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RESEARCH PAPER

Dependence of the Poor on Forest Resources: Evidence from China

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Abstract Quantifying the contribution of forest income to household's total income, especially the poorest, is important to understand rural livelihoods, causes of poverty and designing effective development and conservation strategies. Based on a large-scale household investigation of 1495 rural households of 82 villages in 7 provinces in China in 2014–2015, this study used descriptive statistical analysis and built multilevel models to explain individual heterogeneity. Results showed that: (1) the poorest households are the less dependent on non-farm income than other households due to fewer non-farm work opportunities; (2) forest income is important for all households, although poorest ones relied more on forests; (3) the average forest income of households in the richest group is three times as much as that of households in the poorest group; (4) forest income can be increased with more land accessible to the poor and fairer harvest quota applying system. Improving roads condition and increasing forest cooperatives increase household forest income as well. The findings of this paper will be useful in designing alternative policies to alleviate poverty and protect forest resources.

Keywords Forest reliance · Livelihood strategy · Multilevel model

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Introduction

In the last decade, the role of forest income in rural development and poverty alleviation has gained increased attention around the world. The major reason is the recognition of the significant relationship between forests and poverty (Sunderlin et al. 2008). Forests provide not only means of subsistence and income, but also insurance against risks and shocks (Vira and Kontoleon 2010).

China provides a special case study of forest income's role in poverty alleviation. Since 1998, the Chinese government has strengthened its ecological and forest protection policies due to the series of natural disasters, including the severe drought of the Yellow River in 1997, the massive floods along the Yangtze River in 1998, and serious soil erosion and sandstorms in the late 1990s. The government initiated national forestry projects which led to the rapid increase of forest area and forest growing stock volumes (FAO 2010). China's forest plantation area increased by 4.7 million ha since 1990, reaching 500 million ha in 2012 (Xu 2014). In the meantime, the number of impoverished people in China has decreased by 37.6%, 100 million people (Wang et al 2015). Yet hundreds of millions of people in China are still living below the poverty line, and most of them live in remote mountainous areas where forests serve as important economic income sources and safety nets for poor households (Liu and Xu 2015).

To tackle poverty and strengthen the volume and quality of the forest growing stock, the Chinese government initiated nationwide forest tenure reform (known as collective forest tenure reform)[1] based on family contract management. In addition, the Chinese government carried out a series of supporting policies, including forest ownership mortgage loans, forest property right transferring, forestry cooperatives, and policy-oriented forest insurance, which have promoted improved forest management and increased farmers' forest income (Zhou et al. 2011). The link between the nationwide Priority Forestry Programs (KPFPs)[2] and poverty reduction has also been suggested by many scholars (Bennett 2009; Liu et al. 2011). However, even though the Chinese government has integrated poverty reduction into its forestry plan, the role of forest income in household livelihood is still unclear due to a lack of empirical data and research studies (Katsigris et al. 2010).

Quantifying the contribution of forest income to the poor is important to understanding rural livelihoods, the determinants of poverty, and the reasons for forest degradation, and for designing effective strategies for development and conservation (Angelsen and Wunder 2003; Jagger 2012). Research about the role of forest income in household livelihoods has gained momentum (Cavendish 2000; Vedeld et al. 2004; Tieguhong and Nkamgnia 2012). However, few empirical studies of this issue have been conducted in China, and most of them have focused mainly on the effect of specific policies on household income (Weyerhaeuser et al.

[1] The reform guarantees farmers the long-term and stable rights to manage the collective forestland and own the forest property; these rights have inspired farmers' enthusiasm to manage their forests and have improved the farmers' livelihoods (He and Zhu 2014).

[2] KPFPs include the Sloping Land Conversion Program (SLCP), the Desertification Combating Program around Beijing and Tianjin (DCBT), the Wildlife Conservation and Nature Reserve Program (WCNR), the Industrial Timber Plantation Program (ITPP), and the Shelterbelt Development Program (SBDP).

2005; Xu and Xu 2007; Wang and Virginia 2012). Katsigris et al. (2010) used the survey data from 8 provinces and found that forests contributed greatly to households' economies, comprising 10–20% of their incomes. Hogarth et al. (2013) used data from 240 households in the Guangxi Zhuang Autonomous Region and found that the average forest-related income share was 31.5% and that lower-income households were more dependent on forests than were higher-income households. Peng et al. (2010) concluded that the forest dependence of farmers surrounding the Fanjing Mountain Nature Reserve was 18.6%.

