Grassland rental markets and herder technical efficiency: ability effect or resource equilibration effect?

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To explore whether grassland rental markets improve herder technical efficiency, how and to what extent, this study applies a Metafrontier-DEA approach by employing field data collected from 416 herder households to examine the impacts of herder participation in grassland rental markets on their technical efficiencies. Results show that herders involved in the grassland rental markets can increase their technical efficiency by 2.75%. Compared with the autarky group, the lessors increase their efficiency by 3.36%, and the lessees increase their efficiency by 2.76%. No significant efficiency difference is found between the lessors and the lessees. We conclude that grassland rental markets improve herder technical efficiency mainly through a resource equilibration effect rather than ability effect. Only if the herders participate in the grassland rental markets, can they improve their efficiency by balancing family resources and thus enhance production efficiency. This suggests that under the current institutional environment, more attention should be paid to normalize and guide the grassland rental markets, to allow herders to participate in the markets on their own will rather than address land transfer from the less-able to the more-able producers.

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Key words: grassland rental markets, technical efficiency, ability effect, resource equilibration, Metafrontier-DEA analysis

1 Introduction

Grassland is a dominant land use pattern from which the herders in arid and semi-arid areas generate their main income (McGahey et al., 2014; Asner et al., 2004; Li et al., 2008; Undargaa and Mccarthy, 2016). China has the second largest area of grassland in the world, accounting for about 42% of its territory (Hua and Squires, 2014). Directly and indirectly, grasslands support a population of more than 40 million people, and serve as a crucial ecological barrier to north China. With implementation of the Household Responsibility System (HRS) in grazing areas, the traditional communally managed grasslands with open mobility to herds of the communal were distributed to individual herder households about three decades ago. The original resource combination of “people (labor)-grass(land)-livestock-productive assets” was broken. Together with the subsequent subdivision of grasslands among the grown-ups, the herder household resource combination became unbalanced to a certain extent (Tan and Tan, 2017). Given the Cannikin law (i.e. the water level filled is decided by the shortest board of the cannikin) that livestock production has to follow, the imbalance of family resources reduces herder livelihoods and livestock production efficiency.

Theoretically and empirically, land rental markets are regarded as ways to improve production efficiency by helping farm households adjust land in terms of other non-land resources, or by transferring land from the less-able to the more-able farmers (Feder, 1985; Deininger 2003; Otsuka, 2007; Jin and Jayne, 2013). Can grassland rental markets improve herder household efficiency, to what extent and how? It is important to study this, as the present inefficient livestock production (Huang et al., 2016; Tan et al., forthcoming） aggravated the "pasture overstocking---grassland productivity loss---poverty increase---increased stocking" vicious cycle in the grazing system (Li et al., 2014; Du et al., 2013). Although a series of ecological measures have been taken to alleviate grassland degradation, to recover the deteriorated grazing system and to improve herder livelihoods, the effectiveness of ecological governance is limited (Gao et al., 2016; Hou et al., 2010; Tan et al., 2014; Liu et al., 2016). Furthermore, compared with agricultural production which comprises a combination of people-land-and other production factors, livestock production is more complicated as it adds livestock as a crucial factor. Correspondingly, the unbalanced combination of resources is severe for herders in general compared with farmers. Moreover, the frequent movement of livestock for seeking forage may cause *feet-disaster (Tizai in Chinese)* (Haishan, 2012; Liu, 2016). Grassland rental markets are expected to enable herders to better balance their resources and to break the grassland degradation-poverty cycle. To our knowledge, however, the impact of grassland rental markets on herder efficiency is not well understood.

Understanding the impacts of grassland rental markets and their impact mechanisms on herder livestock production can, in turn, help to normalize and develop functional grassland rental markets. To facilitate this, our study applied a Metafrontier approach to analyze the effects of grassland rental markets on animal husbandry production efficiencies. A comprehensive dataset with 416 sampled herder households from east Inner Mongolia was used for this purpose. The remaining part of the paper is organized as follows: Section 2 reviews literature and proposes hypotheses. Section 3 is the methodology comprising two parts. The first introduces the basic theory of the Metafrontier approach, and how the approach can be applied to examine the impacts of grassland rental markets on herder technical efficiency; the second part introduces the sampling, data collection and variables to be used in the study. Section 4 discusses the results and section 5 concludes the study.

2 Literature review

Land is the most important production factor. In many agriculturally dominant countries, however, land and non-land factors are normally unbalanced for smallholders. Land rental markets can potentially improve production efficiency by equilibrating land and non-land factor ratios across farms in the presence of imperfections in non-land factor markets (Deininger, 2003; Otsuka, 2007). The land tenancy transaction is thus the most common way to adjust different factor endowments among farming households (Deininger et al., 2008; Rahman, 2010; Kimura et al., 2011). Despite the emerging evidence, there remains quite entrenched perceptions that land rental markets may contribute to land concentration for some and increased poverty for the rest. Therefore, understanding the major drivers and allocative roles of land rental transactions is crucial for rural economies, especially in countries with limited land and high population pressure (Holden and Otsuka, 2014).

