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Rural household income distribution and inequality in China: Effects of payments for ecosystem services policies and other factors

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Abstract

In the late 1990s, China initiated the Conversion of Croplands to Forest Program (CCFP) and the Ecological Welfare Forest Program (EWFP) based on the Payments for Ecosystem Services (PES) principle. Positive socioeconomic outcomes of the programs are essential for the long-term success of eco-environment conservation. However, there is lack of understanding of their longer-term (over 10 years) impacts on rural livelihoods. In this paper, we examine income distribution and inequality of rural households under CCFP and EWFP in rural Anhui, China after 12 years of program implementation. Results show that CCFP-participating households have higher income inequality than non-participants, while the EWFP does not have an significant effect. Local off-farm work and out-migration with remittances are the two principal income sources and both add to inequality. A regression-based decomposition of inequality shows that the CCFP indirectly alters livelihoods by increasing out-migration with remittances, but it also adds to inequality from shifting livelihoods to non-agricultural activities. Meanwhile, EWFP payments positively affect agricultural incomes and contribute 16% to agricultural income inequality. Finally, human capital,

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natural capital and physical capital all play important roles in generating income and inequality, but the factors affecting inequality from agricultural and non-agricultural activities are different.

Keywords

Household livelihoods; Inequality; Gini coefficients; Payments for ecosystem services; Environmental policy; Sustainability; Rural China

1. Introduction

Rural poverty closely links to environmental degradation (Leonard, 1989; Reardon and Vosti, 1995; Barbier, 2000; Angelsen et al., 2014). In developing countries, rural farmers often use unsustainable farming practices that degrade land, leading to soil erosion and nutrient depletion. While some farmers may escape the degraded environment by searching for and finding alternative livelihood activities (Anderson and Leiserson, 1980; Bilsborrow, 1992; Barrett et al., 2001), others continue to deplete the natural resources that their livelihoods depend on. The poor who deteriorate the environment become trapped in poverty, particularly in many rural areas of developing countries (Azariadis and Stachurski, 2005; Dasgupta et al., 2005; Barbier, 2010).

To address the adverse nexus between rural poverty and environmental degradation, Payments for Ecosystem Services (PES) programs have been adopted worldwide by policy-makers as an innovative approach for environmental conservation (e.g., Claassen et al., 2008; Pagiola, 2008; Turpie et al., 2008; Ezzine-de-Blas et al., 2016; Song et al., 2018). The PES approach provides economic incentives to potential ecosystem service providers in order to secure the provision or maintenance of ecosystem services (Wunder, 2005; Wunder et al., 2008). The implementation of PES programs in developing countries often relates to land use and targets land parcels used by rural households, sometimes in remote rural areas (Chen et al., 2010). Thus, the government acts on behalf of the public by making payments to rural farmers for environmental conservation. Although the underlying idea of PES is straightforward, putting such programs into practice faces a plethora of challenges (Pattanayak et al., 2010). For one thing, PES programs are often designed with more than one goal, including conserving key ecosystem services and stimulating rural households to adopt alternative livelihoods with more sustainable income. The success of PES programs often depends on the success of the affected households' livelihood shift or diversification. Thus, empirical evidence of socioeconomic outcomes is needed to evaluate the PES programs, including changes in livelihoods.

In the late 1990s, in response to back-to-back major natural disasters of drought and flooding, China implemented a series of new forest policies based on the PES scheme (Zhang et al., 2000). These policies were initiated with ambitious goals of forest restoration and soil and water conservation (Liu et al., 2008). Among all the polices, the Conversion of Cropland to Forest Program (CCFP), also known as the Sloping Land Conversion Program (Lin and Yao, 2014) or the Grain-to-Green Program (Liu et al., 2008), is regarded as the largest forest restoration program. In the CCFP, participating households convert croplands on steep slopes or otherwise in ecologically sensitive areas to forests or grasslands and

receive compensation from the central government (Zhang et al., 2017). Since most of the affected lands are in low-income rural areas, the CCFP also helps to alleviate poverty (Song et al., 2014). By 2014, the central government had invested about 300 billion Chinese yuan on the CCFP, involving 32 million rural households in 25 of the 31 provinces, municipalities and autonomous regions (State Forestry Administration, 2015). In addition to the CCFP, China also adopted new strategies to conserve existing natural forests. The Ecological Welfare Forest Program (EWFP) is one of such programs, which is linked to the classification-based forest management (Dai et al., 2009). The purpose of the EWFP is to preserve natural forests to protect ecosystem services as part of public welfare. In the EWFP, households receive annual payments for giving up commercial timber harvesting privileges, although subsistence use of natural forests, such as fuelwood, is permitted. Thus, the EWFP can also be regarded as a PES program.

Both the CCFP and EWFP programs have direct and indirect impacts on rural livelihoods. The CCFP alters land use (directly reduces the cropland area in use) of households and thereby may release farm labor for non-farm activities (Zhang et al., 2018a). Meanwhile, the EWFP restricts the use of existing natural forests, perhaps stimulating people to rely on activities to make up the income lost from traditional timber sale. Moreover, compensation from the programs may also lead rural households to adjust their income sources. By shifting rural livelihoods, farmers generate income from off-farm activities while reducing the risk of falling back onto dependence on farming, where a household can be devastated by a single crop failure (Ellis, 2000a; Groom and Palmer, 2012).

Since the implementation of the new forest policies, empirical studies have evaluated the socioeconomic impacts of China's PES programs, most focusing on rural household livelihoods under the CCFP (Uchida et al., 2009; Yao et al., 2010; Liang et al., 2012; Kelly and Huo, 2013; Lin and Yao, 2014; Liu and Lan, 2015). Empirical research in three provinces (Sichuan, Shaanxi and Gansu) found that, during 1999–2004, the CCFP had positive impacts on off-farm labor employment for participants since payments can relax the liquidity constraints (Uchida et al., 2009). Similar results were found based on 1998–2006 panel data in Shaanxi Province, but the major reason was the transfer of farm labor to non-farm labor (Kelly and Huo, 2013). However, a more integrated analysis suggested that the positive impacts of the CCFP on household income were mainly indirect and mediated by both labor transfers and liquidity constraint relaxation (Lin and Yao, 2014). In the Loess Plateau region, the CCFP (1999–2006) was found to significantly affect incomes in different economic sectors for participants, but the effects varied by program extent and local economic status (Yao et al., 2010). The impacts of the CCFP on rural livelihoods are also influenced by household composition, according to a household survey in Shaanxi Province after six years of program implementation (Liang et al., 2012). In addition to income generation, the CCFP could increase livelihood diversification, particularly for low-income households (Liu and Lan, 2015).

More recently, investigating rural household income generation in more detail, including its components and distribution, has become of ever increasing interest for research on rural livelihoods under the PES programs. In particular, income inequality has been a major concern with regard to sustainable development in China, particularly in rural areas where

environmental policies have been implemented (Li et al., 2011; Liu et al., 2014). Li et al. (2011) compared income inequality between households participating in CCFP and those not participating in western China and found those participating had lower income inequality seven years after CCFP implementation. Liu et al. (2014) analyzed the effects of three Key Priority Forestry Programs to household income inequality and found that the contributions of the programs change over time and across places. These studies implicitly assumed that rural households could not have negative incomes, which, however, often occurs, especially with agricultural incomes. In addition, they did not directly link inequality to the underlying determinants of household income generation, including the forest policies. The study here in a different location and over a longer time-frame is intended to shed further light on these relationships.

Based on of the findings from previous studies, further research on rural livelihood change under China's PES forest programs is needed. First, existing studies have evaluated the effects of the programs on rural livelihoods in the early years of project implementation, but rural livelihoods changes need time to take effect. Second, most focus on a single program (i.e., the CCFP) in isolation, and cannot capture the effects of programs operating simultaneously at the same location (i.e., concurrent programs), which is very common in practice. Third, few studies explicitly address the driving factors of income inequality in a decompositional manner, making it difficult to explain income distribution under the programs.

Thus, the present paper aims to investigate rural household income distribution and inequality following implementation of two *concurrent* PES forest policies after 12 years of program implementation, which can be considered as providing a medium-term assessment of the impacts of PES programs on livelihoods. We first analyze the income sources for households enrolled in the CCFP and EWFP programs. Then, we examine income inequality and the contributions of different sources of income to total income inequality. Finally, we examine the underlying factors of income generation and their contributions to income inequality. The results will provide useful information on the process of rural livelihood change for the evaluation of the PES programs in China and other developing countries.

2. Study Area

The study area, Tiantangzhai Township, is located in a mountainous region in western Anhui Province, China (Fig. 1). The area covers 189 km^2, with elevations ranging from 363 m to 1,729 m above sea level. The dominant land cover is natural forest, as the area forms part of Tianma National Nature Reserve (Chen et al., 2018; Zhang et al., 2018b). Natural forests within the reserve are designated as Ecological Welfare Forests and protected from commercial logging by local farmers. Due to the beautiful natural scenery, part of the nature reserve has also been developed as a tourist attraction.