Earlier studies often underestimated the real value of forest goods and services by either mistakenly grouping them into other sectors or entirely ignoring it (FAO 2008; Vedeld et al. 2004). This lack of accurate forest income data impedes the understanding of the role of the forest in household economies and rural development for the forest sector and other related economic sectors. This study has adopted the income calculation method introduced by the Poverty Environmental Network (PEN)[3] and has refined the method to incorporate the Chinese authority's definition of forest income and other income sources. Previous studies did not analyze the relationship between forest income and family wealth. In fact, rich farmers are less dependent on the forest, but larger income from the forest than do poor farmers.

The aim of this study is to explore the role of forest income as a livelihood strategy in rural China. Specifically, three questions are examined in this study: (1) What are the main livelihood strategies of poor residents in terms of income sources; (2) To what extent are poor households reliant on forest resources; and (3) What household characteristics and contextual factors determine the magnitude and relevance of forest income for households? To answer these questions, 1710 households in 7 provinces were surveyed. Income quintiles were constructed and one-way analyses of variance were conducted in order to examine the differences in forest income and livelihood strategies in the study area. Multilevel regression models were estimated in order to examine the effects of household-level and village-level on absolute and relative forest dependency of households.

Methodology

Data Collection

Our research group collected data from August 2014 to August 2015. The members of the research group were social science Master and PhD students who had some research experience and strong research interests. The team was trained in research methods and data collection before Rapid Rural Appraisals (RRAs) (Gao et al. 2012) and a household survey were conducted. Multi-stage, cluster sampling was used. First, based on the level of forest resources, 5–10 counties were chosen across all seven provinces. Based on the level of economic development, 2 villages were randomly selected from each of the chosen counties, and 15 households were

[3] For additional detail about PEN, see its website at http://www1.cifor.org/pen.

randomly selected in each village in Hubei, Jiangxi, Shannxi, Guangdong, and Liaoning provinces. More households (30) were randomly selected in each village in Yunan and Sichuan provinces since poverty alleviation and forest reliance are more crucial here.

We developed a survey containing questions on demographic characteristics and household income. The surveyed farmers completed the questionnaire on-site with the in-person assistance of a member of the research group. Initially, most of the households in each village were selected, but some dropped out, mainly because they found the interviews to be too time-consuming or to delve into sensitive issues. We used the definition of a household as "a group of people living under the same roof and pooling resources (income and labor) for their livelihood" (PEN 2007).

Many respondents might not be willing to answer questions about income, we designed a detailed questionnaire including questions about specific production behavior and relevant inputs and outputs, as well as other sources of income. With the help of village leaders and local staff, the research group was able to gather sufficient responses to calculate the farmers' sources of income.

After the survey was completed, the research group cross-checked each questionnaire three times to guarantee the quality of the data. Of the 1710 households surveyed, 1495 questionnaires yielding an 87.4% response rate. The remainder of the respondents were excluded from the analysis. The household head was the main respondent for our surveys. We captured data from the household head's spouse or from other adults (>18 years old) in the household only in cases in which the household head not available.

Income Calculations

Income was defined as the value added from labor and capital (Angelsen et al. 2014). In this study, household total income was measured as income per adult-equivalent unit (Cavendish 2000), including income from crops, livestock, forestry, wages, business, subsidies, and other sources, during a 1-year period. For self-employed households (e.g., households self-employed in agriculture, forestry, or business), income was defined as the gross value less the costs of the purchased inputs. Each household's extraction and production for its own subsistence needs were also included in total income (CIFOR 2007).

Forest income included income from timber (including bamboo) and non-wood forest products (NWFPs) and payment for ecosystem services (e.g., compensation for a household owning public welfare forest[4] or for participating in the SLCP[5]). Timber harvested for sale or for the household's own use (e.g., for building its own house or burning as fuel) were included in timber income. In addition to timber, forests provided a large variety of forest products, such as fruits, vegetables,

[4] Forests in China are divided into two categories—public welfare forests and commercial forests. Most of the public welfare forests are given priority in terms of protection, and logging in them is forbidden. The government compensates the households that own public welfare forests for their losses.

[5] The SLCP was instituted to stop the farming of land that is steeply slope or is prone to soil erosion and to promote the planting of trees instead. The SLCP introduced a fixed-payment incentive mechanism to compensate rural households that participate.

construction materials, mushrooms, ornamental plants, raw materials such as rattan and bamboo for cottage industries, honey, meat, and fish, which were all designated as NWFPs. Most NWFPs came from households' own forests, but some (e.g. wild Chinese medicinal herbs and vegetables) came from gathering activities in public forests. Evaluation of forest products was a difficult task (Angelsen et al. 2014). In this study, we used a market-based approach. Forest gate price was used to estimate the value of products such as fruits and vegetables. Fuel wood was valued by the price of its substitute (i.e., marketable fuelwood).

