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Effects of payments for ecosystem services programs in China on rural household labor allocation and land use: Identifying complex pathways

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Abstract

Payments for Ecosystem Services (PES) is increasingly used in developing countries to secure the sustainable provision of vital ecosystem services. The largest PES programs in the world are embedded in China's new forest policies, which aim to expand forest cover for soil and water conservation and improve livelihoods of rural people. The objective of this study is to identify the complex pathways of impacts of two PES programs − the Conversion of Cropland to Forest Program (CCFP) and the Ecological Welfare Forest Program (EWFP) − on household livelihood decisions, and to quantify the direct and indirect impacts along the identified pathways. We fulfill this objective by developing an integrated conceptual framework and applying a Partial Least Squares-Structural Equation Model (PLS-SEM), based on household survey data from Anhui,

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China. Labor allocation (for on-farm work, local paid work, local business, and out-migration) and land use decisions (i.e., rent in, maintain, rent out, or abandon cropland) for participating households are key to understand PES program effects on livelihoods. Results show that the PES programs have only small direct effects but significant indirect effects via the mediating factor of capital assets. Moreover, group heterogeneity analysis shows that lower-income households do not benefit any more than the better-off households from the PES, while households with medium wealth increase dependence on agriculture. In addition, household demographics, individual attributes, and geographic settings differ in their impacts on labor allocation and land use decisions. We conclude that CCFP and EWFP programs would be more efficient in conserving the environment while improving the economic welfare of lower-income households if capital assets were taken into account in the design of compensation schemes.

Keywords

payments for ecosystem services; labor allocation; land use; PLS-SEM; rural China

1 Introduction

Payments for Ecosystem Services (PES) is an increasingly used policy tool to secure the sustainable provision of vital ecosystem services (Ezzine-de-Blas et al., 2016). The financial incentives from PES can stimulate households to invest in new livelihood options that simultaneously promote environmental conservation and improve economic welfare (Espinosa-Goded et al., 2010; Huber et al., 2017). The extent to which these policies succeed depends on whether rural households successfully alter and diversify livelihoods (Bryan et al., 2018). As the largest developing country by population, China has been facing increasing poverty-environment challenges in rural areas for decades. Starting in the late 1990s, the Chinese government has implemented several PES programs via China's new forest policy (Zhang et al., 2000). The Ecological Welfare Forest Program (EWFP)[1] and the Conversion of Cropland to Forest Program (CCFP) are among the largest PES programs. The EWFP aims to better manage forest resources through bans on commercial logging in natural forests with mountain closures (Dai et al., 2009). The EWFP compensates forest owners for giving up commercial timber logging privileges to preserve natural forests as part of public welfare (Robbins and Harrell, 2014; Song et al., 2018; Zhang et al., 2019). The CCFP − also known as the Grain for/to Green Program (Chen et al., 2009; Dang et al., 2020; Liu et al., 2008) or Sloping Land Conversion Program (Xu et al., 2010) − encourages rural households to retire marginal sloping croplands or other degraded fields and convert to forestland or grassland (Chen et al., 2012; Song et al., 2014). Since CCFP and EWFP make payments as incentives to participating households for forest ecosystem protection, both of them follow the PES principles. Table 1 provides detailed descriptions of CCFP and EWFP. These two PES programs have been implemented now for two decades, with total accumulated government investments of 517 billion yuan for CCFP by 2019 and 80 billion for EWFP by 2013.

[1]The Ecological Welfare Forest Program is different from the Natural Forest Conservation or Protection Program (Ma et al., 2020; Zhang et al., 2000), although both programs are implemented essentially for protecting forests.

Since the initiation of the PES programs, considerable attention has been directed to the evaluation of their outcomes, both ecologically and socio-economically (Chen et al., 2019b; Liu et al., 2008; Smajgl et al., 2015; Xu et al., 2010; Yin et al., 2018; Zhang et al., 2017). Regarding ecological outcomes, most studies report that the PES programs have fostered significant improvement in forest cover (Chen et al., 2019a; Liu et al., 2008), but some others argue that they have encouraged monoculture plantation expansion over the retention of natural forests (Ahrends et al., 2017; Hua et al., 2018; Zhai et al., 2013), leading to serious environmental consequences, including damaging the local water balances and reducing biodiversity, especially in arid and semiarid regions (Gao et al., 2011). Evaluations of the socioeconomic effects of these programs on rural livelihoods and poverty alleviation are even more mixed, and appear to vary by household, the local context, and over time as well as at different stages of policy implementation (Liu et al., 2014; Song et al., 2014; Yost et al., 2020). For example, some studies find that changes in livelihood activities resulting from PES participation help address the poverty-environment nexus as households reallocate labor from extractive or degradation activities (e.g., logging, soil erosion from farming on slopes) to other activities which generate higher incomes, such as off-farm employment (Chao et al., 2017; Kelly and Huo, 2013; Yin et al., 2014). However, others found that PES did not stimulate such a transfer of labor toward non-farm activities (Li et al., 2011), but instead led to the intensification of agricultural activities on the remaining land, or even shifting labor from cultivation to increased extraction of natural resources (Liu et al., 2013).

Such differences in findings may be attributable to the strength and direction of PES effects on household livelihood activities being mediated by other factors, such as local physical/environmental conditions, individual and household characteristics, local market conditions and access, local infrastructure, differences in local government policy implementation, and types of other policy interventions operating concurrently (Bryan et al., 2018; Lawson et al., 2012; Li et al., 2011; Liang et al., 2012; Uchida et al., 2009; Wang et al., 2019). In rural areas, PES programs often induce changes in coupled human-natural (CHN) systems that constitute pathways through which PES programs affect household livelihoods indirectly. Revealing and examining these pathways can thus be vital for unpacking the complexity of the impact-feedback loops of PES programs in the CHN system, which may be useful for informing policy-makers on ways to improve management strategies to achieve targeted outcomes. Although the two main PES programs (EWFP and CCFP) have been operating for two decades, the pathways through which they affect household livelihood decisions have not been examined together, much less quantitatively.

Labor allocation and land use decisions are the two fundamental livelihood strategies of most rural households in developing countries. Understanding the role of PES programs in rural household labor allocation and land use is therefore critical for elucidating PES program effects on poverty alleviation and its sustainability. First, the allocation of the labor time of individuals between on-farm and off-farm activities affects the labor left for the household to allocate to land use. At the same time, the economic returns from land management affect a household's decision about the allocation of labor to farm work vs. other uses. Both labor allocation and land use are affected by factors external to the household. For example, Huang et al. (2012) found the emergence of off-farm employment opportunities exerted significant and positive impacts on stimulating households to allocate more labor to off-farm work and also rent out cropland. Previous studies on rural livelihoods have focused separately on either labor allocation *or* land use decisions (Corsi and Salvioni, 2012; Nguyen et al., 2017; Su et al., 2016) but not both simultaneously. There has been very little attention to assessing the effectiveness of PES programs on shaping livelihood decisions simultaneously regarding individual labor allocation and household land use from an integrated perspective.

It is to be recognized, however, that research on rural livelihoods has made considerable progress, such as on factors affecting livelihood strategies (Dehghani Pour et al., 2018; Johny et al., 2017), livelihood resilience and vulnerability (Li and Zander, 2020; Rajesh et al., 2018), and interactions between livelihoods and the environment (Aitken et al., 2019; Meyfroidt, 2018). Such studies highlight the important roles of household capital assets in the diversification of household livelihoods and building resilience to withstand multiple stressors. A lack of capital assets limits rural households' access to diversified livelihood options, so livelihoods of the rural poor in developing countries often rely on the extraction of natural resources, which leads to further environmental deterioration that can further exacerbate their poverty (Dehghani Pour et al., 2018; Lade et al., 2017; Yang et al., 2018; Zhou et al., 2020). Hence, household capital assets may be a critical factor mediating the strength and direction of PES impacts on household livelihood decisions. However, we are not aware of any empirical research that has examined this potential mediating role of capital assets in the relationship between PES programs and rural livelihoods.

This study aims to explore the linkages between PES programs and household livelihood decisions, drawing on in-depth household survey data from a rural township in China. The livelihood decisions include individual labor allocation between on-farm work, local paid work, local business, and out-migration, while the household land use decision examines the common decision in China about whether to rent land in, rent land out, do both equally (or neither), or abandon cropland parcels. Specific objectives include (i) developing a conceptual model to test hypotheses about factors that directly or indirectly affect livelihood decisions of rural households enrolled or not in the PES programs, (ii) identifying and quantifying the mediating effects of capital assets in the linkages between PES and household livelihood decisions, and (iii) uncovering the complex pathways underlying the relationships between PES programs as well as a host of other factors simultaneously on livelihood decisions at different levels of household wealth. The usual least squares regression models cannot address the complexity of CHN systems, so we have adopted a complex multiple equation approach − Partial Least Squares-Structural Equation Model (PLS-SEM) − to examine the interrelationships and pathways of multiple variables. Such a model has been widely used in research in statistical studies to test and quantify complex pathways in many household decisions, including school enrolments, livelihoods, etc., especially in sociology, but rarely in the fields of geography or environmental studies.

2 Theoretical Framework and hypotheses

2.1 Identification of model components

2.1.1 The two key outcome variables—

The first outcome variable of interest in this study is individual labor allocation. Each household member allocates labor time to competing livelihood activities to fulfill household livelihood goals, such as to ensure food security, obtain sufficient income for other material needs, and for having leisure time (Fisher et al., 2005; Nielsen et al., 2013). Here, we divide labor activities into four types based on whether the income is generated on-farm or off-farm and the location of the work. The definition of each is as follows: (1) *On-farm work* refers to agricultural work on the household's own land and the land rented in from neighbors, including cultivation of subsistence and cash crops, animal husbandry, fruit trees, forest resource management, and other agriculture-related activities. (2) *Local business* refers to work managing a local business, such as a restaurant, renting out rooms, a convenience food store or other retail stores (e.g., clothing, hardware, pharmacy), providing a service (e.g., tailor, barber), running a repair shop or small factory (e.g., for processing tea, canning food), trading, transportation of products or people, etc. (3) *Local paid work* refers to employment in which a wage or salary is received from others, whether as part-time or full-time employees doing agricultural or non-agricultural work, such as in manufacturing, construction, transportation, restaurant, commerce/trade, education/health, government employment, mining, etc. (4) *Out-migration* is defined as work outside the county for at least 6 months consecutively in a year by a former member of the household. Thus, individual labor allocation is measured by percentages of time the person allocated to agricultural work on farmland, local business, local paid work, and out-migration with these percentages sum to 100%.

