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Allocative efficiency or misallocation of resources? The emergence of forestland rental markets and the forest devolution reform in China

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Abstract

This paper evaluates whether the devolution reform of forestland to household management improves allocative efficiency and household welfare through participation in forestland rental markets. Using a household panel dataset from three Chinese provinces, we find positive effects of the emerging forestland rental markets: with the reform, forestland was transferred to forestland-constrained and labour-rich households and households with higher levels of productivity in forestry. Participation in forestland rental markets increases household per-capita income and decreases the likelihood of income falling below the poverty line. We do not find any support for forestland captured by land-richer, wealthier, larger or powerful households.

Keywords: allocative efficiency, household welfare, forestland rental markets, collective forest tenure reform, China

JEL classification: D61, O12, Q15, Q23

1. Introduction

Land reform, by means of changing land tenure arrangements, is an institutional instrument for reallocation of factors of production to and among farm households. In China, the Household Responsibility System (HRS) developed in the late 1970s successfully transformed collectively owned agricultural land to household tenure. Because of the HRS reform, agricultural production increased by 225 per cent within 6 years and rural household income

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had increased five-fold in real terms by 2000 (NBS China, 2014). Following the success of the HRS reform, in the early 2000s, the Collective Forest Tenure Reform was launched to formally devolve forestland owned by village collectives to all member households of the collectives (hereinafter, the Reform). The Reform applied an egalitarian rule to reallocate forestland on a per-capita basis, leading to concerns that fragmented and small operational sizes of forest plots might result. The Reform also gives formal transfer rights to the devolved households. Whether forestland rental markets emerge and can address potential problems in fragmentation of land remains as a question.

This article aims to explore whether the Reform encouraged forestland rental market participation and assess the functioning of forestland rental markets: whether rental markets have improved the allocative efficiency of forestland use or led to misallocation of resources and the impact of renting on household welfare. As discussed in Besley (1995)'s seminal work on the link between investment and property rights, a land owner with property rights is incentivised to invest more when given transfer rights, which makes it easier to rent (or sell) land. It is important to examine whether the Reform, which devolved forest tenure together with transfer rights based on a per-capita basis rather than per-labour basis, allows farmers to transfer land towards the direction for efficiency improvement—i.e. whether more productive farmers and farmers with smaller areas of per-labour holding of forestland will rent in land. If it is true, participating in rental market improves household welfare and meanwhile facilitates rural structural transformation because farmers with higher ability in non-agricultural work (who are relatively less productive in forestry) are able to rent out their land and secure their work in non-agricultural sectors. Furthermore, farmers can use forestland as collateral, making it easier to obtain credit for investment purposes, because forestland is different from farmland in that standing trees store wealth and require less intensive labour. Farm households in places like rural China can benefit from a land rental system, not only through optimising factors' allocation but also by holding forestland as a safety-net asset.

Standing on the unique Reform that involved two-thirds of China's total forestland area and 70 million rural households, our paper contributes to two strands of the literature as follows.

The *first* is to the literature on forest devolution. The worldwide developing countries have increasingly adopted devolution but found inconclusive impacts on forest cover change and forest quality protection (Besley and Ghatak, 2010; Blackman *et al.*, 2017; Chankrajang, 2019). The literature provides no consistency in empirical findings regarding the effects of forest devolution on user investments and forest conditions: in a selection of Asian and African countries as well as in South America, Köhlin and Amacher (2005); Engel *et al.* (2006); Bray *et al.* (2008) and Chankrajang (2019) find positive effects, while Kaimowitz *et al.* (1998); Baland *et al.* (2010) and Coleman and Fleischman (2012) have inconclusive findings. There are concerns that fragmentation and decentralised land tenure may lead to disincentives to invest (Rozelle *et al.*, 2002), richer and elite capture of land (Otsuka, 2007), overexploitation and

suboptimal forestry production (Xu *et al.*, 2013). We provide evidence of impacts of forest devolution policy on household factor reallocation using a large-scale rural household survey in China.

The *second* contribution is to the literature on rental markets and household welfare. The Reform has been found to enhance farmers' tenure security and provide incentives for them to plant more trees and make other forestry-related investments (Qin and Xu, 2013; Yi, Köhlin and Xu, 2014; Xie, Berck and Jintao, 2016; Xu and Hyde, 2019), yet studies on forestland market participation and impacts have been scant. Kimura *et al*. (2011) and Zhu, Zhang and He (2014) have shown the importance of (forestland) tenure factors on (forest)land rentals in China. Zhou *et al*. (2019) have used household data in Jiangxi province and found consistent result of the tenure security effect: households with lower expectations of future forestland redistribution or expropriation are more likely to rent in forestland, and larger area of it. We investigate to what extent devolution encourages households' participation in forestland rental market and the associated welfare impact.

We use a panel dataset from two waves of surveys—of 2005 and 2010—of 1,189 randomly selected households in three Chinese provinces: Fujian, Jiangxi and Yunnan. These provinces were the earliest adopters of the Reform. We take into account the fact that village characteristics correlate with the adoption of the Reform and examine the determinants of forestland rental participation, i.e. how a household chooses among rent-in, rent-out and no-rent. We focus on two factors: a household's endowment of forestland per unit of labour and a derived measure of producers' ability in forestry. This measure is obtained as the fixed term of residual from a Cobb–Douglas forestry production function for each household and can be used to make inferences on the productivity in forestry. Next, we apply a multinomial logit model on determinants of forestland rental participation. Finally, we examine the welfare impacts of rental participation in terms of income and poverty using a propensity score matching (PSM) method. Because renting is non-random and possibly correlated with demographic and resource endowment characteristics, this method uses observable, pre-renting household characteristics and matches for the renting households with similar households from the non-renting samples to construct the counterfactuals as the comparison group.

The rest of this article is structured as follows. Section 2 provides background and the emerging forestland rental markets in China. Section 3 discusses a conceptual model and testable hypotheses. Section 4 presents the empirical strategies. Section 5 describes the data, and Section 6 summarises the main results. Section 7 concludes with policy implications.

2. China's forest devolution reform and emerging forestland rental markets

In the late 1970s, after the end of the Cultural Revolution turmoil, China's forest sector, like many other parts of the economy, was in tremendous need of recovery. Natural forests were largely depleted after 30 years of

overexploitation by the state forest enterprise system, the growing demand for timber shifted towards plantation forests that were run under rural collective system. Giving back the income-generating opportunity of forest uses to ordinary farmers was a major driving factor for Collective Forest Tenure Reform (Xu, White and Lele, 2010).