We treated other income sources as follows. Crop income consisted of income from planting grains, vegetables, and herbs. Livestock income were derived from the own use and sale of animals. Income from fish farming and beekeeping were also included in livestock income. Wage income included earnings from working outside the village and from working inside the village. Business income consisted of income from managing shops, restaurants, inns, and other self-owned businesses. Subsidies were financial aid provided by the government. Other income included remittances, loans, and all other sources not captured by the specified income categories.

Descriptive Analyses

Income quintiles were used in order to examine the differences in forest income and livelihood strategies in the study area. Households were ranked by total income and divided into 5 income groups from poorest (quintile 1) to richest (quintile 5).

One-way analysis of variance (ANOVA) F-tests were used to determine whether there are significant differences in socioeconomic characteristics and income components across the income quintiles.

Fitted curves with 95% confidence intervals were used to estimate the relationship between a household's forest reliance (i.e., forest income divided by total income) and it total income.

Multilevel Regression Analyses

In most traditional models, all individual information was attributed to one level to be analyzed, regardless of whether cross-sectional data or panel data are used. This approach averaged the heterogeneity among individuals and enlarged the parameter estimation errors (Gelman and Hill 2006). In addition, traditional models could not correctly describe and analyze the individual heterogeneity due to the multilevel differences. Although some scholars used dummy variables or control variables to distinguish level differences among individuals, those methods were based on the assumption that the level differences among individuals are fixed effects and thus ignored the random effects of the variable interactions between the environment level and the individual level (Gelman 2006). Meanwhile, the attributes of individuals with hierarchical relationships to each other might correlate with each other, which violated the principle of OLS that samples must be independent.

Multilevel (hierarchical) models relaxed the assumption of sample independence and they could be used to correct the estimate bias caused by non-independent data

(Hox 2002). Moreover, in contrast to a standard cross-sectional regression approach, in which varying intercepts or coefficients were introduced by use of dummy variables and interaction terms, multilevel models enabled the simultaneous and efficient estimation of group-level effects and predictors (Gelman 2006). The model was suitable for the analysis of hierarchically structured data, because it was not subject to traditional statistical hypotheses such as linearity, normality, homogeneity of variance, and sample independence (Gelman and Hill 2006).

We considered the influence of village-level variables on only the intercept for household income and then established the corresponding random intercept model. The model form was as follows.

$$\text{Household - level factors} : c_{ij} = \beta_{0j}^{'} + \beta_{1j}^{'} X_{ij}^{'} + \gamma_{ij}^{'}$$
$$\text{Village - level factors} : \beta_{0j}^{'} = r_{10}^{'} + r_{11}^{'} W_{j}^{'} + u_{1j}^{'}$$

c_{ij} represented a household's total income, absolute forest income, and relative forest income in 3 models. The measures of absolute forest income and total income were natural logarithm transformed to account for the non-normal distribution of the income data and estimated as generalized linear latent and mixed models (GLLAMM). For relative forest income (proportions between 0 and 1), we estimated fractional logit models (Papke and Wooldridge 1996). $X_{ij}^{'}$ represented the household-level factors, which included age, education and political leadership of household head, household size, number of household members with off-farm employment, total forestland area (household level), total cropland area (household level), livestock assets, and the distance from the forestland to roads. $W_{j}^{'}$ represented the village-level factors, which included total forestland area (village-level), total cropland area (village-level), the number of cement roads in the village, the distance from the village center to the township center, and the number of forest cooperatives in the village.

Results and Discussion

Socioeconomic Characteristics of the Sample

As shown in Table 1, household heads in the sample, on average, are 45.2 years old with 6.9 years of education. Of all of the household heads in the sample, 7% are village leaders. The average household include 3.9 adult-equivalent units (AEU). The average numbers of labor-force members and household members with off-farm employment per household are 3.5 and 1.4, respectively. Human capital in the highest income quintile is significantly higher than that in the other quintiles. Education of the household head in the richest quintile (8.0) is significantly higher ($P < 0.05$) than that of lowest-income quintile. And the proportion of village leaders is highest ($P < 0.1$) in the highest income quintile (11%). AEU in the highest income quintile (3.6) is significantly lower ($P < 0.05$) than in the lowest-income quintile, while the number of household members with off-farm employment in the highest-income households (2.0) is the highest ($P < 0.01$).

