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Devolution and Collective Action in Forest Management

The Case of China

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Yuanyuan Yi, Jintao Xu, Gunnar Köhlin, and Klaus Deininger*

Abstract

Since 2003, China has implemented a large-scale forest devolution reform by giving villages the right to devolve tenure rights of collectively owned forests to households. Some villages chose no reform, and the forest continued to be owned and controlled by the village committee. In other villages, the reform was adopted and forests became owned and managed by individual households. In a third group, the reform was adopted and forests became household-owned but are managed jointly. We define the third type as devolution-based collective action, and study how it affects forests and participating households. We exploit a panel dataset of nearly 3,000 households and remote-sensing data in 262 rural villages in eight provinces in China. Using difference-in-difference and propensity score matching methods, we show that the devolution-based collective action increased forest cover in the short term. However, there is only limited evidence that it reduced vegetation degradation in the medium term. We also show that households' income from off-farm work increases, as does their total income. We find that collective action reduces the likelihood of income falling below the poverty line. Our findings are suggestive that property rights-based collective action can lead to improved forest management and more engagement in off-farm work.

Keywords: devolution; collective action; forest management; Collective Forest Tenure Reform; China

JEL Codes: D31, Q15, Q23, Q24, Q56

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1. Introduction

The absence of private property rights is a primary cause of overuse and degradation of economically valuable natural resources (e.g., Hardin 1968; Ostrom 1990; Sethi and Somanathan 1996). This is one reason that the world's forests had a net loss of 129 million hectares in the past two decades (FAO, 2015). Attempting to incentivize sustainable use, more than 27 countries have devolved forests to local communities, with the total area of community forests increasing from 383 to 511 million hectares in the period 2002-2013 (RRI, 2014). However, there is inconclusive evidence as to whether such devolution is effective in terms of participants' welfare and forest health. Many studies that do not find positive impacts attribute this result to absent, weak or insecure ownership or tenure arrangements; problems with accountability of local authorities and the distribution of economic and political power; or illegal activities and corruption (e.g., Kaimowitz et al., 1998; Foster et al., 1997; Baland et al., 2010; Coleman and Fleischman, 2012; Ostrom, 1990, 1992, 2003).

Devolution ranges from individualized user rights (in some cases, full-fledged privatization of forest land) to various forms of collective action in forest management. In this paper, we will draw on the special characteristics of the Chinese Collective Forest Tenure Reform, which involved a unique opportunity for local communities – i.e., rural villages – to choose among a range of management options, including individual user rights, joint management by households, and community administration. Since the impacts of individualization of user rights in China have been fairly well studied (e.g., Xu et al. 2010; Xie et al. 2016; Yi et al. 2014), this paper will focus on the collective management – instead of individualized user rights – that was voluntarily chosen in some villages where the reform was adopted and forest property rights were devolved to households. In particular, we evaluate how such collective forms of management affect both the forests and the welfare of these villagers. Because property rights and voluntary decisions both encourage cooperation, better forest conservation is an expected outcome – in terms of forest cover expansion and forest quality protection (Besley and Ghatak, 2010; Blackman et al. 2017; Chankrajang, 2019). For villagers, voluntary joint management allows people to devote their time to the work they are most capable of. In other words, forests will be managed by people who are good at forestry, while those who are more productive in off-farm work can earn more income in off-farm opportunities.

To analyze these issues, we use remote-sensing data and rural longitudinal household survey data collected in 2006/2007 and 2011 in eight provinces in China. The survey aimed to evaluate the short- and medium-term performance of the Collective Forest Tenure Reform, which officially started in 2003.

Our empirical strategy exploits the data before and after the reform, by dividing the sample into three groups. The treatment group (the "devolution-based collective action" group) consists of villages (and households) where ownership was devolved to households under a collective action management regime after 2001. The control group includes villages (and households) where no reform was adopted between 2000 and 2010, so that forests remain village-owned and collectively managed. In a third group, both ownership rights and management were devolved to individual households. We focus on the treatment and control groups, and bring in the individual management group for robustness checks.

To overcome endogeneity problems in the assignment of treatment, we combine a difference-in-difference estimation with propensity score matching (PSM). We thus compare the control and treatment groups on similar pre-treatment characteristics and control for time-variant factors.

We will assess the potential, short-term efficiency gains of collective action, using both remote-sensing data on forest cover and vegetation status, and the collective actors' estimation on current products value of the standing forest in which they hold property rights. Another major addition to the literature is the use of household-level detailed income data for an evaluation on the welfare impacts. Thus, this paper contributes to the existing literature by empirically providing causal evidence on a heavily discussed research question: whether devolution of property rights in common-pool natural resources can improve the resource and the welfare of the resource-dependent population.

Three main findings stand out. First, the devolution-based collective action significantly increased forest cover in the first one to two years; village forest cover increased by 10 to 12 percentage points in the year after the collective action, equivalent to a 22% to 28% increase relative to the 2001 sample mean of 43.9% forest cover[1]. However, only limited evidence could be found of reduced vegetation degradation, even in the medium term.

Second, we find a large, significant effect of the collective action on the growth in households' income from off-farm work, as well as their total income. Secure property rights can encourage cooperation in taking care of the forest, which allows owners to put more effort into off-farm employment. Compared with the households in the villages

[1] This result is possible given that the forest types in collective forest areas in China are mainly plantations including bamboo trees, fruit trees and other economic forest types.

without reform, we find that the collective action led to an average increase in off-farm income by 1,891 CNY in the treatment households – i.e., a 48% increase in total household income.

Third, the collective action reduced the likelihood of income falling below the absolute or relative poverty line. Thus, our findings suggest a potential for poverty alleviation.

The paper touches upon another issue: forest restoration as a key to nature-based solutions to climate change (IPCC, 2018; Bastin et al., 2019). Because forest ecosystems store carbon, restoring forests can compensate for a large amount of human-caused emissions (van der Gaast et al., 2018). However, this requires incentives for ongoing management by people on the ground, to thwart illegal logging, poaching, and forest fires (Yi et al., 2014).

The article proceeds as follows. Section 2 discusses the background, with an introduction to community forestry in China and the pathway of forest management reforms, and a survey of the related literature in community forestry management. Section 3 introduces the data and empirical strategy. Section 4 discusses the econometric results. Section 5 concludes with some general policy recommendations on common-pool resources management.

2. Background: Collective Action in Forest Management

Collective action requires cooperation, and its decisive role in positive outcomes in sustainable common pool resources management has been widely studied by both policy makers and social scientists (e.g., Dawes and Thaler, 1988; Bromley, 1992; Ostrom, 1990, 1992). A crucial precondition for successful collective action, which is not met in Hardin's "tragedy of the commons" (Hardin, 1968), is clearly defined property rights for each of the agents.

When it comes to collective action and its effects on both conservation outcomes and the welfare of resource-dependent populations, the empirical findings are not conclusive. Bolivia's forest devolution to local governments in the mid-1990s did not benefit the forest or the indigenous people (Kaimowitz et al., 1998). Similarly, Coleman and Fleischman (2012) assessed community forest management in Bolivia, Kenya, Mexico and Uganda, and found community management was only effective under the forest conditions in Mexico, with insignificant effects in other contexts. Other findings show benefit from collective action in forest management (e.g., Agrawal and Goyal, 2001; Poteete and Ostrom, 2004; Somanathan et al., 2007) and conservation reserve programs (Blume et al., 1984; Babcock et al., 1996; Mitani and Lindhjem, 2015; etc.). Yet, many studies find various degrees of resource degradation in forests that are managed by communities (Agrawal and Ribot, 1999; Etoungou, 2003; Ribot et al., 2006; and Burgess et al., 2012).

The literature attributes failures of collective action to a number of potential factors, such as ill-defined property rights (Ostrom, 2003; Agrawal and Ostrom, 2001), social capital and norms (Sethi and Somanathan, 1996; Ostrom, 2014; D'Silva and Pai, 2003), institutions (Adhikari and Lovett, 2006), and group heterogeneity (Somanathan et. al., 2007; Baland and Platteau, 1997). These studies point out a number of factors that raise the transaction costs of coordinating collective action, such as weak, insecure or non-existent ownership and tenure arrangements; low accountability of local authorities; group heterogeneity and problems with distribution of economic and political power; illegal activities and corruption, etc. As a result, it is very difficult for community members to reach an agreement on sharing benefits and costs. Also, as Agrawal and Ostrom (2001) affirmed, decentralized individual rights in decision-making and decentralized property rights can efficiently achieve collective action.

While the positive effect of individualization of forest management in China is fairly well established (see, e.g., Yi et al., 2014; Xie et al., 2016; Yi, 2017), the inconclusive evidence on community management more generally raises the question of the conditions under which devolution is likely to lead to collective rather than individual action.

2.1 Community Management in the Chinese Collective Forest Tenure Reform

Following the successful devolution of agricultural lands to households since 1978, China also started to devolve forest management to private households, with clearly defined tenure (property) rights to forestland in collective forest areas, where forests were owned by rural villages.[2] In the early 2000s, this step was initially tried by some rural villages in Fujian province, located in the forest-rich areas of southern China.[3] The central government soon accepted and formally announced it as the "Collective Forest Tenure Reform" in 2003 (the Reform, henceforth), and started to encourage other provincial governments to spread the reform. One of the primary requirements was that adoption of the reform must be a village-wide collective decision whether or not to devolve village-

[2] In this paper, we do not distinguish the concept of tenure rights from property rights, as in China land does not belong to any private party but is owned collectively or by the country as a whole. However, tenure rights are guaranteed as property rights during the contract period for those who possess the rights according to China's Property Law. Therefore, we use "owned" to refer to the devolved property rights.