The reform of devolving collectively owned and managed forests to member households followed the model of agricultural HRS and officially began in 1981 (CPCC&SC, 1981). This policy is known as the 'Three Fixes'—fixing three forest tenure-related issues: confirming rights to forests for family plots, delimiting boundaries of private plots and establishing a forestry production responsibility system for responsibility plots (Holden *et al.*, 2013; Delang and Wang, 2013; Xie *et al.*, 2016). After the 'Three Fixes' policy, the village collectives hold the *de jure* ownership of forests and the *de facto* management rights are with households. However, disposal rights are partial and incomplete, without formal transferability rights to farmers: harvesting from family or responsibility plots needs approval from the local government; disposal rights of family plots are incomplete, allowing informal land transfers, shareholder rights and inherit rights; no disposal rights to responsibility plots. (Xu, White and Lele, 2010; Delang and Wang, 2013; Zhou *et al.*, 2019).[1]

The 'Three Fixes' policy was halted in 1987 (CPCC&SC, 1987), and the true reason for the failure was never clear. Half decade later, in mid-2003, a state council resolution (Document No. 9, *The Resolution on the Development of Forestry*) reignited another round of reform in the collective forest sector. This new round of reform (i.e. the Reform) has imbedded a number of new elements of legal development in rural China. For example, village collectives' decisions on the adoption and implementation of the Reform are the results of majority voting in village assemblies or representative committees. Households receive forestland certificates that formally document their rights in production, transferability and use as collateral. Along with devolution and local institutional support on land value assessment, efforts have been directed towards reducing transaction costs in forestland transfer market, with the hope of encouraging rental transactions.

Most land reforms by the Chinese government use egalitarian rules for equity purposes. The administrative reallocation of forestland is not an exception. Once a village decided to adopt the Reform and wanted to devolve some formerly collective-managed forestland to households, land was distributed amongst village members on a per-capita basis, which is different from the per-labour basis. Additionally, the redistributable forestland was different across villages: therefore, discrepancy is at large on household endowment of per-labour forestland. Earlier studies have shown that this type of reallocation results in land fragmentation and small household operational size (e.g. Wen, 1989), dis-incentivising land investment because of low expected returns

1 About 70 per cent of the collective-owned forestland was transferred to household management during the 'Three Fixes'. The granted rights and responsibilities to farmers include: which trees to plant, when to plant and fell, preventing others from cutting down their trees, preventing forest fires, promising not to convert forestland to other uses (Delang and Wang, 2013).

(Otusuka, 2007; Kimura *et al.*, 2011). Fragmentation hampers acquisition of timely information about markets due to costly information acquisition relative to the small quantity of goods produced on a small plot. Altogether, the egalitarianism in land (re)allocation has been subject to problems of inefficiency and high transaction costs.[2] Moreover, forest fragmentation concerns environmental scientists for potential negative impacts on forest quality including biodiversity (Tilman *et al.*, 2011).

There could be two reasons for farmers who were managing forestland privately in villages where the Reform was not adopted.[3] First, it might be result of the first round reform. Second, farmers can rent in forestland from village councils (committees) informally. The Reform has granted extended use rights and more complete forestland disposal rights including subcontract, lease, transfer and mortgage forestland use rights and tree ownership.

Thus, more rental market participations are expected in the villages that adopted the Reform than in the villages that did not. In the provinces of Fujian, Jiangxi and Yunnan, the percentage of households participating in forestland rental markets increased from 5 in 2005 to 12.5 in 2010 (Table 1). The percentage of households renting-in forestland increased from 2.1 to 7 from 2005 to 2010, and the increase mainly comes from households with the Reform. The percentage of households renting-out forestland increased from 2.9 to 5.5.[4]

3. A conceptual model and hypotheses

Standard economic theory with very strong assumptions—an identical, constant-returns-to-scale production function for all households, with clearly defined and perfectly functioning markets—says that the initial resource endowment should not be important for allocative efficiency (Bliss and Stern, 1982; Feder, 1985; Bardhan and Urdy, 1999; Deininger, 2003). Under these assumptions, managerial ability (or, productivity) does not differ, land–labour ratios will be efficiently (re)allocated across farm households and output per factor unit will be optimised. However, these assumptions are often not true in reality, and, particularly in developing countries, rental market could result in land or other forms of resources prevalently captured by a small group of people.

2 In addition to the inefficiency of fragmentation of land, concentrated power in the hands of village leaders may create rent-seeking opportunities and preferences for friends and relatives, which would result in misallocation of land (Rozelle *et al.*, 2002; Deininger and Jin, 2005).

3 Prior to the Reform, the disposal rights were incomplete and informal—farmers had partial rights to transfer, shareholder or inherit their family hills upon approval by the local government while responsibility hills had no such rights.

4 In Table 1, among households without the Reform, 5.8 per cent had informal forestland transfers in 2005; among them, 1.4 per cent rented in and 4.4 per cent rented out some land. When villages implemented the Reform, former informal rental contracts for forestland, if still valid, were presented to the leaseholders and tenants for their reassessment of whether to rent again or keep the forestland for own use. So, the 4.4 per cent of the non-reform households who rented out in 2005 do not necessarily appear among the 5.6 per cent of the rent-out households with the Reform in 2010. In addition, compared to the non-reformed households, the reformed households had a larger area of rented-in forestland, and their rented-in forest plots accounted for a larger proportion of the endowment level of forestland.

Table 1. Household participation in forestland rental markets

	2005			2010		
	All	No-Reform	With-Reform	All	No-Reform	With-Reform
Percentage of households renting-in	0.021	0.014	0.026	0.070	0	0.072
Percentage of households renting-out	0.029	0.044	0.017	0.055	0	0.056
Average area of forestland rented-in (*mu*) [a]	0.854	0.274	1.269	4.229	0	4.309
Average area of forestland rented out (*mu*)	2.070	4.189	0.549	2.146	0	2.186
Rented-in forestland as a percentage to endowment	0.012	0.007	0.015	0.041	0	0.042
Rented-out forestland as a percentage to endowment	0.013	0.018	0.009	0.020	0	0.020
Number of households	1189	496	693	964	18	946

Source: Own computation from the two-round survey in collective forest areas in China by the Environmental Economics Program at Peking University.
Note:
[a] 1 *mu* = 1/15 hectare.

Moreover, markets could be imperfect or missing given the presence of transaction costs such as the lack of access to credit. In addition to unclear ownership, one main source of transaction costs arises from asymmetric information between renting partners in the process of making transactions. Such costs include searching, bargaining, enforcing bargains and monitoring tenants (Alston, Datta and Nugent, 1984; Otsuka and Hayami, 1988; Carter and Yao, 2002; Holden, Keijiro and Place, 2009; Kimura *et al.*, 2011). Regulation on land transfers and transferability rights usually distorts the markets of labour, credit and insurance and land (Skoufias, 1995; Rozelle *et al.*, 2002; Deininger and Jin, 2005; Pender and Fafchamps, 2006; Deininger, Jin and Nagarajan, 2008).[5] High transaction costs resulted from the regulations cause the discrepancy between optimal and actual transactions, and the latter systematically transfers land to wealthier, land-rich or powerful households (Deininger and Jin, 2008).

Empirical evidence on the performance of rental markets is mainly about farmland: having variations in geographical and cultural conditions but mixed findings.[6] Forestland markets are worth studying because they differ from

5 Rozelle *et al.* (2002), Deininger and Jin (2005) and Deininger, Jin and Nagarajan (2008) found that varying degrees of regulation on land transfer rights result in high transaction costs that reduce the efficiency of land rental markets. Pender and Fafchamps (2006) find that transaction costs do not necessarily affect rental market participation and efficiency in a negative way in Ethiopia.