Table 1 Socioeconomic characteristics arranged by household income class

	Quintile 1 Poorest	Quintile 2 Poorer	Quintile 3 Medium	Quintile 4 Richer	Quintile 5 Richest	Mean	F value
Demographic variables							
Age of household head (yrs)	47.34	45.22	44.51	44.67	46.34	45.18	1.36
Education of household head (yrs)	5.83	6.78	6.37	7.37	7.98	6.88	3.57**
Political leadership of household head (if headman of village = 1, others = 0)	0.01	0.04	0.03	0.07	0.11	0.07	1.44*
Adult-equivalent units	4.69	4.30	4.00	3.83	3.79	3.88	1.56**
Number of labors	3.22	3.96	3.87	3.55	3.51	3.52	1.55
Number of household members with off-farm employment	0.85	1.25	1.56	1.76	1.98	1.44	2.38***
Average education of all family members (yrs)	5.35	5.95	6.13	6.53	7.15	6.54	1.67**
Family assets variables							
Living area (m^2)	106.25	101.01	107.63	118.56	128.82	113.96	2.54**
Value of livestock (1000 CNY)	45	65	71	119	259	99	2.15*
Distance of living place to nearest market (km)	24	20	21	19	17	20	1.35
Total forestland area (ha)	1.49	2.43	2.63	2.85	3.69	2.67	3.41***
Forestland area per capita (ha)	0.32	0.57	0.66	0.74	0.97	0.69	2.61**
Total cropland area (ha)	0.43	0.49	0.55	0.68	0.99	0.59	3.29**
Copland area per capita (ha)	0.26	0.31	0.35	0.39	0.43	0.35	4.45***

One-way ANOVA *F*-test was used for all variables

*, **, *** Indicates level of significance at the 10, 5, and 1% level, respectively

Duncan's test was applied depending on the variables' homogeneity of variance

Mean conversion rate for the year covered by the survey is 6.2 CNY: 1 USD

Living area and livestock value of the richest quintiles are significantly higher ($P < 0.05$) than that of poorer quintiles, indicating a positive correlation between physical capital and family wealth. The average distance from households' houses to the nearest market is 20 km, which can generally be traveled in 20 min by motorbike or 1 h by bicycle.

The average household forestland and farmland in the sample are 2.7 and 0.6 ha, respectively. Forestland and farmland of the richest households are significantly larger ($P < 0.05$) than those of poor households. Theoretically, farmers' lands are distributed equally according to the family size (Lohmar and Somwaru 2002).

However, the richest households have the fewest members but most of the land. In order to show more clearly the inequality of land distribution in the study area, Table 1 also provides farmland and forestland area on a per capita basis. Forestland per capita is significantly higher for the richest quintiles than for the poorest quintiles (1.0 ha compared to 0.3 ha), and cropland per capita is also significantly higher for the richest quintiles than for the poorest quintiles (0.4 ha compared to 0.3 ha).

It is clear that wealthy households had more natural capital. One possible reason is that households that participate in non-farm work have accumulated sufficient wealth to obtain more land through land transfers (Orlik and Rozelle 2008) or purchases of long-term management and use rights from the land auctions (Lu et al. 2002). Another reason for land inequality may arise during the process of new collective forest reform, which assign to individual households the forestland that have originally been managed by the village as a whole. Due to the exchange of power and interests based on social relationships, there may have been some inequality in that process of allocating the forestland (Zhou 2013). The average forestland obtained of the poorest households through the forest tenure reform was 0.41 ha, while number of the richest households was 0.68 ha according to our survey. However, pursuing the specific reason for the uneven land distribution is beyond the scope of this study.

Income Components

Table 2 and Fig. 1 show the annual income per capita and its components of the five income quintiles. Wage, crop, and forest incomes constitute the three main sources of households' total incomes.

Wage (11043.8 CNY) and business incomes (2420.8 CNY) of the richest households are significantly higher ($P < 0.01$) than that of other households. Wage and business incomes accounts for 68% of total incomes for households in the highest income quartile, while the percentage is only 7% for the poorest households, indicating that the richest households earn significantly more non-farm income than

Table 2 Components of net income per capita by household income class (units: CNY)

	Quintile 1	Quintile 2	Quintile 3	Quintile 4	Quintile 5	Mean	F value
Crop	813.95	1105.53	1646.99	1871.58	2064.94	1500.60	2.84**
Forestry	630.65	781.95	1154.95	1441.05	1893.24	1180.37	3.15***
Livestock	245.97	512.93	1026.26	1224.72	1945.44	991.07	1.76***
Wage	139.59	877.76	3520.80	7380.12	11,043.80	4992.41	3.34***
Business	13.34	20.90	539.60	1801.68	2420.80	1129.26	4.67***
Subsidies	266.38	263.81	243.49	199.37	154.06	255.42	0.24
Others	93.96	289.53	456.73	432.31	394.58	373.42	0.54
Total	2203.84	3852.40	8588.82	14,350.83	19,916.87	10,422.55	3.23**

