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Tragedy of the commons or tragedy of privatisation? The impact of land tenure reform on grassland condition in Inner Mongolia, China

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ABSTRACT: Could private use pattern be seen as a panacea, or rather as a tragedy for sustainable grassland use? These questions were explored by quantitative estimating the impact of land tenure reform on grassland condition in the pastoral area of Inner Mongolia between 1985 and 2008. The timing of the introduction of land tenure reform has differed among counties, a fact which was used to compare the effects of privatisation with different years. On the other hand, the changes in grassland condition over the research period were presented through examining changes in grassland quantity and quality, these being measured using the spatially explicit information based on GIS. In the empirical analysis, we employed a fixed effects model to control for the time-invariant heterogeneity among counties and focused on disentangling the effects of privatisation on grassland condition. The model results provide evidence on the tragedy of the privatisation occurring to grassland condition.

Key words: land tenure, private use, grassland condition, fixed effects, panel data

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1. Introduction

The tragedy of the commons, as speculated by Hardin (1968), has become part of the conventional wisdom in ecology, economics and political science (McEvoy, 1987). Abundant theoretical research contended that resource degradation was inevitable unless the commons were either privatised or maintained as common land whilst allocating rights of entry and use (Hardin, 1968). In the property rights theory (Coase, 1960), a clear assignment of property rights is proposed as a precondition for economically efficient resource allocation and environmental sustainability, which has been accepted by scholars and governments widely. However, Hardin's theory of the tragedy of the commons and consequence of privatisation have been rejected by pastoral specialists, who found that they provided a very poor guide to understanding pastoralism (Behnke, 1994; Sneath, 1998; Feeny et.al., 1990). It is suggested that exclusionary land tenure is counterproductive to sustainable grassland use in arid and semi-arid areas (Galvin, 2009; Turner, 1999). Additionally, some scholars have countered the idea that the traditional common use system would induce the tragedy of the commons, suggesting that it would in fact clearly meet the criteria of "common pool resource" as defined by Ostrom (1990); in this concept, outsiders who do not belong to local community are excluded from the resource, and the self-organization by resource users is seen as being likely to work towards achieving a sustainable Social-Ecological System (Ostrom, 2009).

In practice, the privatisation and clarification of property rights to resource have been implemented by governments all over the world. The same privatisation trend has been observed in Inner Asia and Africa regarding the reform of grassland tenure (Sneath, 1998; Lesorogol, 2008). In China, land tenure reforms have been introduced to pastoral areas since the 1980s, with the aim of assigning rights to grassland use to individual households and displacing traditional common use (Banks et al., 2003). The household-based privatisation of grassland use rights in China is expected to lead to sustainable management of grassland use, on the basis of a belief that clear property rights would stimulate owners to economise on the use of their resources, and encourage exclusive use to avoid overuse by the commons (Squires, et.al., 2009). Since then, traditional nomadism, which has always relied on common land use, is gradually being replaced by permanent settlement and set grazing, with significant impacts on grassland conditions (Li & Zhang, 2009).

With the global rise in privatisation, more and more academic studies are questioning its effects on sustainable grassland use. For instance, Sneath (1998) based on satellite images

proved that grassland degradation was much less severe in Mongolia than Russian and Chinese sectors of Inner Asia because Mongolia remained the common use pattern of grassland; Guelke (2003) revealed that the decline in grassland resource of South Africa was not primarily due to overgrazing, but rather to introducing the private use pattern. The main reasons against privatisation include the following: (1) grassland fragmentation and sedentary grazing caused by the privatisation restricts access of people and animals to heterogeneity in resources, particularly vegetation and water, which harms to human livelihoods and leads to degradation of ecosystems (Hobbs et al., 2008); (2) erecting fences between adjacent land fragments following the privatization of communal lands limits the grazing area. Year-round grazing has to be conducted in limited and specific areas, instead of formerly seasonal migration, meaning that animals graze and trample the same land continuously. Grassland therefore loses its natural regenerative capacity, directly resulting in future grassland degradation (Ao, 2004; Wang, Brown, & Agrawal, 2013); (3) vegetation diversity has been reduced through the declining large-scale mobility of livestock, because the hoofs and manure of nomadic animals used to disperse seeds among different regions and improve the diversity of plant species (De Haan 1996); (4) with the reduction of accessible grassland, rural households' livestock has tended to become single in structure, with an increase in particular in small animals (sheep and goats) but a decrease in larger animals (such as horses, endemic species of cattle etc.), which is detrimental to the effective utilisation of grass resources and benign natural succession, and also results indirectly in grassland degradation (Ao, 2004).

Based on these opposite findings with the prevailing concepts of "the tragedy of the commons", it becomes clear that grassland privatisation needs deliberate and thorough discussion. Considering the fact that grassland degradation is a worldwide problem, and is especially serious in China (Ho & Azadi, 2010), we focus on the grassland condition to examine whether grassland privatisation caused "tragedy" on it. More specifically, it has been proved that the area of degraded grassland in China has risen from 55 to over 90 percent during the last 10 years (Han et al., 2008) – does it result from the privatisation of land tenure? Although some studies have been conducted on the evaluation of the results of privatisation reform (Li & Zhang, 2009), there is lack of quantitative analysis and long-term observation on the relationship between privatisation and grassland condition. This paper, based on empirical analysis, will study the effects of grassland tenure reform focusing on the condition of grassland over a long research period. Moreover, the timing of the introduction of land tenure reform has differed among counties, and a panel data set is thus constituted to

present differences among counties and differences within each county over time. In the following sections, we firstly introduce the grassland tenure reform in China, including the changes in rights to grassland formal use and actual use patterns. Following this, the data collection and descriptive analysis are illustrated. Next, we explain the variables and the predicted results of variables in the model. After that, statistical tests and fixed effects model are used to examine our prediction. This paper will be concluded with some remarks on the effects of privatisation on grassland condition. It is hoped that this paper will provide some policy insights into sustainable grassland use.