Therefore, the outcome variable Y_1 is a vector that represents time of the individual allocated to each of the four activities:

$$Y_1 = [L_F, L_B, L_P, L_M]^T \tag{1}$$

where L_F, L_B, L_P, L_M represent the time allocated to agricultural work, to a local business, to local paid work, and to out-migration employment by the household.

The second outcome variable of interest is household land use decisions concerning land transfers and abandonment, which are the most fundamental and very common land use options adopted by rural farmers in China (Liu and Liu, 2016; Su et al., 2018; Zhang et al., 2018b). Before the farming season begins, households need to decide whether to maintain the current cropland in use, or change the scale of crop cultivation either via land transfers (rent in/out) and/or abandonment, which is based on previous crop yields, available farm labor, and other factors (Wang et al., 2019). Thus, the total amount of area to be cultivated by a household (A*) is the area of land owned (A) plus the land rented in (A_{in}) minus the land rented out (A_{out}) and abandoned ($A_{abandon}$):

$$A^* = A + A_{in} - A_{out} - A_{abandon} = A + \Delta A \tag{2}$$

Given that each household owns multiple cropland parcels and may adopt one option for all or different options for different parcels, we computed the cropland area in each option and divide household land use decisions into four categories, i.e., *net renting in*, *stabilization*, *net renting out*, and *net abandonment* based on the following rules:

1. ΔA=0 represents the household maintains current farm size, i.e., *stabilization*.

2. $\Delta A>0$ denotes net *renting in*.

3. $\Delta A<0$ and $A_{out} \geq A_{abandon}$ means net *renting out*.

4. $\Delta A<0$ and $A_{out} < A_{abandon}$ means net *abandonment*.

Thus, the outcome variable Y_2 can be depicted as the relationship between A_{in}, A_{out}, and $A_{abandon}$:

$$Y_2 = [A_{in}, A_{out}, A_{abandon}, \ \Delta \ A]^T \tag{3}$$

2.1.2 Determinants of household livelihood decisions—The identification of the factors determining rural livelihood decisions is guided by the neoclassical farm household model, such as presented in Singh et al. (1986) and Jogo and Hassan (2010), and the model of agricultural production and land rental market participation developed by Yao (2000) and Deininger and Jin (2005) for rural China. In this framework, a household is viewed as seeking to maximize its utility as a function of the consumption of food or agricultural products (X_A), market goods and services (X_M), and leisure time (L_E), expressed by the usual equation:

$$\max U = U(X_A, X_M, L_E) \tag{4}$$

Each household has a fixed labor endowment at a given time, and has to decide how to allocate total available labor time (L_{Tot}) among on-farm work (L_F, e.g., crop production, animal raising, and collection of forest products), off-farm work (L_{OF}, i.e., local business, local paid work, and out-migration employment), and leisure (L_E):

$$L_{Tot} = L_F + L_{OF} + L_E \tag{5}$$

Since rural households are involved in both consumption and production activities, the quantity of agricultural products (including grain, animal products, and forest products) consumed by the household (X_A) equals products harvested (X_A^H) plus purchased (X_A^P) minus products sold (X_A^S) in the market:

$$X_A = X_A^H + X_A^P - X_A^S \tag{6}$$

The yield of agricultural products depends on labor time spent in on-farm work (L_F), total farmland area cultivated (A^*), agricultural inputs (I_A) (e.g., fertilizer, seeds, and baby animals), and agricultural production assets (ω) (e.g., truck/cart for transport, plows, and hoes):

$$X_A^H = X_A^H(L_F, A^*, I_A, \omega) \tag{7}$$

In addition, a household's consumption of and preference for market goods and services (X_M) depends on household demographics (Ω), including household size, age and composition of household members:

$$X_M = X_M(\Omega) \tag{8}$$

Except for times when extraordinary events happen to a household (e.g., weather shocks, macroeconomic shocks, or health shocks), the primary goal of a household is to seek a balanced budget by keeping its total expenditures equal to or lower than its total income. Therefore, total income should be equal to or larger than total expenditures:

$$P_A \cdot X_A^S + W_{OF} \cdot L_{OF} + E + r \cdot A_{out} \geq P_A \cdot X_A^P + P_I \cdot I_A + P_M \cdot X_M + r \cdot A_{in} \tag{9}$$

where P is the price vector which includes prices of agricultural products (P_A), agricultural inputs (P_I) and other market goods (P_M); W_{OF} is the wage rate for off-farm work; E refers to exogenous household income, such as payments from PES programs; and r is rent from renting out land or rent paid to rent in land.

The wage from off-farm work (W_{OF}) depends on individual attributes (η) (e.g., age, gender, and education) as well as opportunities for off-farm employment, the latter affected by geographic location (θ) (e.g., distances to main road and labor markets), and whether the household has transportation equipment (τ):

$$W_{OF} = W_{OF}(\eta, \theta, \tau) \tag{10}$$

Hence, household decision making can be regarded as an optimization problem, to maximize utility (U) subject to a time constraint (eq. (5)), a production constraint (eq. (7)), and a budget constraint (eq. (9)). The method of Lagrange multipliers can then be applied to solve the utility maximization problem as follows:

$$\begin{aligned} \mathscr{L} &= U(X_A, X_M, L_E) - \lambda_1(L_{Tot} - (L_F + L_{OF} + L_E)) \\ &- \lambda_2\left(X_A^H - X_A^H(L_F, A + \Delta A, I_A, \omega)\right) \\ &- \lambda_3((P_A \cdot X_A^P + P_I \cdot I_A + P_M \cdot X_M + r \cdot A_{in}) - (P_A \cdot X_A^S + W_{OF} \cdot L_{OF} + E \\ &+ r \cdot A_{out})) \end{aligned} \tag{11}$$

where λ_1, λ_2 and λ_3 are the Lagrange multipliers of the time constraint, the production constraint and the budget constraint, respectively. Each endogenous variable (L_F, L_{OF}, X_A^H, X_A^P, X_A^S, I_A, X_M, ΔA, A_{in}, A_{out}, W_{OF}, λ_1, λ_2, λ_3) in this model is expressed as a function of the exogenous variables (L_{Tot}, P, r, Ω, η, θ, τ, A, ω, E) in reduced form. The reduced form equation for labor time used in each of the livelihood strategies is thus given by:

$$Y_1 = [L_F, L_B, L_P, L_M]^T = [L_F, L_{OF}]^T = L(L_{Tot}, P, r, \Omega, \eta, \theta, \tau, A, \omega, E) \tag{12}$$

Similarly, the reduced form equation for land use is given by:

$$Y_2 = [A_{in}, A_{out}, A_{abandon}, \Delta A]^T = A(L_{Tot}, P, r, \Omega, \eta, \theta, \tau, A, \omega, E) \tag{13}$$

According to the theoretical models, the factors affecting household livelihood decisions include total household labor time available (L_{Tot}), prices (P), land rent (r), household demographics (Ω), individual attributes of members in the labor force (η), geographic access (Θ), transportation equipment (τ), cropland area owned (A), agricultural production assets (ω), and exogenous household income (E, here refers to PES payments). Note that the price vector and land rental rates are not explicitly taken into account here as our model is based on only a single year of observations and these values are quite similar for households across the small and fairly homogenous study area.

2.2 Specification of indicators

According to the theoretical model, the factors influencing labor allocation and land use decisions can be aggregated into five categories or groups, viz., *PES*, *capital assets*, *individual attributes*, *household demographics*, and *geographic access*. We can then identify the measurement variables or indicators for each category, drawing on prior empirical studies and data from the study area.

PES programs: Rural household livelihood decisions are sensitive to government policy interventions. In the present case, we are interested in the two PES programs, i.e., CCFP and EWFP. For CCFP, we choose as our variable whether the household participated in CCFP or not. For EWFP, we use the actual subsidy payment since virtually all households were enrolled in the program and received widely varying amounts of payment based on forest land they had.

Capital assets: House type (Category 1 in Table S1) is an important indicator of household capital assets, and is taken here to indicate the financial capital of the household, including its access to credit. Individuals living in poorer houses with presumed less financial capital are generally likely to allocate more of their labor to on-farm activities (Kuang et al., 2019). Labor allocation to on-farm activities is also linked positively to having larger cropland holdings, due to the opportunities for labor applications that produce income from the land (Matshe and Young, 2004). The ownership of agricultural assets, such as farm tools, and of transportation equipment, to facilitate taking farm products to market (Categories 6 and 7 in Table S1) enhances the value of cropland as well. Thus households with more of these assets tend to manage larger and/or more cropland parcels and are more likely to rent in additional land from neighbors, and vice-versa (Dehghani Pour et al., 2018). Animal husbandry generally has a positive association with cropland use in China, as animals provide manure for fertilizer and draft power, as well as a need for more land to produce food for them (Alary et al., 2011). Growing *Gastrodia Elata* (GE, a high priced Chinese medicinal herb) is also widely grown by rural households (about half) in the study site. Economic returns from animals (mostly chickens and eggs and pigs) and GE may be used to invest in agricultural technology, farm equipment, improved seeds, or irrigation to increase cropland productivity, which is also a by-product of manure. Therefore, in sum, the house type, ownership of transportation equipment, farm tools, cropland area, whether grow GE, and animal stock are all selected as indicators of capital assets, which have potential effects on household livelihood decisions.

Individual attributes: Personal attributes (age, gender, and education) of members in the household tend to affect labor allocation decisions. First, the age of an individual can influence his/her on-farm labor participation (Corsi and Salvioni, 2012), participation and time in off-farm work (Lien et al., 2010), and out-migration (Treacy et al., 2018). Second, females may face more barriers than males in searching for jobs in off-farm labor markets, and are socially obligated to take care of children, the elderly, and disabled members in the household (Hajjar et al., 2020). Finally, a lower education limits a person's access to opportunities in local off-farm work or for out-migration for employment in cities (Lee and Malin, 2013), so the less educated are more likely to engage in on-farm work (Wei et al., 2016). In our study, age, gender, and education are all selected together to represent individual attributes.

Household demographics: Livelihood decisions of household members depend also on a host of household demographic characteristics, including household size, household composition by age (the dependency ratio: proportion of population aged under 15 and over 65 divided by those of labor force age, 15–65, as used by demographers), and the household head's age, gender and education. Households with a larger labor supply can cultivate more cropland and at the same time diversify income sources into off-farm economic activities such as off-farm work and out-migration (Ellis, 2000b; Liu and Lan, 2015; Perz, 2005; Stark and Bloom, 1985). However, when there are many dependents (young children, elderly, or disabled household members) with corresponding higher demands for food and caregivers (Chayanov, 1966; Liang et al., 2012), economic activities will tend to be more on-farm even with more adult members. Here, four indices, i.e., household size, number of children, number of non-working adults, and the dependency ratio are used to capture the impacts of household demographic factors on livelihood choices.