One-way ANOVA *F*-test was used for all variables

*, **, *** Indicates level of significance at the 10, 5, and 1% level, respectively

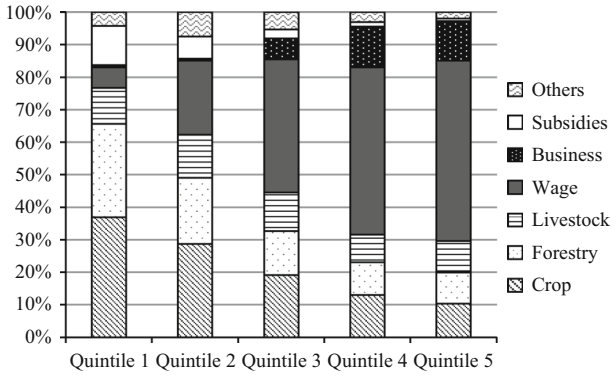

Fig. 1 Contribution of income components to total income according to income quintiles

other households. Many researchers stated that non-farm income played a very important role in the process of poverty reduction in China (De Janvry et al. 2005; World Bank 2009) and was widely regarded as a major approach for alleviating poverty in the forest and rural areas of China (Haggblade et al. 2002). However, many poor households have few non-farm work opportunities, owing to restrictions in labor and skills (Gao et al. 2012).

Crop income of the richest group (2064.9 CNY) is significantly higher ($P < 0.05$) than that of the low-income and middle-income groups. Forest income (1893.2 CNY) and livestock income (1945.4 CNY) of the richest group are significantly higher ($P < 0.01$) than that of the other groups. However, farm income (crop, forestry and livestock income) constitutes 77% of total income for households in the lowest income quintile but only 30% for households in the highest income quintile. It is clear that the richest households obtain the highest farm income, poor households heavily rely on forests and other natural resources for their income. With regard to subsidies and other income, there are no significant differences among the income quintiles.

The Contribution of Forest Income to Household Economics

Figure 2 shows the correlation between households' forest reliance (forest income as a share of total incomes) and the logarithm of their total income: Panel (a) shows all households, and Panel (b) shows forest user households only. For all households, the fitted curve of the relationship between forest dependence and total income has a negative relationship ($R^2 = 0.42$). For forest households, forest dependence is negatively related to income ($R^2 = 0.64$), indicating that higher-income households are less dependent on forests. We also calculate forest income elasticity by regressing households' total income (log) to forest income (log), namely the percentage increase in forest income when total income increases by 1%. The forest income elasticity is 0.64, that is; when total income increases by 1%, forest income

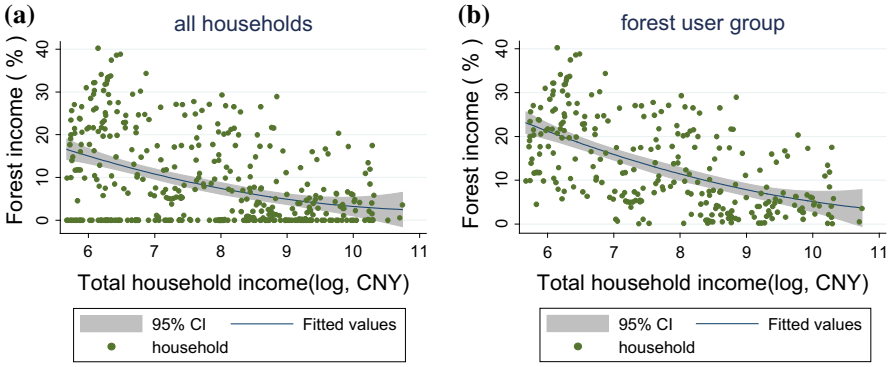

Fig. 2 The relationship between forest reliance and total income **a** for all households; **b** for forest user group only. *Note*: the fitted values were quadratic regression curves CI = 95% confidence interval of the fitted values

increases by 0.64%. This finding shows that increasing total household income will lead to forest income increasing in absolute terms but decreasing forest income as a share of total income.

Figure 3 shows the forest income and forest reliance of each income quintile. The average forest reliance, as measured by forest income as a share of total income, is 11.32%. Forest reliance of the richest group is only 9.5%; however, the proportion is 28.62% for the poorest group. Therefore, we believe that forestry will continue to play a role in supporting livelihoods and reducing poverty, especially in the remote mountainous areas where there are fewer non-agricultural employment opportunities.