[3] A well-known example is the Hongtian village in Yong'an City, which, since the end of the 1990s, had already organized over 20 village leadership and group meetings to discuss forest tenure issues, out of which the decision was to organize village representative meetings to vote on devolution. Over 80% of village members voted "yes". *Fujian Daily*, May 21, 2018. Fujian Forest Tenure Reform (http://www.forestry.gov.cn/main/5383/20180523/1104357.html)

owned forestland to households. The requirement was that at least two-thirds voted for adoption at the village assembly or representatives' meeting. Once adopted, forestland tenure rights are devolved to households, with long (up to 70 years) and secure tenure and strong rights, including productive uses and ownership of returns, as well as the possibility to transfer the land to other uses and to other persons and to use it as collateral. By 2010, household tenure accounted for 70 percent of the village forests, i.e., over 62 million hectares of the total 100 million hectares of village forests were devolved from collective ownership to households, having affected 70 million households and their livelihoods (Xu et al., 2010; State Forestry Administration, 2011).

The village collective decisions formed the following three main tenure types: (i) *un-devolved, village-owned*: there was no reform and forests remained owned and controlled by the village committee[4]; (ii) *household*: the reform was adopted and forests became owned and managed by households individually; and (iii) *devolution-based collective/partnership*: the reform was adopted and forests became household-owned but managed jointly. Household management, with devolved property rights, is found to increase private investment and forestation (Yi et al. 2014; Xie et al., 2016; Yi, 2017), which reinforces Besley (1995)'s classic work that improved property rights provide incentives for investment and private management through the channels of tenure security, gains-from-trade and credit accessibility. In this article, we study collective management and in particular, the role of property rights-based collective management, by focusing on the tenure types of (i) and (iii).The fundamental difference between the two types is that, of type (iii), the households have the property rights of forest, whilst the type (i) households do not.

2.2 Relationship to the Community Forest Management Literature

Many studies have attributed the success of community management to collective action and cooperation among the community members, so as to achieve positive outcomes in sustainable forest management (e.g., Agrawal and Ribot, 1999; Agrawal and Goyal, 2001; Etoungou, 2003; Poteete and Ostrom, 2004; Ribot et al., 2006; Somanathan et al., 2007). The unique type of collective action in question is an outcome of voluntary decisions based on household ownership of forest tenure rights after the Reform. It is thus different from the community management in other contexts such as India, Indonesia, the Amazon forests and forests in Latin America, where forest titling programs were endorsed by the

[4] Such village-controlled management can take different forms, such as village-owned and managed by village committees or professional producers, and villagers access to the forests as open resource.

upper government but implemented at the community level. In those cases, there was a lack of focus on giving property rights to individuals. By contrast, in the Chinese case, villagers received property rights of a share of the formerly village-owned forest. In that case, better forest conservation can be expected from reduced free-riding, illegal logging, and/or better care such as fire control (Besley and Ghatak, 2010; Blackman et al. 2017; Chankrajang, 2019). Collective management can reduce production costs in community forestry through economies of scale, while costly coordination can be reduced by well-defined property rights.

Conceptually, we consider a representative rural household, who lives in a village with some forests that belong to the village and is endowed with family labor and managerial ability in farming, in forestry, and in off-farm work. For each member household, choosing to participate in joint management improves efficiency in resource allocation. Property rights-based joint management – in other words, devolution-based collective action – encourages cooperation and security and benefits member households. There are two possible ways that a household could benefit from cooperation: Firstly, she can dedicate herself to improving her farming or off-farm work efficiency by providing products or services of better quality so that her income from these sources increases. Secondly, because joint/collective management does not change the ownership of forest tenure rights, security provided by the forestland makes forests an important safety-net asset. More importantly, clearly defined property rights and legally confirmed tenure security reduce uncertainty and management risk so that the transaction costs of cooperation are reduced. As a result, forest condition will be improved, and household income will increase.

3. Empirical Strategies

Identification is typically problematic when it comes to welfare impacts of major reforms such as forest devolution. A relevant example of the challenge is Adhikari (2005), which examined the contribution of community forestry to household income and equity in Nepal, where collective access was assumed to be exogenously given. The conclusions that poorer households benefit less while the richer obtain more income from the commons, and that the more educated are less dependent on forestry, are incomplete since potential dynamics on cooperation and benefits are missing. Therefore, household-level panel data are needed to address pre-existing distributional differences, and their correlation to both collective action and the outcomes to be evaluated. It is important to show how collective action first evolves or degrades and then affects the distribution of benefits, while factors affecting both are held constant. This section describes the data and the identification strategy for the impact of collection action on forest and household welfare.

3.1 Data and Descriptive Statistics

We utilize data from two sources. First, on village-level forest cover and vegetation condition, we use remote-sensing data – the MODIS land cover type (MCD12Q1) to construct forest cover and the Landsat 7 Enhanced Vegetation Index (EVI) on average vegetation index value, with a spatial resolution of 500 and 30 meters, respectively.[5] Forest cover is calculated as a percentage of the pixels that are classified as being covered by forests – including evergreen (or deciduous), broadleaf (or needleleaf) and mixed forests – within a village's boundary area. Vegetation condition is measured by the mean value of all the pixels falling into a village's boundary. The data are summarized in Table 1, together with other variables of village characteristics.

The second dataset comes from a two-round survey of rural households and villages in eight Chinese provinces of Fujian, Jiangxi, Zhejiang, Anhui, Hunan, Liaoning, Shandong, and Yunnan. The survey was conducted by the Environmental Economics Program in China (EEPC) of Peking University, in 2006/2007 and 2011. The survey was designed to evaluate the short- and medium-term performance of the Collective Forest Tenure Reform, which officially started in 2003.

The sampling frame was stratified horizontally, from the provincial level to the city, county, township, and village level. In each level, a simple random sampling rule was applied. In each village, 10-20 households were randomly selected. The 2006/2007 survey collected retrospective information for 2000 and 2005, and the 2011 survey collected such information for 2010. Village-level data include socio-economic characteristics and geographical conditions, decision-making process and (if adopted) the implementation of the forest tenure reform. Household-level data include demographic characteristics and economic activities such as farming, forest management and off-farm work, and household income and income composition. Dropping two sample villages in Fujian that had already started to devolve forest tenure rights to households in 2000, the sample reaches a total of

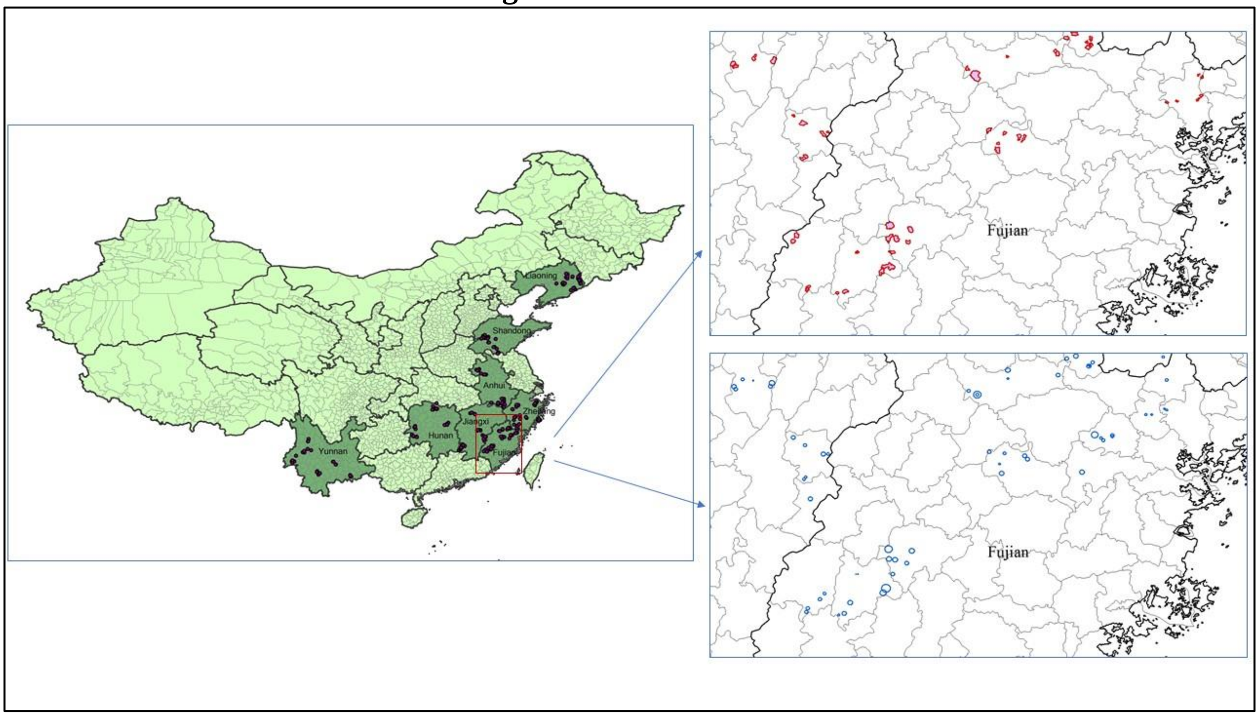
[5] The EVI and the NDVI are two commonly adopted measures of forest conditions. The NDVI is a well-established and widely used measure of vegetation but is prone to contamination by variations in soil or aerosol reflectance and saturation at high levels of plant biomass. The EVI was recently designed to overcome some of these shortcomings, and thus provides a potentially more robust measure of vegetation activity (Huete et al., 2002). Some recent studies compare the two measures and conclude that the EVI-based models are more accurate than the NDVI-based models (see for example, Lobell et al., 2010; Son et al., 2014). Therefore, we adopt the EVI measure in this study.