Geographic access: Geographic location is a key contextual factor that determines the accessibility of a household to both natural resources (viz., croplands and forests) and markets for labor and products. Farther distances to markets imply more time and higher transportation costs to get to work, which lowers local off-farm employment (Escobal, 2001) and increases on-farm work (Gollin and Rogerson, 2014) as well as out-migration (Zhang et al., 2018a). Longer distances to markets and poorer road linkages also make it more difficult for farmers to sell their agricultural products (Omamo, 1998), so they may allocate more labor to subsistence crops and natural resource extraction. Elevation also affects labor allocation choices via this same process: Households in more elevated places supply less labor to off-farm activities due to having less access to roads and hence facing higher travel costs to access off-farm work (Laszlo, 2008). Moreover, adverse ecological conditions (i.e., rough topography, high elevation, etc.) is also linked to lower productivity of cropland, and more cropland abandonment (Kuemmerle et al., 2011; Lakes et al., 2009; Müller et al., 2013). Therefore, elevation, distance to road, and distance to nearest township center are used as measures of geographic access.

2.3 Hypothesized pathways of the effects of PES programs on labor allocation and land use

Based on the theoretical model, we posit a simple but comprehensive conceptual framework to show the direct and indirect pathways from the various factors to the two livelihood decisions (Fig. 1). This framework comprises eight interrelated components: (1) two

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outcome variables of interest, individual labor allocation and household land use; (2) PES programs; (3) two mediating components − capital assets and household labor availability; and (4) three control variables − individual attributes, household demographics and geographic access. The linkages among them show the pathways through which PES programs and the other factors affect household livelihood decisions.

First, PES participation and the two livelihood decisions are directly linked. Participation in the CCFP tends to free up farm labor by reducing the cropland area available for crop cultivation, while participation in the EWFP removes labor involved in commercial timber logging. The freed-up labor can then be reallocated to on-farm work (Chao et al., 2017), local paid work (Uchida et al., 2009; Yin et al., 2014), out-migration or leisure (Zhang et al., 2018a). Regarding land use, the CCFP effects on shrinking a household's cropland area by converting cropland to forests or grasslands could lead to agricultural intensification on remaining land or renting in land from neighbors to offset the area lost (Wang et al., 2019). Thus, based on previous studies, our hypotheses are stated as follows.

H1: PES programs have direct impacts on individual labor allocation (**H1a**) and household land use (**H1b**).

There may be indirect effects as well: the potential mediating roles of capital assets in the linkages between PES and household livelihood decisions. Studies by Lin and Yao (2014) and Dang et al. (2020) suggest that PES payments had indeed enhanced household capital assets (financial and social capital), enabling households to invest in wage-earning skill acquisitions, self-employment in business activities, and financing out-migration, all of which affect the remaining household labor supply as well as household incomes, which may further affect land use decisions. Having more capital also allows the purchase of more productive assets, which can involve either expanding or intensifying agricultural production from existing land or renting in more land. To assess the relationship between PES, livelihood decisions, and capital assets, we therefore further hypothesize:

H2: PES programs may have indirect impacts on individual labor allocation (**H2a**) and household land use (**H2b**) through the mediating roles of capital assets.

Moreover, individual labor allocation and household land use are interrelated. Theories of diversifying household labor and capital allocation across various economic activities have existed for many years, more recently in the New Economics of Labor Migration pioneered by Stark and Bloom (1985), which describes how the economic activities of household members are interrelated, and has been interpreted to include land transfer and abandonment decisions in China (Che, 2016; Huang et al., 2012; Su et al., 2018). Specifically, the impact of individual labor allocation decisions on household land use occurs through its effects via household labor availability. Thus individual labor allocation decisions of working-age persons (to work off-farm or migrate) reduce labor available for farm work. If a household has no labor available (only elderly members), it will shrink cropland area in use, by either renting out or abandoning cropland or both. On the other hand, a household may rent land in if it has sufficient farm labor. Therefore, we state our next hypothesis as follows:

H3: Individual labor allocation decisions have an indirect impact on household land use through their impact on household labor available for farm work.

H4: Based on **H1a** and **H3**, PES programs may have indirect impacts on household land use through their induced impacts on labor allocation. In general, the reallocation of freed-up labor from PES participation to off-farm activities reduces household labor available for farm work, which may lead to a further induced effect on renting out or abandoning more cropland. However, if the freed-up labor is instead allocated to on-farm work, a household may instead rent in more cropland, or, if not, adopt agricultural intensification (apply more inputs of labor per unit of land) on the remaining cropland (Liu et al., 2013).

In addition to the hypothesized pathways described above, we also take into account a host of additional hypothesized pathways between the control variables and the two outcome variables. First, in addition to capital assets, individual attributes, household demographics, and geographic access are directly linked to both labor allocation and land use, as reflected in the theoretical models (Section 2.1.2), and well established in the literature (Ellis, 2000a; Escobal, 2001; Hajjar et al., 2020). Thus differences in individual attributes, household demographics and geographic access across households are associated directly with differences in labor allocation and land use, as well as with these dependent variables via their links to capital assets. Relationships between capital assets and these control variables are thus related in complex ways, which are best determined empirically. Thus, this study will estimate the direction and magnitude of the full range of these direct and indirect associations in this particular context of rural Anhui province in China, drawing on our detailed household survey data.

3 Materials and methods

3.1 Study area and local context

The study area is Tiantangzhai Township, Anhui province, China (Fig. 2), which is situated in the eastern Dabie Mountain Range, in a subtropical monsoon climate zone with a mean annual temperature of 16.4°C and mean annual precipitation of 1,350 mm. The area of the township is 189 km^2 with elevations ranging from 363 m to 1,729 m above sea level, in mountainous terrain. Most of the landscape is occupied by forests (72% of the total area), followed by cropland, grassland and developed land, with 14%, 10%, and 2.5%, respectively. Most cropland plots are on moderately steep slopes, highly fragmented in small sizes with relatively low yields. Like many other rural locales in China (Aitken et al., 2019; Chen et al., 2017; Liu et al., 2018b), households in Tiantangzhai interact with the environment through multiple livelihood options, including cultivating cropland, collecting fuelwood, harvesting trees, as well as in the case of Tiantangzhai, also growing GE. Since grains (rice and corn) and other agricultural crops are vulnerable to natural hazards and wildlife raiding, many households in Tiantangzhai have shifted from cultivating traditional crops to growing GE in recent years. Income from selling GE often accounts for the bulk of agricultural incomes of households engaged in this activity. In addition, 83% of the households in the study area use fuelwood as their main source of fuel (Song et al., 2018). Tiantangzhai Township also is in the Tianma National Nature Reserve (Fig. 2), which has been developed into a “5-A” tourist area, creating lucrative tourism entrepreneurship and employment opportunities, including hotels, restaurants, and stores.

Tiantangzhai Township belongs to Jinzhai County, which was designated as a county in poverty by the Chinese government (CPAD, 2014). The county is located in one of 14 contiguous poverty-stricken areas identified by the Strategy for Regional Development and Priority Poverty Alleviation in 2011 (China State Council, 2011). Tiantangzhai has a resident population of 17,295 in 4,369 households (based on 2012 census data), with about one third of the population below the official poverty line. Both of the two PES programs (EWFP and CCFP) exist in Tiantangzhai. Specifically, the first-round of CCFP began in Tiantangzhai in 2002 and was expanded for another contract period (8 years for ecological forests) at the end of the initial contract in 2007, but compensation was cut in half. At the time of our household survey in 2014, 17.5% of the households were enrolled in CCFP, receiving 125 yuan per mu (1mu=1/15ha) or US$ 301.9 per year per hectare of cropland set aside for reforestation (1 US $ = 6.21 yuan in 2014). The EWFP has been implemented in the study area since 2001. Almost all households have some ecological welfare forests and hence are automatically enrolled in the EWFP, receiving compensation of 8.75 yuan per mu, or US$ 21.10 per hectare per year.

3.2 Data collection

This study uses data collected from a household survey in Tiantangzhai Township in the summer of 2014. We designed, pre-tested and finalized a comprehensive questionnaire that collected extensive socio-economic and related data on the rural household. This included: (1) local physical conditions and geographic accessibility, (2) household demographics, (3) agricultural activities and incomes, (4) household capital and assets, (5) individual labor time allocated to on-farm agricultural work, operation of a local business, local agricultural and non-agricultural paid work, and out-migration, (6) landholdings and transfers, including cropland owned, cultivated, rented in, rented out and abandoned, and (7) participation in and cash compensation from the two PES programs. A stratified disproportionate sampling strategy (Bilsborrow et al., 1984; Kish, 1965) was designed to select a scientifically representative random sample of households in the township, involving oversampling households participating in the CCFP program to ensure approximately equal numbers of participants and non-participants in the sample (Song et al., 2018). We trained and supervised a survey team of university students, collecting data from 481 households. During the interview, we used Global Positioning System units to record the geospatial coordinates and elevations of household locations, and main relevant local infrastructures such as the nearest township center and paved road. In addition, we digitized the major roads and trails in Tiantangzhai based on high spatial resolution satellite imagery.

Among the 481 interviewed households, 30 had missing values relating to labor allocation, so were excluded, leaving 451 households with 993 persons involved in agricultural production and/or wage-earning activities. To further examine possible heterogeneous relationships between individuals from households with different wealth status, we developed a method (see Section 1, Supplementary Materials) to divide the 993 individuals into three groups of equal size based on household wealth, i.e., lower-wealth, medium-wealth, and higher-wealth.

3.3 Partial Least Squares-Structural Equation Model (PLS-SEM)

We adopt the PLS-SEM to quantify the direct and indirect effects of factors affecting individual labor allocation and household land use decisions for the following two reasons. First, it works efficiently even with fairly small sample sizes without requiring strict normal distributions for variables from the sample data, and is robust when missing values are below a reasonable level (Henseler and Sarstedt, 2013). Second, it can assist the development and verification of theoretical models, to test and quantify potentially complex pathways and incorporate important mediating effects (Hair et al., 2016; Wen and Li, 2019). Thus, after its origins in sociological studies of causality dating back to Blalock (1964), the PLS-SEM approach has gained increasing applications in social science research (Carrión et al., 2016; Hair et al., 2012), including a few ecological studies (Wei et al., 2019; Wen and Li, 2019). The PLS-SEM comprises both measurement models that take into account correlations between each exogenous variable and its respective latent variable, and structural models that incorporate the correlations between constructs (Hair et al., 2016), as hypothesized and illustrated in Fig. 1.