2. Background on grassland tenure reform in China

In pastoral areas of China, grassland was formerly owned by princes, lamaseries, landlords or clans for a long time, and the grassland was in common use by tenant herders (Ho, 2000). After that, in the collectivist period of New China, the grassland was owned by the production team or People's commune and the grassland was still managed and used communally. Since the 1980s, with the successful implementation of privatisation reform in the cropland regions through the Household Responsibility System, the Chinese central government has introduced privatisation to pastoral areas of China (Banks et al., 2003), and local governments were responsible for deciding how to implement the new reforms appropriately within their administrative regions (Li et al., 2007). As a result, grasslands witness more and more private use by individual households - instead of common use.

The first "Grassland Law" of China was promulgated in 1985, and stipulated that grassland is owned either by the state or the collective, and that households and collectives are allowed to contract the rights to use rangeland for the "long term" (the maximum period is presently 30 years) (Ho, 2000). From then on, local governments started to assign livestock ownership and grassland use rights to households through a Double Contracting System ("cao xu shuang cheng bao"). To avoid overgrazing after privatisation, those using contracted grassland were obliged to stay within certain limits in terms of the grazing livestock population, based on grass production and the resulting carrying capacity (Li et al., 2007). In 2002, the revised Grassland Law reaffirmed the devolution of land use rights and of liability from the state and collectives to the individual households (National People's Congress of the People's Republic

of China, 2002). The State Council emphasised the specific allocation of the four contracted items (including grassland plots, areas, contracts and user-right certificates) to households to ensure the long-term stability of contract relations in its 2011 'Opinions on the Promotion of Sound and Rapid Development in Pastoral Areas' (Li, 2012).

Nevertheless, the implementation of grassland privatisation reform is not yet complete despite tough efforts by all levels of government for nearly 30 years. Ironically, in some regions, the privatisation of formal use rights is considered only as a paper agreement which not actually changed real grassland use patterns (Yang et.al., 2004). Our survey shows specific data to this effect. In 1985, 6.67% of the total counties in Inner Mongolia formally had assigned grassland use rights to individual households, while the majority of counties remained under collective ownership (owned either by an administrative or a natural village). Although there was a sharp increase in assigning grassland use rights to individual households after 1985, by 2008 this percentage had only reached 81.67%, rather than 100%. In 2008, the average number of years for which the formal use rights have been assigned is 11.55, although the grassland privatisation reform had been introduced since the 1980s. On the other hand, actual changes in the pattern of grassland use following this institutional evolution (i.e. was transferring from collective or group common use) occurred at a slower speed. In 1985, only 5% of the total counties had adopted the practice of private use, while the majority of counties remained under common use. Although there was a sharp increase in adopting private use after 1985, by 2008 this percentage had only reached 63.33%, rather than 100%. In 2008, the average number of years for which private use has been adopted is 8.72, although the grassland privatisation reform had been introduced since the 1980s. It is obvious that whilst the allocation of grassland use rights to individual households had been spreading across Inner Mongolia over the last few decades, it is not yet complete. Moreover, the private use patterns lag behind the reform of formal use rights. In other words, the privatisation of grassland use rights did not run as successfully as the central government expected. Some areas of grassland are still used and managed in common despite the fact that the grassland has been formally contracted to individual households.

Table 1 provides a typology depicting the relation between the ownership of formal use rights and actual use patterns in the grasslands of Inner Mongolia, which is in line with the investigation of the Tibetan plateau by Banks (2003). More specifically, three types of ownership of formal grassland use rights have appeared since the grassland tenure reform, namely individual household ownership, ownership by a group of households and

administrative collective ownership. Correspondingly, there are three types of actual use pattern, including private use by an individual household, joint use[1] by a group of households and common use by all of the villagers.

Table 1 multiple formal grassland use rights and actual use patterns

As presented in table 1, when formal use rights are owned by an administrative or natural village, the actual use pattern is merely common use. If formal use rights are owned by a group of households, the actual use pattern includes common use and joint use. It is worth noting that private use, joint use and common use can exist simultaneously when the formal use rights are owned by an individual household, which reflects the gap between the privatisation of formal use rights and the actual use pattern. Ironically, the situation which was originally envisaged by the Chinese central government was to achieve private use altogether, with formal use rights being allocated to every household through the privatisation reform.

Academic research has criticised (Banks et al., 2003; Ho, 2000), for the failure to privatise land tenure in China's extensive grasslands, compared with the case of cropland areas where household-based private tenure was established virtually overnight. Many scholars have discussed why the land tenure privatisation reform is so difficult to implement in the grasslands and have even expressed scepticism about whether it is an effective policy for sustainable grassland use. Existing opinions on these questions include the following: grassland privatisation is incompatible with the request to maintain livestock mobility due to the heterogeneity of resources in arid and semi-arid areas (Li & Zhang, 2009); the lack of appropriate property rights structures and capital investment for protecting property rights (such as fencing costs) have contributed to the failed implementation of grassland tenure reform (Ho, 1996; Li et al., 2007); grasslands being owned by individual households was inconsistent with local or traditional knowledge on property rights (Richard et al, 2006); and finally, the private use pattern by individual households destroyed the traditional institutions of grassland use and management (Li, 2012) etc. This paper will discuss whether the tragic

[1] Joint use means that a group of households uses the grassland communally. Normally, they are neighbours or relatives.

influences of privatisation on grassland condition discouraged the adoption of private use in pastoral areas.

3. Data description

3.1. Research region

The autonomous region of Inner Mongolia is a province located in northern China. It belongs to the arid and semi-arid areas of China and contains one fourth of China's total grassland (Zhang, 1990). Approximately 66% of the total land in Inner Mongolia is classified as grassland, the majority of which is temperate grassland (Angerer et al., 2008). The region plays an irreplaceable role in China's animal husbandry and ecological security because of its extensive natural grasslands. As a traditionally pastoral region populated by minority ethnicities, the vast majority of its pastureland remains in its natural state and has a relatively low population density in spite of rapid economic growth and soaring population elsewhere in China (Angerer et al., 2008). However, by the end of twentieth century, 90% of the grasslands of Inner Mongolia had been degraded to varying extents (Mei et al., 2013). By 2002, grazing grassland had degraded by 56.9% and the grass yield of all natural grassland had been reduced by 30%-70% (Project to investigate ecosystems on grasslands, 2003).