2.1 Drivers of land rental markets

Empirical analyses on driving forces of land rental markets at farm level are mainly based on a household model (Jin and Deininger, 2009; Tan et al., 2017). Three types of explanatory and control variables are distinguished: 1) The main characteristics of farmers which reflect their farming ability, including the basic information of household head such as age, education level, gender and so on (assuming household land rental behavior and other production decisions are made by the head); or a comprehensive indicator used to reflect the farming ability of household (e.g. Jin and Jayne, 2013; Huang et al., 2014); 2) Farm household resource endowments and their combination, including land, labor force and productive assets; 3) The related institutions and policy environment which may encourage or discourage farmers to participate in land rental markets, for example, land tenure insecurity, law restrictions (e.g. Holden and Ghubru, 2016) and subsidy policy for land transfer, etc.

The existing literature show that farm household failures of equilibrating their resources are the major driving forces of land rental participation（e.g. Jin and Deininger, 2009; Jin and Jayne, 2013; Chamberlin and Ricker-Gilbert, 2016). For example, according to Holden and Ghubru (2016), given other factors, farm households with more cattle in Tigray of Ethiopia tend not to rent out land while, in contrast, households with more land tend to rent out land. Rahman (2010) had similar findings for Bangladesh. Households with more cultivated land did not tend to rent in but tended to rent out land; whereas more household assets encouraged land to be rented-in. More significant results were observed for impacts of livestock on participation in land rental markets (Rahman, 2010).

Jin and Jayne（2013）found that compared with the autarky groups, farmers who rented in land are younger and have higher education levels. This suggests that farmers with higher farming ability represented by age and education level tend to participate more in land rental markets. However, this study did not find that the comprehensive farming ability had significant effects on farmer participation in land rental markets. A recent study on Saharan Africa confirmed that household resource equilibration and farming ability affected their participation in land rental markets (Chamberlin and Ricker-Gilbert, 2016). In Malawi, for example, farm households with more land tended to rent out, but not to rent in land, while households with more adults (representing labor availability) tended to rent in, but not to rent out land. Age of household head (representing farming ability) had the same results. Observations in Zambia are similar with those in Malawi (Chamberlin and Ricker-Gilbert, 2016).

This suggests that farm households tend to equilibrate their resources, keeping the resources in the Bucket for livestock production balanced. Under imperfect non-land factor markets, in order to maintain a higher Bucket level, farmers would equilibrate their resources by renting out surplus land or renting in land when it is lacking with respect to non-land factors so as to avoid sunken cost caused by surplus assets. Besides, household farming ability also plays a key role in land rental market participation.

2.2 Land rental markets and agricultural efficiency

Some existing studies show that auto-participated land rental markets facilitate improvement in both efficiency and fairness (e.g. Crookes and Lyne, 2003；Jin and Deininger, 2009; Jin and Jayne, 2013). The main reasons lie in that land rental markets play as a venue of equilibrating land with non-land resources (Deininger, 2003; Feder, 1985). When the allocated land is out of the optimized managed structure, land rental markets help to transfer land to more-able farmers and thus improve agricultural efficiency (Deininger et al., 2008; Huy et al., 2013). As found by Chamberlin and Ricker-Gilbert (2016) in Saharan Africa, rented-in land improved the welfare of farmers. Jin and Jayne (2013) found that in Kenya, land rental markets allow farmers to get access to land, equilibrating the other factors with land so as to promote efficiency and fairness. In some situations, however, land rental markets may transfer land from land-poor farmers to land-rich farmers, leading to land concentration for the latter and continued poverty for the former, as experienced in Rwanda (Andre and Platteau, 1998), Bukina Faso (Zimmerman and Carter, 1999), India (Kranton and Swamy, 1999) and Ethiopia （Deininger et al., 2009; Ghebru and Holden, 2009).