The township is home to over 4,369 households with a population of 17,295. These households are clustered in 165 resident groups, which are further organized into seven administrative villages. A resident group is a natural cluster of 10 to 40 households, who used to work together on collective farms (Wang et al., 2019). With the implementation of

the rural Household Responsibility System in China in the early 1980s, the collective cropland parcels were distributed to individual households in the resident group (Li et al., 1998; Zhang et al., 2018c). Due to the rugged terrain in the study area, most parcels are small on the slopes with poor soils. Therefore, crop yields are low, and the farmers can barely make ends meet.

To generate more income, households are usually engaged in other economic activities. Some households raise domestic animals such as pigs or chickens, or collect forest resources, such as *Gastrodia Elata* (GE)[1], which is naturally grown on the forest floor. Growing GE is also a lucrative business in the local area. Other households allocate labor to off-farm activities, either in the local area or far away in cities via out-migration (Zhang et al., 2018a). Some households also own local non-farm businesses in the tourist areas within the township, such as hotels and retail stores. In addition, most households receive some government subsidies for farming. Finally, households with any member over 60 years old receive some modest elderly subsidies.

In Tiantangzhai, CCFP and EWFP have been implemented for over 12 years by 2014. The CCFP was initiated in 2002. A total of 753 households had enrolled some of their croplands in this program by 2014, almost all joining in the early years. Under the CCFP, households received 230 yuan/mu/year (1 mu = 1/15 ha; US$1 = 8.2 yuan in 2002) of cropland converted to forest for the first 8-year period, and 125 yuan/mu/year for a second 8-year period following the end of the initial contract period (Song et al., 2014). The selection of cropland for enrollment in the CCFP was largely determined by the local government and implemented by the local forestry station. Although household participation is officially voluntary, cropland parcels that met certain criteria were identified and selected by the local government for reforestation. The local village officials then “persuaded” the farmers to “voluntarily” enroll the identified parcels into the CCFP. The way of enrollment ensures the creation of forest clusters instead of isolated tree patches not forming forest. Thus, there was little or no self-selection bias for households to participate in the CCFP in the study area.

The other PES subsidy, EWFP, is associated with the establishment of the nature reserve in the middle 1990s. Due to the mountainous topography, almost all rural households[2] have some natural forests. The establishment of the nature reserve automatically qualified all natural forests within the reserve to be ecological welfare forests, automatically enrolling the forest owners in the EWFP. As the government adopted the PES approach in the late 1990s, households with EWFP forests began to be compensated with cash at the end of each year for giving up commercial logging and thereby preserving their forest areas. The EWFP compensation rate in Anhui Province was 8.75 yuan/mu/year at the time of the survey in 2014. Because the area of natural forests managed by households varies widely, the amount

[1]Gastrodia Elata (GE) is a fungus that naturally occurs on the forest floor in mountainous areas throughout eastern and southern China. Due to its perceived value in Chinese medicine, GE can also be cultivated as a cash crop. Growing GE requires a high investment initially for seeds (pores). Pores must be inoculated into freshly-cut logs of certain tree species, half buried in partially shaded moist soil. GE sales generate the primary cash income for some households.

[2]This excludes “five guaranteed” households, which are rare cases (Zhang et al., 2018a). “Five guaranteed” households are usually those whose members are too old to support themselves with no other means of livelihood. The local community, or the resident group, collectively provide a livelihood support, guaranteeing these members with food, clothing, housing, medicine, and burial after death.

of compensation received by households from the EWFP also has wide variation. Despite the low compensation rate per mu, most rural households have large areas of natural forest and thus have been receiving reasonable payments from the EWFP.

The study area belongs to a county in poverty in rural China. Therefore, the need to assist/stimulate rural households there (and in other similar areas) is of great policy importance to reduce widespread rural poverty. Since the implementation of the two forest policies, rural residents in Tiantangzhai have been observed to change their livelihood behaviors. Some households abandoned cropland of low productivity and allocated farm labor to other economic activities (Zhang et al., 2018a; Wang et al., 2019). Others, meanwhile, sent out migrants, receiving remittances to increase and diversify their income sources (Zhang et al., 2018c). Such behavioral changes can play critical roles both in sustaining rural livelihoods and forest conservation in the study area in the long run. Thus, Tiantangzhai is an ideal site for addressing the poverty-environment nexus and studying rural livelihoods under the two concurrent PES programs.

3. Materials and Methods

3.1 Household survey

This study uses data from a rural household survey in Tiantangzhai Township implemented during the summer of 2014. In the survey, we used disproportionate stratified sampling technique (Bilsborrow et al., 1984) to select both the resident groups and the households within the selected resident groups, including samples of households participating and not participating in the CCFP. Given that only about one fifth of the rural households participated in the CCFP, a simple random sampling of households would have resulted in only about one fifth of the households in the CCFP. Therefore, we need to oversample CCFP households so the final sample would have similar numbers of households with and without the CCFP participation. The survey was carried out in July-August 2014 by interviewers following training them for two weeks. The fieldwork eventually resulted in 481 successfully interviewed households with complete data, 271 participating in the CCFP and 210 not participating. Selected households have complex sampling weights due to the sampling scheme used. Detailed sampling procedures can be found in Song et al. (2018).

For the household survey, we designed a detailed structured questionnaire which obtained information on incomes from all sources, including farm activities (growing crops and raising domestic animals), cash income from the forests including GE, incomes from small business and local off-farm work, remittances from out-migrants, government subsidies of various types in addition to the PES subsidies, and miscellaneous income such as bank interest, rents from a house/rooms, and gifts (cash or in kind) from former household members or other relatives. Questions used to capture the incomes and costs of these sources are provided in Table A1 in the Appendix. Following the survey data collection, imputations were made for missing data in a few cases on price or volumes of outputs (based on data from other households in the resident group), to avoid deleting household data records (Table A2 and A3 in Appendix).

3.2 Sources of income

Before analyzing incomes and inequality, it is necessary to identify income sources of rural households, which we divide into nine categories: crops and domestic animals (referred to as *Crops* and *Animals*), PES subsidies (*PES*), forest resources (*Forest*), local non-farm business profit (*Business*), local off-farm income (*Off-farm*), remittances from out-migrants since 2000 (*Remittances*), non-PES government subsidies (*Subsidies*), and other income from miscellaneous sources (*Other*) such as social gifts or financial support from others. We then compare the total net income and per capita net income from each source for households 1) with and without CCFP participation and 2) receiving EWFP payments above and below the mean.

Crops harvested and domestic animals raised were not only for sale but also for their own consumption (often most or all of the production) in the study area. Thus, we estimated values of own-consumption of crops and domestic animals in order to estimate total income from these farm activities. We estimated the values of crop production and domestic animals by multiplying the quantities produced by their corresponding unit prices in local markets (Table A4 in Appendix). Total agricultural income is then the sum of incomes from the sales of crops/animals (including animal products such as eggs and milk) and the values of items produced for self-consumption.

Regarding forest resources, cash income from GE cultivated under forest canopy is often the largest source of agricultural income for many households in the study area. In addition, with the ban on timber harvesting in the EWFP forests, fuelwood collection is for personal use and thus is not considered a source of income from forests. Finally, income from the PES programs is the sum of compensations from both the CCFP and the EWFP, while "government subsidy" are the sum of all other subsidies, excluding those from the two PES programs.

3.3 Income inequality

3.3.1 Standard Gini coefficients for non-negative income—The Gini coefficient has been widely used for a long time as an indicator of inequality, especially with respect to assets and income distribution (Leibbrandt et al., 2000). The standard Gini coefficient uses only non-negative values, which lead to the Lorenz curve for a geometrical interpretation. First, households are ranked from the lowest to the highest income; then, the Lorenz curve is constituted as the cumulative proportion of income on the vertical or y-axis against the cumulative proportion of households on the horizontal or x-axis. When all households have the same identical or equal income, the Lorenz curve is a straight line, which is the 45-degree Line of Complete Equality. At the other extreme, when one household holds all income and all others have no income, the Lorenz curve is the horizontal axis out to the last person when it shoots up to the 45 degree Line. The Gini coefficient is the ratio of the area between the Lorenz curve and the Line of Perfect Inequality over the area between the two lines of extreme cases, namely the total area under the 45-degree line. The Gini value is hence 0 for perfect equality of incomes and 1.0 when one household has all the income. The Gini coefficient can be estimated from the following equation:

$$G = 1 - \sum_{i=1}^{n} (X_i - X_{i-1})(Y_i + Y_{i-1}) \quad (1)$$

where n is the number of households, X_i the cumulated proportion of households up to the i^{th} household, and Y_i the cumulated proportion of income for the same households i, with i = 1, 2, …, n, with $X_0 = 0$, $X_n = 1$, $Y_0 = 0$ and $Y_n = 1$.

Given k sources of total income, the concentration coefficient (C_k), also known as the "pseudo-Gini" coefficient, is an important indicator for revealing the inequality of income from source k. The "pseudo-Gini" mimics the Gini coefficient calculation but re-orders source k income according to the household rank in total income (Raffinetti et al., 2017). When C_k is greater than (overall) G, income from source k expands (worsens) total income inequality. When C_k is smaller than G, income from source k reduces total income inequality. The expression for C_k can be written as:

$$C_k = \frac{2cov[Y_k, F(Y)]}{\mu_k} \quad (2)$$

where Y and Y_k are total income and income from source k, respectively, while μ_k is mean income from source k. Meanwhile, $cov[.]$ denotes the covariance function, and $F(.)$ denotes the cumulative distribution of total income (Y). For example, $F(Y)=f(y_1),\ldots, f(y_n)$, where $f(y_i)$ is the rank of y_i divided by the total number of observations (Stark et al., 1986).