6 For example, the following studies found evidence for inefficient farmland markets: Andre and Platteau (1998) in Rwanda, Zimmerman and Carter (1999) in Burkina Faso and Deininger *et al.* (2011) and Holden and Ghebru (2013) in Ethiopia. Others, such as Migot-Adholla *et al.* (1994) in Ghana, Gavian and Fafchamps (1996) in Niger, Yamano *et al.* (2009) and Jin and Jayne (2013) in

farmland markets in a number of aspects. First, the nature of forests means longer-term uncertainty. Second, there are public benefits provided by standing trees. Moreover, relatively larger land size, compared to farmland, requires a considerable amount of rental payment. Because of these characteristics, cash constraints and credit access would be associated with imperfect forestland rental markets, raising the costs of rental contracts and thus dis-incentivising households to rent. Yet forestland functions as a safety-net asset that standing trees store wealth but requires a small amount of labour, renting-out makes it easy for rural labour to engage in off-farm work while still enjoying the benefits of owning the forestland.

We illustrate the decision to rent in or rent out in a simple model. A representative household is endowed with some size of forestland ($\bar{A}$), family labour (L), managerial ability that determines her forestry productivity (α), household characteristics such as risk preferences (ρ), credit and cash constraints (C). Other household characteristics (H) include age and education years of the household head, who is usually the decision-maker in a rural household, and his/her knowledge about forestry. The optimal, utility maximising size of the operational forestland, A^*, is a function of α and characteristics $(\bar{A}, L, \rho, C, H)$ and village-level exogenous factors (V) including natural and social endowments, market access, precipitation and temperature. By participating in the rental market, a household can increase utility by changing the operational size of forestland.

Transaction costs raise when markets are imperfect, property rights are limited and regulations are stringent. We follow Deininger and Jin (2005) on how transaction costs affect rental decisions: denoting T^{in} (T^{out}), the transaction costs associated with rent-in (rent-out) transactions; a household's rental decision is based on the rental payment and opportunity cost (R)—e.g. potential income from managing land, off-farm work and livestock—and transaction costs (T). That is, the household is in one of the three rental states:

$$\begin{aligned} &\text{Rent}-\text{out}(A^* < \bar{A}) \text{ if } MB\left(\bar{A}\right) + \varepsilon_i \leq R - T^{out}; \\ &\text{No}-\text{rent}\left(A^* = \bar{A}\right) \text{ if } R - T^{out} < MB\left(\bar{A}\right) + \varepsilon_i < R + T^{in}; \\ &\text{Rent}-\text{in}(A^* > \bar{A}) \text{ if } MB\left(\bar{A}\right) + \varepsilon_i \geq R + T^{in}; \end{aligned} \tag{1}$$

where $MB\left(\bar{A}\right) + \varepsilon_i$ stands for the marginal benefit (or value) of the forest and non-forest products from managing an additional unit of forestland area. The marginal returns are evaluated at the forestland endowment level and depend on $\alpha, \rho, C, R, T, H, \text{ and } V$. ε_i is an error term containing non-observable factors and following a standard normal distribution.

Kenya, Lunduka, Holden and Øygard (2009) in Malawi, Deininger and Mpuga (2009) and Nkonya *et al.* (2009) in Uganda, Deininger, Jin and Nagarajan (2008) in India, Deininger and Jin (2008) in Vietnam and Carter and Yao (2002), Deininger and Jin (2005) and Kimura *et al.* (2011) in China, found that farmland markets equilibrate factor ratios among households.

In the study area, the rights to rent forestland to other villagers and to any outsiders, the right to use forest plot as collateral and the right to select species—amongst timber, fruit, bamboo and other types of trees—vary across villages. In the forestland certificate for each forest plot, the length of tenure ownership is granted for 30–70 years or even longer (e.g. 'long term' or 'forever'). A rental contract can be as long as that. A household's willingness to participate in rental market is driven by her attitude towards production risk and perception of risk of losing land. The perception of the risk of losing land is highly correlated with whether the housheold has land certification, which enhances security. A cash- or credit-constrained household, whose cropland size is too small to meet its own consumption needs, may rent out some forestland for some cash.

To investigate the Reform's impact on forestland rental markets, the driving factors and the welfare effects, we test the following hypotheses:

Hypothesis 1. *The Reform improves allocative efficiency through forestland rental markets in that forestland is transferred to households with higher levels of productivity in forestry and to forestland-constrained and labour-rich households.*

Suggested by the conceptual model in equation (1), the amount of renting-in of forestland increases in households' forestry ability (α) and decreases in their forestland endowment ($\bar{A}$). Forestland stores wealth and is a production factor. Village committees do not observe α and uses the per-capita rule for administrative reallocation, other than productivity efficiency. Rental markets do reallocations more flexibly by facilitating the 'poor-in-forestland-holding-but-efficient' producers to obtain more forestland from households who are less efficient but rich in per-labour landholdings, *ceteris paribus*.[7]

Hypothesis 2. *Rental market participation has a positive income effect on rent-in households through higher production value in forestry and on rent-out households through more income from off-farm work.*

Hypothesis 3. *Rental market participation has a positive impact on poverty alleviation.*

4. Empirical strategy

4.1. Household forestry production and productivity

First, we estimate the measure of household forestry productivity. We compute an annual incremental value of household forestry production—the value of marginal benefit of leaving the trees to grow for an extra year—from standing timber, economic forests (including fruit trees, herbal medicine and seedling

7 Households with higher levels of productivity have higher levels of marginal production value of forestland at their forestry endowment level $MB(\bar{A})$. They would acquire more land towards their optimal operational level until the marginal value of forestland, $MB(A^*)$, and vice versa.

nursery plantations) or bamboo forests on each forest plot,[8] and then aggregate a Cobb–Douglas forestry incremental value function for a household i in village j at time t, as in equation (2).

$$\begin{aligned}\log y_{ijt} =& \gamma_1 \log L_{ijt} + \gamma_2 \log A_{ijt} + \gamma_3 \log K_{ijt} + \boldsymbol{\gamma_4}' X_{ijt} + \boldsymbol{\vartheta}_j' V_{jt} \\ &+ \eta_t + \mu_i + \epsilon_{ijt}, \end{aligned} \tag{2}$$

where y_{ijt}, L_{ijt}, A_{ijt}, and K_{ijt} are, respectively, annual incremental value of household forestry production, family labour, total operational forestland area and value of inputs. X_{ijt} is a set of household characteristics (ρ, C, R, H), and V_{jt} is a set of village characteristics that could potentially affect forestry production. We control for time effects (η_t) and county year fixed effects for two reasons: first, villages in some counties could be affected by the 2008 global financial crisis and the influences may have lasted until 2010. Second, the Forest Bureaus are at county level, who played a major role in implementing the Reform, and there could be some immediate effects encouraging efforts in production.