Most current studies indicate that effective land rental markets can improve farmer efficiency for the following reasons: on the one hand, farmers can obtain some income by renting out their surplus or insufficiently used land; on the other hand, land rental markets facilitate farm households lacking land (with respect to non-land capitals) to better balance their productive assets (by obtaining extra land). For example, Crookes and Lyne (2003) analyzed the effects of land rental markets on the efficiency and fairness of leases and lessors by comparing their inputs and outputs; Deininger et al. (2008) explored the impact of farming ability on land rent-in and rent-out, and found that transferring land to more-able farmers allowed the improvement of production efficiency. A recent study on the Philippines (Koirala et al., 2016) estimated the impact of land rent on the technical efficiency of rice farmers by applying one-step Statistical Frontier Analysis (SFA). Results show that participation in land rental markets reduced farmer technical efficiency, which is an exception among the relevant studies. This might be caused by the land policy implemented in the Philippines that each farm household could only keep 7 ha land for themselves. The exceeded land area has to be allocated to others, or rented out. Chen et al. (2011) examined the impact of farmland rented-in on agricultural productivity in Beijing, Shanghai and Guangdong, and found that rent-in reduced technical efficiency, but improved scale efficiency. The net effect is positive, resulting in increased agricultural productivity. The study on rice farmers in Jiangxi province by Huang et al. (2014) indicated that farmers having land rented in had significantly higher technical efficiencies than their counterparts with no land market participation.

Despite these studies, none explicitly uncovered how land rental markets improve farmer efficiency and to what extent. Better understanding the impacts of land rental markets on farmer efficiency and fairness is needed based on existing studies. The present paper intends to examine this by analyzing household field data that was personally collected by the authors.

2.3 Methods used

Major methods used by the existing studies examining impacts of land rental markets on farmer efficiency can be summarized as three types: 1) to measure farmer efficiency firstly, then to analyze the impact of farmer participation in land rental markets. This method can be further divided into one-step SFA (e.g. Huang et al., 2014; Koirala et al., 2016), and Date Envelop Analysis (DEA) together with Tobit model (e.g. Chen et al., 2011); 2) first to classify farm households into groups in terms of their participation in land rental markets, then to estimate the impacts of land rent on farmer income and agricultural productivity and so on (e.g. Jin and Jayne, 2013；Chamberlin and Ricker-Gilbert，2016); 3) to compare the differences in income and input/output between farm households with and without participation in land rental markets, or simply to deduce the effects of land rental markets on farmer efficiency by examining the transfers of land from farmers with different characteristics. For example, if land is transferred from less-able farmer to more-able farmer, the effect is regarded as positive (e.g. Deininger et al., 2008; Kimura et al., 2011). Although theoretically, land rental markets bring about efficiency by transferring land from farmers with lower ability to those with higher ability, or equilibrating resources owned by farm households, the existing studies did not reveal this. It is desirable to understand why land rental markets can enhance agricultural efficiency, to what extent and how. In doing so, an appropriate method which enables us to measure, compare and reveal the mechanisms of land rental markets on farmer efficiency improvement is needed.

2.4 Hypotheses

Based on the above analyses, given the existing institutional environment and without considering transaction costs and unfair trade, the study proposes three hypotheses:

H_1: Land rental markets allow farmers to equilibrate their family resources, namely to make up what is short or to trim the excess resources of the farm production Bucket by adjusting land area and the non-land resources. The resulting effect is called *resource equilibration effect* (TE_R), assuming such an effect is equal for the lessors and the lessee ($TE_{Rin}=TE_{Rout}>0$), as both would equilibrate their family resources by participating in the land rental markets.

H_2: Land is transferred from less-able to more-able households, giving rise to improved efficiency. This effect is called the *ability effect* (TE_A). Assuming the lessees have ability-related efficiency TE_{Ain}, and the lessors have ability-related efficiency TE_{Aout}, then the *ability effect* $TE_A=TE_{Ain}-TE_{Aout}>0$;

H_3: Considering the potential existence of the two effects, we argue that if farmers want to participate in land rental markets, their efficiencies can be improved either (or both) through equilibrating family resources or (and) through enhancing farming ability. Using TE_{in} to represent the integrative effect of the lessee, TE_{out} of the lessors, and TE to represent the efficiency of non-participating farm households, we have $TE_{in}=TE_{Rin}+TE_{Ain}>TE$ for the lessees, and $TE_{out}=TE_{Rout}+TE_{Aout}>TE$ for the lessors. *As* $TE_{Rin}=TE_{Rout}$ (H_1), and $TE_{Ain}>TE_{Aout}$ (H_2), thus $TE_{in}>TE_{out}$.

3 Methodology

In order to test the above three hypotheses, we use the Metafrontier-DEA model to estimate the impacts of land rental markets on farmer technical efficiency based on data collected from field surveys. This section will first briefly introduce the Metafrontier method; then, we will explain the sampling and data collection procedure, and present the variables to be used and their descriptive statistics. Lastly, we will introduce how the DEA models are designed to test the three hypotheses stated in 2.4.