3.3.2 Normalized Gini coefficient with negative income—Negative incomes can arise in empirical studies, particularly with agricultural incomes (Raffinetti et al., 2015). In this case, the Gini coefficient can be outside of the range of 0–1. Thus, it is necessary to adjust the coefficient in order to compare inequality between groups which may have some households with negative values. Here, a normalized Gini coefficient developed by Raffinetti et al. (2015) is applied. This normalizing approach not only deals with the standard estimation but also handles cases when some households have negative incomes.

Starting from the standard estimation with non-negative values, the Gini coefficient can also be expressed as the "relative mean difference" of unordered incomes, as shown in eq. (3):

$$G = \frac{\left(\frac{1}{2N^2}\right)\sum_{i=1}^{N}\sum_{j=1}^{N}|Y_i - Y_j|}{\left(\frac{1}{N}\right)\sum_{i=1}^{N} Y_i} \quad (3)$$

where Y_i and Y_j are incomes for the i^{th} and j^{th} households, respectively, and N is the total number of households.

Normalization deals with the mean of household incomes, i.e., the denominator in eq. (3), taking into account total amounts of both positive and negative incomes in absolute terms. Thus, the normalized Gini coefficient can be written as:

$$norm\_G = \frac{\left(\frac{1}{2N^2}\right)\sum_{i=1}^{N}\sum_{j=1}^{N}|Y_i - Y_j|}{\left[\frac{(N-1)}{N^2}\right][|\sum_{i=1}^{N} max(0, Y_i)| + |\sum_{i=1}^{N} min(0, Y_i)|]} \quad (4)$$

where *max*(.) denotes the higher of the two values in the parenthesis, and *min*(.) the lower.

Similarly, the normalized concentration coefficient takes into account both negative and positive incomes from source *k*, but also considers the relationship between the orders of source *k* income and total net income, as shown in eq. (5):

$$norm\_C_k = \frac{\left(\frac{1}{2N^2}\right)\sum_{i=1}^{N}\sum_{j=1}^{N}(Y_{k,i} - Y_{k,j})I_{k,i-j}}{\left[\frac{(N-1)}{N^2}\right][|\sum_{i=1}^{N} max(0, Y_{k,i})| + |\sum_{i=1}^{N} min(0, Y_{k,i})|]} \quad (5)$$

where $Y_{k,i}$ and $Y_{k,j}$ are incomes from source *k* for the i^{th} and j^{th} households, respectively, and $I_{k,i-j}$ is an indicator that ranks source *k* incomes following the non-decreasing order of total net income. The indicator takes the value of 1 when $Y_i > Y_j$, and −1 when $Y_i < Y_j$. In the case of $Y_i = Y_j$, the value of the indicator depends on source *k* incomes for the i^{th} and j^{th} households, taking 1 if $Y_{k,i} \geq Y_{k,j}$ and −1 if $Y_{k,i} < Y_{k,j}$. The interpretation of the normalized Gini and concentration coefficients are the same as that of the standard ones.

3.4 Determinants of income generation and inequality

Underlying factors such as assets and human capital can play critical roles in income generation for rural households (Ellis, 2000b) and thus contribute to income inequality. In this study, we use a regression-based approach (Wan and Zhou, 2005; Wan, 2002) to explore the contributions of various potential income driving factors to the overall Gini coefficient. We first develop an income generation function for total income. Based on the livelihoods framework, we propose that total household income depends on human capital, natural capital (land endowment), physical capital such as household assets, and exogenous political-economic factors including the PES programs.

We construct three models with the dependent variables being agricultural income, non-agricultural income and total net income. Agricultural income is from crops, domestic animals and forests, while non-agricultural income includes business profits, local off-farm incomes and remittances from migrants who were formerly household members. The explanatory variables include the highest education among adult (aged 15+) household members (*Education*), age and gender of that key member with the highest education (*Age* and *Gender*), numbers of male adults and female adults currently living in the house (*Male adults* and *Female adults*), percentage of household members able to provide farm labor (*Farm labor*), total amount of cropland owned (*Cropland*), whether the household raises domestic animals (*Animal raising*), whether the household extracts forest resources such as GE (*Forest resources*), adult labor time (per 100 person-days) engaged in the previous 12 months in local off-farm work of household members (*Off-farm labor*), adult labor time (per 1000 hours) engaged in local non-farm businesses (*Business labor*), whether the household

sent any out-migrant since 2003 who have not returned (*Out-migration*), and two indices of household potential producer assets available, farm tools and equipment (*Farm tools*) and transportation equipment (*Transportation*). In addition to age of the key household member, we include age squared (Age^2) in the model to control for possible nonlinear effects of age. For instance, a young child who is still at school or an older person may be associated with low incomes while an middle-aged adult has a higher income. To incorporate the effects of the PES programs, the model includes two variables relevant to the two forest policies – the EWFP forest area (*EWFP area*) and the CCFP reforesting area withdrawn from cultivation (*CCFP area*). Since the compensation rate is fixed, the amount of payment depends exclusively on the area of CCFP or EWFP land.

It should be noted that we use the individual attributes of the *adult household member with the highest education* instead of those of the household head because the former is usually a better representative of the person in the household who is most responsible for the generation of household income, which will often be the person working off-farm or managing any household business; this is even more likely when the titular household head is a quite old parent as is very often the case in rural Chinese households. We also note that the calculations of household wellness scores for farm tools and transportation are derived from questions in the survey provided in Table A5 in the Appendix. Independent variables with their means and standard deviations are provided in Table 5.

We use the mixed-effects model to analyze the determinants of income generation since it allows for random effects of the intercept to control for unmeasured differences across resident groups (a rough control for contextual factors). The general model can be written as:

$$y_{ij} = \beta_0 + \sum_{p=1}^{P} \beta_p x_{ijp} + \mu_j + \varepsilon_{ij} \tag{6}$$

where y_{ij} is total net income (or total agricultural or total non-agricultural income) for the i^{th} household in the j^{th} resident group, and x_{ijp} is the p^{th} predictor for that household. Fixed effects of the intercept and of the independent variables are captured by β_0 and β_p, respectively, with β_p corresponding to x_{ijp}. Random effects at the household level and the community level are captured by ε_{ij} and μ_j, respectively.

Given the income generation function, we derive the contributions of independent variables to the overall Gini using the regression-based approach (Wan, 2002). First, replace all x_q's (for $q = 1, 2, \ldots, P$) with the sample mean values $\bar{x}_q$ to predict total income. Let this predicted income be Y_q. Then, let $G(Y_q)$ be the Gini coefficient of Y_q, which can be considered as the contribution of all other independent variables except one, X_q. Thus, the difference between the Gini of the original income Y and the Gini of the predicted income Y_q, written as $G_q = G(Y) - G(Y_q)$, can be attributed to the effect of the omitted variable, X_q. This effect is referred to as the first-round effect of X_q, as shown in eq. (7) and eq. (8):

$$Y_q = f(X_1, X_2, \ldots, \bar{X}_q, \ldots, X_P) \rightarrow G(Y_q) \tag{7}$$

$$G_{q,1} = G(Y) - G(Y_q) \tag{8}$$

The procedure can be extended to as many rounds as the number of independent variables. For example, at the second round, two variables X_q and X_r are replaced by their means. The second round effect of X_q can be calculated as $C_q = G(Y_r) - G(Y_{qr})$, for $r = 1, 2, \ldots, P$ and $r \neq q$. Within each round, we can obtain more than one Gini contributing values for a certain independent variable, so the final round effect is the average of these values, as shown in equations (9–12):

$$Y_{q,r} = f(X_1, X_2, \ldots, \overline{X}_q, \ldots, \overline{X}_r, \ldots, X_P) \rightarrow G(Y_{qr}) \tag{9}$$

$$Y_r = f(X_1, X_2, \ldots, \overline{X}_r, \ldots, X_P) \rightarrow G(Y_r) \tag{10}$$

$$G^r_{q,2} = G(Y_r) - G(Y_{qr}) \tag{11}$$

$$G_{q,2} = \frac{1}{P-1} \sum_{p=1}^{P} G^p_{q,2}, (p \neq q) \tag{12}$$

Finally, we average the effects of all rounds to generate the final effect for that variable (i.e., X_q), as shown in eq. (13).

$$G_q = \frac{1}{P} \sum_{p=1}^{P} G_{q,p} \tag{13}$$

4. Results and Discussion

4.1 Income sources and levels

Based on our survey in 2014, incomes from local off-farm work and remittances from out-migrants are the two principal sources of income for households in Tiantangzhai (Tables 1 and 2). Thus, most rural households rely on these two sources of income more than that from agricultural activities, consistent with the findings of a previous study (Song et al., 2014). Meanwhile, subsidies from the PES programs, which include both CCFP and EWFP, account for the smallest share of income of any source listed. Households participating in the CCFP or with large areas of EWFP forests received larger payments from the two PES programs, as expected.