In terms of the land tenure reform on grassland, the grasslands of Inner Mongolia was the main and first target for implementing the reform. According to the provincial government report, the government of Inner Mongolia focused on assigning grassland ownership to each administrative village during the period of 1982-1989. From 1989 to 1995, the rights of grassland use were assigned individual households, household groups or villages through the Double Contracting System (cao xu shuang cheng bao). After that, the Two Rights and One System policy (shuang quan yi zhi) was introduced to strengthen the grassland use rights owned by individual households. In practice, the specific timing and extent of the grassland tenure reform differed between counties in Inner Mongolia. This paper is therefore based on county-level data with the aim of disentangling the effects of privatisation. Figure 1 presents the autonomous region of Inner Mongolia with its 102 affiliated counties.

Figure 1 Inner Mongolia autonomous region and its 102 counties

3.2. Data collection

We gathered county-level data covering 1985-2008, the main period during which land tenure privatisation reform was implemented across Inner Mongolia. The data on land tenure reform was collected through questionnaires in every county, focusing on when formal use rights were owned by collectives, groups and households, as well as when grassland was in actual patterns of common use, joint use and private use[2]. The contents of questionnaire are based on the case shown in table 1. The questionnaires were answered by employees of the local Animal Husbandry Bureau and key informants on their local grassland tenure reform. Ultimately, we obtained feedback from 74 out of 102 counties.

With respect to the data on grassland conditions, commonly used research approaches to the ecological evaluation of grassland include sampling tests in fieldwork and experimental research with remote sensing. The former focuses on measuring the specific indices of grass production and vegetation diversity, while the latter estimates the grassland area based on satellite images (Gu & Li, 2013). In this study, the method of remote sensing is more appropriate because we aim to quantify the changes in grassland condition in various areas of grasslands. Our data on grassland condition and climate therefore relies on a database developed by the Chinese Academy of Sciences with original data from Landsat Thematic Mapper / Enhanced Thematic Mapper (Plus) (TM/ETM+) images (Deng et al. 2011). Due to time limitations when collecting land data through satellite images, our research years cover only 1985, 1995, 2000, 2005 and 2008. In addition, the related social-economic data is based on the existing statistic data collected by local governments. After deleting the urban counties and those counties showing unusual changes in grassland areas, 60 counties are retained as the research samples. In short, these 5 periods and 60 samples constitute our panel data, which includes 59% of the counties of Inner Mongolia and refers to the main period of grassland tenure reform in Inner Mongolia, namely from 1985 to 2008.

3.3. Descriptive analysis

This paper focuses on discussing the impact of land tenure privatisation reform on grassland condition. The implementation of privatisation involves two dimensions: the allocation of

[2] Considering that some counties have private use, joint use and common use simultaneously, we denote a county as having a private use pattern if more than 50% of the grassland area of this county was used by individual households. The same principle is applied to formal use rights.

formal grassland use rights and the transformation of actual patterns of use. The progress of land tenure reform in each sample county is therefore quantified by the number of years that the formal grassland use rights had been allocated and the number of years that private use had been adopted until year t. On the other hand, the grassland condition refers to both the quantity and the quality of grassland. The quantity of grassland is directly represented by the total area of grassland. To demonstrate grassland quality, the grasslands are divided into three categories according to the canopy cover, including dense grassland, moderate grassland and sparse grassland. Dense grassland has the highest quality with a canopy cover which exceeds 50 percent, while moderate grassland has a canopy covering 20-50 percent of the land, and sparse grassland has a canopy cover of 5-20 percent. Areas with less than 5 percent canopy cover are not counted as grassland (Deng et al. 2011). Hence, the grassland condition in this paper is represented by the following measurements: total grassland area, dense grassland area, moderate grassland area and sparse grassland area.

Based on the above explanation of the measurement of our crucial indicators, table 2 illustrates the general trend of grassland tenure reform and grassland condition in the 60 sample counties between 1985 and 2008. The trend of land tenure reform is represented by the proportion of the 60 counties in which formal use rights are privatised and the proportion of the 60 sample counties which show private use patterns. The relative change in grassland condition is represented by the average ratio of the total grassland area of each county in year t and in 1985, and the same index for dense, moderate and sparse grassland areas. We can see that the proportion of counties in which formal use rights have been privatized increased from 1985 to 2008; the proportion of counties showing private use patterns also rose accordingly. Both showed a sharp increase from 1995 to 2000. In addition, the areas of total, dense and moderate grassland show a general decreasing trend between 1985 and 2008, while only sparse grassland has shown an increasing trend. It is obvious that compared with 1985, the grassland condition has generally degraded. Dense grassland in particular presents the most serious reduction, with a decrease of 93.27% by 2008, although this trend reverses slightly around 2005.

Table 2 General trend of grassland tenure reform and grassland condition

Table 2 indicates that grassland condition underwent a process of degradation while the grassland privatisation reform was spreading. Can we presume that the increase in

privatisation caused or prompted grassland degradation? This question will be examined in the following empirical model.

4. Empirical model

4.1. Framework of fixed effects model

The fixed effects model has been widely used in economic research (e.g., Fergusson et al., 2002; Huan et al., 2006). It is used primarily to study the causes of changes within an entity over time because the effect of the time-invariant characteristics of each entity are removed.