Model development to implement the empirical framework involves two main steps (Hair et al., 2016; Henseler et al., 2016). The first step is to specify the structural and measurement models. A structural model defines the relationships between constructs (unobservable variables), while a measurement model identifies the relationships between each construct and its manifest indicators (Hair et al., 2016). Within the structural models, *PES*, *individual attributes*, *household demographics*, and *geographic access* are considered exogenous constructs, serving only as independent variables in the model. *Capital assets* and *household labor availability*, *and individual labor allocation* are mediating endogenous constructs that operate as both independent and dependent variables. The constructs of *household land use* is the dependent variable that has only arrows pointing into it (see Fig. 1). The paths that directly link the independent variable constructs to the two target constructs of *individual labor allocation* and *household land use* depict direct effects, while the paths that go through the mediating endogenous constructs measure indirect effects.

Within the measurement models, constructs can be categorized into two types, called *reflective constructs* and *formative constructs*, based upon the relationships between the construct and its manifest indicators (Hair et al., 2016). In particular, *household demographic characteristics* and *geographic access* are reflective constructs, as they capture the most common information of manifest indicators. In contrast, *PES*, *individual attributes*, *capital assets*, and *household labor availability*, as well as the two dependent variables of *individual labor allocation* and *household land use* are formative constructs, which cover the most distinguishable aspects of their manifest indicators, with each indicator showing a distinct domain of its corresponding construct.

The second step is to parameterize and evaluate the measurement and the structural models. For a reflective measurement model, the coefficients between the construct and its indicators are called outer loadings (l). Each l is estimated independently through a single regression between the construct and its associated indicators. The reflective measurement model can be evaluated from three aspects: internal consistency reliability, convergent validity, and discriminant validity. For a *formative measurement model*, the coefficients between the construct and its indicator are called outer weights (w). All outer weights are estimated simultaneously by a partial multiple regression between the construct and its manifest indicators. The formative measurement model is evaluated on the basis of its convergent validity, collinearity, and the statistical significance of the w. The structural models use partial regressions to obtain the path coefficients (β). Each endogenous construct is specified as a dependent variable, and its corresponding predecessor constructs are its independent or explanatory variables. OLS regression is used to estimate each equation in the structural model. Key criteria for assessing the structural model include collinearity, the overall coefficient of determination (R^2), the magnitudes of the effects (f^2), and the statistical significance of β.

We use the SmartPLS 3.2.9 software package (Ringle et al., 2015) to construct the model, estimate parameters, evaluate model components and relationships, and test hypotheses. For the basic settings of PLS-SEM, we follow the guidelines described by Hair et al. (2016) and Garson (2016). Specifically, the PLS algorithm stops when the change of parameters between two consecutive iterations is smaller than 10^{-7} or the number of iterations reaches a maximum of 300. Additionally, we use a bootstrapping procedure that draws 5000 subsamples randomly from the original data to test the significance of parameters. Finally, we evaluate all measurements and structural models (see details in Section 2, Supplementary Materials).

However, it worth noting that our analyses is based on data from only one time point and hence cannot capture lag effects or address longitudinal analyses.

4 Results

4.1 Descriptive statistical analysis

Table 2 provides the descriptive statistics on the two dependent variables, the labor allocation of working individuals in the household and land use for all households in the sample, and for households categorized into thirds according to their household wealth: lower wealth, medium wealth and higher wealth. Of the 993 working-age individuals, slightly over half (54%) allocate their labor time primarily to on-farm work, with the remainder primarily involved in off-farm employment of various types (46%). Among the three types of the latter, the percent engaged in local paid work (21%) is the highest, followed by out-migration employment (19%) and local business (6%). Regarding land use, the most common decision adopted by households was cropland abandonment (34%), followed by stabilization (30%). Thus 36% of the households changed their cropland area in the year via land transfers, with 19% renting cropland out and 17% expanding it by renting in. Rural households in the study area continue to have more adults working mainly in agricultural activities than off-farm activities, allocating more time to the more remunerative agricultural activities of growing GE or raising livestock (Zhang et al., 2019).

Note that somewhat different labor allocation and land use patterns are observed in Table 2 at different levels of household wealth. First, there is a statistically significant difference between the three categories in on-farm employment as determined by one-way ANOVA ($p<0.001$). As wealth rises, we observe a decline in labor allocation to on-farm work, although for all three wealth tiers it still represents the larger labor allocation category. This illustrates that lower-wealth households are less engaged in the usually higher income off-farm employment opportunities, likely because of lower education and less access to markets, due to geographic factors (living on average at higher elevations and being farther away from the nearest paved road and the township center), both restricting their access to off-farm labor markets. Second, among the forms of off-farm labor allocation, the ANOVA test reveals significant differences between the three groups in terms of participation in local businesses and out-migration, but no significant differences in local paid work. Although having a local business is the smallest form of labor allocation for all wealth categories, it consistently rises with wealth, which is expected since capital is required for most forms of business. Similarly, the out-migration rises with wealth status, with persons from lower-wealth households engaging less in out-migration than those from the higher-wealth group (marginally significant at $p<0.10$). The reason could be that they have less education and therefore fewer opportunities to migrate for work, but it is interesting that the difference is less than that for having a business.

Turning to land use decisions, we observe significant differences across the three wealth groups in both renting in and renting out land but not in land abandonment, which appears common among households of all wealth levels as China transitions rapidly from a primarily rural, agricultural-based country to a modern urban society based on manufacturing and services. Nevertheless, as expected, the share of households expanding cropland decreases with wealth while the proportion of renting out land increases ($p<0.05$). This is consistent with the data comparing differences in individual employment on-farm vs. off-farm by level of wealth.

Table 3 provides definitions and descriptive statistics of all explanatory or independent variables affecting individual labor allocation and household land use, including mediating factors. The one-way ANOVA analysis shows that most variables are significantly different across the three wealth groups, though participation in the two PES programs does not significantly differ. At the individual level, the sample is comprised of 56% males and 44% females, with a mean age of 48 and mean education of 5.5 years. Gender composition is virtually identical across the three groups, but mean age is a bit higher in the lower-wealth group than the other two. What is most different across wealth levels at the individual level is education, being significantly lower for the lower wealth households and highest for the higher wealth category.

At the household level, the overall enrollment rate in CCFP in the sample was 57.7%, with households participating in EWFP receiving a mean of 501 yuan/year (US$ 81). Differences across the three wealth groups were minimal in both programs, with medium-wealth households having a slightly higher enrollment rate in CCFP and receiving larger EWFP subsidies than the other two. However, households at different wealth levels did differ significantly in many other characteristics. Thus, medium- and higher-wealth households have larger household sizes, more children, and higher local off-farm employment than lower-wealth households. Households from the medium-wealth group tend to adopt more diverse agricultural activities, such as growing GE and raising animals, both of which require more initial agricultural capital investment (e.g., expensive seeds for GE) but produce higher returns. In contrast, lower-wealth households have more adverse locational conditions (i.e., higher elevations and farther from the nearest paved road or township center), live in poorer quality houses, and possess fewer livelihood assets (such as farm tools and transportation equipment). Therefore, it is more difficult for them to access local labor markets as they have to overcome these physical obstacles and poorer transportation linkages while at the same time being less likely to have transportation equipment.

4.2 Direct, indirect and total effects

To better understand the underlying mechanisms of the association between rural household livelihood decisions and potential explanatory factors including PES programs, we use the PLS-SEM to investigate the direct, indirect and total effects of each of these factors on individual decisions about on-farm vs. off-farm work and household land use. Each total effect is the sum of the direct and indirect effects, which may reinforce or offset each other. We study the hypothesized pathways in the model, including the sign, magnitude and significance level (p-value) of each standardized path coefficient (β) in each equation in the structural model. The direct, indirect, and total effects of the independent variables on differences across households in labor allocation and land use decisions under different pathways are presented in Tables 4 and 5, respectively. Note that in the case of indirect effects, it is necessary to multiply the partial standardized coefficients to obtain the size and sign of the indirect effect, as illustrated below in the next paragraph. If two negative signs are multiplied together, the result is a positive indirect effect. Estimations for each measurement model are summarized in Fig. 3 and Table 6 (columns 1 and 2), in which the loadings (l) or weights (w) for each indicator and their significance level (p-value) are provided.

4.2.1 Impact on individual labor allocation—We first interpret the relationships between *individual off-farm work* and the factors affecting it, as presented in Table 4. First, and interestingly, the direct impact of PES programs on *individual off-farm work* is insignificant, while the indirect effect, mediated by capital assets, is marginally statistically significant at the 6% level, so our hypothesis **H2a** is supported while **H1a** not. Note the size of the path measuring the indirect effect is the product of the coefficients ($-0.017 = 0.089 \times -0.198$). Since the direct and indirect correlations of PES programs with *individual off-farm work* are in the same (negative) direction, thus the total effect is larger ($\beta = -0.055$, $p<0.10$) due to the sum (reinforcement) of direct and indirect impacts. In the measurement model (see bottom of Fig. 3), the construct of PES programs is positively associated with its two manifest indicators, CCFP participation and EWFP subsidies. These results suggest that the two PES programs combined tend to lower rural farmers' inclinations to seek off-farm employment, but stimulate them to increase household farm labor, as the indirect effect of PES programs on household labor availability is positive ($\beta = 0.009$, $p<0.10$). This is contrary to the expectations of the policy, which aims to stimulate rural farmers to shift or diversify their livelihoods, instead of retaining farm labor in agricultural work.

Capital assets has a negative *direct* association with *individual off-farm work* (β=−0.198, p<0.01). Note that *capital assets* is a comprehensive construct, embodying various forms of capital, and is negatively associated with house type, transportation equipment and cropland area, but positively correlated with investments in agricultural production assets (farm tools) and most strongly of all with diversifying agricultural activities into animal husbandry and GE (Table 6). Combining the measurement and structural models, results show that a household with more agricultural production assets/diversified activities tends to have more farm labor, while the ownership of a better house, transportation equipment and larger cropland area is linked to a larger share of household labor going to off-farm work. The reason why individuals from households with more cropland tend to adopt off-farm work may be because they have a larger household size, as per capita cropland is quite similar, and household size has a positive relationship with off-farm work, though insignificant (Fig. 3).