Estimating equation (2) using a household-level fixed effects linear regression model on the panel dataset, we obtain the measure of forestry productivity (α_i) as the time-invariant constant term in the residual (μ_i): $\alpha_i = \widehat{u_i}$. This term has been used by Deininger and Mpuga (2009), Jin and Deininger (2009), Jin and Jayne (2013) and Chamberlin and Ricker-Gilbert (2016) to represent a household's fixed, endowment level of farming ability.

4.2. Determinants of forestland rental market participation

We then examine the determinants of rental market participation in equation (3):

$$\tau_{ijt} = \delta_1 \alpha_i + \delta_2 \left(\frac{A}{L}\right)_{ijt} + \delta_3 FTR_{jt} + \delta_4 X_{ijt} + \delta_5 T_{ijt} + \delta_6 V_{jt} + \varepsilon_{ijt}, \tag{3}$$

First, we use a categorical response of $\tau_{ijt} \in \{0,1,2\}$ to indicate $\{Rent\ out, No\ rent, Rent\ in\}$. Second, τ_{ijt} defines the difference between the desired and the endowed forest area, $A^* - \bar{A}$ (i.e. the amount of rented area). Household's forestry productivity (α_i), the pre-rental area of forestland per unit of labour $\left(\left(\frac{A}{L}\right)_{ijt}\right)$ and the number of years with the Reform (FTR_{jt}) allow us to test Hypothesis 1 by the signs and marginal effects from δ_{1-3}.

8 This value of marginal benefit is computed in a manner similar to the decision to invest the stumpage for an interest return: for timber forest, the self-estimated standing timber volume is multiplied by the village-reported timber price and annual interest rate; for economic forests—fruit trees, herbal plantations, etc.—it is the annual production value; and for bamboo forest, the value is a summation of annual production value of bamboo shoots and the bamboo fibre volume times output price and interest rate. This value function differs from the forest valuation function in which the (discounted) present value of forest rent is maximised based on a decision of optimal rotation in the long run. Because the rural household survey did not target on detailed data for tree species and associated optimal rotation years, we cannot evaluate a long-term impact of the Reform on forestry productivity.

The coefficient of the length of the Reform (δ_3) estimates the Reform's effect in encouraging rental transactions. An immediate effect of the Reform could increase $\left(\frac{A}{L}\right)_{ijt}$ once a village decided to adopt the Reform and reallocate some forestland. Yet, rental transactions may take time and increase over time with the Reform.[9] An empirical issue stems from the potential selection bias: the adoption of the Reform is not exogenous and village natural endowments and socio-economic characteristics may drive the adoption and determine the development of local rental markets as well as households' willingness to rent.

To tackle this bias, we use the control function (CF) approach by defining:

$$FTR_{jt} = z_j\xi' + \upsilon_{jt}, \tag{4}$$

where z_j is a vector of village characteristics prior to the Reform (z_{j0}) and in the current period (z_{jt}). The exogeneity assumption is satisfied when $E\left(z_j, \upsilon_{jt}\right) = 0$. However, the endogeneity of FTR_{jt} in equation (3) implies that $E\left(FTR_{jt}, \varepsilon_{ijt}\right) \neq 0$ and that

$$\varepsilon_{ijt} = \beta\upsilon_{jt} + e_{ijt}, \tag{5}$$

The equation (5) by construction assumes $E\left(\upsilon_{jt}, e_{ijt}\right) = 0$.

By plugging equation (5) into equation (3), we have equation (6):

$$\tau_{ijt} = \delta_1\alpha_i + \delta_2\left(\frac{A}{L}\right)_{ijt} + \delta_3 FTR_{jt} + \delta_4 X_{ijt} + \delta_5 T_{ijt} + \delta_6 V_{jt} + \beta\upsilon_{jt} + e_{ijt}, \tag{6}$$

Controlling for υ_{jt}, the error term e_{ijt} is uncorrelated with FTR_{jt} or υ_{jt}. We obtain $_{jt}$ from $\upsilon_{jt} = \widehat{\upsilon_{jt}} = \widehat{FTR_{jt}} - z_j\widehat{\xi'}$, which is predicted from estimating equation (4). There are two main advantages of the CF approach: first, the null hypothesis of the endogeneity of FTR_{jt} can be tested simply by the statistical significance of the parameter β; second, the average partial effects are easy to compute when equation (6) is estimated by a nonlinear (and multinomial response) model (Petrin and Train, 2006; Wooldridge, 2010). We estimate equation (6) by the multinomial logit model and the random effects tobit model, respectively. Tobit estimators allow us to account for the corner solution for the households not renting forestland.

To interpret α_i and the coefficient δ_1, we acknowledge that α_i also captures some other things that do not vary with time, e.g. soil quality (Jin and Jayne, 2013). Soil quality of plots with standing trees is believed to be more stable, that is, time-invariant, than that of plots with crops. Assuming that a household is more likely to rent out (forest)land with lower soil quality than to maintain such land for own use, δ_1 is likely to be downward biased than to overestimate the effect of productivity on renting-in or -out forest plots.

9 For example, it takes time to arrange forestland transfers, to obtain professional services such as appraisal of the value of land with standing trees and to develop information platforms. Owners' confidence in tenure security may also take time to develop.

X_{ijt} is the same set of household-level factors as in equation (2) including ρ, C, R, H and T_{ijt}. Two examples of transaction costs (T_{ijt}): one is the tenure security effect from holding a forestland certificate, which guarantees future rights; the other refers to the rights to change forest types, to transfer forestland to other villagers and outsiders and to mortgage forestland. Village-level characteristics (V_{jt}) include demographic and resource endowment, distances to cement-paved road, to the downtown and to local bank and precipitation and temperature that are important for forest growth.

4.3. Welfare impacts of forestland rental market participation

To quantify the impact of rental participation on household welfare and test Hypotheses 2 and 3, we estimate a set of models of the average treatment effect of rental participation on: (i) household per-capita income; (ii) income share from off-farm work; (iii) income share from forestry and (iv) probability of income falling below the poverty line. Obviously, the treatment is not randomly assigned but a self-selection process; some factors may drive households to rent and also correlate with their welfare outcomes. We apply PSM methods to correct the self-selection bias, based on observable pretreatment differences between the treatment and the control groups. Theoretically, we use a random utility framework to model the difference between the utility from renting (in or out) (U_1) and that from not renting (U_0), and a latent variable, D_i^*, defines the difference in utility (Becerril and Abdulai, 2010). D_i is observed as a household's actual rental behaviour given a set of observable household and forestland characteristics (Z_i) according to the decision function (7):

$$D_i^* = g(Z_i) + u_i,\ D_i = \begin{cases} 1\ if\ D_i^* = U_1 - U_0 \geq 0 \\ 0\ if\ D_i^* = U_1 - U_0 < 0, \end{cases} \tag{7}$$