For CCFP households, as shown in Table 1, mean total annual net income is 35,440 yuan (US$5,716, US$1 = 6.2 Chinese yuan at the time of the survey), which is only slightly (4%) higher than that for non-CCFP households with 34,130 yuan (US$5,505). Per capita annual income of CCFP households (13,900 yuan or US$2,242) is also slightly (6%) higher than

that of non-CCFP households (13,090 or US$2,111). CCFP households have significantly higher total net incomes, as well as income proportions in total incomes and per capita incomes, from all three of the agricultural activities, including crops, domestic animals, and forest resources, compared to households not participating in the CCFP. This suggests that households who enrolled cropland in the CCFP achieved higher outputs from these agricultural activities, which is consistent with the findings in other study areas that in the short-run (first round of the CCFP, 6–8 years after implementation) farm productivity rises as they seek to maintain farm production even on less land (Liu and Lan, 2017). In the Anhui study area, CCFP households earned forest income (mainly from *Gastrodia Elata* or GE) at nearly double the level of non-CCFP households, with the difference being statistically significant at the 10% level. Hence, growing more GE (which is done in the forest, not on cropland) appears to be done more by CCFP households to increase on-farm income to replenish income lost from withdrawing cropland, which had freed up some farm labor. Perhaps at times the subsidy payments themselves were used to purchase the expensive seeds to commence GE cultivation.

Meanwhile, CCFP households have only slightly higher incomes than non-CCFP households from local off-farm work and remittances from out-migrants, with the differences between the two groups not statistically significant. Contrary to what was expected, CCFP participants received less income, albeit insignificantly less, from businesses than non-CCFP households, showing the small PES subsidies did not lead to more entrepreneurial activity. Furthermore, both household groups received similar modest amounts of *other* government subsidies, such as grain and comprehensive subsidies. Finally, the large difference in the mean miscellaneous income of the two types of households might be attributed to the extreme cases of income from “social gifts”, which are common in rural China (whether paying or receiving). However, the amount of income from this source is usually modest compared with incomes from other sources, fluctuates widely from one year to another (receipts greater than expenditures only when the household has a new baby, wedding or death), and over time tends to be offset by households’ social gifts to others. Thus, miscellaneous income is not further discussed here.

Regarding the EWFP, as shown in Table 2, households with higher EWFP payments have higher, albeit insignificantly, total annual net incomes than the other household group receiving lower payments due to having less forest land (mean income of the former being 37,060 yuan or US$5,977 versus 33,970 yuan or US$5,479, a difference of 9%). In addition, households receiving higher EWFP payments have significantly higher incomes (and per capita incomes as well) from domestic animals and forests, leading to much higher income shares in total incomes for these two sources. Meanwhile, incomes, particularly per capita incomes, from local non-farm businesses, off-farm work and remittances for these households with above-mean EWFP payments are slightly *lower* than those for households with below-mean EWFP payments. This is probably because households with lower EWFP payments usually live at lower elevations and thus have better access to local off-farm work and business opportunities (Zhang et al., 2018c). Finally, we did not find statistically significant differences in mean government subsidies or other incomes between these two groups.

4.2 Income inequality among income sources

Fig. 2 illustrates the Gini coefficients for total net income as well as agricultural and non-agricultural income with Lorenz curves for the different household groups. Overall income inequality in Tiantangzhai is captured by the Gini of about 0.40, which is slightly lower than that of China as a whole of 0.47 in 2014 (Han et al., 2016), reflecting the tendency for rural incomes to be less varied than urban ones in general.

The Gini coefficient of total annual net income for CCFP households (0.466) in Tiantangzhai is higher than that for non-CCFP households (0.397), indicating greater inequality among CCFP participants (Fig. 2, top left), who also have a higher mean income. This result from comparing inequality of households with and without CCFP participation differs from one based on other study areas in western China (Li et al., 2011), where income inequality among CCFP participants was lower after seven years of policy implementation. The difference here may be attributed to greater induced changes in income generation activities over time in CCFP households, as discussed above, or to differences due to the different geographic settings of CCFP and non-CCFP households. Regarding the former, in Tiantangzhai by the time of the survey in 2014, livelihood behaviors of the study households reflect more what may be referred to as medium-term (after 10–13 years) rather than short-term implementation effects. At the same time, the two Lorenz curves for the households with EWFP payments above and below the mean are almost identical, with Gini coefficients of 0.402 versus 0.405 (Fig. 2, top right). This suggests that EWFP payments are distributed randomly among households of different income levels.

Dividing total income into agricultural and non-agricultural incomes reveals intriguing differences in Gini coefficients and Lorenz curves for the household groups (Fig. 2, middle and bottom panels). It should first be recalled that negative incomes, as depicted in Lorenz curves, tend to appear mostly in agricultural activities. In general, CCFP households have greater inequality in both agricultural and non-agricultural incomes than non-CCFP households, with the difference in inequality of non-agricultural incomes considerably larger (0.620 versus 0.488) than that of agricultural incomes (0.588 versus 0.551). As CCFP participants retired croplands, they have become more willing to take risks of engaging in both agricultural and non-agricultural activities, although poorer CCFP participants may not be successful in generate more incomes, particularly from non-farm activities.

On the other hand, the above-mean EWFP recipient household group has a lower Gini coefficient (more equal) in agricultural income than the below-mean group. This can be explained by the fact that poorer households tend to be at higher elevations and own larger areas of EWFP forest land and thus receive more EWFP subsidies (Zhang et al., 2018c), which helps increase inputs and outputs of agricultural activities, leading to more equal distributions of agricultural income among these households. In terms of non-agricultural incomes, inequality is slightly greater for the above-mean group, due to that better-off households in this group tend to use income from the EWFP payments to invest off-farm activities.

Table 3 provides measures of inequality attributable to different income sources of CCFP households and non-CCFP households. Overall, negative income values occur in the

livelihoods of farming crops, raising domestic animals, extracting forest resources (highest) and running a local non-farm business (very slight). Since local off-farm work incomes and remittances have the largest income shares in total income, their effects on total income inequality in terms of the "pseudo-Gini" coefficients tend to be larger than those of the other income sources.

For CCFP participants but not for non-participants, an income source that expands inequality is forest resources, which has a slightly higher "pseudo-Gini" coefficient of 0.481 than the total Gini of 0.466. Incomes from crops, domestic animals, PES payments, business, other subsidies and other miscellaneous sources of income all have lower pseudo-Gini coefficients than the total Gini, thus lowering income inequality. It should be noted that the direct effect of PES payments is to improve income distribution, a worthy policy achievement even if not an explicit objective of the PES program. But the CCFP seeks to shift rural households' livelihoods towards non-farm activities, and in a sustainable way, and seems to have succeeded for many rural households enrolled in the program. These two induced effects involve principally increasing involvement in off-farm non-agricultural work plus out-migration resulting in the subsequent substantial remittances from migrants (Zhang et al., 2018a), both of which tend to *worsen* income distribution among CCFP households, more than counteracting the direct effects of the CCFP subsidies. Moreover, some low-income CCFP participants who retired land may be unable to overcome obstacles to enter the off-farm job market, due to lack of education or skills or locational obstacles combined with lack of transportation, nor did they improve existing agricultural activities, such as by taking advantage of forest resources. Thus, some low-income households with land enrolled in the CCFP end up being even more trapped in low-income traditional agricultural activities.

For non-CCFP households, in addition to off-farm incomes and remittances, business profits and other miscellaneous incomes worsen income distribution. In contrast to CCFP households, income from business for non-CCFP households increases inequality, with its pseudo-Gini (0.663) much higher than the total Gini (0.397). This is because fewer households engage in business (only 6.6%, compared to almost double that for CCFP households) and some of these have high incomes. Incomes from the "Other" source also widen total inequality, due likely to a few extreme cases of households receiving high social gifts in the year. Similar to CCFP households, incomes from agricultural activities for non-CCFP households account for low shares of total income and lessen inequality. PES subsidies, which all come from the EWFP for non-CCFP participants, has a negative pseudo-Gini coefficient, suggesting that EWFP subsidies are received primarily by low-income households, viz., those living at the higher elevations who tend to have more forest lands.

The general patterns regarding sources of income and their effects on inequality are similar for the two household groups classified according to their level of EWFP payment (Table 4). Similar to the results for household groups classified by CCFP participation, incomes from off-farm work and remittances are the major sources of income inequality for both EWFP household groups. In addition, business profits make significant contribution to inequality despite their low shares in total income, due to the small proportions of households engaged in running businesses and the high profits of some. Income from all three agricultural

activities (i.e., farming crops, raising domestic animals and growing GE) all tend to lower inequality, as above, and the EWFP subsidies directly reduce inequality, even more than the CCFP payments. But unlike the CCFP, the EWFP does not affect (reduce) cropland area, nor does it free up farm labor from cultivation.

4.3 Income generation and inequality decomposition

4.3.1 Income generation factors—Before presenting and discussing the results of the statistical model of the determinants of household income, it is important to present descriptive statistics on the explanatory variables that may influence income generation. Table 5 lists and defines the independent variables, along with their means and standard deviations. The mean highest level of education of the adult household member with the highest education is 9 years, corresponding to completed middle school. These persons have a mean age of 35 years, with 32% being females. The mean number of male and female adults currently living in the house at the time of the household survey is 1.1 and 1.2, respectively. About one third of all household members are adults available to farm, and sample households own a mean of 5.38 mu (0.36 ha) of cropland altogether, scattered in 3–5 plots usually.