2,918 households in 262 villages. The dataset has an effective sample size of 2,918 households of 262 villages for 2000 and 2005, and 2,117 for 2010.[6]

To construct the forest cover and vegetation measures, we combine a total of 156 village boundary maps that were available with the remaining 106 villages using buffers (circles) that are created based on the village center GPS coordinates and total land area. Figure 1 depicts the distribution of villages (the left panel) and illustrates actual shapes and buffers of the villages (the right panels). With a large degree of geographical dispersion, the sample is representative of the collective forest areas in China. We also show in Appendix Table A1 that the buffer method does not show an overall overestimation of forest cover and vegetation condition compared to using the actual maps.

[6] There is attrition of two village samples, due to administrative consolidation of two villages, ecological relocation of one village, and trouble between village leaders and member households. The reasons for attrition are not relevant to the forest devolution decision process. The survey at household level collected a total of 2,941 samples in the first round, with missing data in some samples. The second round lost about 25% of the original sample, because the previous household representative could not be surveyed due to temporary absence, e.g., some were in the hospital, some were busy at work, and some were absent because of migration or death. Our propensity-score matching method based on pre-treatment observables helps deal with potential attrition bias, such as the possibility that a richer household or a household more likely to migrate into cities is more likely to be missing in the second round.

Figure 1. Distribution of Surveyed Villages and Method of Extracting Village Forest Cover



Source: Authors located villages using GPS coordinates and village boundary maps collected during the surveys. Village forest cover (in percentage points) and average vegetation conditions (using the Enhanced Vegetation Index value) are computed based on village locations and area. A total of 158 villages have actual boundary maps, and for the rest of the sample villages, buffers (circles) are created based on the village center coordinates and total land area. The right panels depict our method – the upper panel shows the polygons from available village maps and the lower panel shows the buffer zones created for all the villages. The shapes do not differ much between the two panels, and as reported in the Appendix Table A1, the mean values of buffer-generated forest cover are overall lower and the average EVI are very similar between the two measures.

Defining the '**Control**' villages as those where the Reform was not adopted by 2010 and thus the forests remained collectively owned and managed by village committees, the treatment is the '***Devolution-based collective action***' villages – where *forest tenure is devolved to households and they voluntarily decided to manage their forests jointly* ('collective-action', henceforth).[7] Of the 262 sample villages, 125 belong to the *collective-action* group, 22 that did not devolve forest tenure, and the remaining 115 chose to devolve and let forests be owned and managed by households ('individual', henceforth). A

[7] One empirical issue is that the treatment group had the Reform adopted between 2001 and 2010, and we drop the households in villages that had already adopted the reform in 2000 because their pre-treatment data is unavailable.

fundamental difference between the treatment and the control is that the households in the treatment villages have property rights in forestland but those in the control villages do not.

Table 1 summarizes the socio-economic and geographic characteristics for each of the three types of villages in 2000, 2005 and 2010. In Table A2 in the appendix, we present the *t*-test results on the differences between the control group and the collective-action group. On average, villages in each forest-tenure type group had a steady growth in social and economic development, such as population and household count, per capita income and the development of labor and timber markets. Public infrastructure improved greatly in the decade, with distance to a road feasible for vehicle transportation reduced by more than half, and the share of population having a telephone had an almost three-fold increase. Natural conditions were stable, with slight changes including precipitation.[8] Total land and cropland area on average remained stable during the period 2000-2010, but total forestland area increased by 10 percent. This change may be related to the reform, because the 'Collective-action' and 'Individual' groups of villages experienced a larger degree of this increase. Taking the 'Collective-action' villages, forestland area has a 4 percent increase from 2000 to 2005, and a further 9 percent increase to 2010; in contrast, the figure decreases from 3,471 to 3,124 mu (from 231 to 208 hectares, approximately) in the control villages.

[8] Forest growth relies on rainfall, which may or may not be related to household forest management decisions as well as farming activities. We obtained rainfall data from the China Meteorological Data Sharing Service System (CMDSSS). The CMDSSS records daily minimum, maximum and average temperature, precipitation, and solar radiation in 820 weather stations (with exact coordinates) distributed across all of China. Using village center coordinates taken by the survey team with GPS devices, we match each village with the closest weather station.

Table 1. Summary of Village Characteristics

	2000			2005			2010		
	Control	**Collective-action**	**Individual**	**Control**	**Collective-action**	**Individual**	**Control**	**Collective-action**	**Individual**
Forest cover (%)	/	/	/	21.6	58.9	37.2	27.3	64.3	42.6
Average EVI value	0.703	0.649	0.649	0.660	0.637	0.617	0.636	0.631	0.611
Forest tenure reform adoption (%)	0.0	0.0	0.0	0.0	54.4	27.0	0.0	100.0	99.1
Total number of households	351	331	326	381	348	342	460	380	390
Total population	1,665	1,297	1,240	1,723	1,353	1,274	1,793	1,432	1,422
Average net income per capita (CNY)	2,184	2,000	2,185	3,005	2,602	2,797	4,314	4,175	4,155
Distance to paved road (km)	0.225	0.632	8.244	0.225	0.535	8.162	0.178	3.120	0.302
Distance to county center (km)	20.250	31.795	30.304	20.250	31.699	30.270	25.182	28.541	29.474
Households having telephone (%)	36.9	31.6	33.5	83.8	75.8	76.2	97.8	93.6	92.9
Labor market wage (CNY/day)	32.955	34.712	30.728	47.013	49.862	41.212	70.700	75.435	73.895
Labor worked off-farm (%)	27.1	18.9	22.1	34.0	28.3	33.3	38.7	31.7	33.3
Total land area (mu)	3,988	27,192	12,778	3,946	27,255	12,794	4,337	27,552	17,618
Cropland area (%)	51.4	25.5	34.7	48.4	21.0	30.2	48.9	23.7	32.5
Total forestland area (mu)	3,471	14,530	8,050	3,503	15,117	8,098	3,124	16,440	8,677
Price of timber for sale (CNY/m3)	331	300	365	448	411	481	544	962	745
Average altitude (m)	3,470	4,780	4,346	3,462	4,809	4,367	3,452	4,806	4,369
Precipitation: average (mm)	33.90	39.08	35.76	35.54	39.77	37.48	36.62	50.73	39.46
Precipitation: std. dev. (mm)	110.67	99.58	99.40	115.27	107.60	112.48	104.73	129.89	107.88
No. of villages	22	125	115	22	125	115	22	125	115

Source: Own computation from the EEPC survey data in 2006/2007 and 2010, and remote-sensing data of the MODIS land cover type and Landsat 7. Forest cover in 2000 is not available from the MODIS land cover type data.

Notes: Mu is the land area unit in rural China, equal to one-fifteenth of a hectare. Forest cover is not available for 2000 according to the MODIS land cover data. For 2001, the mean values of forest cover are 43.9% for the whole sample, and 25.7%, 53.4%, and 37.2% for the Control, Collective-action and Individual groups, respectively.

Prior to the Reform decision, the villages in the collective action group appear to have had lower average per-capita income than villages in the other two groups, by over 180 CNY in 2000, but this is not statistically significant (see Appendix Table A2). The collective action group has on average much more land than the other two groups – i.e., 27,192 *mu* vs. 12,778 *mu* of the ‘Individual’ villages, and 3,988 *mu* of the ‘Control’ villages. The ratio of cultivated land to the total land area is the highest in the control villages (51%), lower in the individual villages (35%) and the lowest in the collective-action villages (26%). The largest forest land area is in the collective action villages (14,553 mu vs. 8,050 mu in the ‘Individual’ and 3,471 mu in the ‘Control’ villages). This finding points out that the Reform adopters rely more on forestry.

Compared with the villages of the control group, the collective-action villages are more likely to be located in remote areas, farther from the county center – by 10 kilometers on average (see Appendix Table A2). They had 8 percentage points less labor engaged in off-farm work in 2000 (19% vs. 27% in the control group), but the demand for labor seems higher in the collective-action villages, with a slightly higher daily wage for off-farm labor. Also, they are larger in size on average, and have greater forest coverage (53.4% vs. 25.7% in 2001) but worse average vegetation condition (0.649 vs. 0.703). The observable, pre-existing differences will be dealt with in the estimation of the average treatment effect on forest and welfare, with a detailed discussion on identification strategy given in Section 3.2.

Table 2 summarizes the variables of households in each type of village in 2000, 2005 and 2010 (with the results of *t*-tests on the differences between the treatment and the control households presented in Appendix Table A3). In 2000, i.e., the pre-treatment period, the demographic characteristics are very similar among groups, except that the households in reformed villages are more likely headed by males (96% vs. 90% have male heads). There is limited evidence that either individualization or collective action is associated with political power, in terms of the heads’ membership of the Communist Party and village leadership.