We then carry out PSM to identify the average renting effects (equation 8):

$$I_i = p(Z_i) + \theta D_i + \sigma_i, \tag{8}$$

where I_i refers to each of the aforementioned welfare indicators. $p(Z_i)$ defines the propensity to be treated as in $p(Z_i) = \Pr[D_i = 1|Z_i] = F\{h(Z_i)\}$, and $F\{\cdot\}$ can be normal or logistic cumulative distribution; σ_i is a normal error term. Following Rosenbaum and Rubin (1983), counterfactual situations for those who rented (i.e. the treatment, if $D_i = 1$) will be statistically matched with those (i.e. the control, $D_i = 0$) who did not rent and had the same probability of assignment to the treatment ($p(Z_i)$). Conditional on the propensity score ($p(Z_i)$), the coefficient of rental participation (θ) will be unbiased and inferred as the average treatment effect on the treated (ATT) as in equation (9):

$$\theta = ATT = E\{E[I_{i1}|D_i = 1, p(Z_i)] - E[I_{i0}|D_i = 0, p(Z_i)]|D_i = 1\}, \tag{9}$$

The PSM approach relies on two assumptions. First, the Conditional Independence Assumption implies that participation is independent of potential

outcomes given the covariates. The second is that the ATT is defined only within the region of common support. The selection of covariates in Z_i is crucial for the matching. Our selection of Z_i includes all the determinants in estimating equation (6). To match the 'neighbours' of each rent-in (or rent-out) household very similar to a no-rent household, we apply the most commonly used algorithms: the nearest neighbour matching (NNM) and the kernel-based matching (KBM). The NNM matches each treatment with a control that has the closest propensity score. The KBM matches each treatment observation with a weighted average of all controls, in which the weights are inversely proportional to the distance between the propensity scores of treatment and control.

5. Data

We use a panel dataset from a nationally representative survey in eight provinces with rich forests in China. The survey was conducted by the Environmental Economics Program in China at Peking University. In 2006, 10–20 households were selected in each village based on a stratified random sampling rule and they were revisited in 2011. Household data include demographic and social-economic characteristics, labour allocation, agricultural production, plot-level forest management activities, income and assets, social relationships, (forest)land use practices and tenure arrangements in 2005 and 2010. Village-level data cover natural and resource endowments, socio-economic characteristics for 3 years (2000, 2005 and 2010) and whether, when and how the Reform was implemented.

This paper uses the samples of over 1,000 households in three provinces: Fujian, Jiangxi and Yunnan.[10] They are among the earliest adopters of the Reform. It is expected that investigating the earliest adopters provides a better understanding of the emergence and evolution of forestland rental markets. In total, 1,189 and 964 households were interviewed in 106 villages in the two waves, respectively. This gives an attrition rate of 19 per cent.[11]

Table 1 defines the main variables of interest—rental market participations, between households in the '*With-Reform*' villages and those in the '*No-Reform*' villages in each period. We also present the differences in household characteristics in Table A1 and those in village characteristics in Table A2.

Sizeable differences exist between the *With-Reform* and *No-Reform* households in landholdings, tenure rights and ownership security (Table A1). On average, the *With-Reform* households had larger endowment of forestland than

10 The survey in other provinces did not ask questions about renting of forestland in 2005.

11 The first wave surveyed 480, 300 and 600 households in Fujian, Jiangxi and Yunnan, respectively (1,380 in total). In the second wave, 325, 228 and 528 households were available to be resurveyed (1,081 in total). The sample size for the analysis comes to 1,189 and 964 excluding observations with missing data. The main reason for attrition is that respondents were temporarily unavailable at the time of the survey. Concerns exist about potential attrition bias if the reasons that households were not resurveyed are non-random with respect to their forestland rental market participation. We take this into account for robustness check in the later analysis.

did the *No-Reform* households (58 vs. 37 *mu* in 2005 and 53 vs. 12 *mu* in 2010). Larger shares of the *With-Reform* households had rights to change forest type, to transfer and to mortgage forestland. The percentage of households receiving forestland certificates increased from 19 to 65 in 2005–2010. The share of household having positive perception on tenure security increased from 50 to 93 per cent.

It appears that 4 out of the 106 sample villages who are forest rich—90 per cent of land were forests—took the lead by having already devolved 43 per cent of the collectively owned forests to households in a spontaneous and informal way in 2000 (Table A2). Small villages in population but large in forestland seem to be the first-movers. Richer villages are more likely to select the Reform, where the average income is higher and demand for timber is higher—higher prices of commercial timber. By 2010, the 105 *With-Reform* villages had devolved 62 per cent of the collective forests to households. Higher percentage of forestland transfers is observed in the *With-Reform* villages vs. the *No-Reform* villages in 2000 (11 vs. 6 per cent), 2005 (8 vs. 2 per cent) and 2010 (10 per cent vs. 0).[12]

To illustrate the extent to which the hypotheses on forestland markets are borne out, Table 2 presents the key variables by rental status, reform status and time. On average, in both 2005 and 2010, the rent-in households with the Reform had smaller endowment area of forestland per unit of labour (17.61 and 13.07 *mu*) and the households who rented out had larger endowment (38.15 and 43.34 *mu*). Among the *No-Reform* households, the gap is bigger, with nearly 80 *mu* of forests in rent-out households and only 6 *mu* in rent-in households in 2005. In 2010, none of the 18 *No-Reform* households rented any forestland. Comparing the per-labour area of endowment and currently managed forestland between rent-out and rent-in households suggests a decreased gap in landholdings by rental participation, and this gap is smaller in the *With-Reform* households than in *No-Reform* ones. Forestland markets seemed transfer land from households richer in per-labour forest-landholdings to those with less forestland per-labour unit.

The rent-in households had the highest value of investment in forestry, compared with the rent-out and no-rent households. Their annual value of all forest and non-forest products on plots is the highest. Participation in off-farm work does not differ much by rental status, suggested by per-labour workdays, but off-farm income is the highest in the rent-out households and the lowest in the rent-in households in 2005. In 2010, the rental market participants seem to work more days and earn higher per-capital income than the no-renters.

Forestland is likely to be transferred from households with older heads to those with younger heads. The renters are located closer to local bank, and

12 Interestingly, the *With-Reform* villages have higher level of precipitation. Weather data on rainfall and temperature is obtained from the China Meteorological Data Sharing Service System (CMDSSS). The CMDSSS records daily minimum, maximum and average temperatures, precipitation and solar radiation in 820 weather stations (with exact coordinates) distributed across all of China. Using village centre coordinates taken by the survey team with GPS devices, we match each village with the closest weather station. As shown in the bottom of Table A2, we calculate average and standard deviation of annual precipitation.