With regard to absolute forest income, the richest group has the highest forest income 1893.24 CNY, which is three times as much as the income of the poorest group. This finding shows that although forest income is more important to poor households, rich households harvest more forest products. Rayamajhi et al. (2012)

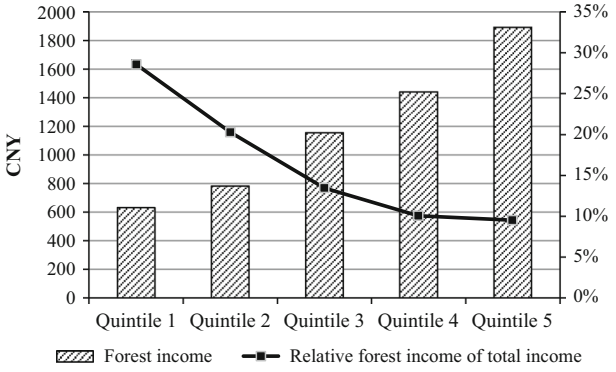

Fig. 3 Absolute and relative forest income by income classes. Mean conversion rate for the year covered by the survey is 6.2 CNY: 1 USD

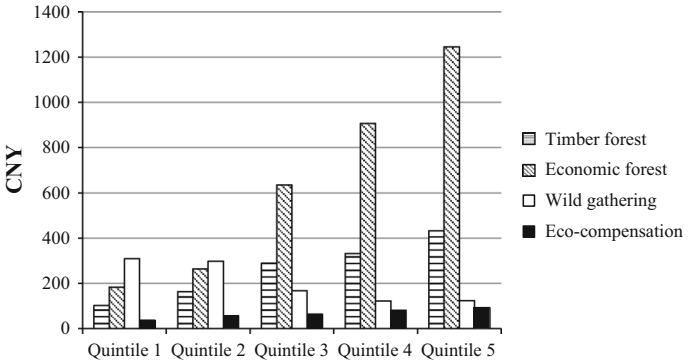

Fig. 4 Contribution of forest-related income sources to total forest income according to income quintiles

also found that average forest income of households in the lowest 25% forest-income bracket constituted only one-third of that of the highest 25% forest-income bracket. Therefore the government should be vigilant and avoid forests becoming a means of wealth accumulation among the wealthier, privileged households. On one hand, they have the most forestland (see Table 1). On the other hand, they have higher social capital, which help them to win the harvest quota and find the best sales approach (Zhou 2013).

Figure 4 shows the components of forest income for each income quintile. Timber income for all households is low, accounting for only 21% of total forest income, due to the Chinese government's strict forest conservation policy (e.g., ecological public welfare forest protection policy and wood harvest quotas[9]). However, households in the richest group earn the most timber income. The reason for that inequity may be that the richest households can obtain more harvest quotas in the village-level harvest quota allocation process, due to their better social relationships (Stark et al. 1986). The proportion of households who perceived it was easy to apply for harvest quota for the poorest households was 17.39%, while the number for the richest households was 34.21%. The main factor that leads to the disparity in forest income is the inequality of economic forests[6] incomes. Because there are no government constraints on management of economic forest, the richest households gain more economic forest benefits through owning and managing more economic forestland and adopting technology. The poorest households gain the most income from gathering wild resources.[7] Wild resources gathering is very time-consuming and labor-intensive. Wild resources gathering usually take a person an average of 5 h, walking 2–5 km in high mountains according to our survey, and most (75%) of the collectors surveyed said that the required collection distance was farther and the time consumed was longer than during the previous 5 years. In

[6] An economic forest (cash tree) is a type of forest that produces mainly fruits, edible oils, industrial raw materials, medicinal herbs, and other non-wood forest products.

[7] The main wild resources gathered are Chinese herbal medicines, such as Chinese caterpillar fungus, unibract fritillary bulb, rhizoma coptidis, rhizoma gastrodiae, grifola, eucommia bark, poria cocos, and honeysuckle.

addition, households have more income sources than they did previously; thus, a decreasing number of households engage in wild resource gathering. However, because the value of wild herbal medicine is very high, wild resource gathering income is a very important source of income for the poorest households.

Household and Contextual Determinants of Forest Income and Reliance

Table 3 reports the coefficients and standard errors of the three multilevel regression models, in which the dependent variables are absolute forest income (log), forest income's share of total income, and absolute total income (log).