The general theory is presented as follows:

$$Y_{it} = \alpha + \beta X_{it} + U_i + \varphi_{it} \qquad (1)$$

where i and t present the ith entity and year t. Y_{it} is the dependent variable. X_{it} denotes the vector of independent variables that we are interested in. U_i is the unknown intercept for each entity, which represents all time-invariant (fixed) factors of entity i that influence the dependent variable, including both observable and unobservable variables. φ_{it} is the random error term. The difficulty in estimating the parameters of α and β is that U_i involves unobserved variables.

Fortunately, it is proved that the same estimator for β is obtained if the model is performed in deviations from individual means (Verbeek, 2012). In this case, the fixed individual effects U_i are eliminated. To comprehend this, first note that:

$$\bar{Y}_i = \alpha + \beta \bar{X}_i + U_i + \bar{\varphi}_i \qquad (2)$$

where $\bar{Y}_i$ is the mean value of Y_{it} over t years. Similarly, $\bar{X}_i$ is the mean value of X_{it}, and $\bar{\varphi}_i$ is for φ_{it}. Consequently, a model in deviations from individual means is:

$$(Y_{it} - \bar{Y}_i) = \beta(X_{it} - \bar{X}_i) + (\varphi_{it} - \bar{\varphi}_i) \quad (3)$$

this transformation in equation (3) is called the within transformation. The OLS estimator for β based on this transformed model is called the within estimator or fixed effects estimator (Verbeek, 2012). The most significant feature of this transformation is that it provides a

method of estimating the parameter of β that takes the observable as well as unobservable time-invariant variables (U_i) into account, but the estimation does not dependent on the value of U_i (Fergusson et al., 2002). In addition, this model usually assumes that X_{it} are strictly exogenous, and their current, past and future values are uncorrelated with any values of error term.

4.2. Application of fixed effects model

Fixed effects model is appropriate to our research question and feasible with the data status in this study. For instance, the results of land tenure reform can be studied effectively within each county over time by controlling for the unmeasured heterogeneity between counties; the independent variable of interest shows changes in value across our 5 research years for a substantial proportion of samples because the beginning years of privatisation in our 60 sample counties show differences, thus satisfying the basic data requirement of the fixed effects model (Daun-Barnett, 2011). In addition, our research period spanning from 1985 to 2008 is relatively long and the panel only has 60 samples, which means that the fixed effects model is more preliminarily appropriate than the random effects model. Last but not least, our research focuses on Inner Mongolia and the data draws from almost every specific non-urban county of Inner Mongolia, which is an advantage when using the fixed effects model. Nonetheless, the feasibility of fixed effects model will be further examined by statistical tests.

Based on the existing academic research on the causes of grassland degradation in China, we consider three aspects that have been accepted as the main factors impacting upon the grassland condition, including geographic factors (Deng et al. 2011; He et al., 2014), climatic factors (Gao et al., 2010; Li et al., 2012) and human activities (He et al., 2014), as well as the factor of land tenure that we focus on specifically in this paper[3]. We then formulate the effects of these considered factors on grassland condition into the basic fixed effects model (see equation (1)). The assumed relationships between the grassland condition and its considerable explanatory variables are represented as the following equations:

[3] Overgrazing was discussed as a considerable reason of grassland degradation. But here we do not include a specific variable on it since every household with private grassland use rights is enforced to obey a carrying capacity that is the maximum livestock population grazed by households within their titled private grassland area. In other words, the variables on land tenure involve in the consideration of overgrazing.

$$G_{it} = g_i + a_1 L_{it} + a_2 L_{it}^2 + a_3 T_{it} + a_4 T_{it}^2 + a_5 F_{it} + a_6 F_{it}^2 + a_7 TF_{it} + a_8 C_{it} + a_9 C_{it}^2 + \varepsilon_{it} \quad (4)$$

$$D_{it} = d_i + b_1 L_{it} + b_2 L_{it}^2 + b_3 T_{it} + b_4 T_{it}^2 + b_5 F_{it} + b_6 F_{it}^2 + b_7 TF_{it} + b_8 C_{it} + b_9 C_{it}^2 + \mu_{it} \quad (5)$$

$$M_{it} = m_i + c_1 L_{it} + c_2 L_{it}^2 + c_3 T_{it} + c_4 T_{it}^2 + c_5 F_{it} + c_6 F_{it}^2 + c_7 TF_{it} + c_8 C_{it} + c_9 C_{it}^2 + \gamma_{it} \quad (6)$$

$$S_{it} = s_i + d_1 L_{it} + d_2 L_{it}^2 + d_3 T_{it} + d_4 T_{it}^2 + d_5 F_{it} + d_6 F_{it}^2 + d_7 TF_{it} + d_8 C_{it} + d_9 C_{it}^2 + \sigma_{it} \quad (7)$$

where i and t present the i[th] county and year t. As we described in the descriptive analysis, grassland condition is presented by total grassland area (G_{it}), dense grassland area (D_{it}), moderate grassland area (M_{it}) and sparse grassland area (S_{it}); here, we treat them as four dependent variables in the four equation above. Equation (4), (5), (6) and (7) are denoted as total grassland model, dense grassland model, moderate grassland model and sparse grassland model, respectively.

L_{it} denotes the variable in which we are particularly interested, namely land tenure status of county i in year t, which is specifically presented by the number of years that the private use had been adopted by county i until year t. Considering that the adoption of actual patterns of private use always lagged behind the formal privatisation of use rights, as shown in table 2, and that is the actual pattern of use, rather than the formal use rights, that has a real impact on grassland condition, the number of years for which formal use rights had been allocated is excluded to present land tenure reform. Technically, this is done in order to avoid multicollinearity in the model since the correlation value between the years of formal privatised use rights and actual private use patterns reaches 0.7328. We suppose that land tenure reform has a non-linear relationship with changes in grassland condition, therefore L_{it}^2, the square term of L_{it}, is taken into account. Climate factors are presented by temperature (T_{it}) and precipitation (F_{it}). Their squared terms (T_{it}^2 and F_{it}^2) and cross term (TF_{it}) are also considered. C_{it} and its square term of C_{it}^2 are used to explain the factors of human activity, which are presented by the percentage change of cultivated land in county i during the last five years of year t. Cultivation and the land use transfer between grassland and arable land are proved to have significant and direct effects on grassland degradation in China (Feng et al., 2009). In addition, plenty of geographic factors either do not change with time, or barely change for years, such as elevation, terrain slope, soil pH value, soil clay, soil sand, distance to the provincial capital etc.; we therefore treat these variables as time-invariant (fixed) factors (U_i in equation (1)) that g_i, d_i, m_i and s_i represent in the model. Next, a_n, b_n, c_n and d_n (n=1, 2,... 9) are the corresponding coefficients of the independent variables. The error

terms are ε_{it}, μ_{it}, γ_{it} and σ_{it}. The specific definition of each variable and their overall statistical description of the panel data set are listed in table 3.