3.1 Metafrontier method

Efficiency measurement is deeply rooted in production theory and in the concept of distance functions (O'Donnell et al. 2008). In this section, we follow O'Donnell et al. (2008) to introduce the Metafrontier analysis method, and explain how to apply this method to fulfill the purposes of the present study. Using $\mathbf{y}$ and $\mathbf{x}$ to represent farmer's real outputs and inputs, we have metatechnology set T, which contains all technologically feasible input-output combinations, namely,

$$T=\{(\mathbf{x},\mathbf{y}):\mathbf{x}\geq\mathbf{0};\mathbf{y}\geq\mathbf{0};\mathbf{x}\text{ can produce }\mathbf{y}\}. \quad (1)$$

Where x is a vector of inputs and y is an output vector, given technology set T. Output set is defined as:

$$P(\mathbf{x})=\{\mathbf{y}:(\mathbf{x},\mathbf{y})\in T\} \quad (2)$$

The frontier of output set is metafrontier. Assuming that T satisfies the standard regularity properties listed in Färe and Primont (1995), the output metadistance function can be defined as:

$$D(\mathbf{x},\mathbf{y})=\inf_{\theta}\{\theta>0:(\mathbf{y}/\theta)\in p(\mathbf{x})\} \quad (3)$$

This function gives the maximum amount by which a farm household can expand its output vector, given an input vector. The distance function inherits its regularity properties from the regularity properties of the output set. If and only if $D(\mathbf{x},\mathbf{y})=1$, the performance of a farm household (x,y) can be considered technically efficient with respect to the metafrontier.

Group frontiers

We assume that each herder group has its own accessible and representative productive technology set, which determines the frontier of potential production. In this study, we classify the herders into three groups: the rent-in, rent-out and autarky groups. Assuming herders from another group is not allowed to select a technologically feasible input-output combination from the technology set of this group, given resource and environmental constraints confronted by the herders, they can select the input-output combination from their own technology set:

$$T^{k}=\{(\mathbf{x},\mathbf{y}):\mathbf{x}\geq\mathbf{0};\mathbf{y}\geq\mathbf{0};\mathbf{x}\text{ can be used by firms in group }k\text{ to produce,}\mathbf{y}\} \quad (4)$$

The technology set of this group can be indicated by its output set and distance function:

$$P^k(\mathbf{x}) = \{\mathbf{y} : (\mathbf{x}, \mathbf{y}) \in T^k\}, k = 1, 2, ..., K; \quad (5)$$

$$D^k(\mathbf{x}, \mathbf{y}) = \inf_\theta \{\theta > 0 : (\mathbf{y} / \theta) \in p^k(\mathbf{x})\}, k = 1, 2, ..., K \quad (6)$$

The output boundary of each group is referred as group frontier. If an output set $P^k(\mathbf{x})(k = 1, 2, 3..., K)$ satisfies the standard regularity properties, then the distance function $D^k(\mathbf{x}, \mathbf{y})(k = 1, 2, ..., K)$ also satisfies the requirements of the standard regularity properties. Irrespective of the properties of these sets and functions, the following deductions exist (O'Donnell et al. 2008):

R1: if $(\mathbf{x}, \mathbf{y}) \in T^k$ for any k then $(\mathbf{x}, \mathbf{y}) \in T$;

R2: if $(\mathbf{x}, \mathbf{y}) \in T$ then $(\mathbf{x}, \mathbf{y}) \in T^k$ for some k ;

R3: $T = \{T^1 \cup T^2 \cup \cdots \cup T^K\}$; and

R4: $D^k(\mathbf{x}, \mathbf{y}) \geq D(\mathbf{x}, \mathbf{y})$ for all $k = 1, 2, ..., K$.

These properties follow from the fact that the group-specific output sets $P^k(\mathbf{x})(k = 1, 2, 3..., K)$ are subsets of the unrestricted output set $P(\mathbf{x})$.

Figure 1 shows single input-output production possibility frontiers of 3 herder groups, namely k = 1, 2, 3. The frontier of group k is $k - k'$, which is assumed to be convex. All the possible input-output combinations of the herders in each group are enveloped by its frontier. The meta-frontier is also assumed to be convex, consisting of the three frontiers.

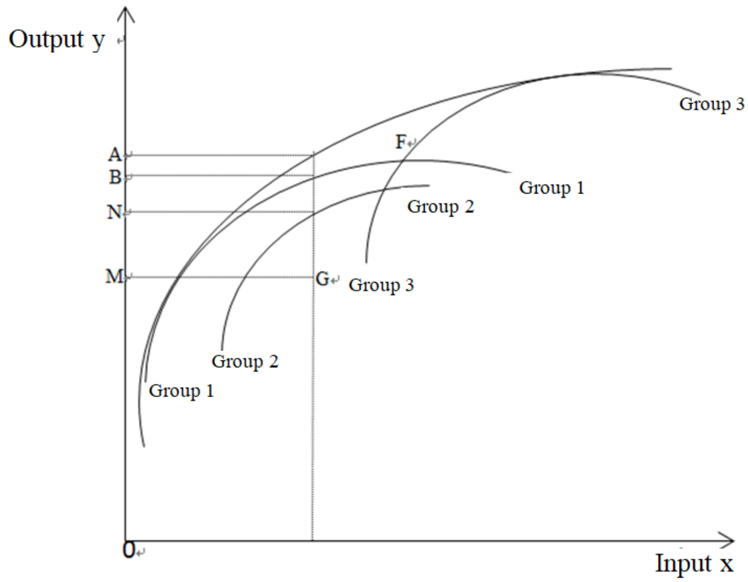

Figure 1 Technical efficiencies and metatechnology ratios

Technical efficiency (TE) and Metatechnology ratios (*MTR)*

In an output-orientated method, the technical efficiency of a herder with performance (x, y) with respect to the metatechnology is