Table 2. Household Characteristics

	2000			2005			2010		
	Control	Collective-action	Individual	Control	Collective-action	Individual	Control	Collective-action	Individual
Head of household:									
Male head (%)	90.3	96.6	95.7	90.4	96.3	95.3	90.8	95.2	94.8
Age	46.38	45.14	44.37	51.38	49.89	49.62	55.25	53.33	53.08
Education (years)	5.750	5.893	5.812	5.843	5.979	5.813	5.463	5.970	5.744
Communist Party member (%)	15.7	17.2	14.5	15.7	19.4	16.1	22.1	22.6	18.2
Village leadership member (%)	5.6	6.6	6.2	5.6	7.0	6.1	8.6	7.1	4.5
Household:									
Household size	4.673	4.451	4.292	4.667	4.453	4.291	4.466	4.521	4.274
House value (10,000 CNY)	/	/	/	7.574	4.125	4.698	18.586	12.554	11.859
Per capita days worked off-farm	68.28	68.73	65.65	86.28	90.46	89.17	84.44	92.18	82.89
Owned cropland per capita (mu)	1.514	1.610	2.014	1.566	1.739	1.757	1.846	1.741	1.702
Forestland access per capita (mu)	1.78	32.34	5.10	1.78	31.85	5.14	4.31	21.46	6.77
Labor input in forest (days/mu)	4.085	7.838	5.749	5.407	9.912	8.932	7.941	11.565	17.160
Investment in forest (CNY/mu)	104.11	84.20	167.69	213.00	137.61	270.05	179.74	243.39	511.78
Owning forestland in 20 years	/	/	/	0.562	0.478	0.602	0.663	0.794	0.798
Transferability of forestland	/	/	/	0.677	0.816	0.712	0.831	0.873	0.921
Total score of forest tenure rights	/	/	/	4.964	5.544	5.047	5.543	5.794	6.172
Income and welfare measures:									
Total income (CNY per capita)	3,916	2,907	3,230	6,636	4,859	5,461	7,889	9,407	8,918
Off-farm income (CNY per capita)	2,529	1,831	2,081	3,780	3,072	3,422	4,297	6,121	5,192
Off-farm income (%)	51.7	47.8	46.9	58.0	55.9	54.6	50.6	57.2	48.2
Farming income (CNY per capita)	344	368	435	562	576	613	1,160	1,253	1,149
Forestland value (CNY per capita)	13.39	44.12	94.39	41.96	102.26	351.78	83.55	447.16	1468.75
Absolute poverty (%)	43.1	51.2	47.6	20.9	28.2	27.4	11.0	13.6	17.6
Relative poverty (%)	41.9	51.1	50.2	24.1	31.6	33.6	22.7	25.9	26.6
No. of households	248	1,370	1,300	249	1,367	1,290	163	1,071	883

Source: Own computation from the EEPC survey data in 2006/2007 and 2010.

Notes: Data on 2000 is collected based on respondent's retrospective assessment. Mu is the land area unit in rural China, equal to one-fifteenth of a hectare. Owned forest land includes forest plots converted from own cropland through the Sloping Land Conversion Program (SLCP). These SLCP plots are very small and not involved (overlapped) with the Collective Forest Tenure Reform of interest. The score of forest tenure rights is a summation of nine rights including forestland use and production, transferability, right to use as collateral and inheritance. Household relative poverty is defined as total income below the county average income. Forestland value is based on respondent's self-estimation: volume in cubic meters for timber land (accounted with timber price), annual products value for fruit trees or bamboo forests.

In general, the control group has wealthier households than the treatment group, indicated by their higher house value in 2005 and 2010. On average, the control households had access to forestland of less than 2 mu (per person) in 2005 and 4.3 mu in 2010. However, the households in the ‘Individual’ villages had more than 5 mu per person, and those in the collective-action villages were entitled to have access to 30 mu of forestland by 2005, and 21 mu in 2010. This huge difference is due to the adoption of the forest devolution reform, because we do not observe any significant difference in the per-capita ownership of cropland across the three types of villages, nor any remarkable increase during the study period.

The household-level survey investigated forest management practices such as days of labor and CNY value of non-labor inputs and care for the forests. A general discrepancy lay in whether they have property rights: forest input and investment increase by a larger extent in the households that have property rights to the forests. To be specific, labor input by the households in the control villages increased from 4 days per mu in 2000 to less than 8 days per mu in 2010, and increased from 8 to 12 by the households in the collective-action villages, and from 6 to 17 days by the households managing forests individually. Regarding the CNY value of forest investment, which involves costs of silviculture, afforestation and reforestation, there was a three-fold increase in the households with property rights to forests – from 84 to 243 per mu in the forestland of collective-action and from 168 to 512 per mu in the individual-managed forestland – whilst households’ average forest investment in the control villages was 104 and 180 per mu in 2000 and 2010, respectively, which was lower than in the other two types in 2010. This finding is consistent with Besley (1995) and Besley and Ghatak (2010), and with what Yi et al. (2014) finds in the collective forest areas in China: that the increased investment is associated with property rights.

Household income and income composition have significant divergences among types of villages. Among the households in the three types of villages, per-capita income of the collective actors increased from the lowest in 2000 (2,907 CNY vs. 3,916 CNY in the control villages and 3,230 in the individual managers) to the highest in 2010 (9,407 CNY vs. 7,889 and 8,918 CNY in the other two types of villages, respectively).[9] Also, the collective actors had considerable off-farm income growth, accounting for 48% of total household income in 2000 and 57% in 2010 – higher than that of the control households by 7 percentage points. On poverty status, we use both the absolute poverty line – of 1.25

[9] Monetary terms such as income and wages are converted into 2000 CNY value.

USD per day per person, according to the World Bank definition – and a relative measure – the likelihood that a household's per-capita income is below the rural average of the county. Following an overall decrease in poverty status, the collective-action households had a significantly higher poverty rate than the control households in 2000 (51% vs. 42%), but this difference became statistically insignificant in 2010.

3.2 Estimation Strategies

The main aim of this paper is to investigate whether the devolution-based collective action leads to changes in forest condition and household incomes. To do so, we use the following fixed effects specification when the outcome variables are of continuous nature,

$$\boldsymbol{W_{it} = \alpha_i + \lambda_t + \delta D_{it} + \gamma X_{it} + \varepsilon_{it}} \qquad (1)$$

where $\boldsymbol{W_{it}}$ is the dependent variable for village (household) $\boldsymbol{i}$'s forest cover or average vegetation status (income/welfare measures) at time $\boldsymbol{t}$. The income/welfare measures include household per-capita income, per-capita off-farm income and its share of total income, per-capita farming income, self-estimated forestland value per capita (i.e., a proxy for potential forestry income), and absolute and relative poverty status. $\boldsymbol{D}$ is a dummy variable indicating treatment status according to the year that the village agreed on devolution and collective management of the forest, and $\boldsymbol{\delta}$ is the difference-in-difference estimate of the average treatment effect. $\boldsymbol{\alpha_i}$ is the village (household) fixed-effect which captures the unobserved time-invariant factors that may correlate with the outcome variables, such as geographical conditions, e.g., the elevation, slope, and distance to market (Agrawal and Chhatre, 2006). $\boldsymbol{\lambda_t}$ captures the nationwide change in year $\boldsymbol{t}$ that could affect all the village (household) outcomes in the same way. $\boldsymbol{\varepsilon_{it}}$ is an error term.

$\boldsymbol{X_{it}}$ is a vector of exogenous time-variant characteristics that are relevant to village forest and household welfare outcomes. The village-level characteristics include village total population, average income per-capita, total land area, farmland share and total forestland area, population that have telephones, labor wage, timber price, and weather conditions. Population and income level, together with land endowment such as total land area and forested area, and land available for cultivation, are regarded as factors that create pressure for agricultural expansion and thus forest clearing (Barbier, 2001; Agrawal and Chhatre, 2006). Natural conditions such as the average of precipitation and its variability (e.g., standard deviation) and the same for temperature are relevant to forest growth. Labor and timber prices differ in their impact on forests. Higher labor price helps restore forests by driving people away from their forest and agricultural land. Higher timber price, on the one hand implying higher demand for timber, would lead to more deforestation; on the other hand, it implies scarcity of forest resources, and, as a result, people are alerted and call for conservation so that forests recover and grow (Foster and Rosenzweig, 2003). In the estimation of household welfare impact of the collective action, in addition to the above-mentioned village-level characteristics, household demographic and social characteristics, and resource endowments, as shown in Table 2, are relevant to their economic outcomes and thus added into $\boldsymbol{X_{it}}$.

It is possible that the estimation specified as equation (1) is affected by endogeneity problems given the fact that the treatment is an outcome of all villagers' voluntary and collective decision. Reverse causality could be one problem. Worse forest conditions may encourage cooperation. Or, the opposite may be true: better forest conditions – and thus better forest-related outcomes – may encourage willingness to cooperate. Omitted variables such as social norms and preferences in cooperation and dealing with public goods could drive the formation of collective action and thus potentially bias the estimate of $\boldsymbol{\delta}$ upwards. If the omitted variable or the variable that drives the village or household to self-select into treatment is time-invariant, the specification with fixed-effects ($\boldsymbol{\alpha_i}$) estimation helps mitigate the bias (Baland et al., 2010). Nevertheless, if the variable varies with time, the problem remains.

To address the endogeneity problem, the paper exploits the propensity score matching difference-in-difference approach, which accounts for the correlation between the treatment and the observable pre-treatment characteristics. To this end, a first-stage logit model regresses the likelihood of a village (household) being a collective actor on the village (and household) social, economic and geographic characteristics in the period prior to the treatment.[10] Using the predicted probabilities from the logit estimation as propensity scores, we apply a one-to-one matching algorithm to form the comparison group. This method allows us to match the control villages (households) to the treatment villages (households), and to estimate the counterfactual outcome for the treatment observations (Rosenbaum and Rubin, 1983).[11] To match, we estimate $p(\boldsymbol{X_0}) = \Pr\,(D = 1|\boldsymbol{X}_0)$, i.e., the probability of a village (household) in the treatment group conditional on its characteristics

[10] This step is not for causality interpretation, but only to balance between the treatment and the control based on the covariates, in order to construct a plausible comparison group by matching the treatment households with similar control villages (households).