Table 3 variable definition, statistical description and predicted results

Furthermore, table 3 provides our predicted positive or negative impacts of all the explanatory variables on grassland condition. Firstly, it is noted that the deterioration of grassland condition includes not only the reduction of grassland area but also the degradation of grassland quality in terms of a decrease of grassland area with high canopy cover. In this case, we assume that the indicators of grassland degradation reflected by our dependent variables include the decrease of total, dense and moderate grassland areas, as well as the increase of sparse grassland area[4]. According to the current controversial academic opinions on grassland privatisation, it is suggested that grassland privatisation has aggravated grassland degradation because it has caused destruction of the grassland ecosystem (Cao et al., 2013; Guelke, 2003; Galvin, 2009), a view which is mainly supported by scholars specialising in pastoralism. We therefore expect negative coefficients for L_{it} in the total, dense and moderate grassland models, and a positive coefficient in the sparse grassland model. Importantly, we suspect whether actual patterns of private use will have positive effects on grassland condition after a few decades, as the tragedy of the commons has probably been avoided but the corresponding benefits of privatisation are being demonstrated only slowly. Thus, we expect positive coefficients for L_{it}^2 in total, dense and moderate grassland models, and a negative coefficient in sparse grassland model. Additionally, low temperature and especially scarce precipitation are always by some scholars proposed as the significant reasons for grassland degradation in Inner Mongolia (Li et al., 2012). We expect positive coefficients for T_{it}, F_{it} and TF_{it} in the total, dense and moderate grassland models, and negative coefficients in the sparse grassland model. However, temperature and precipitation may have nonlinear relationships with grassland condition - too much warmth or too much rainfall, for example, would be conversely detrimental to grassland condition. We then expect negative coefficients for T_{it}^2 and F_{it}^2 in the total, dense and moderate grassland models, and positive coefficients in the sparse grassland model. Cultivation and the increase of arable land are suggested as having

[4] Given that the total grassland area either reduces or does not change, the increase of sparse grassland area is attributed to the degradation of grassland quality from higher canopy cover to lower canopy cover.

negative impacts on grassland condition (Feng et al., 2009). We expect negative coefficients for C_{it} in the total, dense and moderate grassland models, and a positive coefficient in the sparse grassland model. The negative effects of cultivation may arrive the worst when the increase of arable land is fast enough, we therefore expect positive coefficients for C_{it}^2 in the total, dense and moderate grassland models, and a negative coefficient in the sparse grassland model.

5. Model results

In this section, we firstly examine whether our data is appropriate to the fixed effects model through a series of statistical hypothesis tests, including the choice of fixed effects or random effects, cross-sectional dependence and heteroskedasticity. Moreover, we examine whether the variable of land tenure reform (L_{it}) and its square term (L_{it}^2) are endogenous variables because L_{it} is the number of years for which the private use pattern has been adopted, which might have been decided by the county per se so as to delay or even not to follow the implementation of the government arrangement. After these tests, the appropriate estimation is performed in order to further examine our predicted results in table 3.

The Hausman test is employed to determine whether a fixed or random effects model is more effective here. Its null hypothesis indicates that the random effects model is more effective than the fixed effects model, whereby it basically assumes that the fixed term (U_i) is uncorrelated with the regressors (Verbeek, 2012). In the test results of the total, dense and moderate grassland models, all of their null hypothesis are rejected at $p<0.05$, and thus the fixed effects are more effective to estimate these four models than the random effects. Cross–sectional dependence in panel–data models (also called contemporaneous correlation) is then tested using Pasaran CD test, given that our data includes many more cross-sectional units than only five time-series observations. It is basically used to test whether the residuals are correlated across entities, and the null hypothesis is that residuals are not correlated. Our test results indicate no cross–sectional dependence as the null hypothesis is not rejected in any of the four models. The tests of heteroskedasticity reject the null hypothesis of homoskedasticity for all four models and conclude heteroskedasticity.

With respect to the suspicion of endogeneity on L_{it} and L_{it}^2, the Durbin-wu-hausman test is employed to examine this feature. The null hypothesis states that both OLS estimator and instrumental variables estimator yield consistent estimates, and the alternative hypothesis indicates that instrumental variable techniques are required because the endogenous variable

which existed impacts upon the estimation (Verbeek, 2012). The test results rejected the null hypothesis of exogeneity of L_{it} in both the total grassland and the dense grassland models, but failed to reject it in the moderate and sparse grassland models. The null hypothesis of exogeneity on L_{it}^2 is rejected in the total, dense and moderate grassland models, but not in the sparse grassland model. In other words, L_{it} presents endogeneity in the total and dense grassland models, and L_{it}^2 presents endogeneity in the total, dense and moderate grassland models. They therefore require instrumental variables. The number of years for which formal use rights have been allocated is strongly correlated with the number of years for which actual private use patterns have been adopted (correlation value=0.7328), and therefore we consider using it and its square term as the instrumental variables of L_{it} and L_{it}^2. The instrumental variables tests indicate that the number of years of allocating formal use rights and its square term are valid and not weak instrumental variables for L_{it} and L_{it}^2 because they are correlated with L_{it} and L_{it}^2 but not with the residuals. After these requisite tests, our four models are run by fixed effects and with instrumental variables; the final results are listed in table 4.