Individual attributes has the largest direct association with *individual off-farm work* and the impact is positive and strongly significant (β=0.581, p<0.01). This shows, not surprisingly, that individual-level labor allocation decisions are dominated by the person's own characteristics far more than by household or other factors, as expected (Howley et al., 2013). Meanwhile, the indirect impact mediated by capital assets is much smaller, but is significant and in the same direction, thus reinforcing their total effect on individual labor allocation. *Individual attributes* is positively associated with being male and having more education and negatively linked to age. Therefore, younger, male, and better-educated individuals are much more likely to undertake off-farm work, especially for out-migration, followed very closely by local paid work, and somewhat less by having a local business.

For *household demographics*, the indirect effect on *individual off-farm work* is small but significant while the direct effect is not. Interestingly, the direct and indirect effects have opposite signs, leading to an insignificant total effect as they partially offset each other. As shown in Fig. 3, there is a negative relationship between *household demographics* and *capital assets*, which results from the manifest indicators selected from the data to capture household demographic characteristics, specifically large household size with more dependents, which tends to have a better house type and transportation equipment. While this (especially transportation equipment) may stimulate off-farm work (facilitate commuting), it also, along with diversifying agriculture into raising animals (which children help with) also stimulates more on-farm activities, so overall the effects cancel, as indicated in the inconsequential total effect.

Regarding *geographic access*, the direct and indirect influences on *individual off-farm work* are both negative and statistically significant, with the indirect effects via capital assets significant at a higher level (p<0.001), indicating strong effects of distance/isolation on the accumulation of farm tools and land (via *renting in*), both related to on-farm work. Thus, the total effects are larger and with higher levels of significance due to the reinforcement of direct and indirect impacts. Farmers, who live in higher elevations, greater distance from roads, and greater distance from the town center all are likely to be associated with less access to off-farm opportunities, and thus less likely to engage in off-farm work.

4.2.2 Impact on household land use—Next, we examine the relationships between *household land use* and its determinants from the results presented in Table 5, following the same general order of assessment of paths from explanatory factors. As with labor, the PES programs have an insignificant direct effect but a significant indirect effect via the mediating factor of capital assets, which confirms hypothesis **H2b** but not **H1b**. As the direct and indirect effects have opposite signs, their effects are offsetting, resulting in a very small and insignificant overall effect. The construct of *household land use* has a positive correlation with renting out and abandonment but negative on renting in, reflecting the tendency in Anhui as well as throughout rural China towards declining land in crops.

Capital assets has both direct and indirect associations (mediated by individual labor allocation) on *household land use* and both effects are significant and negative, leading to a larger total impact and higher significance level (β=−0.361, p<0.01), though practically all of this effect is direct. Looking at this direct effect further by combining the two measurement models of capital assets and cropland use with the structural model (multiplying the mixed signs from the six “components” of the measurement model of capital assets times the negative sign from the structural model times the signs of the three aspects of cropland use), yields results that show that the *renting in* decision for cropland is positively associated with access to farm tools, growing GE, and raising domestic animals. Thus, a household with more agricultural production assets/diverse agricultural activities tends to both increase its farm labor and expand cropland in use, compared to the overall downward trend associated with ownership of better houses and more advanced transportation equipment, which in turn is linked to higher likelihoods of *renting out* or *abandoning* cropland, and more off-farm labor.

The association between *individual attributes* and *household land use* are mainly indirect, with the two sets of indirect effects, one mediated by both individual labor allocation and household labor (β=0.054, p<0.01) and the other via capital assets (β=0.051, p<0.01) − both positive and significant and with remarkably similar overall indirect effects. Thus, households with more younger, male, and/or better-educated members are more likely to rent out or abandon cropland.

Moreover, we find that both direct and indirect impacts of *household demographics* on *household land use* are significant but have opposite signs, with the direct effect (β= −0.106, p<0.01) being much larger and stronger than the indirect effect (β=0.034, p<0.05). Consequently, the total impact of *household demographics* on the *household land use* decision construct is negative, so larger households with more dependents tend to renting in land to meet food consumption needs.

The direct influence of *geographic access* (measuring lack of access) on *household land use* is small and insignificant, but the indirect impact as mediated by capital assets is highly significant, so is the total impact. Thus, households at higher elevations in the mountains with poor access to paved roads and markets tend to accumulate farm tools and engage more in animal husbandry and GE cultivation, and are more likely to expand cropland use by renting in land.

Finally, we observe a significant indirect correlation between *individual off-farm work* and *household land use* through the mediating factor of *household labor availability* (β=0.092, p<0.01), providing support for hypothesis **H3**. However, due to the lack of a direct impact of PES on individual labor allocation, the indirect impact of PES on household land transfers and abandonment decisions mediated by labor allocation is also small and insignificant, so hypothesis **H4** is not supported.

4.3 Analysis of differences according to wealth category

To examine whether the associations between the PES programs and household livelihood decisions vary across groups of different economic status, we reran the analysis for survey households divided into three equal-size groups according to their level of wealth (capital assets), hence lower, medium, and higher wealth groups. We interpret the results focusing on the policy variables (Table 6 and Table 7). While there are many interesting differences in the loadings and weights across the three wealth groups for many of the variables in Table 6, in the interest of brevity, we only discuss those involved with PES programs and capital assets here. Regarding PES, we see that the positive but marginally significant loading of CCFP on the structural construct PES is due to the higher wealth households, while the more significant loading of EWFP results from both the middle and higher wealth households, so neither affects lower wealth households. For capital assets, the loadings do not differ for most components, except for being stronger and/or more statistically significant for the lower wealth group for precisely the three factors more linked to their behavior − house type, transportation equipment and cropland area. Implications for total effects are noted below.

Continuing with including the structural models to examine total effects of the PES construct (Table 7), we find the only significant impact is on *capital assets* for the medium-wealth households (β=0.207, p<0.01), which indirectly affects *individual off-farm work* (β= −0.171, p<0.05) for this same group (although similar statistical links are found between capital assets and off-farm work for the other two wealth groups as well). Combining results from the measurement models (Table 6, though not significant), the two PES programs tend to stimulate some accumulation of farm tools and engagement in diversification into other agricultural activities (animal husbandry and GE cultivation). This is because the households in this group have more non-working adults and higher dependency ratios (Table 3). The linkage between household demographics and capital assets for medium group is positive (Table 7), which may indicate that households in this group with more dependents tend to accumulate more agricultural production assets (i.e., farm tools) and work more in diversified agricultural activities (animal raising and GE cultivation), to make it easier for them to take care of children, the elderly, and disabled household members.

Thus, the PES subsidies may have a small role to play in providing cash that facilitates part of the initial capital cost of purchasing seeds for GE, baby animals for animal husbandry, and/or for paying to rent land. In addition, for all wealth groups, more capital assets is significantly associated with less *individual off-farm work* and (therefore) more *household labor availability* for on-farm work, both effects with magnitudes increasing with wealth. Finally, it is noteworthy that geographic access has the largest impact on capital assets, individual labor allocation to (reducing) off-farm work and increasing household labor available for on-farm work, and land use (renting in) for the medium-wealth group.

5 Discussion

5.1 Complex policy effects on household livelihoods

First, the direct impact of PES on individual labor allocation is insignificant in our study area, which differs from previous findings from for Shaanxi, Sichuan, and Gansu, where the CCFP program was seen to free farm labor from land cultivation, accelerated the (policy-desired) labor transfer into off-farm sectors, and out-migration (Démurger and Wan, 2012; Kelly and Huo, 2013; Uchida et al., 2009). This difference may mainly be due to the difference in study periods, as these other studies were based on survey data collected within the first few years of policy implementation, effects of which may have disappeared over time. A household survey conducted in Shaanxi province in 2017 also found that participants had low perceptions of the economic benefits of the program (Dang et al., 2020). Thus, our result is consistent with more recent studies, which suggest that the longer-term impacts of CCFP on agricultural production, off-farm work, and other socio-economic factors were negligible (Liu and Henningsen, 2016; Wu et al., 2019). An important factor explaining why rural households, especially the lower-income ones, have not benefited much from the program could be their low levels of education, geographic obstacles (living at higher elevations and farther from roads and markets), and a lack of new skills and knowledge of modern technology (Bennett, 2008; Uchida et al., 2007). Such circumstances make it difficult for them to effectively use the payments and freed-up labor from PES programs to participate in more reliable and profitable off-farm activities. Finally, this study examined the effects of CCFP and EWFP on household livelihood decisions together, however, previous work by Wang et al. (2019) and Zhang et al. (2018a) showed that they can have different or even offsetting effects on land use and labor allocation, resulting in a smaller overall impacts.

Second, empirical evidence from this study reveals that capital assets have a significant mediating impact on linkages between PES programs and household livelihood decisions. While policy-makers (and economic theorists) desire to see labor shift from agriculture activities to local off-farm work in rural towns, we find that PES has no direct effects and only significant indirect impacts on both individual labor allocation and household land use through the mediating factor of capital assets. This reduced farmers' inclinations to seek off-farm work, and instead promoted households to rent in more cropland. Specifically, PES payments are positively linked to capital assets, apparently facilitating the accumulation of agricultural assets (farm tools, animal stocks, seeds for GE), thus stimulating households to increase farm labor and expand the cropland area through renting land in. This is consistent with Wang et al. (2017), who found that PES programs increased household agricultural assets, thus promoting agricultural intensification. Nevertheless, these findings are in contrast to other case studies that suggest PES payments enhance financial capital, relaxing a liquidity constraint which enabled investment in wage-earning skill acquisition and a shift from subsistence farming to non-farming activities (Dang et al., 2020; Lin and Yao, 2014).

5.2 Policy implications

The underlying pathways revealed in this study can be used to inform future PES programs to better improve the livelihoods of participating populations. We have a special interest in the lowest wealth households in order to achieve the greatest impact on poverty alleviation. Our results here show a lack of direct impacts of the PES programs (together) on household livelihood decisions in our study area. This could be attributable to the flat-rate compensation scheme with little differentiation for households (Bennett, 2008; Chen et al., 2010). Thus these PES programs are not efficient in targeting the poor with better-off households benefitting as much or more. Although the government has committed unprecedented expenditures to the PES programs, the subsidies received by each rural household are very small due to the huge area covered. These subsidies may not be sufficient to cover income lost from foregone cultivation and/or logging, especially as market prices have risen. Thus, we suggest for the next round of PES programs to adopt a differential payment scheme to focus on the rural poor, such as for the 14 contiguous poverty-stricken areas identified in the Strategy of Regional Development and Priority Poverty Alleviation, most being mountainous, ecologically fragile and prone to natural disasters and/or crop/animal/tree disease (Zhou et al., 2020). The rural poor in these areas tend to have both geographic obstacles and low human capital limiting their access to off-farm work, so current levels of PES payment are insufficient to facilitate a livelihood shift. National and local governments and policymakers should, therefore, consider how to help them overcome these barriers, such as by improving the local infrastructure, and/or stimulating creation of more local off-farm jobs as well as other support, such as training, credit, and information services (Ren et al., 2018; Zhang et al., 2008).