In terms of other livelihood activities, about 83% and 57% of the sample households engaged in raising domestic animals and cultivating GE under forest canopy, respectively. The mean labor time engaged in local off-farm work is about 55 days or nearly 2 months per year (the mean for households with off-farm activities is 137 days or 4.5 months per year, and 54% engaged in this activity, see Table 5). However, the mean labor time for businesses is only about 230 hours/year for all households in the sample, although the mean value for the households with business (11%) is 1,980 hours (nearly three months). On average, 55% of sample households have sent out-migrants since 2003 (who are still outside the house at the time of the survey). As for household wellness index, households generally possess basic farm tools such as hoes, an ox, and an electric pump, with a mean score of 2.40 for farm tools and equipment (see Table 2 in Appendix). The mean index score for transportation equipment is 2.48, indicating the average transporting condition is at a level between having an electric bike and a motorcycle.

Finally, households have 47.7 mu of EWFP forests on average, or about 3.2 ha, which is about a magnitude larger than the mean area of cropland (5.4 mu or 0.36 ha) and the area of land enrolled in the CCFP (1.14 mu or 0.076 ha). Accordingly, the mean amount of EWFP payments (417 yuan/year or US$67 per year) received by households triples that of the CCFP (140 yuan/year or $22 per year) in the previous 12 months to the survey time in 2014. Note that mean values refer to those received by all sample households, including both CCFP households and non-CCFP households. The mean CCFP area for CCFP households (i.e., excluding non-CCFP households) is about 2 mu, meaning that these participants receive 250 yuan (US$40) per year on average.

4.3.2 Determinants of income generation—Table 6 provides the results for the effects of the underlying factors on generating household incomes from agricultural activities (crops, domestic animals and forests), non-agricultural activities (business, off-

farm work, and remittances) and total income. We focus on interpreting the results from those factors that have statistically significant effects on income generation, examining agricultural incomes first, followed by non-agricultural and finally total income. We also first discuss the statistical results for the regression coefficients and later discuss the G columns.

In the first model on the determinants of agricultural income, a number of factors reflecting human capital, farm labor availability and relevant physical assets appear to be important in income generation. For individual attributes of the household member with the highest education, gender plays a key role, as when this person is male, growing crops, raising domestic animals and extracting forest resources tend to be more successful. Nevertheless, among all the factors, the availability of farm labor (including female adults) has a large effect on agricultural income generation, together with the two other factors, raising domestic animals and cultivating GE. Meanwhile, total cropland area and farm tools also have significantly positive effects. All these results are consistent with expectations, as they reflect the factors involved in agricultural livelihood activities. Regarding the two PES programs, only the EWFP area has a statistically significant association with agricultural income, although the effect is trivial and the amount of subsidies small relative to total agricultural incomes. This is even more true for CCFP, whose effect is not statistically significant. A plausible explanation for the effect of EWFP is that households with large EWFP forest lands (thus receiving higher payments) may use the cash to invest in agriculture, such as fertilizers and farm equipment. If a household receiving high EWFP payments also participates in the CCFP (i.e., retires some cropland parcels to reforest), it is even more likely to intensify agriculture on its remaining cropland.

Moving on to the factors explaining non-agricultural incomes, among those with statistically significant effects, out-migration has a strong positive relationship with total non-agricultural income, showing that rural households have increasingly come to rely on remittances from out-migrants (Chen et al., 2014). This, together with positive effects of local off-farm work and business, is expected since these activities directly generate income such as via waged labor and profits. In addition, when the person with the highest education is male, this has a substantial positive effect on non-agricultural income generation, even though it is often the female adult who finds local off-farm employment such as tertiary sector jobs in hotels, schools, tourism, and restaurants (note strong positive coefficient for female adults in household). Another factor that has a statistically significant effect is transportation equipment, which facilitates household members accessing non-farm work in the township. Lastly, significant effects were not found for either CCFP or EWFP on non-agricultural income generation, as the cash subsidies per se account for so little of non-agricultural and therefore total income. As for the CCFP, it influences income mostly through its indirect impacts on labor allocation for out-migration and off-farm employment (Lin et al., 2014). Since these livelihood factors are already controlled in the model, the direct effects remaining on non-agricultural incomes are insignificant. This is in accordance with findings in other areas that the CCFP can indirectly increase income through labor transfers and liquidity relaxation (Uchida et al., 2009; Démurger et al., 2012; Lin et al., 2014).

Results from the last model on total net income generation are generally consistent with those of non-agricultural model, as non-agricultural incomes account for most of total household income. First, off-farm labor and out-migration again have the largest effects on determining total household income. Among individual attributes of the household member with the highest education, although education does not have a significant effect, this person's age (young) and gender (male) significantly contribute to total income generation. Again, this could be because that person is likely to be engaged in off-farm work, as higher earnings may be available to young males. Transportation equipment continues to contribute significantly to total net income, by providing access better off-farm labor and business opportunities. In addition, cropland area and female labor also contribute significantly, albeit at the 10% significance level, to total income, suggesting the importance of natural capital such as land endowments and females' off-farm work as contributors to household overall income. Finally, both the CCFP and EWFP do not significantly affect total net income generation directly, as their effects are mostly indirect via non-agricultural income.

4.3.3 Income inequality—Based on the regression-based determinants of household income, inequality of agricultural incomes, non-agricultural incomes and total net income can be decomposed to assess the ultimate underlying factors contributing to the inequality of rural household incomes in the study area, based on their effects on Gini coefficients (Table 6). Since the contributions to income inequality depends on the estimation of coefficients of variables and their significance, we focus on those variables with statistically significant effects on the determinants of income generation.

In the first model, on the determinants of agricultural incomes, not surprisingly, the supply of farm labor has the greatest explanatory power on agricultural income inequality, as its contribution to the total Gini coefficient reaches 19%. Strikingly, the second strongest contributor to agricultural income inequality is EWFP area. On the one hand, households receiving higher EWFP subsidies tend to live in more remote areas and thus not only receive more but are also inclined to use the cash compensation primarily for improving their food production and other agricultural activities, as it is hard for them to get to places for off-farm work. Meanwhile, households with smaller EWFP subsidies are more likely to live closer to the township center with better access to off-farm market, thus relying less on agricultural activities. Finally, the wide variation in EWFP subsidies (indicating inequality in itself), results in its providing more explanatory power of income inequality in agriculture. The next three important factors are each linked directly to the direct sources of agricultural income, each contributing 10–15% to agricultural income inequality: engagement in extraction of forest resources, crop cultivation and domestic animal ownership. First, the extraction of forest resources, which contributes 14.6% to agricultural income inequality, is not surprising as GE is generally sold at a good price to tourists and dealers. However, high costs (e.g., for seeds, labor time and planting techniques) are also associated with high risk of failure, leading to negative incomes for some households (Tables 3 and 4). Crops and domestic animals both contribute about 10% to total inequality, which is as expected since they pertain to primary livelihoods in agriculture. Farm tools are the one final significant factor contributing (9%) to inequalities in agricultural incomes—those who have produce more

income with more advanced tools than those with primitive tools. All other factors have trivial contributions, including CCFP area.

For non-agricultural incomes, off-farm labor time and out-migration are the major factors that contribute to inequality (23% and 13%, respectively), although they also generate income for most households. Transportation equipment contributes 10%, apparently for facilitating access to off-farm work. In addition, youthful age of the household member with the highest education and the number of female adults both explain similarly large amounts of non-agricultural income inequality. All other factors including the PES programs have little effects on non-agricultural income distribution.

For total net income, the amount of time allocated to off-farm labor is the most important single factor contributing to inequality (as well as to most household's total income, which is not a surprising coincidence). Revenues from off-farm activities are the major sources of income for most households in the study area. Households unable to access off-farm labor markets are often poor. Off-farm activities, together with transportation equipment, account for one-third of all income inequality. Off farm activities also benefit from younger workers with better education, shown as the second most important factor. Young people with the highest education have an effect of 17%, although education alone has only a trivial effect.

Although out-migration is a strong predictor of income generation, particularly non-agricultural income via remittances, it explains only 4.4% of total income inequality and this effect is only marginally significant. This is an intriguing finding. Apparently in this study area at least, both low-income and high-income households are more or less equal-opportunity senders of out-migrants, as suggested first by the overall proportion of study area households having an out-migrant being as high as 55%.[3] This may explain the halcyon effects of remittances on *reducing* poverty, but it still calls for further research on the extent to which lower-income households send out migrants compared to the better-off, and/or on whether it is the lower-income households who are more likely to receive remittances from their migrants as they need them more (Ecer and Tompkins, 2013).

Meanwhile, cropland area exhibits a large effect on total income, indicating that variations in land endowments (albeit small compared to most developing countries) can still be of importance for total income generation. This is particularly true when households with small parcels or fewer parcels receive negative incomes from some parcel(s), which offsets other sources of income in total income. Finally, and not surprisingly, CCFP and EWFP land areas (and hence payments received) explain only very small shares of total income inequality (0.7% and 1.6%, respectively). PES payments depend exclusively on the areas of natural forest land (EWFP forest) or cropland being reforested (CCFP forest). Since the amounts of cash payments account for small shares of total household income, their effects on income *distribution* among households are likely to be tiny also, compared to incomes from other sources.