Table 4 Model results of fixed effects

In table 4, the coefficient of L_{it} is significant in the dense grassland model (-1273.95). It indicates that when other variables are controlled, dense grassland area decreases by 1273.95 hectares for county i as its actual pattern of private use increases by one year. Similarly, the significant coefficient of F_{it} (207.22) explains that rainfall has a beneficial impact, causing dense grassland to increase significantly, while the growth of arable land (C_{it}) has significant negative effects on dense grassland (-33047.87).

In the moderate grassland model, the coefficient of L_{it} is significant (-2137.97). This indicates that when other variables are controlled, moderate grassland area decreases by 2137.97 hectares for county i as its actual pattern of private use increases by one year. The growth of arable land (C_{it}) has a significant negative effect on moderate grassland (-50368.11), with a nonlinear relationship as presented by the significant and positive coefficient of C_{it}^2 (230107.50).

In the sparse grassland model, the coefficients of L_{it} is significant (-569.16). This indicates that when other variables are controlled, sparse grassland area decreases by 569.16 hectares for county i as its actual pattern of private use increases by one year. Interestingly, the coefficient of L_{it}^2 is significant (61.62), which indicates that the number of years adopting private use has a nonlinear relationship with the sparse grassland area. The positive coefficient of L_{it}^2 (61.62) represents that the nonlinear relationship possibly exists a turning point in which the sparse grassland area will increase after years of decrease as the increase in the number of years adopting private use. In addition, precipitation (F_{it}) has a significant and negative effect on sparse grassland (-110.58), with a nonlinear relationship as presented by the significant and positive coefficient of F_{it}^2 (0.16). The cultivated land growth (C_{it}) has a significant and positive effect on the sparse grassland area (20782.77), with a nonlinear relationship as presented by the significant and negative coefficient of C_{it}^2 (-81822.8).

Ultimately, the coefficients of L_{it} is significant (-3066.29). This indicates that when other variables are controlled, total grassland area decreases by 3066.29 hectares for county i as its actual pattern of private use increases by one year. Interestingly, the coefficient of L_{it}^2 is significant (85.80), which indicates that the number of years adopting private use has a nonlinear relationship with the sparse grassland area. The positive coefficient of L_{it}^2 (85.80) represents that the nonlinear relationship possibly exists a turning point in which the total grassland area will increase after years of decrease as the increase in the number of years adopting private use. In addition, the significant and negative coefficient of T_{it}^2 indicates temperatures have a nonlinear relationship with the total grassland area (-812.17). The cultivated land growth (C_{it}) has a significant and negative effect on the total grassland area (-62499.71), with a nonlinear relationship as presented by the significant and negative coefficient of C_{it}^2 (167454.20).

Comparing the above model results with our predicted results in table 3, the coefficients of significant variables in the models are almost consistent with our expectation on negative or positive, besides the coefficients of L_{it} and L_{it}^2 in sparse grassland model. We then focus on the model results on our crucial variables of privatisation to investigate how private use patterns impact on grassland condition.

Figure 2 Relationships between private use years and various grassland areas

We employ the significant regression coefficients of L_{it} and L_{it}^2 to specifically depict the changes in various grassland areas as the number of years of private use increases, as presented in figure 2. The trends of dense and moderate grasslands present a continued decrease since their coefficients for L_{it}^2 are not significant. And the moderate grassland area decreases more quickly than dense grassland. Remarkably, both sparse and total grassland areas demonstrate an upward trend after the initial decrease, because their coefficients for L_{it}^2 are significant and positive. That is, sparse and total grassland areas decrease at first but then start to increase after a number of years of private use. The turning point is 4.6 years for sparse grassland area and 18 years for total grassland area. In fact, the increase of sparse grassland area might possibly contribute to the degradation of grassland quality, that is the transformation of grassland quality from higher to lower canopy cover, which furthers the increasing trend of total grassland area as a consequence. Although the total grassland area would turn to increase since the private use has been adopted for 18 years, the total grassland area in the 30th year is still less than in the initial 1st year starting with private use in figure 2. These results therefore indicate that grassland quantity and especially quality are in degradation with the increase in years of private use. Moreover, the degradation of dense and moderate grasslands does not improve after several years of experience with private use. The empirical analysis thus indicates that the tragedy of privatisation occurs, and this tragedy remains over time.

6. Conclusion and discussion

This paper used the number of years of actual patterns of private use to realistically describe the progress of land tenure reform in Inner Mongolia. The potential endogeneity of actual adoption of land tenure reform is also taken into account. Our empirical model may be more reliable than qualitative analysis or remote sensing observation since we control other potential factors that may impact upon grassland condition, such as climate factor and human activity. The empirical analysis is based on the fixed effects model, which also controls for the unobserved heterogeneity that may obscure the relationship between grassland condition and privatisation. In addition, we believe that our data presents a convincing attempt to examine the results of land tenure reform on the grassland in China. The span of our research period is from 1985 to 2008, which covers the main period during which grassland tenure reform was implemented in Inner Mongolia. To conduct a thorough investigation of the results of land tenure reform on grassland conditions, the study measures the impact of

privatisation on various categories of grassland, defined according to the canopy cover of the grass.

Our model results proved that the tragedy of privatisation occurs in Inner Mongolia, in line with the research by Sneath (1998), which was based on a comparison of the changes in landscapes with and without privatisation of grassland in Inner Asia, and with Li (2007) , who conducted empirical household surveys about the results of privatisation of grassland in Inner Mongolia. More specifically, our data show that the higher quality grassland areas (dense grassland and moderate grassland) decrease as the number of private use years increases, and the total grassland area also decreases during the first years of private use. This indicates that both the quality and the quantity of grassland are degrading as privatisation increases. Although the low quality (sparse) and total grassland areas present an increasing trend after several years of reduction, this stems from the degradation of good quality grassland. Importantly, grassland degradation in quantity and especially in quality do not improve after several years of privatisation, but rather only the superficial restoration of sparse grassland area and total grassland area. In addition, we proved that climate factors play a significant role in improving grassland condition and that increasing the area of cultivated land is also detrimental to grassland condition.