These suggestions are consistent with the finding here that PES has not direct but indirect impacts on individual labor allocation, household labor supply and household land use through the mediating factor of capital assets. This suggests policy interventions could be improved by taking into account household heterogeneity, particularly of the discrepancy in their capital assets, to implement differential compensation schemes based on household endowments, education/capabilities and location, as discussed above. In addition, for some households located in high elevations with poor road, etc., they could, provided it being voluntary, be relocated to lower levels with farm plots or apartments and access to retraining and non-farm work. For some younger or middle-aged residents who prefer remaining in agriculture, local governments could encourage them to upgrade from smallholders into mainly commercial or “professional” farmers by facilitating shifting “ownership” of local abandoned lands (and switching and consolidating contiguous plots by trading with other smaller local farmers), providing better access to credit and agricultural extension services and training in new technology. Moreover, for those migrant workers with most of their time staying in urban areas, the internal collective economic organizations could encourage households to voluntarily withdrawal their cropland and residential land (Liu et al., 2018a). There is some discussion ongoing in China about land reform and titling, to allow land markets, with purchase and consolidation of dispersed plots to improve the efficiency of land use. Given cropland abandonment is increasingly common (Zhang et al., 2014), the CCFP could enroll abandoned land in the program and encourage farmers to grow economic forests, such as tea, walnut, kiwi fruit, to make better use of land, augment food production, benefit the environment, and free farm labor to diversify livelihoods. If the goal, however, is to improve rural livelihoods to reduce the flood of migrants going to cities in China, then additional policies to stimulate jobs in small towns will also be needed.

5.3 Limitations of the study

Our research illustrates the complex relationships between PES policies and rural livelihoods that can be identified from a comprehensive, integrated statistical approach, which in turn requires detailed household survey data. It thereby shows how policy outcomes involve complex linkages and feedbacks among individual labor choices, household labor supply and land use, with potential time lags and heterogeneity (Aitken et al., 2019; An et al., 2005). There are several ways in which this study could be improved. First, the full interrelationships among PES, individual and household level livelihood decisions cannot be captured by a structural equation model since there are likely feedback effects. We are already exploring the development of an agent-based model which will be able to investigate these reciprocal feedback effects in the coupled human-natural systems. Second, due to the lack of longitudinal data, our study can only take a snapshot of rural livelihood decisions, and analyze differences across households linked to individual, household, and geographic factors, in addition to the policies of special interest here. It thus cannot capture the dynamics over time nor lag effects that may involve transitions and structural shifts between strategies as affected by policy interventions and other factors that change over time. We therefore hope to undertake a follow-up survey on the same household or plots (since all are geo-referenced) to be able to examine the dynamic processes over time, including the impacts of changing policies. Third, labor allocation decisions of household members are interrelated, e.g., the migration decision of one person may force someone else to give up a non-farm job to keep the farm going. However, this study does not treat individual labor allocation as interrelated but independent. Related to this is the aggregation problem, combining the decisions into a household labor allocation variable, and examining individual and household level livelihood decisions together may inevitably lead to the aggregate bias. Finally, apart from distance to various infrastructure, this study does not take into account the effects of contextual factors on either off-farm vs. farm work labor allocation or land use decisions. There are some other contextual factors, such as community facilities (e.g., schools, health center), local resources (e.g., tourism and mineral resources), and environmental factors that should be controlled for in our future model.

6 Conclusion

This study develops a complex conceptual framework postulating various direct and indirect linkages between PES programs and rural household livelihood activities and then uses a Partial Least Squares-Structural Equation Model to empirically test and quantify the hypothesized pathways. A key finding is that direct impacts from the PES programs on individual labor allocation and household land use are small and insignificant, but indirect effects especially mediated through household capital assets are significant. We use the model to evaluate the pathways formed by PES, rural households' livelihood decisions, household demographic characteristics, individual attributes of members in the labor force, geographic access of the household, and capital assets, which is found to have a number of important mediating effects on the dependent variables of labor allocation and land use. A major conclusion is the importance of geographic location of the rural households in livelihood decisions. Specifically, poorer farmers tend to live in areas at higher elevations and further away from a main road or town, and are hence less likely to pursue local off-farm work or migrate away for higher incomes in the burgeoning cities of China, and instead are more likely to expand their cropland area. This supports the existence of spatial poverty traps in low-income rural areas in China. Both household demographic factors and individual attributes strongly influence labor allocation and land use decisions, with individual factors dominating, especially gender and education. Thus more educated males are more likely to pursue employment via out-migration or adopt local paid work, while households with larger households and more dependents tend to continue their farm-based livelihoods, even expanding their cropland area by renting in land. We also observe considerable heterogeneity in the effects of the PES programs on households with different wealth levels. Given that both CCFP and EWFP in China existing now for two decades, and that China continues to face major challenges in achieving sustainability of its vital ecosystem services, it is an appropriate and desirable time to extend the PES programs with greater cost efficiency. This is a major challenge for the coming decades, and doubtless a major policy debate, to which we hope this study can contribute.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Highlights

- China's core forest PES programs have differential effects on livelihood decisions.
- PES programs indirectly influence labor allocation and land use via capital assets.
- Personal attribute has stronger effects on livelihoods than household demographics.
- Geographic location is also a key determinant of labor allocation and land use.

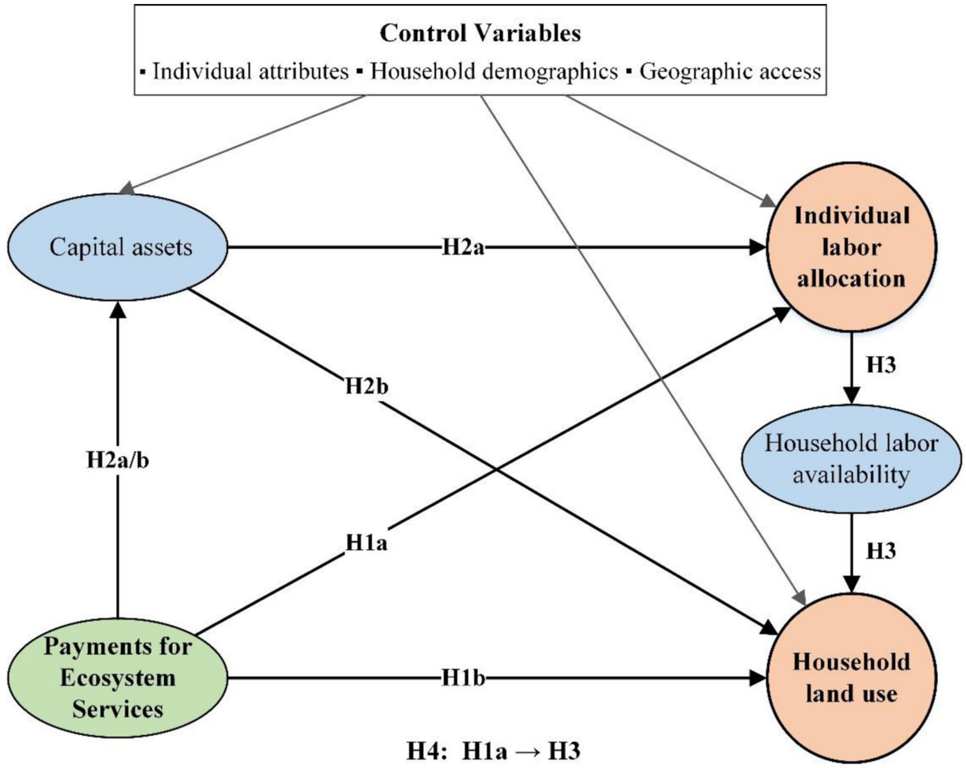

Figure 1.
Hypothesized pathways of control variables, PES, and household labor availability on livelihood decisions (labor allocation and land use), via capital assets.
Notes: The two outcome variables of interests are highlighted in orange, the two mediating constructs in blue, and the PES programs in green. Arrows depict hypothesized relationships.

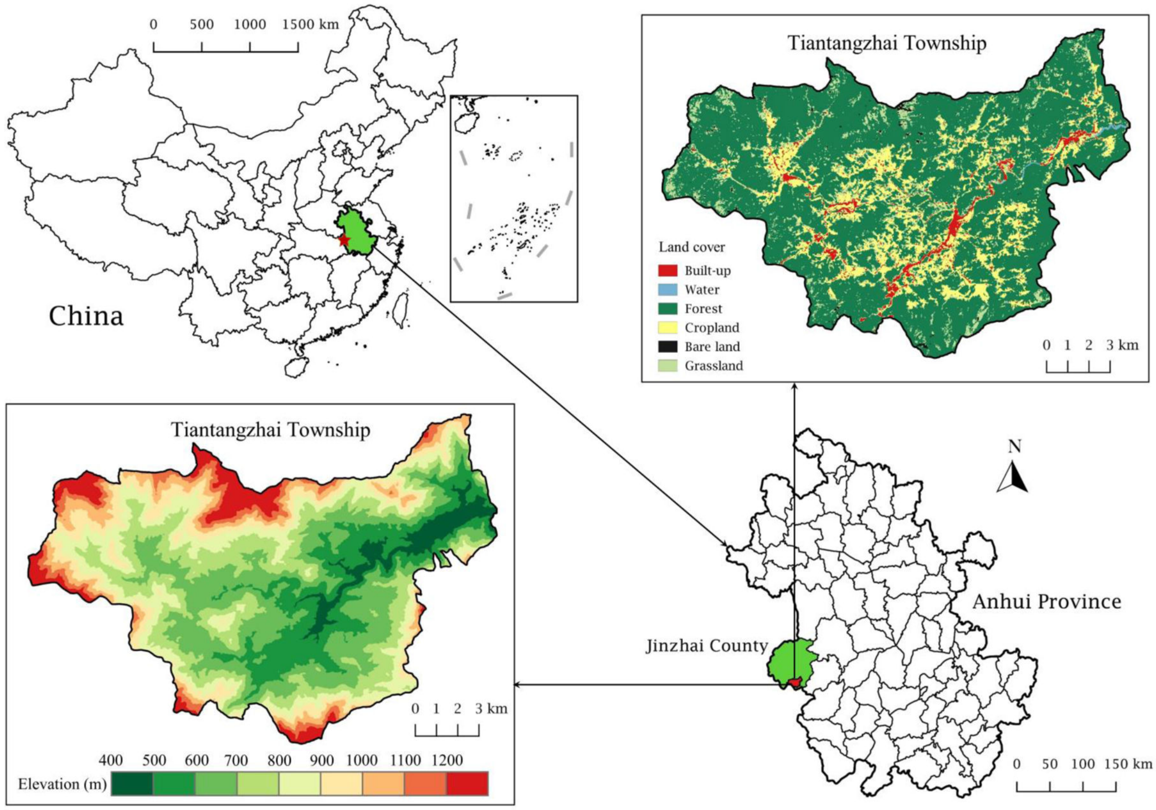

Figure 2.
Location of study area, showing land-use/cover and elevations.