$$TE(\mathbf{x},\mathbf{y}) = D(\mathbf{x},\mathbf{y}) \qquad (7)$$

With respect to the production frontier of group k, its technical efficiency is

$$TE^k(\mathbf{x},\mathbf{y}) = D^k(\mathbf{x},\mathbf{y}) \qquad (8)$$

R4 states that the output distance function $D^k(\mathbf{x},\mathbf{y})$ of group k can take a value no less than the output metadistance function $D(\mathbf{x},\mathbf{y})$. The output-orientated metatechnology ratio for group k is defined as:

$$MTR^k(\mathbf{x},\mathbf{y}) = \frac{D(\mathbf{x},\mathbf{y})}{D^k(\mathbf{x},\mathbf{y})} = \frac{TE(\mathbf{x},\mathbf{y})}{TE^k(\mathbf{x},\mathbf{y})} \qquad (9)$$

The technical efficiency of a particular input-output combination can be deconstructed into:

$$TE(\mathbf{x},\mathbf{y}) = TE^{k}(\mathbf{x},\mathbf{y}) \times MTR^{k}(\mathbf{x},\mathbf{y}) \tag{10}$$

This shows that technical efficiency measured with reference to the metafrontier (representing the existing state of knowledge) can be dissembled into the product of technical efficiency measured with reference to the group k frontier (representing the existing state of knowledge and the physical, social and economic environment that characterizes group k) and the metatechnology ratio for group k (which measures how close the group-k frontier is to the metafrontier) (O'Donnell et al. 2008).

In Figure 1, G represents the production performance of a herder household. If the household belongs to group 1, then its group technical efficiency is $TE^{1} = OM / OB$, the metafrontier efficiency is $TE = OM / OA$, and the metatechnology ratio of group 1 is $MTR = OB / OA$. But, if the household belongs to group 2, then its group technical efficiency, metafrontier efficiency and metatechnology ratio can be represented respectively as:

$$TE^{2} = OM / ON$$

$$TE = OM / OA$$

$$MTR = ON / OA$$

By comparing the average metatechnical efficiencies of these groups, we know the livestock production performance of herder households in each group. Furthermore, by comparing their metatechnology ratios, the technological states that these groups can reach are clear. For instance, using G to represent the performance of two households in group 1 and group 2, although the group technical efficiency score of group 2 is higher than that of group 1, the household in group 1 would have higher productivity with respect to the metafrontier. This means with the same input, the herders in group 1 can produce AB/OA more than their counterparts in group 2 by applying their available technologies.

3.2 Sampling and data collection

Data used in this study were for 2011 collected during 2011-2012 in Hulun Buir and Xilin Gol. The two leagues cover about one-third of the total grassland area and produce one-fourth of the total livestock in Inner Mongolia. They also cover major types of grasslands including meadow steppe, steppe, desert steppe and desert vegetation. Except for Abaga Banner, all of the 12 purely grazing banners in these two leagues were visited.

Table 1Characteristics of the sampled herder households and their livestock production

	Rent in		Autarky		Rent out		Whole sample	
	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
Samples [1] (household)	129		223		70		416	
Age (year)	42.2**	9.41	44.9	11.4	48.7**	11.9	44.69	11.18
Education (year)	8.75***	2.61	7.80	3.61	6.80**	3.34	7.92	3.33
Share of livestock income (%)	82.7**	20.2	76.5	26.7	49.6***	36.0	74.0	28.8
Productive assets (10 thousand yuan)	2.10***	2.85	1.99	4.73	0.84***	1.13	1.85	3.86
Family labor available (persons)	2.09	0.93	2.02	1.01	1.50*	1.11	1.96	1.03
Contracted grassland area (hm^2)	292	338	318	255	370***	339	313	287
Livestock income (10 thousand yuan)	12.4	14.3	6.48	6.05	5.32	6.06	8.10	9.85
Machine input (10 thousand yuan)	3,39	4,60	2.43	3.33	2.55	5.91	2.77	4.29
Investment in veterinary services (10 thousand yuan)	0.32	0.35	0.26	0.53	0.21	0.46	0.274	0.475
Expenditure on forage (10 thousand yuan)	3.49	6.91	2.93	2.01	0.58	1.13	2.73	1.53
Labor spent on livestock production (man·days)	841	467	786	343	658	297	782	385
Stocked sheep units (head)	374	369	324	290	228	339	321	326

Note: [1]6 households both rented in and rented out grasslands.