Table 2. Household characteristics by rental and reform status

	2005						2010			
	No-Reform			With-Reform			No-Reform	With-Reform		
	Rent-out	No-rent	Rent-in	Rent-out	No-rent	Rent-in	No-rent	Rent-out	No-rent	Rent-in
Demographic characteristics										
Number of household members	5.364	4.695	4.429	4.750	4.810	3.833	5.611	4.604	4.836	5.029
Number of labour equivalents	3.955	3.213	2.714	3.833	3.526	2.778	3.556	3.283	3.326	3.603
Household head's age	45.73	44.67	43.57	51.83	50.09	42.22	54.67	53.67	50.68	49.35
Household head is male	0.909	0.921	0.857	1	0.968	1	0.667	0.887	0.954	0.971
Household head is Communist	0.182	0.111	0.143	0.083	0.182	0.167	0.111	0.189	0.171	0.206
Household head is village leader	0	0.058	0.143	0	0.071	0	0	0.0566	0.053	0.103
Average education in years	6.284	4.988	3.897	6.093	5.445	5.581	6.897	4.896	5.546	5.844
Has work experience in forestry	0.046	0.011	0.143	0	0.026	0	0	0.076	0.047	0.074
Forestland, cropland, assets and incomes										
Forestland, endowment (*mu*/labour) [a]	79.76	9.443	6.224	38.15	18.46	17.61	5.331	43.34	16.04	13.07
Forestland, currently managed (*mu*/labour)	44.67	9.440	13.18	28.07	17.69	37.30	5.331	34.85	15.47	35.15
Value of non-labour investment in forestry (CNY)	481.0	803.2	1,353	525	515.8	1,487	706.7	819.1	1,265	3,005
Present value of forestry production (CNY)	69.47	1,272	11,014	2,486	5,569	10,436	6.624	915.8	732.6	2,593
Cropland (*mu*/capita)	2.433	1.995	3.641	0.789	1.370	1.432	0.552	1.473	2.034	1.393
Off-farm work days per labour	75.73	78.41	74.88	110.1	127.9	112.9	139.9	111.5	109.2	123.4
Total off-farm income (CNY)	13,965	7,973	5,097	27,278	15,042	11,847	28,067	29,726	24,565	38,310
Total livestock value (CNY)	1,907	2,489	1,509	300.8	592.0	118.9	343.3	2,807	4,118	2,037
Total house value (10 000 CNY)	3.725	3.251	1.294	2.563	3.512	2.749	44.69	10.98	10.21	18.53

(continued)

Table 2. (Continued)

	2005						2010			
	No-Reform			With-Reform			No-Reform	With-Reform		
	Rent-out	No-rent	Rent-in	Rent-out	No-rent	Rent-in	No-rent	Rent-out	No-rent	Rent-in
Income per capita (CNY)	4,478	3,037	3,679	8,087	4,800	5,306	7,256	9,340	8,632	10,443
Risk perception, credit constraint, and tenure rights										
Has forestland certificate	0	0	0	0.167	0.185	0.333	0	0.811	0.644	0.559
Perceived no credit constraint [a]	0.909	0.762	1	0.833	0.794	0.889	1	1	0.942	0.971
Credit access by distance to local bank in km	3.159	10.97	10.79	4.208	6.478	7.861	0.311	7.323	9.721	6.168
Perception of ownership/production risk [a]	0.886	0.953	1	0.500	0.504	0.500	0.889	0.943	0.930	0.941
Has right to change forest type	0.773	0.870	1	0.833	0.889	0.778	0.556	0.755	0.810	0.868
Has right to transfer forestland within village	0.273	0.663	0.643	0.854	0.726	0.667	0.500	0.689	0.683	0.787
Has right to transfer forestland to outsiders	0.250	0.598	0.500	0.688	0.642	0.611	0.333	0.660	0.603	0.706
Has right to mortgage forestland	0.114	0.416	0.643	0.500	0.442	0.583	0.361	0.236	0.305	0.397
Length of period with the Reform	0	0	0	2.667	2.197	2.833	0	6.245	6.010	6.941
Percentage of forestland involved in transfers in 2000	0.015	0.015	0.045	0.163	0.070	0.061	0.059	0.079	0.068	0.104
Number of observations	22	467	7	12	663	18	18	53	826	67

Notes: In 2010, none of the 18 sample households in the non-reform village rented any forestland.
[a]1 *mu* = 1/15 hectare. Perceived credit constraint is defined by the perceived ability to borrow 500 CNY within a week, taking value 1 if yes implying no credit constraint is perceived, and 0 if otherwise. Perceived tenure security is based on owner's perception on the likelihood of owning the forestland in the next 10 years, taking value 1 if secure, and 0 if otherwise.

more of them perceived no credit constraint, than the no-renters.[13] The other variables, including the regulations on forestland use and transfer rights, do not differ significantly, except that higher shares of the rent-in households perceived rights to mortgage forestland: 64, 58 and 40 per cent vs. 11, 50 and 24 per cent of the rent-out households in 2000, 2005 and 2010, respectively.

Note that the rent-in households are never the richest, nor are the rent-out households the poorest, in terms of values of house and livestock. Further, renters' Communist Party membership of the heads of households and their village cadre position do not indicate a consistent difference. Altogether, evidence on forestland captured by the hands of wealthy or powerful people is limited given the descriptive statistics so far. In the next section, we will exploit econometric methods to explore whether the allocative efficiency improvement or the misallocation of resources is true, controlling for endogeneity and other factors.

6. Results and discussion

6.1. Household forestry productivity

The household fixed-effect estimates of the Cobb–Douglas forestry production function is presented in Table A3. The models include year, county year (Col. 1) or village year (Col. 2) dummies. Results indicate that the annual incremental value in forestry is significantly higher in households with higher value of investment, with more days of off-farm work and with lower variation in rainfall. The output elasticity of forestry investment is 0.258 to 0.278, suggesting a 1 per cent increase in value of investment associated with higher forestry product value by 0.3 per cent. Longer off-farm work, say averagely 11 more days per labour (that is 1 per cent of the sample mean of 109 days), is associated with higher forestry product value by 326 CNY (0.13 per cent of the sample mean of 2,512 CNY).

The measure for household forestry productivity, $\alpha_i = \widehat{u_i}$, has a distribution as in Figure A1. Overall, the productivity measure shows a normal distribution, with various degrees of dispersion across province and time. Active rental markets and better factors mobility are believed to contribute to a more concentrated normal distribution of productivity towards a zero mean; more spikes and larger dispersion of the distribution would be due to inactive land rental markets and less off-farm or migration opportunities, which impede factor mobility. Similar to what Deininger and Jin (2005) found on household farming productivity, we find more dispersed distribution of forestry productivity in poor rural areas such as Jiangxi and Yunnan than in Fujian, likely due to less-developed factor markets.

13 Credit constraint is measured by the answer to whether the respondent believes that he or she could successfully borrow 500 CNY within a week. 500 CNY is wage income of two weeks of off-farm work in rural areas in the three provinces.

6.2. Forestland rental market participation and allocative efficiency or resource misallocation

We estimate the determinants of forestland rental market participation by multinomial logit models on the equation (6), with the no-rent households as the base category. Table 3 reports the marginal effects of the main estimates using the entire two-period sample, and the full results are presented in Table A4 in the Appendix. As discussed earlier, the model has two generated regressors—α_i as forestry productivity and $\widehat{v_{jt}}$ representing the reform selectivity (first-stage regression result for the prediction of $\widehat{v_{jt}}$ in Table A5). In all models, the coefficient of $\widehat{v_{jt}}$ is statistically significant, implying that the estimation bias of the reform's time effect is corrected.