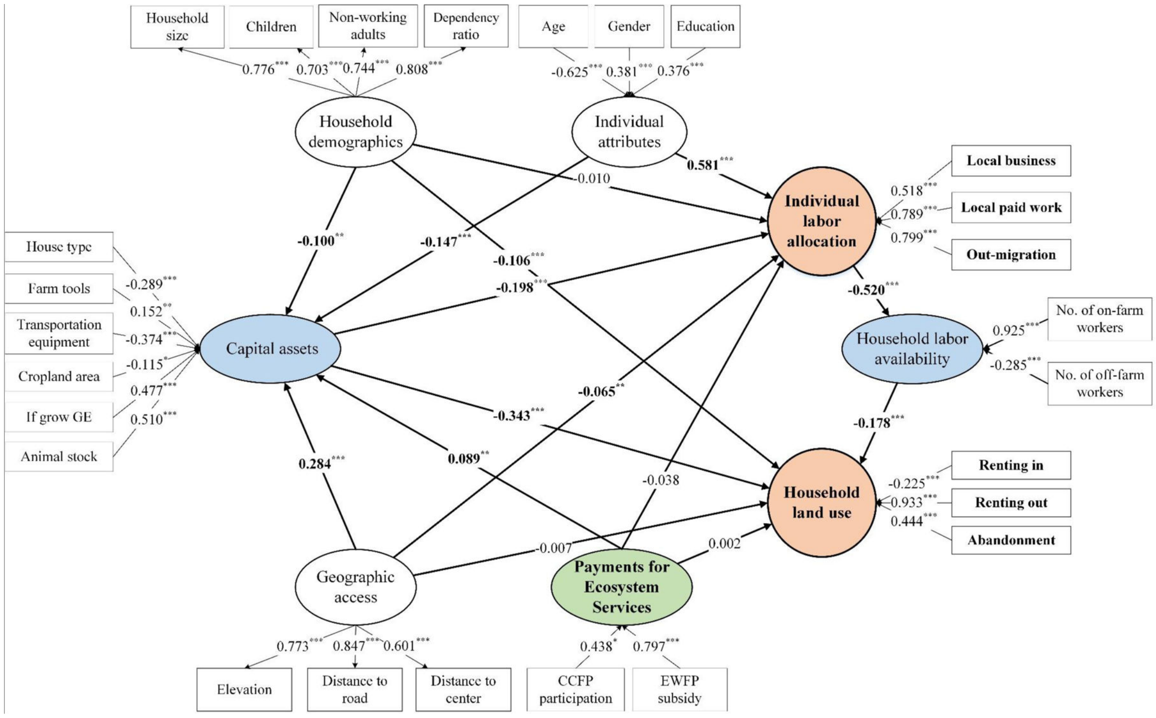

Figure 3.

PLS path analyses of factors affecting household livelihood decisions (labor allocation and land use).

Note: Reflective constructs are Household demographics and Geographic access (arrows going out), with all others formative (arrows going in). On-farm labor and stabilization of cropland use are residual categories, thus do not appear explicitly in the model.

Table 1.

Description of the two principal national payments for ecosystem services programs in China.

Program	Initial year	Coverage	Purposes	Target behavior/ change of rural households	Subsidies provided [a]	Expenditures of the State [a]	Achievements
CCFP	1999	Pilot carried out in Shaanxi, Gansu and Sichuan Provinces, extended in 2000–2001 to 22 more provinces across China, covering 2,434 counties	Primary goal of ecological restoration and second goal of poverty alleviation	Convert sloped cropland into forest or grassland. Trees to plant mostly ecological, decided upon by local government	Yangtze River Basin: 230 yuan/mu/year Yellow River Basin: 160 yuan/mu/year	During 1999–2013, 442.5 billion yuan	During 1999–2013, 139 million mu cropland converted to forest or grassland; 262 million mu barren land afforested; 46 million mu mountain closure areas reforested
	2007				Yangtze River Basin: 125 yuan/mu/year Yellow River Basin: 90 yuan/mu/year		
	2014	More focus on high poverty areas	More emphasis on poverty alleviation	Convert cropland on slopes into forest or grassland. Encourage farmers to plant economic trees, such as tea, walnut, and kiwi fruit	Convert cropland to forest: total compensation of 1500 yuan to be paid three times: First year: 800 yuan /mu Third year: 300 yuan /mu Fifth year: 400 yuan /mu, if meet requirements of afforestation. Convert cropland to grassland: total compensation of 1000 yuan: First year: 600 yuan /mu Third year: 400 yuan /mu	During 2014–2019, 74.9 billion yuan	During 2014–2019, 67.8 million mu cropland converted to forest or grassland; 1 million mu barren land afforested
EWFP	2001	Implemented in 658 counties or forest bureaus in 11 provinces across China	Prohibit commercial logging in natural forests; and restore forest/shrub/ grass vegetation, and afforestation through mountain closures, aerial seeding, and human planting	Give up timber harvesting from natural forests they own	5 yuan/mu/year	During 2001 and 2013, 80.1 billion yuan	During 1998–2019, total area of ecological welfare forests had increased by 300 million mu
	2004	Extended to all 31 provinces			5 yuan/mu/year		
	2010				10 yuan/mu/year		
	2014				15 yuan/mu/year		

Note:

[a] 1 mu = 1/15 ha; one US$ = 6.21 yuan in 2014.

Sources: China State Council (2002, 2007); Ministry of Finance and State Forestry Administration (2004, 2011, 2014); State Forestry Administration (2020a, 2020b)

Table 2.

Descriptive statistics of dependent variables on rural livelihoods (percentages).

Livelihood decisions	Full sample (N=993)		Lower wealth (N_1=309)		Medium wealth (N_2=347)		Higher wealth (N_3=337)		Mean difference between groups			One-way ANOVA [a]
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Lower vs. Medium	Lower vs. Higher	Medium vs. Higher	Sig.
Labor allocation												
On-farm work												
Agricultural work on own land	54.41	47.5	63.49	45.98	53.92	47.07	46.58	48.01	0.10***	0.17***	0.07**	0.000***
Off-farm work												
Local business	6.13	23.04	3.59	18.1	5.88	22.16	8.72	27.36	−2.29	−5.13***	−2.84	0.018**
Local paid work	20.7	37.92	17.09	34.97	22.65	39.27	22.01	38.97	−5.57*	−4.92*	0.65	0.127
Out-migration employment	18.76	38.6	15.83	36.3	17.54	37.35	22.69	41.58	−1.72	−6.86**	−5.15*	0.060*
Land Use												
Renting in land (net)	17.12	37.69	21.36	41.05	16.43	37.11	13.95	34.69	4.93*	7.41**	2.48	0.040**
Stabilization	29.51	45.63	27.18	44.56	30.55	46.13	30.56	46.14	−3.36	−3.38	−0.02	0.560
Renting out land (net)	19.03	39.28	14.89	35.65	18.16	38.60	23.74	42.61	−3.27	−8.85***	−5.58*	0.014**
Abandonment	34.34	47.51	36.57	48.24	34.87	47.72	31.75	46.62	1.70	4.82	3.12	0.423

Note:

[a] One-way ANOVA analysis for differences in means of livelihood decisions between groups at different wealth levels.

*** $p<0.01$

** $p<0.05$

* $p<0.10$, same in other tables and figures.

Table 3.

Descriptive statistics of independent variables for analysis of rural livelihood decisions.

Variables	Description	Full sample (N=993)		Lower wealth (N_1=309)		Medium wealth (N_2=347)		Higher wealth (N_3=337)		Mean difference between groups			One-way ANOVA[a]
		Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Lower vs. Medium	Lower vs. Higher	Medium vs. Higher	Sig.
Individual attributes													
Age	In years	48.35	12.55	51.25	13.23	47.28	11.19	46.80	12.83	3.97***	4.44***	0.47	0.000***
Gender	1=male; 0=female	0.56	0.50	0.57	0.50	0.56	0.50	0.56	0.50	0.01	0.01	0.00	0.933
Education	Years of schooling	5.46	3.56	4.70	3.61	5.90	3.41	5.69	3.55	−1.21***	−1.00***	0.21	0.000***
Household demographics													
Household size	Number of household members	3.86	1.45	3.25	1.34	4.09	1.56	4.19	1.24	−0.85***	−0.94***	−0.09	0.000***
Children	Number of children aged 0–11	0.44	0.63	0.33	0.56	0.47	0.67	0.52	0.62	−0.14***	−0.19***	−0.05	0.000***
Non-working adults	Number of adults who do not work	0.42	0.66	0.31	0.53	0.54	0.71	0.38	0.69	−0.24***	−0.08	0.16***	0.000***
Dependency ratio	Dependents divided by workers	0.71	0.79	0.58	0.73	0.88	0.87	0.66	0.72	−0.30**	−0.08	0.22*	0.002**
Geographic access													
Elevation	Elevation of house (m)	672.2	100.2	686.5	110.6	677.8	98.0	653.4	89.3	8.66	33.07***	24.41***	0.000***
Distance to nearest road	Walking distance to road (minutes)	11.53	14.54	15.56	17.92	12.77	13.95	6.56	9.38	2.79**	9.00***	6.20***	0.000***
Distance to center	Distance to township center (hours)	3.70	0.88	3.88	0.91	3.70	0.84	3.49	0.87	0.17	0.39***	0.22	0.001***
Capital assets													
House type	Score of house type	2.99	1.76	1.37	0.94	2.82	1.56	4.66	0.76	−1.46***	−3.29***	−1.83***	0.000***
Farm tools	Score of farm tools	2.64	1.61	1.89	1.39	2.75	1.62	3.22	1.53	−0.86***	−1.33***	−0.46***	0.000***
Transportation equipment	Score of transportation equipment	2.70	1.33	1.72	1.54	3.01	0.89	3.28	0.94	−1.29***	−1.57***	−0.28***	0.000***
Cropland area	Area of cropland owned (mu)	5.81	2.73	5.01	2.44	6.01	2.67	6.34	2.88	−1.00***	−1.33***	−0.33	0.000***
If grow GE	1=yes, 0=no	0.609	0.488	0.589	0.493	0.643	0.480	0.593	0.492	−0.054	−0.004	0.049	0.286