In short, we have proved that the tragedy of privatisation is indeed occurring, based on the case in Inner Mongolia whereby grassland condition is deteriorating in relation to grassland tenure reform. A possible explanation of this phenomenon is that, private use directly triggers grassland degradation through mechanisms such as grassland fragmentation, reduction of vegetation diversity through restricted livestock mobility and single livestock structure with a resulting decrease in accessible grassland. As such, the negative influences of land tenure reform on grassland are more obvious and serious than the benefits of avoiding “the tragedy of the commons” through privatisation. It might discourage the adoption of private use patterns in pastoral areas. On the other hand, some scholars (see e.g. Li et al., 2007) have argued that the failing of privatisation to sustainable grassland use is caused by its failed implementation because of the fencing costs which are unaffordable for rural households; private land tenure requires the building of fences around grassland to exclude other users, but some rural households cannot afford such fencing, which results in the overusing of open private grassland. our next research will explore in more detail the question whether the tragedy of privatisation has its roots in privatisation per se or its failed implementation.

The privatisation of both formal land tenure rights and actual use patterns have transformed the common use of grasslands to private use; the results are far-reaching and pervasive challenges which are being confronted by most pastoral societies across the global (Galvin et al., 2008). Such challenges show the urgent need for policy insights into sustainable grassland use for all pastoral societies. So far, there has been a steady trend towards privatisation of grasslands all over the world, and this overwhelming tendency is unlikely to stop (Lesorogol, 2003; Little, 1992), although the fact that this paper and other research prove that land tenure privatisation does not mitigate grassland degradation, but instead exacerbates it. As such, drawing on the theory of "common pool resource" which involves self-organisation by the local community in efforts to achieve a sustainable social-ecological system (Ostrom, 2009), and considering the fact that individual households cannot always afford private fencing costs and that the heterogeneity of grassland resources is exacerbated (e.g. uneven water distribution) under private use, it is recommended that the government stimulates the local community to practice common use and management of grasslands based on private land tenure. It may be efficient to monitor access to the resource system for community members as well as to exclude outsiders from using their resource. In addition, such cooperation could enable joint investment in fencing costs and diminish the limitations which arise from the heterogeneity of resources.

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Table 1 multiple formal grassland use rights and actual use patterns

Formal use rights owned by	Grassland use patterns		
	Private use	Joint use	Common use
Household	+	+	+
Group	----	+	+
Collective/ administrative village	----	----	+

Source: adapted from "formal and de facto grassland management units" (Banks et al., 2003)

Note: ---- means non-existent situations.

Table 2 General trend of grassland tenure reform and grassland condition

	Unit	1985	1995	2000	2005	2008
The proportion of counties in which formal use rights are privatised	%	6.67	23.33	76.67	80.00	81.67
The proportion of counties with actual patterns of private use	%	5.00	15.00	58.33	63.33	63.33
Total grassland area	%	100.00	98.01	96.28	95.52	95.73
Dense grassland area	%	100.00	98.56	92.54	93.28	93.27
Moderate grassland area	%	100.00	97.96	97.28	96.14	96.08
Sparse grassland area	%	100.00	97.76	100.67	99.78	100.62

Source: based on our survey

Table 3 variable definition, statistical description and predicted results

Variable	Variable definition	Unit	Mean	Std. Dev	Predicted results			
					Total grassland model	Dense grassland model	Moderate grassland model	Sparse grassland model
G_{it}	Total grassland area of county i in year t (canopy cover of grass exceeds 5 percent)	hectares	767206	803728	Dependent variable			
D_{it}	Dense grassland area of county i in year t (canopy cover of grass exceeds 50 percent)	hectares	370656	512489		Dependent variable		
M_{it}	Moderate grassland area of county i in year t (canopy cover of grass is between 20 and 50 percent)	hectares	275380	371740			Dependent variable	
S_{it}	Sparse grassland area of county i in year t (canopy cover of grass is between 5 and 20 percent)	hectares	121171	159512				Dependent variable
L_{it}	The number of years for which actual private use patterns had been adopted by county i until year t	Years	4.1133	6.0853	-	-	-	+
L_{it}^2	Square term of actual private use years	$Years^2$	53.83	111.14	+	+	+	-
T_{it}	The annual average temperature of county i in year t	Degrees Celsius	4.4414	2.8144	+	+	+	-
T_{it}^2	Square term of temperature	$Degrees\ Celsius^2$	27.62	21.63	-	-	-	+
F_{it}	The average annual precipitation of county i in year t	Millimetre	318.05	104.35	+	+	+	-
F_{it}^2	Square term of precipitation	$Millimetre^2$	112010	65590	-	-	-	+
TF_{it}	Cross term of temperature and precipitation	Degrees Celsius* Millimetre	1346	1003	+	+	+	-

C_{it}	The average percentage change of cultivated land in county i during last five years of year t	Percent	0.0183	0.0736	-	-	-	+
C_{it}^2	Square term of cultivated land percent change	$Percent^2$	0.0057	0.0178	+	+	+	-