[11] The validity of the matching approach is based on two conditions. The first is the "conditional mean independence" (CIA), which requires that $E(\boldsymbol{W^0}|\boldsymbol{X}, \boldsymbol{V}, D = 1) = E(\boldsymbol{W^0}|\boldsymbol{X}, \boldsymbol{V}, D = 0)$. This implies that, conditional on the covariates $\boldsymbol{X}, \boldsymbol{V}$, the observations in the control group have the same mean outcomes as the treated observations would have had if they had not been treated. Secondly, the common support condition, $0 < p(\boldsymbol{X}, \boldsymbol{V}) < 1$, requires that valid matches of $p(\boldsymbol{X}, \boldsymbol{V})$ can be found for all values of $\boldsymbol{X}, \boldsymbol{V}$.

in the baseline period ($\boldsymbol{X_0}$), that is, in 2000. In this way, a treatment is statistically matched to a group of non-treated observations with similar values of $p(\boldsymbol{X}_0)$, which are obtained as the fitted values from the logit model. To find the closest match possible, it is desirable to overparameterize the logit model and condition the match on variables that may be highly correlated with the outcome variables (Heckman and Navarro-Lozano, 2004; Gilligan and Hoddinott, 2007). Based on $p(\boldsymbol{X}_0)$, we match the treatment and control observations using the nearest-neighbor algorithm. Finally, the estimation of eq. (1) is re-run on the pair-wise matched sample while controlling for the fixed-effect and time-variant characteristics.

4. Empirical Results

4.1 Forest Cover and Vegetation Status

Property rights, with long-term security in use and security to claim the returns on investment, create a greater incentive for the locals to plant more trees (Chankrajang, 2019), as well as to cooperate in taking care of the forests, such as monitoring against illegal logging and fire control. As a result, improvement in forest quality can be expected in the long run. To investigate whether the devolution (of property rights) based collective action is successful in encouraging forestation and improving forest quality, we use the GIS technique to construct the village-level interpreted satellite imagery of forest cover (in percentage share) and vegetation quality (by average EVI value), as explained in Section 3.1.

Table 3 presents the baseline result of the fixed-effects estimation, making use of forest cover and vegetation index data in as many years as possible, with forest cover from 2001 to 2012 and EVI from 1999 to 2017 (as shown in Appendix Table A1). It appears that the collective action had a significant effect in increasing forest cover in the first three years, but not statistically significant in improving the condition of vegetation. The point estimate of the collective-action variable ranges from 0.017 to 0.030, implying that, with property rights, collective action is associated with an average increase in forest cover by 3 to 5 percent in the short term, given the regression sample mean of forest cover (56%).

Table 3. Devolution-Based Collective Action and Forest Conditions

Panel A.	**Forest cover**			
	Year 0	**Year 1**	**Year 2**	**Year 3**
Devolution-based collective action	0.017**	0.025***	0.030***	0.008
	(0.008)	(0.008)	(0.008)	(0.008)
Number of villages	147	147	147	147
Number of observations	1,764	1,764	1,764	1,617
R-squared	0.162	0.165	0.168	0.140
Panel B.	**EVI**			
	Year 0	**Year 1**	**Year 2**	**Year 3**
Devolution-based collective action	0.001	0.000	0.004	0.009*
	(0.006)	(0.006)	(0.005)	(0.006)
Number of villages	147	147	147	147
Observations	2,793	2,646	2,499	2,352
R-squared	0.173	0.073	0.075	0.081

Notes: Village fixed effects regressions on forest cover and average vegetation status (mean EVI value). Significance is denoted: *** p<0.01, ** p<0.05, * p<0.1.

The baseline fixed-effects estimations control for the village level of time-invariant factors that may be correlated with collective action and forest outcomes, such as local social norms and preferences for collectivity, which are often regarded as stable in the long run. The baseline estimations can still be affected by omitted variable bias and the possibility of endogeneity. In Table 4, we present the estimation results of adding the village characteristics, in order to control for time-variant factors. Then, in Table 5, we show the results of adding the individually managed forests into the reference category as a robustness check. Finally, in Table 6, we present the results of PSM-based fixed-effects estimations, treating the control villages as the *counterfactuals* of the collective actors from a statistical perspective.

The results in Table 4, making use of data on the village characteristics collected from the EEPC survey, are based on the three years of 2000, 2005 and 2010. Further control for province-year fixed-effects are added, to capture the changes caused by policies that the provincial government made relevant to the Reform and environmental protection. The magnitude of the estimated coefficient of the collective action increases, and that on vegetation status shows a positive and statistically significant relationship with the collective action two years after the treatment. Adopting the Reform and deciding on collective management of forest is found to be associated with an increase in forest cover by 7 percentage points in the current year, and the effect lasts to the next year, with a 9.5 percentage points increase.

On forest quality, as measured by average EVI value, it is not surprising that the effect is found not statistically significant in the beginning but may emerge later, because trees, especially newly planted trees, need some time to grow for their canopy to be captured by the satellite. Hence, in the third year ('Year 2'), we find that the collective-action villages have a significantly higher average EVI value, by 0.044. A higher EVI value, calculated from the band values of satellite imagery, means that the piece of land in the picture has a denser vegetation canopy.

Table 4. Impact of Devolution-Based Collective Action on Forest: Adding Control Variables

Panel A.	**Forest cover in**			
	Year 0	**Year 1**	**Year 2**	**Year 3**
Devolution-based collective action	0.071**	0.095***	0.037	0.009
	(0.035)	(0.029)	(0.025)	(0.040)
Village characteristics	Yes	Yes	Yes	Yes
Province year fixed effects	Yes	Yes	Yes	Yes
Number of villages	147	147	147	147
Number of observations	294	441	441	294
R-squared	0.323	0.323	0.347	0.333
Panel B.	**EVI in**			
	Year 0	**Year 1**	**Year 2**	**Year 3**
Devolution-based collective action	-0.000	-0.027	0.044***	-0.021
	(0.017)	(0.017)	(0.016)	(0.017)
Village characteristics	Yes	Yes	Yes	Yes
Province year fixed effects	Yes	Yes	Yes	Yes
Number of villages	147	147	147	147
Observations	441	441	441	441
R-squared	0.261	0.210	0.290	0.470

Notes: Village fixed effects regressions on forest cover and EVI using the 125 treatment and 22 control villages. Each column reports the result of estimation using the dependent variable of forest cover (or EVI) in Year 0, 1, 2, and 3 since the adoption of devolution-based collective action, respectively. Controlled village characteristics include population, average net income per capita, daily labor wage, population share having telephone, timber price, and weather variability – average and standard deviation of precipitation, days with temperature of 0-35 degree Celsius and with temperature above 35 degree Celsius. Significance is denoted: *** p<0.01, ** p<0.05, * p<0.1.

So far, the fixed-effects estimations have been applied to the collective actors and the control villages. As a robustness check, we re-estimate the base specification using the whole sample, by adding the villages that devolved property rights to households for individual management. Now the excluded category consists of the forests in the control villages and in the individually managed villages. Interestingly, the estimated effect of the collective action on forest cover declines to 4 percentage points and is statistically significant at the 5% level in the second year since the action. This is not an unexpected finding because devolution of property rights to households encourages investments such as tree-planting and reforestation (Xie et al., 2016) and silvicultural investment (Yi et al., 2014). It appears that vegetation improvement remains significantly better in the collective-action villages in the third year (0.042), similarly to Table 4. This may be attributed to the collective management (*versus* individual management) that could avoid segmentation of the forest, so that various individual decisions of reforestation may reduce the short-term average vegetation of the whole area. Hence, the villages of the devolution-based collective action outperform those without property rights and those of non-collective action.

Table 5. Impact of Devolution-Based Collective Action on Forest: Adding Individually-Managed Forests

Panel A.	**Forest cover in**			
	Year 0	**Year 1**	**Year 2**	**Year 3**
Devolution-based collective action	0.035	0.039**	0.008	0.009
	(0.023)	(0.017)	(0.014)	(0.025)
Village characteristics	Yes	Yes	Yes	Yes
Province year fixed effects	Yes	Yes	Yes	Yes
Number of villages	262	262	262	262
Number of observations	524	786	786	524
R-squared	0.299	0.273	0.318	0.314
Panel B.	**EVI in**			
	Year 0	**Year 1**	**Year 2**	**Year 3**
Devolution-based collective action	0.005	-0.009	0.042***	-0.004
	(0.011)	(0.011)	(0.010)	(0.012)
Village characteristics	Yes	Yes	Yes	Yes
Province year fixed effects	Yes	Yes	Yes	Yes
Number of villages	262	262	262	262
Observations	786	786	786	786
R-squared	0.226	0.230	0.305	0.414

Notes: Village fixed effects regressions on forest cover and EVI using all the villages – the 125 treatment and 22 control villages, and the 115 villages with individual management of forest. Each column reports the result of estimation using the dependent variable of forest cover (or EVI) in Year 0, 1, 2, and 3 since the adoption of devolution-based collective action, respectively. The reference category includes the control villages and villages that have devolved forestland to household management. Regressions control for village characteristics including total population, average net income per capita, daily labor wage, population share having telephone, timber price, and weather variability – average and standard deviation of precipitation, days with temperature of 0-35 degrees Celsius and with temperature above 35 degrees Celsius. Significance is denoted: *** p<0.01, ** p<0.05, * p<0.1.