ANOVA of Rent-in with autarky, and rent-out with autarky group.

***Significant at 1% level, ** significant at 5% level, *significant at 10% level.

Taking into account the natural conditions and socio-economic factors such as population density, herder household wealth (roughly represented by heads of livestock), etc., 2-7 townships from each selected banner, 3-4 villages from each township, and 4-8 herders from each village were randomly selected for interview, resulting in 422 effective samples, among which, 201 were from Hulun Buir and 221 were from Xilin Gol (for details, see Tan et al., 2017). But 6 samples have no full information for the model used in this study, there remaining 416 effective samples, among which, 196 were from Hulun Buir and 220 were from Xilin Gol. Among these samples, 196 were from Hulun Buir and 220 from Xilin Gol. Major characteristics of the samples are shown in Table 1. Generally, around 47% of the sampled households are involved in grassland rental markets, of which, two-thirds of the households (129) participated in rent-in markets and more than one-third households (70) participated in rent-out market. It is worth noting that 6 households were involved in both rent-in and rent-out markets.

3.3 Designing DEA models

Variables used in the DEA model are shown in the lower part of Table 1, namely: 1) livestock income, including the current year livestock sales and animal products such as dairy products, wool, cow hide, sheep skins, grassland rent, and so on; 2) machine investment, i.e., if households used their own machines, the investment is the discount value together with the fuel expenditure of the current year; if households rented machines from others, the investment is the rent together with the fuel expenditure; 3) Investment in veterinary services, including medicines, breeding and other services used in the current year; 4) fodder investment, including expenditure on forage, hay and additives, etc.; 5) labor input, including family labor input and hired labor during the current year; 6) the initial herds of livestock in standard sheep units (SSU), i.e., 1 goat=1 sheep=1 SSU, 1 cow=5 SSUs, 1 horse=6 SSUs, and 1 camel=7 SSUs. Table 1 shows the descriptive statistics of the basic characteristics of the rent-in, autarky and rent-out households and their livestock production.

4 Results and discussion

4.1 Survey results

The upper part of Table 1 demonstrates the main characteristics of the herder households that participated in grassland rental markets versus the non-participating households, mainly their initial family resources and human capitals. In some empirical studies, a farm household's farming ability is normally estimated by production functions derived from a multi-phase dataset (e.g. Jin and Jayne, 2013; Chamberlin and Ricker-Gilbert, 2016). It is a pity that our cross-section data does not allow us to apply such a method. Based on the literature review and the theoretical hypotheses, we thus decided to use *age* and *education* level of household head to be proxy variables of herder farming ability. We used the initial herds of livestock (in SSU), productive assets owned by the herder family (such as grassland cutting and harvesting machines, etc.), the available family labor force and contracted grassland area to represent herder household resource endowments. The share of livestock income to total income is used to reflect the extent that herder household depends on animal husbandry.

Results show that herder household's farming ability does influence grassland transfer. More specifically, compared with the autarky herder group, household heads participating in the rent-in market are significantly younger, while rent-out household heads are older. On average, household heads participating in grassland rent-in market are 2.7 years younger, while heads involved in grassland rent-out market are 3.8 years older than their non-participating counterparts. In contrast, on average, the heads with grassland rented-in had one year more of formal education, while heads with grassland rented-out were educated one year less than the head of households with no involvement in grassland rental markets. This means that grasslands were transferred from the less-able (i.e., those older and less educated), to the more-able (i.e., those younger, and more educated). Nowadays, as grassland animal husbandry involves very heavy and complicated work, each individual operated household has to undertake more than 10 activities in their animal husbandry production cycle, including delivering the new born lambs, grazing, milking, cutting grass and harvesting wool, etc. Old herders are normally not as strong as their younger counterparts (for example those less than 40 years). Herders with higher education levels are generally more capable in dealing with multiple complicated animal husbandry activities. Seen from these two indicators, it is confirmed that grasslands were transferred from the less-able to the more-able, as found by many empirical studies (e.g., Jin and Jayne, 2013; Huang et al., 2014). However, this cannot fully explain the behavior of herders who both rented in and rented out their grasslands. Moreover, it is not clear whether the more-able rent-in households performed better than the less-able rent-out counterparts.