[3]Alternatively, the poorer households may be less likely to send out a migrant, but those who do are more likely to reap the benefits in large remittances compared to the higher income households sending out migrants. Whether this tends to happen in our study area, or in other contexts in developing countries, is an important research question (Zhang et al., 2018a).

5. Conclusions

In this paper, we use data from a detailed household survey to analyze income levels and structures of rural households receiving PES payments, including both CCFP and EWFP subsidies, in a rural area of Anhui, China. We also tally the contributions of all livelihood activities to total household income, followed by analyzing their contributions to income inequality. Finally, we investigate the ultimate factors determining household incomes and inequality in the study area. Unlike previous studies, our analysis also takes into account negative incomes, which are mainly found in agricultural activities and forest extraction.

Results show that, first, both income levels and income inequality are slightly higher among CCFP-participating households compared to non-CCFP households. Income from local off-farm work and remittances from out-migrants are the greatest contributors to both levels of income and income inequality as they make up the greatest shares of total household income for most households. Among the other sources of income, income from forest resources worsens inequality among CCFP participants, while local non-farm business incomes tend to worsen equality for non-CCFP households. Meanwhile, income levels between households receiving high versus low EWFP payments are similar, as is income inequality. Moreover, EWFP subsidies appear to be higher for the lowest-income households who tend to live higher in the mountains, and also tend to have less farmland eligible for the CCFP subsidy.

The statistical model of the ultimate determinants of household incomes demonstrates the important roles played by human capital, household assets, land endowments and especially labor availability and its allocation to off-farm work in generating income and its inequality. Different factors are found important in contributing to incomes from agricultural and non-agricultural activities, as expected. For the former, the availability of farm labor, farm tools and cropland area are the most important factors that affect agricultural income and its inequality. In contrast, labor time in local off-farm work, out-migration, and transportation assets have the strongest effects on non-agricultural income and its inequality.

Finally, regarding the two PES programs examined, EWFP and CCFP do not have statistically significant direct effects on total income generation, nor on total income inequality. However, the effect of EWFP forest area and hence the size of the payment to households is statistically significant and positive on agricultural income and also contributes to reducing agricultural income inequality. Thus, the poorer households higher in the mountains who receive higher EWFP payments often use the cash payment to increase agricultural inputs (and hence outputs). At the same time, the CCFP has only trivial and insignificant direct impacts on income generation and distribution, but contributes positively to changes in livelihood activities, such as out-migration (Zhang et al., 2018a), which lead to higher incomes but also increase inequality among rural households, as some participating households do not adjust by re-allocating farm labor to off-farm work and out-migration.

Our findings have significant policy implications for design of PES projects in China and beyond. Both CCFP and EWFP, in addition to their main objective of eco-environmental restoration and conservation through forest rehabilitation and protection (Liu et al., 2008; Song et al., 2014; Chen et al., 2018), have a secondary goal of altering livelihoods and

improving incomes of poor farmers. Thus project implementation areas are often poor, remote and mountainous, and considered as target areas for alleviating rural poverty and improving livelihoods (Song et al., 2014; Liu and Lan, 2015). Therefore, the main issue for the sustainability of PES programs pertains to whether livelihoods are improved along with the achievement of ecological conservation: farmers are not likely to participate and abide by environmental policies if they do not see benefits for themselves. Based on our results, the EWFP reduces agricultural income inequality via cash compensation, which tends to be used for agricultural activities, especially by poorer households. Therefore, EWFP helps provide a safety net for the rural poor while conserving natural forests. The EWFP program should be expanded in other poor areas where deforestation threatens the provision of important ecosystem goods and services.

On the other hand, the main direct effect of the CCFP is to free farm labor from cultivating cropland (Zhang et al., 2018a), since the subsidy payment makes up only a trivial share of household income. According to our findings, in contrast to the better-off participants, the poorer CCFP-participants often seems to not be successful in entering the off-farm labor market due to lack of skills and/or geographical obstacles. Hence, they are more likely to remain trapped in low-income subsistence agriculture after retiring some cropland for reforestation. At that time, the success of environmental conservation seem likely to be threatened in the absence of other development policies that focus on infrastructural or educational improvement (Zhang et al., 2008; Liu and Lan, 2015; Ren et al., 2018), aimed at the poorest rural households participating in the CCFP. In particular, we recommend technical training as an integral component of similar PES programs in the future for those with low education and skills to enhance and diversify their livelihood options, in coordination with other development programs to stimulate or subsidize their agricultural production.

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Appendix

Table A1.

Questions used to collect data to compute net income from different sources.

Source	Code and question
Crops	(*For each crop, in the past 12 months*) 1) How much did you harvest? 2) How much was sold? 3) What was the unit price? 4) What was the total value of sales? (*For all crops, in the past 12 months*) 5) What were the costs of materials (e.g., fertilizer, pesticides, etc.) and hiring labor?
Animals	(*For each type of domestic animal*) 1) How many of this type of domestic animal do you currently have? 2) How many were sold in the past 12 months? 3) How much did you earn from selling them in the past 12 months?

Source	Code and question
	4) How much did you earn from selling animal products in the past 12 months? (*For all* domestic *animals, in the past 12 months*) 5) What are the costs involved in raising domestic animals (e.g., animal feed)?
PES	1) How much compensation did you receive from the CCFP in the past 12 months? 2) How much compensation did you receive from the EWFP in the past 12 months?
Forest	(*For each type of forest resources, in the past 12 months*) 1) How much did you earn from extracting the forest resources? 2) What were the costs involved in producing, extracting and selling the forest resources?
Business	(*For each business, in the past 12 months*) 1) What was the total gross revenue in a usual month? 2) How much were the estimated monthly costs (e.g., rent, utilities, repairs)?
Off-farm	(*For each type of work of each person, in the past 12 months*) 1) What were the total earnings from this job of this person?
Remittances	1) How much money altogether has your household received from the out-migrant in the past 12 months? 2) (*If received goods*) What was the estimated value of the major goods the out-migrant sent/brought to the household in the past 12 months? 3) (*If received money or goods from anyone who was not a household member*) What was the estimated total money sent by other persons? 4) What was the estimated total value of goods sent by other persons?
Subsidies	(*For each type of (non PES) government subsidy, in the past 12 months*) 1) How much in government subsidies did your household receive?
Other	1) How much other income did you earn in the past 12 months? Could you specify the income source? (For example: social gifts, rental income from properties or domestic animals, income from interest on savings account or investments)

Table A2.

Imputations for incomes and costs for extracting forest resources and remittances.

Code	Source	Income	Cost	HH-ID
M404	*Gastrodia Elata*	3000	1500	565
M404	*Gastrodia Elata*	5000	2500	667
Q10c	Remittances	20000	-	302
Q10c	Remittances	20000	-	343
Q10c	Remittances	20000	-	385
Q10c	Remittances	20000	-	404

Table A3.

Data imputations for estimating governmental subsidies when missing.

Subsidy	Qualification	Imputation	Number of households
Elderly	If has household member aged 60+	660 yuan per person	17
Comprehensive and agriculture	If plant crops	village mean	39

Table A4.

Unit prices for estimating values of food produced only for home consumption.

Code	Crops	Unit price (Yuan/kg)	Code	Animals	Unit price (Yuan)
100	Rice	2.3	200	Cattle	4500
101	Wheat	1.8	202	Pigs	1000
102	Oil seeds	4	203	Goats/Sheep	750
103	Corn	2.4	205	Chicken	750
104	Sweet potatoes	1.8			
105	Beans	3			
106	Peanuts	2			

Table A5.

Questions used for computation of scores for household producer assets

Question	Item	points
What farming tools and equipment do you have?	Tractor/Transporting tractor (>2000 Yuan)	5
	Thrasher machine/Other small process machine	4
	Electric pump	3
	Ox	2
	Hoes, other farming tools	1
	None	0
What do you use for transportation?	Sedan or minivan	5
	Mini-truck	4
	Motor cycle/Motorized tricycle	3
	Electric bike	2
	Bike or human-powered tricycle	1
	None	0

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Highlights

- We examine rural household income distribution under two concurrent PES programs.
- CCFP positively affects non-farm income via out-migration followed by remittances.
- EWFP positively affects agricultural income and adds slightly to inequality.
- Factors affecting agricultural and non-agricultural income distributions differ.