Robustness checks include three ways: first, the results using the 2005 and 2010 samples, respectively, are presented in Columns (2) and (3) in the Table A6. Furthermore, we use the inverse probability weighting (IPW) method introduced in Wooldridge (2010, p. 837) to deal with the 19 per cent attrition from the second wave.[14] The coefficients from the IPWs-adjusted specifications (Col. 2, Table A7) maintain the statistical significance and signs, suggesting that attrition bias should not be a major concern.

In all specifications, as Tables A6 and A7 show, the coefficients of the forestry productivity variable are significantly positive in all 'rent-in' columns and negative in all 'rent-out' columns, except for the 2010 'rent-out' column and the attrition-correction model. Take Table 3, evaluated at sample means, an increase in productivity, from the bottom to the top in the sampled households, increases the likelihood to rent in by 16.1 percentage points.[15] Households with younger (older) heads are more likely to rent-in (rent-out), implying a net transfer from less able to more able households, together with similar associations for education. These findings suggest that more productive households are more likely to rent in forestland and those less productive are more likely to rent out.

Household pre-rental, per-labour holding area of forestland has a positive and statistically significant effect on the likelihood of renting out and a negative and significant effect on the likelihood of renting in. Holding other factors constant, for a household where per-labour forestland increases by 100 per cent from the average (16.6 *mu*), the likelihood for the household to rent out some forestland will be 2.5 percentage points higher; the likelihood of renting in will decrease by 1.7 percentage points (Table 3). Given the average percentage of renting-out households (5.5) and that of renting-in households (7.0) in 2010, such effects are sizeable.

14 First, we estimate the probability of a sample household stays in the second-round survey conditional on the first-period observable characteristics $Pr_{i,2010} = \Phi\left(X_{i,2005}\right)$, and then use the inverse predicted probabilities as weights ($IPW_i = 1/Pr_{i,2010}$) for each variable of 2010 in the estimation of equation (6).

15 We estimate the effect of increasing productivity from the bottom (–11.88) to the top (11.31) on the likelihood of each rental outcome, by computing the change in marginal effects of productivity at the bottom and at the top levels, respectively, holding other factors at their mean values.

Table 3. Determinants of forestland rental market participation (Multinomial Logit model)

	Rent-out		No-rent		Rent-in	
	dy/dx	Std. Err.	dy/dx	Std. Err.	dy/dx	Std. Err.
Forestry productivity (α_i)	−0.005	0.003*	−0.003	0.003	0.008	0.002***
Ln (Forestland endowment, mu/labour)	0.025	0.006***	−0.007	0.009	−0.017	0.006***
Ln (Household head's age)	0.047	0.024**	0.011	0.031	−0.058	0.022***
Household head is male	−0.011	0.017	0.020	0.025	−0.010	0.019
Household head is Communist	0.002	0.018	0.000	0.021	−0.003	0.012
Household head is village leader	−0.023	0.030	0.009	0.033	0.014	0.017
Average education is primary school	−0.017	0.038	−0.420	0.061***	0.437	0.053***
Average education is middle school	−0.020	0.038	−0.417	0.061***	0.437	0.054***
Average education is high school or higher	−0.038	0.044	−0.388	0.069***	0.425	0.057***
Has work experience in forestry	0.008	0.021	−0.014	0.030	0.006	0.022
Ln (Cropland per capita in mu)	−0.015	0.009	0.012	0.012	0.003	0.009
Ln (Total house value)	0.000	0.005	−0.008	0.006	0.007	0.005
Ln (Days worked off-farm, per labour)	0.002	0.002	−0.003	0.003	0.001	0.003
Perceived no credit constraint	0.035	0.018	−0.059	0.025**	0.024	0.020
Holding a forestland certificate	0.012	0.016	−0.028	0.021	0.016	0.011
Has right to change forest type	−0.006	0.012	0.006	0.015	0.001	0.010
Has right to transfer forestland within village	−0.018	0.022	0.032	0.026	−0.014	0.018
Has right to transfer forestland to outsiders	0.013	0.017	−0.024	0.021	0.011	0.016

(continued)

Table 3. (Continued)

	Rent-out		No-rent		Rent-in	
	dy/dx	Std. Err.	dy/dx	Std. Err.	dy/dx	Std. Err.
Has right to mortgage forestland	−0.005	0.010	−0.009	0.013	0.014	0.009*
Perceived tenure security	−0.025	0.023	−0.022	0.044	0.046	0.038
Ln (Average income per capita in village)	−0.021	0.028	0.055	0.031*	−0.034	0.014**
Ln (Timber price)	0.023	0.009**	−0.026	0.012**	0.003	0.008
Share of households having telephone at home	−0.029	0.059	0.159	0.083*	−0.130	0.043***
Village forestland area share	0.026	0.026	0.004	0.033	−0.029	0.017*
Ln (Distance to county centre in km)	0.004	0.010	0.019	0.012	−0.024	0.008***
Annual precipitation: average (mm)	−0.004	0.002**	0.004	0.002	0.000	0.001
Annual precipitation: standard deviation (mm)	0.001	0.001**	−0.001	0.001	0.000	0.000
Number of years with the forest reform	−0.003	0.012	−0.030	0.015**	0.033	0.007***

Notes: Marginal effects are computed using Delta-method from multinomial logit model of Column (1) of the Table A6. We estimate the effect of increasing productivity from the bottom (−11.88) to the top (11.31) on the likelihood of each rental outcome, by computing the change in marginal effects of productivity at the bottom and at the top levels, respectively, holding other factors at their mean values. Significance is denoted by *** for $p < 0.01$, ** for $p < 0.05$, and * for $p < 0.1$.

A longer period with the Reform in place increases the likelihood of renting-in forestland (Tables A4 and A7) and, for 2005, increases the rent-out likelihood (Table A6). One more year with the Reform increases the rent-in likelihood by 3.3 percentage points (Table 3). This finding is consistent with Zhou *et al.* (2019), who have used 289 households' renting-in transactions of forestland in Jiangxi province and shown that the increased probability of rent-in is associated with more use of rights to rent and to mortgage and with stronger tenure security perception.

Altogether, these findings support Hypothesis 1 on that, via forestland rental markets, the forest devolution reform improves allocative efficiency. The findings are consistent with the literature on agricultural land rental markets and the effects on allocative or productive efficiency (e.g. Deininger and Mpuga, 2009; Jin and Deininger, 2009; Jin and Jayne, 2013; Ma *et al.*, 2017).

Next, the random effect tobit models using the amount of area and the percentage of rented forestland with respect to the pre-rental level further acclaims the earlier result (Table A8). The negative (positive) coefficients of the per-labour forestland endowment accompanied by the positive (negative) coefficients of household forestry productivity on the area and area share rented-in (rented out), strongly support the allocative efficiency effect of rental markets.