In addition, the initial family resources between households with and without participation in the grassland rental markets also show some significant differences. Compared with the autarky group, the rent-in households have significantly more livestock, while the rent-out households have less. Moreover, the rent-out households have fewer productive assets and less family labor available. The rent-in households have on average less contracted grassland than that of the autarky group, although the variance analysis result does not show any significance. In contrast, the rent-out households have significantly more contracted grassland, i.e., the grassland distributed from village during the implementation of the HRS. The unbalanced resource endowments for the households in the three groups make it possible for them to adjust their resource combination for livestock production by participating in grassland rental markets. Generally, those with relatively more non-land resources tend to rent in grassland, while those with relatively more grassland than household resources tend to rent in grassland to avoid their productive assets becoming sunk costs, as found by Jin and Jayne (2013) in Kenya, and Holden and Ghubru (2016) in Ethiopia. However, it is not clear whether this kind of land transfer will bring about improved efficiency for the participant households, to what extent, and how. Is *ability effect* and *resource equilibration effect* equally important? In the following section, we will apply the methods introduced in section 3 to analyze the effects and to test the hypotheses proposed above.

4.2 Model results

In order to test the three hypotheses proposed in section 2.4, we designed the following models: First, we will test the first part of H_3, namely if herder households participate in grassland rental markets on their own will they are supposed to be able to better adjust their resource combination and/or better manage livestock production, and thus improve efficiency, therefore we have $TE_{in\text{-}out}>TE$. To test this, we classified the 416 sampled households into the autarky group and the market participation group. DEAP2.1 is applied to estimate the input-oriented models with constant scale return, resulting in values of TE^k, *TE* and *MTR* for both groups (Table 2).

Table 2 Descriptive statistics of *TE* and *MTR* values

	Autarky				Rental participation			
	Mean	Std. ev.	Max.	Min.	Mean	Std. ev.	Max.	Min.
TE^k	0.867	0.088	1.000	0.551	0.860	0.080	1.000	0.590
TE	0.835	0.085	1.000	0.533	0.858	0.079	1.000	0.590
MTR	0.963	0.023	1.000	0.864	0.998	0.007	1.000	0.961

	Autarky		Rent in		Rent out	
	Mean	Std. ev.	Mean	Std. ev.	Mean	Std. ev.
TE^k	0.867	0.088	0.871	0.079	0.884	0.083
TE	0.834	0.085	0.857	0.075	0.863	0.085
MTR	0.962	0.024	0.984	0.024	0.976	0.021

In the upper part of Table 2, the descriptive statistics of TE^k, *TE* and *MTR* for these two groups are shown. The average *TE* value of the autarky group is 0.835, while that of the participant group, $TE_{in\text{-}out}$ is 0.858. This indicates that households in the grassland market participation group perform better as they have technical efficiency values 2.75% higher than that of their counterparts without market participation.

In order to verify the statistical significance of the results, we make two-sample heteroscedasticity variance t-tests to *TE* and *MTR*T values of the two groups. Results show that grassland rental market participants performed better and had higher technological state, both are significant at 1% level. This confirms that land rental markets facilitate more efficient agricultural/livestock production. We therefore have verified he first part of H_3, namely $TE_{in\text{-}out}>TE$.

Then we tested the remaining hypotheses, namely: whether the improved technical efficiency is caused by an ability effect (H_2: $TE_{Ain}>TE_{Aout}$), or by a resource equalization effect (H_1: $TE_{Rin}=TE_{Rout}>0$), or a mixed effect of the two (the second part of H_3: $TE_{in}>TE_{out}$)? The models to test these hypotheses are designed as follows: we classify the 416 samples into three groups, i.e., the rent-in group, the rent-out group and the autarky group. We used the same ways as above to estimate the efficiency results. The descriptive statistics of the TE^k, *TE* and *MTR* for the three groups are shown in the lower part of Table 2. The *TE* value for the autarky group is 0.834, while TE_{in}=0.857 and TE_{out}=0.863. The technical efficiency value is improved by 2.76% and 3.36%, respectively compared with that of the autarky group.

Table 3 T-test of participation and autarky groups

(Two-sample heteroscedasticity variance hypothesis)

	TE		*MTR*	
	Rental participation	Autarky	Rental participation	Autarky
Mean	0.8580	0.8345	0.9977	0.9627
Variance	0.0063	0.0072	0.0001	0.0005
t-test	**2.9222***		**4.6917***	
T- double tail critical	1.9658		1.9688	
P(T<=t) double critical	0.0037		0.0000	

Note: *** significant at 1% level, ** significant at 5% level.