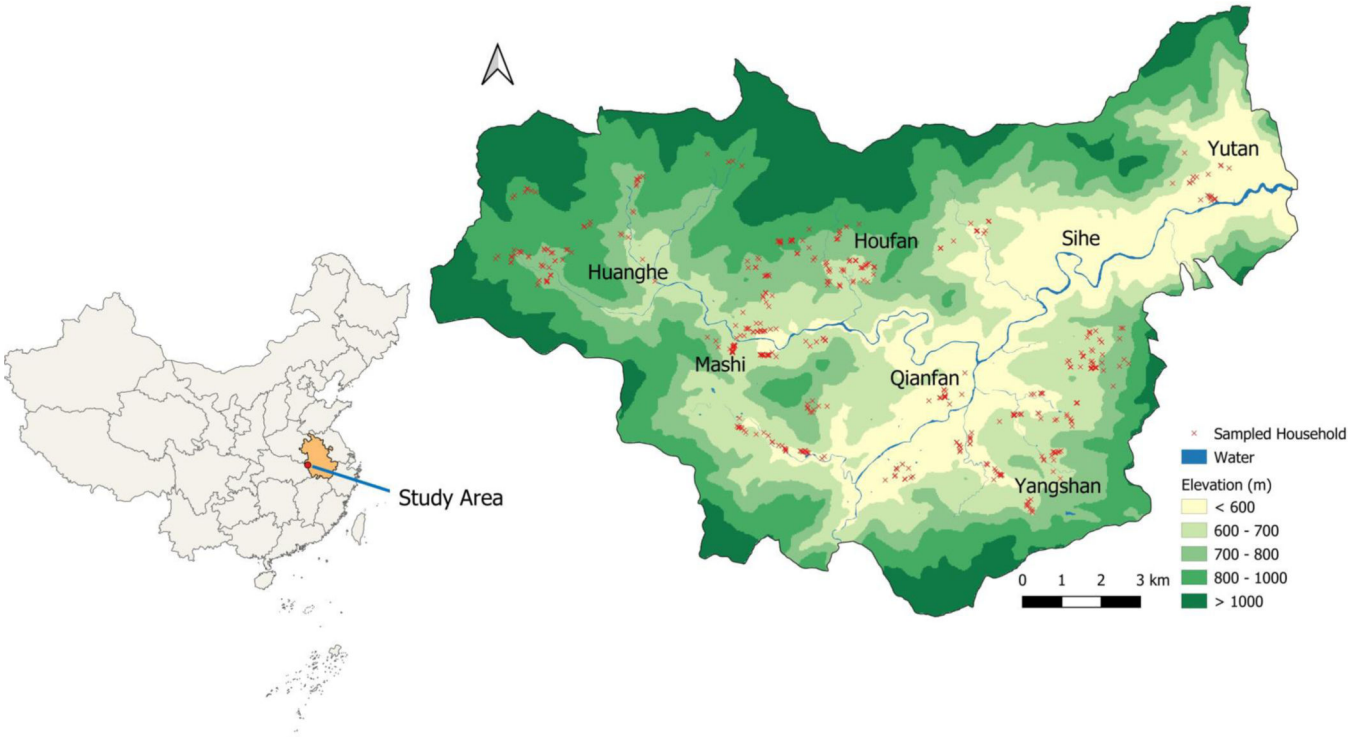

Fig. 1.
Study area of Tiantangzhai Township in Anhui, China.

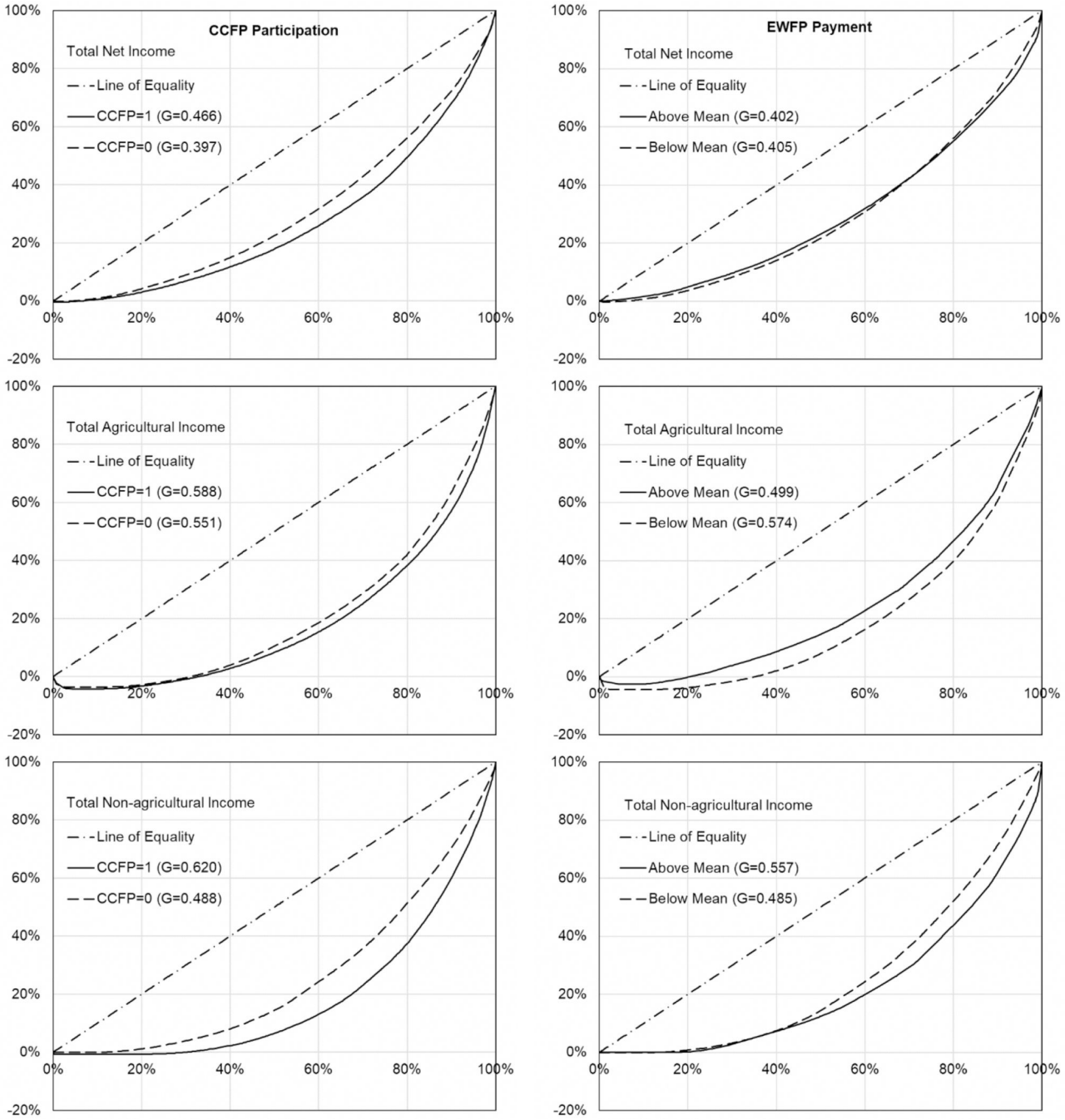

Fig. 2.

Normalized Lorenz curves of household income.

Note: Total net income (top), agricultural income (middle) and non-agricultural income (bottom) for households with and without CCFP participation (left panel) and households receiving EWFP payments above and below the (right panel). The x-axis shows cumulative percentage of households, while the y-axis shows corresponding cumulative percentage of income.

Table 1

Total annual net incomes of rural households from different sources, with and without CCFP participation.

	Income			Income share			Per capita income		
Source	**CCFP=1**	**CCFP=0**	**Difference in means**	**CCFP=1**	**CCFP=0**	**Difference in means**	**CCFP=1**	**CCFP=0**	**Difference in means**
Crops	2.76	2.38	0.38*	7.8%	7.0%	0.8%	1.13	0.94	0.19*
Animals	3.06	2.28	0.78	8.6%	6.7%	1.9%	1.27	0.86	0.42**
PES	0.73	0.34	0.39***	2.1%	1.0%	1.1%	0.32	0.14	0.18***
Forest	2.22	1.32	0.91*	6.3%	3.9%	2.4%	0.82	0.49	0.33*
Business	1.57	2.24	−0.67	4.4%	6.6%	−2.1%	0.57	0.74	−0.17
Off-farm work	11.63	11.24	0.38	32.8%	32.9%	−0.1%	3.75	3.80	−0.05
Remittances	9.46	8.79	0.67	26.7%	25.7%	0.9%	4.56	4.03	0.53
Other subsidies	1.78	1.71	0.07	5.0%	5.0%	0.0%	0.80	0.73	0.07
Other	2.24	3.83	−1.59	6.3%	11.2%	−4.9%	0.68	1.36	−0.67*
TOTAL	35.44	34.13	1.31	100%	100%	-	13.90	13.09	0.82

*
p < 0.1;

**
p < 0.05;

***
p <0.01

Note: Unit for total net income and per capita income is 1,000 yuan. T-tests are used to test for differences in means of income and per capita income between two household groups.

Income sources: Crops, income from growing crops; Animals, income from selling domestic animals and animal products; PES, payments from CCFP and EWFP; Forest, income from extracting forest resources; Business, local non-farm business profit; Off-farm work, local off-farm income; Remittances, remittances from out-migrants from household since 2003; Other subsidies, income from other government subsidies excluding CCFP and EWFP; Other, other miscellaneous sources of income.

Table 2

Total annual net incomes of rural households from different sources according to EWFP payments received being above or below the mean.