Little evidence is found on elite capture of forestland, i.e. to a specific kind of landholders, by either the size of landholdings, political connections or wealth. Political connections such as membership in the Communist Party or village committee, or work experience in forestry departments, have no statistically significant effect suggesting a higher likelihood to consolidate more forestland. An exception is that a household head being in the village leadership was less likely to rent forestland out in 2005 (Table A6). Additionally, wealthier households, in terms of higher house value, are more likely to rent in forestland (statistically significant at 10 per cent level). However, this does not necessarily mean that forestland was captured by the rich or powerful people, since there is no significant effect suggesting that poorer households are more likely to rent out.

Timber price determines the value of a forest plot on rental markets. A price increase would drive the market supply up; thus, more rental transactions would be anticipated. As expected, we find that the likelihood and magnitude of rent-out increase with an increase in timber price (Tables A4, A6, A7 and A8). Another important factor that would make the expected returns to land differ is the restrictions on forestland use—the right that owners could change forest type amongst timber, bamboo and economic forests.[16] This right allows owners to rationalise their use for profit maximisation of a forest plot. Controlling for the right does not affect the driving effects of factor endowment and productivity.

16 It is restricted in rural China to change forestland to other uses, such as cropland or for construction.

A household's opportunity costs in view of agricultural and livestock production and off-farm work do not have a statistically significant impact on rental participation. Note that households with smaller area of cropland tend to rent out forestland (statistically significant at 10 per cent level for 2005, Table A6), probably due to cash constraints and the need to fulfil their own consumption of food.

Finally, village social-economic development affects rental participation. On average, villages with higher level of average per-capita income and greater share of population having telephones entail high pressures on forests, which may discourage households from participating in rental markets. Weather conditions, on which forests depend for growth, affect rental participation. Households are more likely to rent out (Table 3) and to rent out a greater amount of forestland (Table A8) in places with lower average rainfall and greater variation.

6.3. Impact of forestland rental participation on household welfare

Notable differences exist in the main welfare indicators between the no-renters (Column A) and the rent-in households (Column C), the rent-out households (Column D) and the households rented (Column B, Table A9). Compared to the no-renters, the rent-in and rent-out households have higher annual per-capita income, ranging from 1,930 to 2,448 CNY, and lower probability of income falling below the absolute poverty line by more than 10 percentages.[17] The renting households have higher off-farm income than the no-rent households, by 1,766–2,758 CNY a year. The difference in products value of per-*mu* forestland does not significantly differ by rental status. It is plausible that the average forestry productivity of the incumbent managers is satisfactory, given that the rent-out households have significantly lower income from forestry production than do the no-renters by 6 percentage points.

Next, we estimate the average treatment effects for each of the three treatments—renting (either rent-in or rent-out), rent-in and rent-out, separately. First, we estimate the propensity to be treated, $p(Z_i)$, on the determinants of rental market participation.[18] The common support condition of the PSM assumes that the treatment and the control are in the same domain. Figure A2 provides a visual inspection by the substantial overlap in the distribution of the propensity scores for the treatment and the control groups, indicating that the common support condition is satisfied.

Table 4 presents the estimates of the average treatment effect of renting, rent-in and rent-out, using the Epanechnikov kernel estimator (KBM) with a

17 The poverty line is defined as 2000 CNY for 2005 and 2300 CNY for 2010, in accordance with the World Bank's global poverty standard, i.e. 1.25 Purchasing-Power-Parity U.S. dollars a day in 2005.

18 The logit models for propensity scores, results presented in Table A10, have Pseudo-R^2 values of 0.132, 0.167 and 0.180. These values are similar to the levels as in recent literature using the PSM strategy, e.g. Becerril and Abdulai, 2010; Kassie *et al.*, 2011. However, significant parameter estimates (t-test) or goodness-of-fit measures like pseudo-R^2 can be misleading (Heckman and Navarro-Lozano, 2004; Lee, 2013). They only show association and are used to balance the observed distribution of covariates across the treated and the control groups, in order to provide good matches for the estimation of ATT.

Table 4. Welfare effects of forestland rental participation (PSM estimates)

	Average treatment effects (ATT, θ)					
Welfare indicator	Renting	Std. Err.	Rent-in	Std. Err.	Rent-out	Std. Err.
Income per capita	1543.84	(694.86)**	1303.72	(890.80)	1772.35	(945.39)*
Absolute poverty	−0.090	(0.029)***	−0.089	(0.040)**	−0.086	(0.050)*
Off-farm income per capita	1444.27	(623.18)**	1432.25	(866.32)*	1578.35	(834.96)*
Off-farm income share	0.034	(0.028)	0.024	(0.035)	0.067	(0.041)
Forestry product value per *mu*	1.71	(66.61)	74.67	(151.22)	−78.18	(20.66)***
Income share from forestry	−0.019	(0.017)	0.022	(0.021)	−0.047	(0.019)**

Notes: Table reports results of average treatment effect in the treated (ATT) using the matching algorithm – the Epanechnikov kernel estimator (KBM) with bandwidth 0.06. Standard errors, in parentheses, are bootstrapped with 200 iterations. Significance is denoted by *** for $p < 0.01$, ** for $p < 0.05$, and * for $p < 0.1$.

bandwidth of 0.06. We also apply other matching algorithms including the KBM with bandwidth 0.1 and NNM with 1, 5 and 10 neighbours, of which the results are similar (Table A11). Overall, renting-in forestland could increase household income through forestry production and renting-out land could release labour for off-farm work. As expected, participation in forestland rental markets has a positive impact on household annual per-capita income, of more than 1,500 CNY increase, and reduces the probability of income falling below the poverty line by 9 percentage points: in support of Hypotheses 2 and 3.

Looking at the respective impact of renting-out and renting-in, we find that renting-out forestland leads to higher off-farm income, with an average treatment effect of 1,578 CNY a year, and 6.7 percentages higher income from off-farm work. The findings lend support to our contention that renting-out forestland enables family labour to engage better in off-farm jobs. This is plausible since the per-labour off-farm working days do not differ across rental status (Table 2).

Interestingly, although renting-in forestland does not significantly increase forestry production value, renting-out significantly decreases the income from forestry, by an average value of 78 CNY per *mu*, and lowers the forestry income share by almost 5 per cent. An underlying condition could be that the no-renters are doing well as forest managers such that they prefer to keep forestland for own use rather than rent out.

7. Conclusion

This paper finds that with the tenure rights reform in the forest sector, rental markets have improved allocative efficiency and household welfare. The number of transactions of forestland transfers is still very small compared to the rental transactions in agricultural land. Obviously, the devolution in

agricultural land to households started 20 years earlier than the devolution in forest management.

One important finding is the importance of factor endowment and managerial ability which determines productivity in forestry and drives the direction of resource reallocation. Transparent, well-functioning land exchange platforms/markets have been in place at the municipal level by the Chinese central government. Policies that promote the inclusion of forestland in these markets and the extension of such exchange platforms to counties and communities could encourage forestland rental market development.

The current low participation rate in forestland rental markets implies a potential for a future market. By far, we have not found evidence on forestland being captured by the larger, wealthier or more powerful landholders. Given the results that rental participation enables households to better engage in off-farm work, forestland could provide a household not only with a safety-net asset but also with improved off-farm employment.

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Supplementary data

Supplementary data are available at *ERAE* online.

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