As a further robustness check to address the endogeneity problem in villages' selection of devolution and collective action, following the discussion in Section 3.2, we use PSM and the 22 villages in the control group as the 'counterfactuals' for treatment observations. For each of the 22 'control' villages, a 'treatment' village is matched based on the closest propensity score. Table A4 in the Appendix reports the first-stage logit estimates of a set of covariates that may be correlated with the treatment (in column 1). To check the quality of matching, Table A5 in the Appendix (in column set 1) presents the mean values of the covariates between the treated and the control in 2000 – the pre-treatment period. The very similar mean values on most of the covariates imply a satisfactory matching quality, suggesting that the constructed counterfactuals are identical to the treatment prior to the intervention.[12] Accordingly, the estimations using the matched sample improve the causality identification by comparing the net effect between the treatment villages and their 'counterfactuals', and by further controlling for time-variant characteristics of each village in the coming years.

Table 6. Impact of Devolution-Based Collective Action on Forest: Matching Based on Propensity Score

Panel A.	**Forest cover in**			
	Year 0	**Year 1**	**Year 2**	**Year 3**
Devolution-based collective action	-0.008	0.124**	0.040	-0.053
	(0.066)	(0.055)	(0.038)	(0.074)
Village characteristics	Yes	Yes	Yes	Yes
Province year fixed effects	Yes	Yes	Yes	Yes
Number of villages	44	44	44	44
Number of observations	88	132	132	88
R-squared	0.592	0.333	0.439	0.465
Panel B.	**EVI in**			
	Year 0	**Year 1**	**Year 2**	**Year 3**
Devolution-based collective action	-0.029	0.019	0.052*	-0.061*
	(0.035)	(0.038)	(0.026)	(0.034)
Village characteristics	Yes	Yes	Yes	Yes
Province year fixed effects	Yes	Yes	Yes	Yes
Number of villages	44	44	44	44
Observations	132	132	132	132
R-squared	0.493	0.373	0.469	0.663

Notes: Estimation uses pairwise matching based on the propensity scores of the results in column 1 of Table A4. A total of 22 pairs of villages are matched, satisfying the common support condition. For each of the 22 villages in the control villages, one similar village from the 'treatment' group – the villages with devolution-based collective action – is matched based on the most similar propensity score. Each pair should be similar in terms of the values of the covariates. Propensity score tests are reported in Table A5 (column set 1).
Each column reports the result of estimation using the dependent variable of forest cover (or EVI) in Year 0, 1, 2, and 3 since the adoption of devolution-based collective action, respectively. Regressions control for village characteristics including total population, average net income per capita, daily labor wage, population share having telephone, timber price, and weather variability – average and standard deviation of precipitation, days with temperature of 0-35 degrees Celsius and with temperature above 35 degrees Celsius. Significance is denoted: *** p<0.01, ** p<0.05, * p<0.1.

Compared to the earlier findings, the magnitude of the average treatment effect on forest cover is larger and is found in the next year. Taking column 2 of panel A, the point estimate of 0.124 suggests that the collective action led to an increase in forest cover by more than 30%, given the sample mean of 0.347 of the 22 pairs of matched villages. This is a sizable effect and can be attributed to property rights sharing in devolution-based collective action, which is not the case in the control villages, while they share many other

[12] It is important to note that the selection of covariates aims to estimate propensity scores of participation in the treatment and should not be interpreted as a causal link, because t-tests on the significance of individual parameters and goodness-of-fit measures can be misleading (Smith and Todd, 2005; Heckman and Navarro-Lozano, 2004). We conducted the propensity score matching using the psmatch2 procedure with one nearest neighbor and no replacement in Stata (Leuven and Sianesi, 2003).

observable characteristics with the treatment villages. On the average treatment effect on vegetation quality, the result is weakly significant and positive in the third year.

4.2 Does the Collective Action Lead to Increase in Household Income?

In the pre-reform periods, or for the villages without the reform, the village committee owns the forest, whilst villagers do not own any part of the forest in a formal way but can access the forest as an open resource. A lot of effort was spent in guarding the forest, which is unnecessary after the reform. Guaranteed use and expected returns that are embedded in the property rights of forests under community forestry increase the incentives for the villagers to cooperate in the protection of the forest, and we find evidence in support of this conjecture, as shown in Section 4.1.

The estimations in this section are done at the household level using equation (1), as discussed in the Section 3.2. Table 7 present the results of the difference-in-difference estimator of the impact of the devolution-based collective action on off-farm income and its share of total household income; income from farming; the household's self-estimation of the current forest production value to which it is entitled; total household income; and poverty status – measured by the absolute (USD 1.25 per day) and relative (the county's average level) poverty lines.

Panel A of Table 7 includes the households in the 22 villages in the control group and the 125 villages in the treatment group, totaling 1,712 households for three years – 2000, 2005 and 2010. The control variables include household and village characteristics, household and year fixed effects, respectively, and county year fixed effects in order to control for the variation in regional growth or policies in different periods that may influence the outcome variables. The coefficient of the treatment variable in Column (1) suggests that the collective action is associated with an average higher per-capita income from off-farm employment, by 2,121 CNY. Yet, Column (2) suggests that the higher share of off-farm income out of the household's total (0.074) is not statistically significant.

There is a trivial difference between the treatment and control groups in the average number of days that a household worked in off-farm jobs (see Table 2). In 2000, the collective actors worked 69 days per person on average, and so did the households in the control group (68 days per person). In 2010, the treatment group worked a little more, by 8 days per person, though it is statistically insignificant. Given our finding that the laborer seems not to work longer, yet has more off-farm income, a higher wage rate is a plausible explanation. It suggests that collective action improves allocative efficiency, by allowing the worker to seek a job that pays a higher wage or has a longer-term contract. How can collective action help a laborer get a job that pays more? The laborer does not have to worry about his/her rights in use and ownership of the forest, so he/she accesses to the job market until he/she finds a job that fits him/her the best; then, dedication to the job and improvement in the ability to work secure the job and wage payment.

Also, we find that the collective action significantly increases households' total per-capita income, by 2,357 CNY, in Column (5). An income increase would imply a reduction in poverty status, and we find that there does exist a reduction of the likelihood of a treatment household falling below the absolute (relative) poverty line, by 12 (18) percentage points (in Columns 6 and 7). The treatment effect on other outcomes, i.e., farming income, and households' estimates of forest product value, are insignificant.[13] The insignificant effect on farming income, in Column (3), *versus* the significant effect on off-farm employment, plausibly explain that the opportunity cost of collective action, if a treatment household had not done so, is much higher in terms of income from off-farm jobs than farming income. The findings are consistent with our conjecture that the voluntary collective management enables a household's labor to better engage in working off-farm.

As a related robustness check, Panel B of Table 7 add the households that are individually managing forestland into the reference category, and we find that the treatment effect is in general smaller than that found earlier, as in Panel A. Importantly, the decision to individually manage the forestland does not mean that the labor will be kept on the land. The not-so-labor-intensive feature of forestry would allow the individual managers to work off-farm as they want since the tenure of the forestland is secured. Therefore, compared to all other households – those in the control villages together with the households who are managing their own forestland – the collective actors have an increase in their per-capita off-farm income by 953 CNY (Column 1), and in overall per-capita income by 1,088 CNY (Column 5). Interestingly, the result in Column (2) suggests that their income from off-farm employment is 4.5 percentage points higher due to the collective action (significant at the 5% level). Noting that individual (household) management based on devolved ownership of forestland increases owner households' forest investment (Yi et al., 2014) and consumption of fuelwood – from own forestland plots and via the income effect as of increased income from forestry activities (Yang et al., 2017) – their welfare is improved. So, adding them into the reference category, as expected, reduces the estimated poverty

[13] In column (4) of Table 7, large standard errors explain the lack of statistical significance of the treatment effect on the value of forest products. This may attribute to the large deviation in households' self-estimations on the value of all forest products over the forestland that they are entitled to own a share.

reduction effect (in Columns 6 and 7) by half, to 6 – 7 percentage points *versus* the 12–18 percentage points in Panel A, if only comparing the collective actors with the households in the control group.

Table 7. Impact of the Devolution-Based Collective-Action on Household Income

	Off-farm Income (1)	Off-farm income (%) (2)	Farming Income (3)	Forest prod. Value (4)	Total Income (5)	Absolute Poverty (6)	Relative Poverty (7)
Panel A.							
Devolution-based collective action	2,121***	0.074	16.967	99.420	2,357***	-0.122**	-0.184***
	(654.689)	(0.048)	(140.591)	(111.868)	(593.454)	(0.055)	(0.056)
Household & village char.	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Household FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
County year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Number of households	1,712	1,712	1,712	1,712	1,712	1,712	1,712
Observations	4,165	4,165	4,165	4,165	4,165	4,165	4,165
R-squared	0.265	0.128	0.212	0.173	0.328	0.260	0.177
Panel B.							
Devolution-based collective action	953.4***	0.045**	-43.259	143.304	1,088**	-0.056**	-0.067**
	(365.763)	(0.022)	(174.529)	(138.732)	(419.731)	(0.024)	(0.029)
Household & village char.	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Household FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
County year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Number of households	3,066	3,066	3,066	3,066	3,066	3,066	3,066
Observations	7,285	7,285	7,285	7,285	7,285	7,285	7,285
R-squared	0.254	0.111	0.211	0.061	0.332	0.241	0.163

Notes: The income and value variables are in per capita levels. Panel A include households in the control villages and the villages of devolution-based collective action, and panel B adds the households that are individually managing forestland into the reference category. Standard errors are clustered at village level. Significance is denoted: *** p<0.01, ** p<0.05, * p<0.1.

