.87
	(1.48)	(1.06)	(0.98)	(2.12)	(2.81)	(0.48)	(0.24)	(327.35)
Govi-Altai	2.60*	-6.36***	6.04***	1.00	7.11**	1.28*	-0.62**	384.82
	(1.49)	(0.91)	(1.05)	(2.10)	(2.90)	(0.71)	(0.26)	(295.61)
Bayan-Ulgii	17.21***	-4.68***	7.05***	11.24***	14.47***	8.33***	2.19***	2,070.14*
	(2.33)	(1.16)	(1.21)	(2.64)	(3.24)	(1.85)	(0.57)	(360.02)
Khovd	6.28***	-5.95***	5.07***	4.70**	13.69***	0.71	-0.51*	793.06**
	(1.68)	(1.03)	(0.90)	(2.13)	(2.80)	(0.71)	(0.27)	(319.67)
Uvs	7.33***	-5.64***	3.66***	3.93**	9.42***	1.42***	0.17	1,015.86*
	(1.41)	(0.90)	(0.90)	(1.86)	(2.92)	(0.49)	(0.28)	(405.27)
Survey month dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Constant	17.59***	5.70***	12.70***	35.83***	20.63***	0.17	-0.57	3,726.78*
	(3.78)	(2.09)	(2.71)	(4.93)	(6.60)	(1.62)	(0.64)	(763.88)
Observations	2,827	2,827	2,827	2,827	2,827	2,827	2,827	2,827

Note: 1) *** p<0.01, ** p<0.05, * p<0.1. Robust standard errors clustered at month and PSU are in parentheses. Degradation class is considered endogenous, and is instrumented by precipitation in 2013 and 2014 and temperature in 2013 and 2014. Coefficients for survey month dummies are not shown for the sake of space saving.