	Income			Income share			Per capita income		
Source	**Above mean**	**Below mean**	**Difference in means**	**Above mean**	**Below mean**	**Difference in means**	**Above mean**	**Below mean**	**Difference in means**
Crops	2.49	2.64	−0.15	6.7%	7.8%	−1.0%	00.97	1.08	−0.11
Animals	4.16	2.13	2.03***	11.2%	6.3%	5.0%	11.59	0.89	0.70**
PES	1.19	0.30	0.89***	3.2%	0.9%	2.3%	00.50	0.14	0.36***
Forest	3.21	1.26	1.95***	8.7%	3.7%	5.0%	11.15	0.48	0.67***
Business	1.65	1.95	−0.30	4.4%	5.7%	−1.3%	00.35	0.76	−0.41*
Off-farm work	10.20	11.98	−1.78	27.5%	35.3%	−7.7%	22.89	4.13	−1.25**
Remittances	9.02	9.22	−0.20	24.3%	27.2%	−2.8%	33.64	4.62	−0.98
Other subsidies	2.12	1.59	0.53	5.7%	4.7%	1.0%	00.88	0.72	0.16
Other	3.03	2.90	0.13	8.2%	8.5%	−0.4%	00.76	1.07	−0.31
TOTAL	37.06	33.97	3.09	100%	100%	-	112.71	13.89	−1.18

* $p < 0.1$;

** $p < 0.05$;

*** $p < 0.01$

Note: The mean value of annual EWFP payments is 417 yuan. Units used for total net income and per capita income are expressed in 1,000 yuan. The t-test is used to test for the differences in means of income and per capita income between the two household groups.

Table 3

Measures of inequality attributed to different income sources for households with and without CCFP participation.

	CCFP = 1					CCFP = 0				
Source	**Percent positive values**	**Percent negative values**	**Gini for positive income**	**Gini**	**Pseudo Gini**	**Percent positive values**	**Percent negative values**	**Gini for positive income**	**Gini**	**Pseudo Gini**
Crops	0.882	0.044	0.385	0.456	0.084	0.867	0.015	0.383	0.461	0.062
Animals	0.815	0.033	0.682	0.747	0.244	0.733	0.041	0.644	0.729	0.231
PES	1.000	0.000	0.395	0.395	0.034	0.990	0.000	0.481	0.482	−0.119
Forest	0.465	0.092	0.606	0.846	0.481	0.395	0.096	0.406	0.816	0.161
Business	0.114	0.007	0.461	0.949	0.405	0.081	0.004	0.338	0.937	0.663
Off-farm work	0.491	0.000	0.532	0.749	0.566	0.610	0.000	0.468	0.637	0.403
Remittances	0.439	0.000	0.582	0.815	0.587	0.429	0.000	0.535	0.774	0.459
Other subsidies	0.989	0.000	0.542	0.546	0.119	0.986	0.000	0.619	0.625	0.190
Other	0.332	0.000	0.648	0.894	0.355	0.381	0.000	0.738	0.905	0.554
TOTAL	0.985	0.015	0.454	0.466	0.466	0.990	0.007	0.388	0.397	0.397

Table 4

Measures of inequality attributed to different income sources for households receiving EWFP subsidies above and below the mean.

Source	EWFP above mean					EWFP below mean				
	Percent positive values	Percent negative values	Gini for positive income	Gini	Pseudo Gini	Percent positive values	Percent negative values	Gini for positive income	Gini	Pseudo Gini
Crops	0.857	0.029	0.350	0.390	0.199	0.883	0.035	0.396	0.486	0.020
Animals	0.807	0.043	0.610	0.662	0.274	0.768	0.041	0.660	0.751	0.243
PES	1.000	0.000	0.240	0.240	−0.006	0.994	0.000	0.365	0.365	−0.058
Forest	0.600	0.107	0.443	0.732	0.284	0.367	0.106	0.463	0.855	0.262
Business	0.100	0.014	0.389	0.976	0.729	0.097	0.003	0.367	0.927	0.586
Off-farm work	0.500	0.000	0.436	0.624	0.462	0.560	0.000	0.486	0.664	0.424
Remittances	0.407	0.000	0.693	0.871	0.543	0.446	0.000	0.485	0.742	0.436
Other subsidies	1.000	0.000	0.541	0.541	0.091	0.982	0.000	0.626	0.635	0.234
Other	0.350	0.000	0.640	0.907	0.501	0.355	0.000	0.733	0.897	0.523
TOTAL	0.986	0.014	0.401	0.402	0.402	0.988	0.012	0.393	0.405	0.405

Table 5

Independent variables for the model of the determinants of income generation, with means and standard deviations.

Variable	Description	Mean	Std. Dev.
Education	Highest education of adult household member (years completed)	9.24	3.02
Age	Age of member with highest education	35.0	16.7
Gender	Gender of member with highest education (1=male, 0=female)	0.32	0.47
Male adults	Number of male adults (aged 16+) currently living in the house	1.11	0.67
Female adults	Number of female adults (aged 16+) currently living in the house	1.20	0.63
Farm labor	Percentage of adult labor available for farm work	0.33	0.26
Cropland	Total amount of cropland owned (mu)	5.38	2.84
Animal raising	Whether household raises domestic animals	0.83	0.37
Forest resources	Whether household extracts forest resource (e.g., *Gastrodia Elata*)	0.57	0.50
Off-farm labor	Adult labor time in local off-farm work (per 100 days)	0.55	0.94
Business labor	Adult labor time in local non-farm business (per 1000 hours)	0.23	0.82
Out-migration	Whether household has any out-migrant since 2003, still living away	0.55	0.50
Farm tools	Score for farm tools and equipment (0–5)	2.40	1.59
Transportation	Score for transportation equipment (0–5)	2.48	1.44
CCFP area	CCFP forest area (mu)	1.14	1.53
EWFP area	EWFP forest area (mu)	47.7	59.0

Note: The sample size is 481. The labor time in local off-farm work among households with off-farm labor (54%) is 137 days (about 4.5 months), while in local non-farm business among households with business (11%) is 1,980 hours (nearly three months). The mean CCFP area for CCFP-participating households (56%) is about 2 mu.

Table 6

Factors determining income generation and the contribution of each to income inequality.

Variable	Agricultural Income			Non-agricultural Income			Total Net Income		
	Coef. (*SE*)	*G*	*G* %	Coef. (*SE*)	*G*	*G* %	Coef. (*SE*)	*G*	*G* %
Education	0.14 (0.27)	0.006	1.6%	0.84 (0.85)	0.020	5.6%	0.53 (1.05)	0.0058	2.2%
Age	−0.08 (0.12)	0.022	5.8%	−0.56 (0.34)	0.045	12.5%	−1.35 (0.69) *	0.0456	17.4%
Age^2	0.00 (0.00)	-	-	0.01 (0.00) *	-	-	0.02 (0.01) **	-	-
Gender	2.26 (0.83) ***	0.015	4.0%	7.13 (2.54) ***	0.015	4.2%	8.23 (3.43) **	0.0111	4.2%
Male adults	−0.13 (0.87)	−0.001	−0.2%	1.94 (3.29)	0.008	2.2%	1.71 (3.68)	0.0055	2.1%
Female adults	1.01 (1.17)	0.011	2.9%	6.61 (2.47) ***	0.032	8.8%	7.07 (3.73) *	0.0213	8.1%
Farm labor	7.50 (2.51) ***	0.073	18.9%	−6.57 (5.83)	0.011	2.9%	7.49 (6.91)	0.0035	1.3%
Cropland	0.47 (0.20) **	0.039	10.2%	0.89 (0.74)	0.016	4.5%	1.91 (1.06) *	0.0279	10.7%
Animal raising	3.30 (0.82) ***	0.038	9.9%	−1.27 (3.38)	0.000	0.1%	−5.38 (7.44)	0.0009	0.3%
Forest resources	2.98 (0.75) ***	0.056	14.6%	−0.83 (2.91)	0.001	0.3%	0.40 (3.28)	0.0004	0.2%
Off-farm labor	0.56 (0.64)	0.005	1.3%	8.27 (0.96) ***	0.085	23.4%	9.47 (1.50) ***	0.0545	20.8%
Business labor	−0.59 (0.62)	0.007	1.7%	3.95 (1.27) ***	0.018	5.0%	3.82 (2.07) *	0.0090	3.4%
Out-migration	0.98 (1.54)	0.004	1.0%	12.87 (3.62) ***	0.048	13.2%	9.51 (4.88) *	0.0116	4.4%
Farm tools	0.65 (0.31) **	0.035	9.1%	0.69 (1.34)	0.005	1.3%	0.78 (1.58)	0.0044	1.7%
Transportation	−0.45 (0.31)	0.005	1.2%	2.75 (1.06) ***	0.036	10.1%	3.85 (1.60) **	0.0330	12.6%
CCFP area	0.33 (0.44)	0.010	2.6%	0.99 (0.90)	0.006	1.5%	0.55 (1.15)	0.0017	0.7%
EWFP area	0.04 (0.02) **	0.060	15.6%	−0.02 (0.03)	0.004	1.0%	0.03 (0.04)	0.0043	1.6%
Constant	−4.32 (3.16)	-	-	−6.72 (15.9)	-	-	13.8 (27.3)	-	-

* $p < 0.1$;

** $p < 0.05$;

*** $p < 0.01$

Note: *G* denotes the contribution to the total Gini coefficients. *G* % denotes proportionate contribution of that factor to the total Gini coefficient. NA means not applicable.