Table 4 shows the results of the two-sample heteroscedasticity variance hypothesis. Compared with the autarky group, both the rent-in and rent-out groups have better performance in livestock production and have higher technological states, *TE* and *MRT* are significant at 1% level. However, compared with the rent-out group, the rent-in group does not show significance in *TE*. That is to say, statistically, $TE_{in}=TE_{out}$. This means that the second part of H_3 ($TE_{in}>TE_{out}$) is not confirmed. Moreover, as $TE_{in}=TE_{Rin}+TE_{Ain}$, $TE_{out}=TE_{Rout}+TE_{Aout}$, we have $TE_{Rin}=TE_{Rout}$, so $TE_{Ain}=TE_{Aout}$, indicating that H_2 ($TE_{Ain}>TE_{Aout}$) is also not confirmed. This suggests that although the rent-in group is more-able than the rent-out group (Table 1), under the current institutional environment, they cannot bring their ability into full play. The improved technical efficiency is mainly brought about by the resource equilibration effect. Put another way, grassland rental markets allow the participating herder households to adjust their family resources by either cutting the long piece of the bucket, or making up the short piece of the bucket. Through participating in the grassland rental markets, the herder households can enhance their resource combination by better balancing the grassland with the non-land factors such as labor, productive assets and livestock. In this way, H_1 is confirmed, i.e., $TE_R = TE_{Rin} = TE_{Rout} > 0$.

Table 4 *TE*, *MTR* and t-test values of rent in, rent out and autarky groups

(Two-sample heteroscedasticity variance hypothesis)

	TE		*TE*		*TE*	
	Rent in	Autarky	Rent in	Rent out	Rent out	Autarky
Mean	0.8567	0.8338	0.8567	0.8627	0.8627	0.8338
Variance	0.0057	0.0072	0.0057	0.0072	0.0072	0.0072
t-test	**2.6181*****		**-0.4961**		**2.4824****	
T- double tail critical	1.9681		1.9787		1.9808	
P(T<=t) double critical	0.0093		0.6207		0.0145	
	MTR		*MTR*		*MTR*	
	Rent in	Autarky	Rent in	Rent out	Rent out	Autarky
Mean	0.9842	0.9619	0.9842	0.9757	0.9757	0.9619
Variance	0.0006	0.0006	0.0006	0.0004	0.0004	0.0006
t-test	**2.6181*****		**2.6089*****		**4.6917*****	
T- double tail critical	1.9681		1.9745		1.9777	
P(T<=t) double critical	0.0093		0.0099		0.0000	

Note: *** significant at 1% level, ** significant at 5% level.

Differing from what Teklu and Lemi (2004) found in Ethiopia, that land rental markets did not play a role in equalizing resource proportions, this study demonstrates that grassland rental markets do enable herders to improve technical efficiency by better balancing their family resources. This finding is consistent with Pender and Fafchamps (2006) who claim that land rental markets can help farmers to adjust their production factors to be proportionally suitable for their land size. It is a pity that this is the only available formal study which confirms the resource equalization effect of land rental markets, and is based on a small sample in Ethiopia.

The present study provides a strong support for this hypothesis. Besides, we have an unexpected finding from this research: the grassland market participation group has generally a higher technology state than their autarky counterparts, 0.998 versus to 0.963 in *MTR*. Moreover, the *MTR* score is 0.984 for the rent-in group, 0.976 for the rent-out group, and 0.962 for the autarky group. All the two-sample variance heteroscedasticity test results show 1% significance (Tables 3 and 4). This implies that participation in grassland rental markets promotes herder households to adopt improved technologies.

5 Concluding remarks

Land is the most important production factor and livelihood source for smallholders. Exploring the impact of land rental market participation on herder technical efficiency is crucial for agricultural policy intervention. Some studies demonstrate that land rental markets can help improve efficiency, but did not explicitly examine to what extent and how. This makes it difficult to propose policy suggestions aimed at facilitating market development. This study distinguishes the effects of grassland rental markets on herder technical efficiency into resource equilibration effect and ability effect. Here, we explore herder participation in grassland rental markets on their technical efficiencies by applying the Metafrontier-DEA method to field survey data. . Main findings indicate that renting-in land and renting-out land can significantly enhance efficiencies by 2.8% and 3.4% for lessees and lessors, respectively. The major source of efficiency improvement is from the resource equilibration effect, namely from herder adjustment of their unbalanced production factors through participating in grassland rental markets. Moreover, the study finds that involvement in land rental markets facilitates promotion of technology and thus improvement of livestock productivity, especially for lessees.

Existing studies mainly suggest that land be transferred from less-able to more-able producers, so as to improve agricultural efficiency. The present study does not find that more-able herders (lessees) perform better than their less-able counterparts (lessors). Put another way, the study does not confirm that efficiency improvement in grassland rental market participations comes from the ability effect. This implies that under the current institutional environment, the ability effect is limited while the resource equilibration effect makes sense in land rental markets. We therefore suggest that currently, it is desirable to let market forces play a big role in promoting land rental markets rather than transferring land from the less-able to the more-able herders. Policy needs to normalize well-functioning developed markets on one hand; on the other hand, policy should induce farmers to voluntarily participate in land rental markets. Only with participation in land rental markets, can participants be expected to improve their technical efficiencies by balancing their resource combinations, and enhance the state of their agricultural technology.

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