Family Characteristics

Age of the household head had a negative relationship with total household income but a positive relationship with both absolute and relative forest incomes. One reason may be that older household heads, due to less education of traditional ideas, are more inclined to engage in traditional farm work. In addition, compared with younger people, older people have more difficulty in obtaining non-farm employment opportunities. As we expected, education of the household head has a positive effect on absolute household income (both forest income and total income) but a negative effect on relative forest income. When the education of the household head increases by one year, the household's absolute forest income increases by 4.6% ($P < 0.05$), its total income increases by 10.3% ($P < 0.01$), and its relative forest income decreases by 7.2% ($P < 0.05$). Higher education usually related to additional opportunities to obtain new information and increasing openness to various views and ideas about jobs opportunities (Liu and Xu 2015); therefore, higher education reduces the household head's dependence on forestry. Political leadership of the household head also significantly increases both absolute forest income and total income. Compared with other households, households whose heads are village leaders earn 9.7% more absolute forest income ($P < 0.01$) and 4.7% more total income ($P < 0.05$). Village leaders can more easily seek benefits for themselves during the harvest quota distribution process and the forestland allocation in order to earn more forest income (Zhou et al. 2011). Moreover, village leaders are the elite in their villages, they earn more total income.

Household size has a negative effect on both absolute forest income and total household income. A household size increase of 1 AEU, equates to a 15.1% decrease in absolute forest income ($P < 0.10$) and a 16.8% decrease in total income ($P < 0.05$). The important reason is that income in this study is measured in AEUs. However, household size has a positive (but not statistically significant) effect on relative forest income. The effect may occur due to the difficulty and time-consuming nature of forest resource exploitation. Large households, with more laborers, may be more likely to engage in forestry production activities. The number of household members with off-farm employment has a negative effect on both absolute and relative forest income but a positive effect on total household income. A 1 AEU increase in the number of household members with off-farm employment equates to a 10.2% decrease in absolute forest income ($P < 0.05$) and an 11.6%

Table 3 Multilevel regression models

	Forest income		Total income (log)
	Absolute (log)	Relative (% of total income)	
Household-level variables			
Age of household head (yrs)	0.007	0.007*	−0.006
	(0.014)	(0.022)	(0.035)
Education of household head (yrs)	0.046**	−0.072**	0.103***
	(0.073)	(0.137)	(0.297)
Political leadership of household head (if headman of village = 1, others = 0)	0.097***	0.031	0.047**
	(0.184)	(0.225)	(0.350)
Household size (adult equivalent unites)	−0.151*	0.101	−0.168**
	(0.134)	(0.076)	(0.042)
Number of household members with off-farm employment (persons)	−0.102**	−0.116***	0.211***
	(0.115)	(0.121)	(0.167)
Total forestland area (log)	0.016**	−0.012*	0.008*
	(0.078)	(0.072)	(0.041)
Total cropland area (log)	−0.324	−0.536*	0.138**
	(0.193)	(0.133)	(0.068)
Livestock assets	−0.021	−0.039*	0.054**
	(0.048)	(0.039)	(0.013)
Distance from forestland to roads (km)	−0.148*	−0.105*	−0.001
	(0.047)	(0.180)	(0.014)
Forestland slop (steep = 1, others = 0)	−0.281**	−0.127*	0.000
	(0.065)	(0.340)	(0.007)
Village-level variables			
Village-level total forestland area (log)	0.283***	0.192**	−0.130*
	(0.335)	(0.401)	(0.113)
Village-level total cropland area (log)	−0.228**	−0.319*	0.239**
	(0.298)	(0.335)	(0.100)
Number of cement roads in village	0.419	−0.086	0.073**
	(0.298)	(0.387)	(0.112)
Distance of the village center to the township (km)	−0.024	0.002*	−0.003**
	(0.014)	(0.013)	(0.004)
Number of forest cooperatives in village	1.365**	0.482*	0.048
	(0.276)	(0.451)	(0.093)
Constant	8.056	4.087	6.221
	(4.233)	(3.353)	(1.191)
Log-likelihood	−651.04	−675.85	−490.57

Table 3 continued

	Forest income		Total income (log)
	Absolute (log)	Relative (% of total income)	
AIC	1833.56	1433.50	1015.14
BIC	1956.76	1445.88	1080.67

Values in the parentheses are standard errors

Relative forest income was estimated as fractional logit multilevel model

Absolute forest income and total income was estimated as generalized linear and latent mixed models (Gllamm)

*, **, *** Indicates level of significance at the 10, 5, and 1% level, respectively

decrease in relative forest income ($P < 0.01$) but a 21.1% increase in total household income ($P < 0.01$). Forests provide lower returns than other income sources; thus, they are usually classified as inferior production environments (Angelsen and Wunder 2003). Because laborers tend to be assigned to more productive income sources, households that engage in a large amount of non-farm work are faced with high opportunity costs of forest resources extraction and thus may be less likely to engage in forestry production activities.