We need to bear in mind the pre-existing differences between the collective-actor households and the households in the non-reform villages (see Table 2 and the Appendix Table A3, of year 2000). Again, we take advantage of the panel data setting and construct the counterfactuals of the treatment households. Using PSM and the nearest-neighbor matching algorithm, we obtain 248 pairs of households with similar village- and household-levels of characteristics in 2000.[14] For each pair, the two households were very similar in 2000 given all the covariates, and in 2010, one was treated but the other was not, so that the change in outcome can be inferred as a treatment impact. Furthermore, we control for the time-variant factors that may affect the outcome. Certainly, this exercise has a premise that any matched pairs of treatment and control observations should be very close on the covariates; the same applies to the village-level analysis that uses the same approach.

[14] The first-stage estimation result, using the logit model, is reported in Table A4 in the Appendix.

To assess the matching quality, Column set (2) of Table A5 in the Appendix, for the matched sample, presents the mean value for the treated and the control for each of the covariates. We also conducted a series of t-tests of the logit specification on the balance between the treatment samples and the comparisons of the control group to understand the quality of matching. The mean values of the observables and the predicted propensity scores are both very close between the treatment and the matched controls.

Table 8 presents the results of the difference-in-difference estimators based on PSM, with Panel A on the 248 pairs of households, Panel B using the households in the 22 pairs of (earlier) matched villages, and Panel C restricting the matched pairs of households in the 22 pairs of villages. The point estimates of the treatment impact on off-farm income and on total household income in Panel A are similar to the same set of estimates of Panel A in Table 7. Those on the other outcomes are not statistically significant. These findings strongly support the labor efficiency improvement in off-farm work due to the collective action. Further, restricting the pairs of household samples in the treatment and control villages that have very similar conditions, this impact is estimated stronger in magnitude – ranging from 2,864 to 3,204 CNY increase in off-farm income per person, and from 3,548 to 4,014 CNY of per-capita income increase in a household (Panels B and C).

Table 8. Collective-Action and Household Income: Household Matching Results

	Off-farm Income (1)	Off-farm income (%) (2)	Farming Income (3)	Forest prod. Value (4)	Total Income (5)	Absolute Poverty (6)	Relative Poverty (7)
Panel A. Pairwise matching							
Devolution-based collective action	1,891***	0.067*	512.312	198.032	2,378**	-0.032	-0.075
	(624.340)	(0.037)	(409.005)	(180.687)	(979.081)	(0.055)	(0.058)
Number of households	496	496	496	496	496	496	496
Observations	1,128	1,128	1,128	1,128	1,128	1,128	1,128
R-squared	0.237	0.107	0.141	0.081	0.280	0.259	0.146
Panel B. Households in the 44 matched villages							
Devolution-based collective action	2,864***	0.052	11.329	413.338	3,548**	-0.012	-0.080
	(951.124)	(0.045)	(178.253)	(366.601)	(1,352.474)	(0.075)	(0.074)
Number of households	389	389	389	389	389	389	389
Observations	819	819	819	819	819	819	819
R-squared	0.185	0.113	0.294	0.120	0.241	0.261	0.147
Panel C. Matched households in the 44 villages							
Devolution-based collective action	3,204***	0.063	61.936	486.375	4,014***	-0.012	-0.079
	(882.814)	(0.047)	(184.899)	(417.574)	(1,348.551)	(0.079)	(0.077)
Number of households	351	351	351	351	351	351	351
Observations	756	756	756	756	756	756	756
R-squared	0.217	0.121	0.299	0.134	0.258	0.259	0.149

Notes: The income and value variables are in per capita levels. Estimation uses pairwise matching based on the propensity scores (the first-stage results reported in Appendix Table A4, col. 2, and the balancing of covariates is reported in Table A5, column set 2). Panel A includes 248 pairs of matched households in the total of 147 villages; panel B includes the households in the 44 pairwise-matched villages (as in Table 6), and panel C includes the pairwise-matched households in the 44 villages. All the regressions control for village- and household-levels of characteristics that are variant in time. Standard errors are clustered at village level. Significance is denoted: *** p<0.01, ** p<0.05, * p<0.1.

Altogether, the above results show a large, significant effect of the devolution-based collective action on average income growth. Noting that the treatment households had over 1,000 CNY less per-capita income than did the control households before the action was taken, they caught up and surpassed by more than 1,500 CNY in 2010 (Table 2). Taking the average per-capita income of 3,062 CNY in 2000, the estimates of the treatment effect suggest the income growth of 78 percent, to 1.3-fold. In addition, the estimates on off-farm income (Column 1) and total income (Column 5) imply that the overall income effect came mostly from the off-farm income effect.

5. Conclusion and Policy Recommendations

China's forests account for 5 percent of the world's total and rank fifth in area size (FAO, 2015). The Collective Forest Tenure Reform has devolved and secured rights to forest resources to rural households; these rights are institutionally acknowledged and legislatively confirmed. For the large part of the population that is natural resource-dependent, sustainable and efficient management of natural resources is paramount for poverty alleviation and welfare improvement.

In this context, this paper is among the first investigations using detailed household-level income data together with a unique quasi-experiment to causally identify benefits of voluntary collective action. To overcome the endogeneity problem often faced in the existing literature, we utilize household-level fixed effects and propensity score matching based difference-in-difference estimations to correct potential bias driven by self-selection into treatment.[15] We have shown that the collective management based on devolved property rights to households encourages tree planting, which increases forest cover and protection of forests, while improvement in the canopy of vegetation may need a longer period to be seen. Collective action can also allow households to improve off-farm employment. Labor income in off-farm work can increase, so that households with time and capital constraints can benefit from economies of scale in joint management. Both increased off-farm income and efficient forest management can improve household welfare.

Altogether, our findings offer salient support that, with property rights, collective action can lead the allocation of resources towards efficiency – i.e., improved forest management and better engagement in off-farm work given the respective capabilities of the forest owners. We believe the reform fits well into China's rapid transformation from rural to urban economic activities that have increasingly demanded labor from rural villages. Forestland and standing trees store wealth; thus, as a productive and safety-net asset, the forest sector has a promising potential to contribute to the structural transformation process.

We suggest follow-up policies to further expand the coverage of the reform and to remove obstacles that impede cooperation. By providing clear property rights to secure tenure, policies can also be well-directed to reduce transaction costs that discourage efficient inter-household coordination, using methods such as cooperative meetings organized by village governments. For these collective actors in forest management, efficiency can be further improved through more education on silviculture and improved access to forest-product markets. Also, labor market policy can reduce transaction costs to help laborers get access to off-farm jobs, since labor market imperfection is pervasively faced by laborers in under-developed regions. Further, given the current contract period

[15] We acknowledge that there may exist some unobservable and time-variant factors that may correlate with the formation of collective-action and outcomes of interest. Abrupt changes in local social norms or individual social preferences are examples of such. In these cases, it is still possible that the estimates are subject to biases, as it is difficult even for the most rigorous empirical techniques to capture and correct all of these.

(e.g., 70 years) and secure ownership of forestland, a longer-term point of view of sustainable forest management can be fit into the collective action scheme. This will help the reform achieve a double-dividend effect in the long run – given the positive impact that we find on forest cover and on household income, and recalling that the earlier reforms had neither let households own forests nor have contracts longer than 30 years.

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Appendix

Table A1. Mean Values of Forest Cover and Vegetation Index: Polygon vs. Buffer

Year	Forest cover		EVI value	
	Boundary	Buffer	Boundary	Buffer
1999			0.498	0.488
2000			0.643	0.630
2001	0.496	0.406	0.634	0.620
2002	0.525	0.443	0.627	0.622
2003	0.533	0.440	0.605	0.590
2004	0.538	0.447	0.623	0.613
2005	0.534	0.434	0.618	0.609
2006	0.574	0.470	0.621	0.617
2007	0.577	0.475	0.617	0.604
2008	0.607	0.507	0.636	0.620
2009	0.596	0.497	0.622	0.613
2010	0.594	0.500	0.621	0.613
2011	0.604	0.510	0.627	0.616
2012	0.625	0.524	0.634	0.623
2013			0.645	0.633
2014			0.645	0.631
2015			0.648	0.635
2016			0.657	0.638
2017			0.670	0.660

Notes: Mean values of forest cover and EVI are reported for the measures using village-map boundaries and those using buffers created based on village center coordinates and total land area, for the 158 villages for which the village maps are available.