Variables	Description	Full sample (N=993)		Lower wealth (N_1=309)		Medium wealth (N_2=347)		Higher wealth (N_3=337)		Mean difference between groups			One-way ANOVA[a]
		Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Lower vs. Medium	Lower vs. Higher	Medium vs. Higher	Sig.
Animal stock	Value of animals (1,000 yuan)	5.08	7.59	5.10	9.34	5.07	6.76	5.06	6.55	0.03	0.04	0.01	0.998
Household labor availability													
Farm labor	Number of farm workers	1.47	0.87	1.46	0.77	1.47	0.97	1.47	0.85	−0.01	−0.01	0.01	0.982
Off-farm labor	Number of local off-farm workers	1.02	0.95	0.76	0.85	1.07	0.80	1.22	1.10	-0.32^{***}	-0.46^{***}	-0.14^{**}	0.000^{***}
Payments for ecosystem services													
CCFP participation	1=yes, 0=no	0.577	0.494	0.563	0.497	0.588	0.493	0.579	0.495	−0.025	−0.016	0.009	0.812
EWFP subsidy	Subsidies from EWFP (yuan)	500.63	620.81	498.30	592.90	515.39	602.57	487.03	666.46	−17.09	11.27	28.36	0.849

Note:

[a]One-way ANOVA analysis for differences in means of determinant variables between groups at different wealth levels.

Table 4.

Direct-, indirect- and total effects of factors affecting individual labor allocation via different pathways

Pathway	β	p-value
Direct effects		
PES -> Individual off-farm work (**H1a**)	−0.038	0.196
Capital assets -> Individual off-farm work	−0.198	0.000***
Individual attributes -> Individual off-farm work	0.581	0.000***
Household demographics -> Individual off-farm work	−0.010	0.614
Geographic access -> Individual off-farm work	−0.065	0.013**
Indirect effects		
PES -> Capital assets -> Individual off-farm work (**H2a**)	−0.017	0.060*
Individual attributes -> Capital assets -> Individual off-farm work	0.028	0.000***
Household demographics -> Capital assets -> Individual off-farm work	0.020	0.023**
Geographic access -> Capital assets -> Individual off-farm work	−0.057	0.000***
Total effects		
PES -> Individual off-farm work	−0.055	0.070*
Capital assets -> Individual off-farm work	−0.198	0.000***
Individual attributes -> Individual off-farm work	0.609	0.000***
Household demographics -> Individual off-farm work	0.010	0.770
Geographic access -> Individual off-farm work	−0.122	0.000***

Table 5.

Direct-, indirect- and total effects of factors affecting household land use via different pathways

Pathway	β	**p-value**
Direct effects		
PES -> Household land use (**H1b**)	0.002	0.882
Capital assets -> Household land use	−0.343	0.000***
Household demographics -> Household land use	−0.106	0.007***
Household labor availability -> Household land use	−0.178	0.000***
Geographic access -> Household land use	−0.007	0.801
Main indirect effects		
PES -> Capital assets -> Household land use (**H2b**)	−0.030	0.048**
Individual off-farm work -> Household labor availability -> Household land use (**H3**)	0.092	0.000***
PES -> Individual off-farm work -> Household labor availability -> Household land use (**H4**)	−0.004	0.235
Capital assets -> Individual off-farm work -> Household labor availability -> Household land use	−0.018	0.000***
Individual attributes -> Capital assets -> Household land use	0.051	0.000***
Individual attributes -> Individual off-farm work -> Household labor availability -> Household land use	0.054	0.000***
Household demographics -> Capital assets -> Household land use	0.034	0.019**
Geographic access -> Capital assets -> Household land use	−0.098	0.000***
Total effects		
PES -> Household land use	−0.033	0.442
Capital assets -> Household land use	−0.361	0.000***
Individual attributes -> Household land use	0.107	0.000***
Household demographics -> Household land use	−0.071	0.084*
Household labor availability -> Household land use	−0.178	0.000***
Geographic access -> Household land use	−0.116	0.000***
Individual off-farm work -> Household land use	0.092	0.000***

Note: We only present main indirect pathways, except for PES, those indirect paths with impact size smaller than 0.01are not listed in the table.

Table 6.

Loadings and weights from the measurement models for full sample and the three wealth groups.

Variables	Full sample		Lower wealth		Medium wealth		Higher wealth	
	l / w	**p-value**	***l / w***	**p-value**	***l / w***	**p-value**	***l / w***	**p-value**
Individual attributes (w)								
Age	−0.625	0.000***	−0.709	0.000***	−0.624	0.000***	−0.440	0.000***
Gender	0.381	0.000***	0.403	0.000***	0.466	0.000***	0.354	0.000***
Education	0.376	0.000***	0.311	0.006***	0.317	0.003***	0.498	0.000***
Household demographics (l)								
Household size	0.776	0.000***	0.724	0.000***	0.758	0.002***	0.628	0.042**
Children	0.703	0.000***	0.584	0.000***	0.698	0.006***	0.548	0.050**
Non-working adults	0.744	0.000***	0.747	0.000***	0.339	0.427	0.502	0.228
Dependency ratio	0.808	0.000***	0.896	0.000***	0.260	0.601	0.514	0.255
Geographic access (l)								
Elevation	0.773	0.000***	0.762	0.000***	0.895	0.000***	0.538	0.000***
Distance to road	0.847	0.000***	0.820	0.000***	0.764	0.000***	0.766	0.000***
Distance to center	0.601	0.000***	0.648	0.008***	0.231	0.073*	0.696	0.000***
Capital assets (w)								
House type	−0.289	0.000***	−0.219	0.030**	−0.166	0.201	−0.113	0.182
Farm tools	0.152	0.014**	0.101	0.381	0.230	0.405	0.329	0.018**
Transportation equipment	−0.374	0.000***	−0.407	0.020**	−0.017	0.993	−0.287	0.035**
Cropland area	−0.115	0.070*	−0.349	0.014**	0.080	0.447	−0.031	0.827
If grow GE	0.477	0.000***	0.324	0.033**	0.691	0.000***	0.417	0.003***
Animal stock	0.510	0.000***	0.569	0.000***	0.261	0.167	0.458	0.001***
Household labor availability (w)								
Farm labor	0.925	0.000***	0.927	0.000***	0.929	0.000***	0.950	0.000***
Off-farm labor	−0.285	0.000***	−0.224	0.031**	−0.338	0.003***	−0.167	0.214
Payment for ecosystem services (w)								
CCFP participation	0.438	0.056*	0.060	0.247	0.114	0.541	0.517	0.099*
EWFP subsidy	0.797	0.000***	0.296	0.406	0.953	0.000***	0.659	0.021**

Variables	Full sample		Lower wealth		Medium wealth		Higher wealth	
	l / w	**p-value**	***l / w***	**p-value**	***l / w***	**p-value**	***l / w***	**p-value**
Labor allocation (w)								
Local business	0.518	0.000^{***}	0.313	0.000^{***}	0.531	0.000^{***}	0.634	0.000^{***}
Local paid work	0.789	0.000^{***}	0.737	0.000^{***}	0.798	0.000^{***}	0.835	0.000^{***}
Out-migration employment	0.799	0.000^{***}	0.830	0.000^{***}	0.783	0.000^{***}	0.771	0.000^{***}
Household land use (w)								
Renting in	−0.225	0.008^{***}	−0.222	0.233	0.251	0.345	−0.121	0.662
Renting out	0.933	0.000^{***}	0.697	0.019^{**}	0.943	0.000^{***}	0.982	0.000^{***}
Abandonment	0.444	0.000^{***}	0.567	0.024^{**}	0.397	0.184	0.332	0.068*

Note: *l* indicates reflective construct, *w* formative construct (see text).

Table 7.

Total effects analyses of household livelihood decisions for the three wealth groups.

Path	Low wealth		Medium wealth		High wealth	
	β	p-value	β	p-value	β	p-value
PES -> Capital assets	−0.017	0.436	0.207	0.009***	0.154	0.135
PES -> Individual off-farm work	−0.012	0.938	−0.066	0.178	−0.097	0.152
PES -> Household land use	0.002	0.578	−0.040	0.647	−0.077	0.465
PES -> Household labor availability	0.007	0.939	0.035	0.188	0.050	0.174
Individual off-farm work -> Household labor availability	−0.547	0.000***	−0.527	0.000***	−0.511	0.000***
Individual off-farm work -> Household land use	0.118	0.026**	0.066	0.103	0.086	0.052*
Household labor availability -> Household land use	−0.216	0.023**	−0.126	0.094*	−0.169	0.043**
Capital assets -> Individual off-farm work	−0.135	0.032**	−0.171	0.013**	−0.244	0.000***
Capital assets -> Household labor availability	0.074	0.040**	0.091	0.021**	0.125	0.000***
Capital assets -> Household land use	−0.380	0.032**	−0.102	0.828	−0.397	0.000***
Household demographics -> Capital assets	−0.179	0.025**	0.151	0.183	−0.022	0.966
Household demographics -> Individual off-farm work	0.064	0.286	0.019	0.610	0.016	0.998
Household demographics -> Household labor availability	−0.036	0.308	−0.010	0.617	−0.008	0.998
Household demographics -> Household land use	−0.053	0.429	−0.110	0.111	−0.076	0.296
Individual attributes -> Capital assets	−0.213	0.020**	−0.056	0.467	−0.082	0.251
Individual attributes -> Individual off-farm work	0.612	0.000***	0.596	0.000***	0.601	0.000***
Individual attributes -> Household labor availability	−0.334	0.000***	−0.313	0.000***	−0.306	0.000***
Individual attributes -> Household land use	0.151	0.037**	0.047	0.197	0.082	0.022**
Geographic access -> Capital assets	0.152	0.085*	0.337	0.000***	0.292	0.004***
Geographic access -> Individual off-farm work	−0.099	0.028**	−0.149	0.001***	−0.109	0.022**
Geographic access -> Household labor availability	0.054	0.031**	0.079	0.002***	0.056	0.036**
Geographic access -> Household land use	−0.064	0.529	−0.211	0.017**	−0.141	0.128