Table 4 Model results of fixed effects

Variable	Total grassland model (G_{it})		Dense grassland model (D_{it})		Moderate grassland model (M_{it})		Sparse grassland model (S_{it})	
	coefficient	z	coefficient	z	coefficient	z	coefficient	t
L_{it}	-3066.29***	-3.49	-1273.95*	-1.78	-2137.97**	-2.12	-569.16*	-1.67
L_{it}^2	85.80*	1.86	-6.85	-0.18	84.24	1.46	61.62***	3.45
T_{it}	5817.37	1.52	4097.36	1.31	116.18	0.03	1370.21	0.70
T_{it}^2	-812.17***	-2.68	-356.23	-1.44	-227.41	-0.81	-181.93	-1.18
F_{it}	80.96	0.75	207.22**	2.37	-31.48	-0.32	-110.58**	-2.02
F_{it}^2	-0.02	-0.17	-0.17	-1.62	0.01	0.06	0.16**	2.37
TF_{it}	-6.37	-0.83	-8.60	-1.38	4.87	0.69	-2.42	-0.62
C_{it}	-62499.71***	-3.24	-33047.87**	-2.10	-50368.11***	-2.86	20782.77**	2.12
C_{it}^2	167454.20*	1.75	4989.18	0.06	230107.50**	2.59	-81822.8*	-1.68
Constant	757320.20***	33.45	333232.90***	18.07	287707.00***	13.68	140156.3***	12.15
R^2	0.2004		0.1548		0.0365		0.1255	
Obs	300		300		300		300	

*significant at 10%; **significant at 5%; ***significant at 1%.

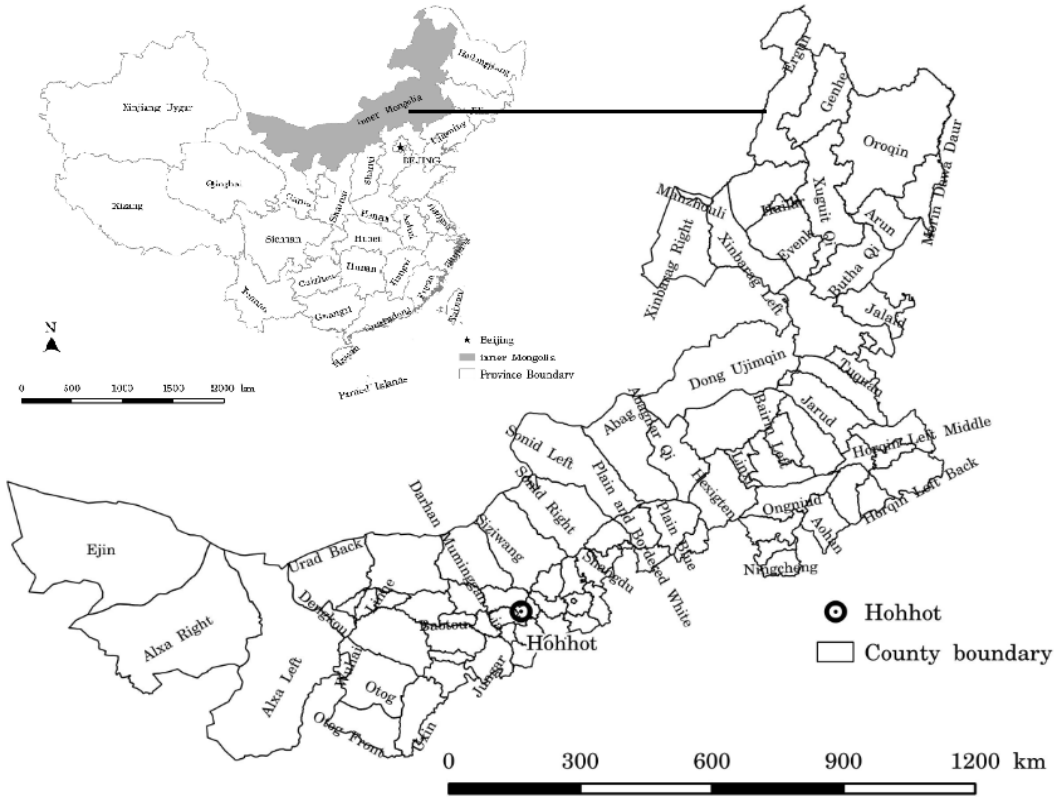

Figure 1 Inner Mongolia autonomous region and its 102 counties

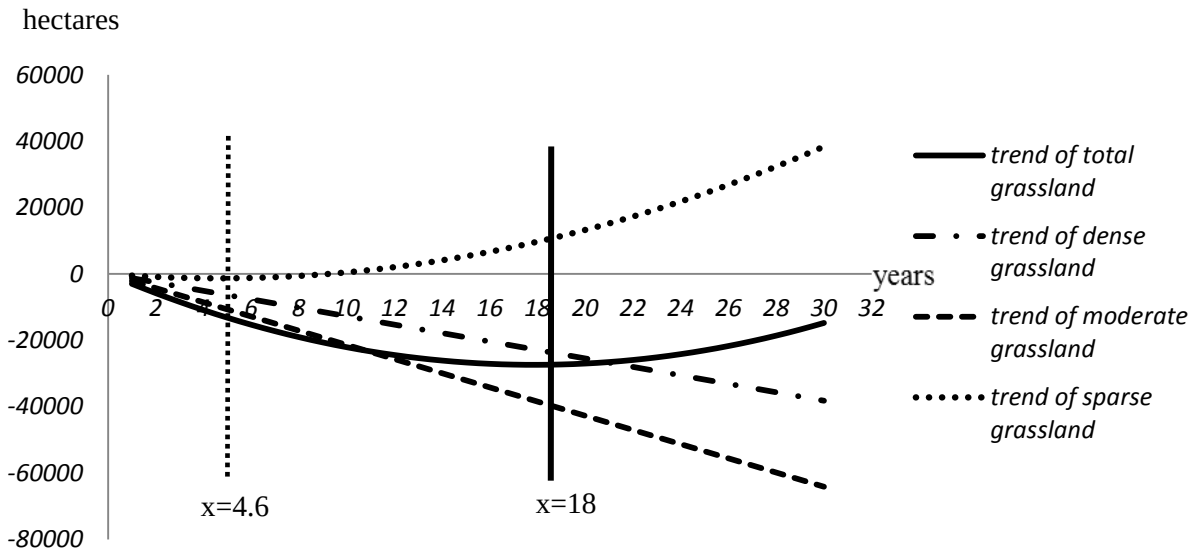

Figure 2 Relationships between private use years and various grassland areas