Table A2. Village Characteristics: Control Villages vs. Villages with Devolution-Based Collective Action

	2000				2005				2010			
	Total	Control	Collective-action	t-test	Total	Control	Collective-action	t-test	Total	Control	Collective-action	t-test
Forest cover (%)					53.3	21.6	58.9	***	58.7	27.3	64.3	***
Average EVI value	0.657	0.703	0.649	**	0.640	0.660	0.637		0.632	0.636	0.631	
Forest tenure reform adoption (%)	0.0	0.0	0.0		46.3	0.0	54.4	***	85.0	0.0	100.0	
Total number of households	334	351	331		353	381	348		392	460	380	
Total population	1,352	1,665	1,297	*	1,408	1,723	1,353		1,486	1,793	1,432	
Average net income per capita (CNY)	2,027	2,184	2,000		2,662	3,005	2,602		4,196	4,314	4,175	
Distance to paved road (km)	0.571	0.225	0.632		0.489	0.225	0.535		2.679	0.178	3.120	
Distance to county center (km)	30.067	20.250	31.795	**	29.986	20.250	31.699	**	28.038	25.182	28.541	
Households having telephone (%)	32.4	36.9	31.6		77.0	83.8	75.8	*	94.2	97.8	93.6	
Labor market wage (CNY/day)	34.449	32.955	34.712		49.436	47.013	49.862		74.726	70.700	75.435	
Labor worked off-farm (%)	20.1	27.1	18.9	**	29.2	34.0	28.3		32.8	38.7	31.7	
Total land area (mu)	23,203	3,988	27,192	***	23,399	3,946	27,255	***	23,967	4,337	27,552	***
Cropland area (%)	29.4	51.4	25.5	***	25.1	48.4	21.0	***	27.5	48.9	23.7	***
Total forestland area (mu)	12,875	3,471	14,530	***	13,379	3,503	15,117	***	14,447	3,124	16,440	***
Price of timber for sale (CNY/m3)	304	331	300		417	448	411		899	544	962	
Average altitude (m)	4,584	3,470	4,780		4,608	3,462	4,809		4,603	3,452	4,806	
Precipitation: average (mm)	38.31	33.90	39.08	*	39.14	35.54	39.77		48.62	36.62	50.73	***
Precipitation: std. dev. (mm)	101.24	110.67	99.58	*	108.75	115.27	107.60		126.13	104.73	129.89	***
No. of villages	147	22	125		147	22	125		147	22	125	

Source: Own computation from the EEPC survey data in 2006/2007 and 2010, and remote-sensing data of the MODIS land cover type and Landsat 7. Forest cover in 2000 is not available from the MODIS land cover type data.

Notes: 'Collective action' is defined as the treatment (the devolution-based collective action) and is the outcome of self-selection at the village level, i.e., member households *voluntarily* and the village *collectively* made the decision on the adoption of the reform to devolve forest tenure rights to member households and to manage their forests jointly. Mu is the land area unit in rural China, equal to one-fifteenth of a hectare. Asterisks indicate t-tests for significance of differences in mean values between the control and treatment groups. * = sig. at 10%; ** = sig. at 5% and *** = sig. at 1%.

Table A3. Household Differences Between the Control Villages and Villages with Devolution-Based Collective Action

	2000				2005				2010			
	Total	**Control**	**Treatment**	**Test**	**Total**	**Control**	**Treatment**	**Test**	**Total**	**Control**	**Treatment**	**Test**
Head of household:												
Male head (%)	95.6	90.3	96.6	***	95.4	90.4	96.3	***	94.7	90.8	95.2	**
Age	45.33	46.38	45.14		50.12	51.38	49.89	*	53.58	55.25	53.33	**
Education (years)	5.871	5.750	5.893		5.958	5.843	5.979		5.903	5.463	5.970	*
Communist Party member (%)	17.0	15.7	17.2		18.8	15.7	19.4		22.5	22.1	22.6	
Village leadership member (%)	6.4	5.6	6.6		6.8	5.6	7.0		7.3	8.6	7.1	
Household:												
Household size	4.485	4.673	4.451	*	4.486	4.667	4.453	*	4.514	4.466	4.521	
House value (10,000 CNY)	/	/	/		4.656	7.574	4.125	***	13.351	18.586	12.554	**
Per capita days worked off-farm	68.66	68.28	68.73		89.81	86.28	90.46		91.16	84.44	92.18	
Owned cropland per capita (mu)	1.596	1.514	1.610		1.713	1.566	1.739		1.755	1.846	1.741	
Forestland access per capita (mu)	27.66	1.78	32.34	***	27.22	1.78	31.85	***	19.19	4.31	21.46	***
Labor input in forest (days/mu)	7.263	4.085	7.838	**	9.218	5.407	9.912	***	11.086	7.941	11.565	
Investment in forest (CNY/mu)	87.26	104.11	84.20		149.23	213.00	137.61	**	234.98	179.74	243.39	
Owning forestland in 20 years	/	/	/		0.491	0.562	0.478	**	0.776	0.663	0.794	***
Transferability of forestland	/	/	/		0.795	0.677	0.816	***	0.868	0.831	0.873	
Total score of forest tenure rights	/	/	/		5.455	4.964	5.544	***	5.761	5.543	5.794	
Income and welfare measures:												
Total income (CNY per capita)	3,062	3,916	2,907	***	5,132	6,636	4,859	***	9,206	7,889	9,407	**
Off-farm income (CNY per capita)	1,938	2,529	1,831	***	3,181	3,780	3,072	**	5,880	4,297	6,121	***
Off-farm income (%)	48.4	51.7	47.8		56.3	58.0	55.9		56.3	50.6	57.2	**
Farming income (CNY per capita)	365	344	368		574	562	576		1,241	1,160	1,253	
Forestland value (CNY per capita)	39.41	13.39	44.12	**	92.97	41.96	102.26	**	399.13	83.55	447.16	**
Absolute poverty (%)	50.0	43.1	51.2	**	27.0	20.9	28.2	**	13.3	11.0	13.6	
Relative poverty (%)	49.7	41.9	51.1	***	30.4	24.1	31.6	**	25.4	22.7	25.9	
No. of households	1,618	248	1,370		1,616	249	1,367		1,234	163	1,071	

Source: Own computation from the EEPC survey data in 2006/2007 and 2010.

Notes: The treatment is defined as devolution-based collective action, i.e., member households and the village collectively made the decision on adopting the reform to devolve forest tenure rights to member households and to manage their forests jointly. Mu is the land area unit in rural China, equal to one-fifteenth of a hectare. Asterisks indicate t-tests for significance of differences in mean values between the control and treatment groups. * = sig. at 10%; ** = sig. at 5% and *** = sig. at 1%.

Table A4. Logit Estimates of Factors Correlated with the Devolution-Based Collective Action

	Village	Household
Distance to county center, km	0.055**	2.277***
	(0.025)	(0.873)
Distance to road with transport, km	0.070	0.421
	(0.085)	(0.518)
Ln (population)	0.219	4.042**
	(0.604)	(1.782)
Ln (Average income per capita)	1.300*	4.426**
	(0.678)	(1.811)
Population share having telephone	-1.801	-4.747**
	(1.537)	(2.047)
Farmland share	-2.027*	-29.55***
	(1.084)	(9.462)
Non-farm work labor share	-3.002	-9.002**
	(3.221)	(4.197)
Ln (Timber price)	0.994	2.243**
	(0.876)	(1.104)
Ln (Labor market wage)	-0.788	-10.48*
	(0.824)	(5.578)
Precipitation: average	0.213***	0.738**
	(0.078)	(0.287)
Precipitation: std. dev.	-0.104***	-0.338**
	(0.034)	(0.136)
Days with 0-35 degrees Celsius	0.000	
	(0.001)	
Days above 35 degrees Celsius	0.028	
	(0.116)	
Ln (altitude)	0.407	-1.424**
	(0.357)	(0.725)
EVI, one lagged year	2.420	
	(3.483)	
Ln (village forestland area)		-0.827
		(0.625)
Household-managed forest (%)		-0.807
		(1.659)
Household size		-0.026
		(0.077)
Male household head		1.097***
		(0.346)
Age of household head		0.008
		(0.009)
Educated years of head		0.139***
		(0.039)
Head is village leader		1.125
		(0.785)
Ln (Days of off-farm work)		-0.016
		(0.055)
Ln (Cropland area)		1.543***
		(0.578)
Ln (Forestland area)		0.120
		(0.121)
Observations	147	1,079
Log Likelihood	-34.71	-143.1
Pseudo-R	0.441	0.754

Notes: Dependent variable equals 1 if the village (col. 1) or household (col. 2) was participating in devolution-based collective action between 2001 and 2010 -- i.e., whose village adopted the Collective Forest Tenure Reform to devolve the ownership of forest tenure rights in this period and they voluntarily decided to manage forests jointly; and 0 if there had been no such reform adopted in the household's village by 2010. The constant term is not reported. Robust standard errors (in parentheses) are clustered at the village level. Significance is denoted: *** p<0.01, ** p<0.05, * p<0.1.

Table A5. Assessment on the Balancing of Matching Covariates

	(1) Matched villages		(2) Matched households	
Covariates	**Treated**	**Control**	**Treated**	**Control**
Distance to county center, km	12.982	20.250	2.309	2.454
Distance to road with transport, km	0.005	0.225	0.167	0.102
Ln (population)	6.897	7.080	6.996	7.094
Ln (Average income per capita)	7.368	7.474	7.329	7.482
Population share having telephone	0.404	0.369	0.366	0.413
Farmland share	0.355	0.514	0.137	0.453
Non-farm work labor share	0.093	0.086	0.218	0.323
Ln (Timber price)	5.553	5.675	5.611	5.696
Ln (Labor market wage)	3.535	3.423	3.696	3.422
Precipitation: average	39.940	33.897	39.057	32.677
Precipitation: std. dev.	107.47	110.67	101.02	104.950
Days with 0-35 degrees Celsius	6363	5919.6		
Days above 35 degrees Celsius	4.300	2.759		
Ln (altitude)	7.307	6.696	5.458	4.656
EVI, one lagged year	0.493	0.525		
Ln (village forestland area)			8.462	6.627
Household-managed forest (%)			0.591	0.686
Household size			4.444	4.673
Male household head			0.948	0.903
Age of household head			46.290	46.375
Educated years of head			5.726	5.75
Head is village leader			0.089	0.056
Ln (Days of off-farm work)			3.216	3.074
Ln (Cropland area)			0.764	0.777
Ln (Forestland area)			1.381	0.449

Notes: Based on the first-stage logit regressions (results reported in Table A2), the propensity scores are predicted, and the matching uses the algorithm of the nearest neighbor matching without replacement. The mean values of the covariates for the treatment and the control households in the matched sample are reported. In total, there are 22 pairs of villages (column set 1) and 248 pairs of households (column set 2).