Assets

Forestland area has a positive effect on households' forest (absolute and relative) and total incomes. A 1% increase in forestland area equates to a 1.6% increase in absolute forest income ($P < 0.05$), a 1.2% decrease in relative forest income ($P < 0.10$), and a 0.8% increase in total household income ($P < 0.10$). Farmland area and livestock value have positive effects on households' total incomes ($P < 0.05$) but negative (but not statistically significant) effects on absolute forest incomes, indicating a potential crowding-out effect (competition for labors for crops, livestock, and forestry). Unexpectedly, farmland area and livestock value have negative effects on households' relative forest incomes ($P < 0.10$), showing that asset-poor rural households rely more on forestry. Livestock value is highly correlated with household income ($\rho = 0.87$), which further shows that poor households are more dependent on forestry than are rich households.

Forestland Characteristics

The distance from forestland to roads has a negative effect on households' absolute and relative forest incomes. A 1 km increase in distance equates to a 14.8% decrease in absolute forest income ($P < 0.10$) and a 10.5% decrease in relative forest income ($P < 0.10$). As expected, forestland slope has a negative effect on households' absolute and relative forest incomes. Compared with households that own flat forestland, households that own steep forestland earn 28.1% less absolute

forest incomes ($P < 0.05$) and 12.7% less relative forest incomes ($P < 0.10$). Those characteristics of forestland has no significant effect on households' total incomes.

Village Characteristics

The more forestland a village has, the higher its households' absolute and relative forest incomes and the lower its households' total incomes. Village cropland area has the opposite relationship with the three measures of income: the more cropland area a village has, the lower its households' absolute and relative forest incomes and the higher it households' total incomes. The number of cement roads has a positive effect on absolute forest and total household incomes but a negative effect on relative forest income; the number of cement roads acted as a proxy for traffic, indicating that traffic improves household income and reduced forest dependence. Similarly, the distance from the village center to the township has a negative effect on absolute and relative forest incomes but a positive effect on relative forest income; the distance from the village center to the township is a proxy of marketization, suggesting the higher the marketing degree is, the more household income and the less forest dependence. The number of forestry cooperatives has a positive effect on absolute and relative forest and total household incomes.

Conclusions and Policy Implications

In this study, we conducted a household investigation of 1495 rural households across 82 villages from 7 Chinese provinces. We performed descriptive statistical analysis and constructed empirical econometric models. Those analyses have showed the important role of forestry in the livelihood of rural households, especially poor households.

Richest households earned significantly higher non-farm income than did other households. Wage and business incomes account for 68% of total income for households in the highest income quartile, while the percentage is only 7% for the poorest households. Although non-farm income is widely regarded as a major approach for alleviating poverty in the forest regions, many poor households have few non-farm work opportunities, owing to lack of labor and skills. Therefore we recommend attaching great importance to the role of traditional income sources, such as crop and forest income, in poverty reduction besides non-farm work, because the poorest households depend mainly on income from the land.

Although forest income is important for all households, the poorest ones rely most heavily on forests. Higher household income is associated with lower forest dependence. The average forest dependence for the sample is 11.32%, while the ratio of the richest group is only 9.5% and the ratio of the poorest group is 28.26%. Forestry will continue to play a role in supporting livelihoods and reducing poverty, especially in the poor areas where there are few non-agricultural employment opportunities.

Even though the richest households are the least dependent on forests, they earned the highest forest incomes. The average forest income of households in the

richest group is three times that of households in the poorest group due to the greater amounts of forest land and better social relationships. The government's poverty alleviation policy must pay more attention to the poorest households, those that own fewer resources, and try to reduce the inequity through resource reallocation, compensation, and other policies.

With regard to the components of forest income, the main reason for the disparity in forest income across the income quintiles is the inequality of economic forest income. Poor households should be encouraged to plant economic forests to earn more forest income. Existing evidence suggests that a large number of households have achieved large profits by managing economic forests (He and Zhu 2014). The government can provide seedlings, technical training, market sales information, and other assistance to help poor households to take advantage of economic forests.

The results of the multilevel regression models show that education and political leadership of household heads have significant positive effects on households' forest incomes. Village leaders can more easily seek benefits for themselves during the harvest quota distribution process, hence the harvest quota application system should be made more transparent and fair in order to increase households' timber incomes. Forestland area and number of forest cooperatives also proved to have positive effects on households' forest incomes. Forest cooperatives should also be encouraged to help the rural households earn more forest benefits. Distance from forestland to roads and forestland slope have significant negative effects on households' forest incomes. Infrastructure building is needed in forest areas to improve roads condition. However, for those forestlands far from roads or too steep to manage, collecting non-wood forest products is a good way to increase household incomes. For example cultivating herbs used in Chinese medicine.

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