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The Effects of China’s Sloping Land Conversion Program on Agricultural Households[*]

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Abstract: In the late 1990s, China aimed to mitigate environmental degradation from agricultural production activities by introducing the world’s largest ’Payments for Environmental Services’ (PES) program—the Sloping Land Conversion Program (SLCP). In order to analyze its effects on agricultural households, we develop a microeconomic Agricultural Household Model (AHM), which can model the production, consumption, and non-farm labor supply decisions of agricultural households in rural China in a theoretically consistent fashion. Based on this theoretical model, we derive an empirical specification that we use to econometrically estimate the effects of the SLCP and other exogenous factors. Using a large longitudinal farm household survey data set, we estimate the empirical model with the Hausman-Taylor estimation method. The empirical results are generally consistent with the results of our theoretical comparative static analysis, e.g. that the SLCP significantly decreases agricultural production. While the SLCP increases non-farm labor supply and total consumption in the Yellow River basin, these effects could not be observed in the Yangtze River basin. The recent reduction of the SLCP compensation payment rates has had some notable, but generally small effects.

Keywords: Sloping Land Conversion Program; Agricultural household model; Household behavior; Hausman-Taylor Estimator; China

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1 Introduction

Rapid economic growth often goes along with environmental degradation, especially in the earlier and middle stages of economic development; therefore many developing countries are currently facing this problem (Dinda, 2004). In recent years, Payments for Environmental Services (PES) have been increasingly used to reduce the negative environmental effects of farming activities (Landell-Mills and Porras, 2002, Scherr et al., 2003). PES works by compensating those who provide environmental services (ES), e.g. specific land uses (e.g. afforestation is frequently promoted, particularly in developing countries) (Engel et al., 2008), while payments come from ES users, government revenues, or third-party donors. Pagiola et al. (2005) and Pattanayak et al. (2010) argue that this scheme is institutionally simpler and more cost-effective than traditional conservation programs. In addition, since ES are often supplied by poor households in rural areas, PES could also contribute to poverty reduction through direct payments if the compensation payments and indirect benefits such as improved local institutions or structural reallocation of labor participation exceed the losses due to participation in the PES (Wunder, 2008; Uchida, 2009).

However, while the theory of PES is relatively straightforward, the practice is much more difficult. Farmers are expected to participate in the PES program, if the compensation payment is higher than the expected loss from participating in the program. However, Anderson (2006) and Pattanayak et al. (2010) suggest that responses to financial incentives may vary in ways that are different from those predicted by simple models of rational choice. For instance, in certain cases (e.g. small payment), this financial (external) incentive may also weaken the participants' conversation incentives (Cardenas et al., 2000). Better knowledge and empirical evidence of the impacts of PES programs will help to design better-targeted PES programs.

To mitigate environmental degradation, China initiated the world's largest PES program—the Sloping Land Conversion Program (SLCP)—in the late 1990s. The most obvious impacts of a PES program on participating households are the effects on production activities and the effects on household income, which include both direct income impacts and a range of second-order impacts[1] (Pagiola et al., 2005). For instance, Li et al. (2011) demonstrate that the SLCP has

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[1] Generally, payments for environmental services could provide additional incomes to the participating households. On the other hand, the conservation set-aside program indirectly induces structural changes in

significant positive impacts on household income, especially for low- and medium-income families, whereas income inequality is lower among participating households than among non-participating households. Yao and Li (2010) find that the effects of program participation on incomes from crop production, animal husbandry, and off-farm work strongly vary between households, and these effects are positively related to local economic conditions, program extent, and political leadership. Using propensity score matching, the difference-in-differences method, and difference-in-differences matching analysis, Uchida et al. (2007) also find that the program has a moderately positive effect on income. On the other hand, using 1999 and 2002 data for both participants and non-participants, Xu et al. (2004) argue that the SLCP has, on average, negligible impact on the participants' income. Additionally, indirect effects on off-farm employment are also expected. For example, Uchida et al. (2009) claim that participating households are increasingly shifting their labor endowment from on-farm work to the off-farm labor market, because the program is relaxing the households' liquidity constraints. However, Kelly and Huo (2013) suggest that the shift from on-farm labor to off-farm labor does not arise from alleviating liquidity constraints, but rather from shifting some labor that is freed from cultivating the afforested cropland into off-farm employment or non-farm self-employment. Yao and Li (2010) found that the SLCP increased agricultural productivity by 15.8% during the period of 1998–2004, with the gain mainly coming from the development of animal husbandry and more intensive land use. In addition, Feng et al. (2005) suggest that the impact of the SLCP on grain supply is significant at the local level, e.g. that the reduction of grain production reached above 20% in western China, while this impact was only in the range of 2-3% at the national level, and thus, the SLCP might not have a major effect on China's grain supply.

Although these previous studies provide some rigorous empirical evaluations of the current policy implementation, one common limitation is that their sample size is small and the analyzed time period is rather short. Moreover, these studies are not based on a sound theoretical framework that integrates the households' production, consumption and labor supply decisions, although a systematic analysis of farm household behaviour has to take into account the interdependence of these decisions (Singh et al., 1986).

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household livelihood strategies by reducing the demand for labor for cultivating crops. However, the reallocation of the freed-up labor time is highly dependent on the individuals' resources and other factors (Engel et al., 2008, Uchida et al., 2009).

The objective of this paper is to analyze and estimate the effects of the SLCP on the participating households, i.e. their agricultural production, household consumption, and non-farm labor supply. Such a comprehensive study of the socio-economic effects of the SLCP has not been conducted before. We base our study on a microeconomic Agricultural Household Model (AHM) that is able to model the complex interactions between the household's production, consumption and labor supply decisions, and allows us to empirically analyze the effects of the policy intervention in a theoretically consistent fashion (Singh et al., 1986). Given the characteristics of rural China, we develop a non-separable agricultural household model assuming an imperfect labor market (Singh et al., 1986, Benjamin, 1992, Sadoulet et al., 1998, de Brauw and Rozelle, 2008). The non-separability of the household model is caused by transaction costs on the labor market implied by observed and unobserved heterogeneity of labor (Henning and Henningsen, 2007). Therefore, the non-separability of consumption, production and labor supply decisions not only implies that production and consumption decisions are interlinked, but also that labor allocation decisions are likely to be determined through shadow wages rather than the market price of labor.

The theoretical model and the empirical specification that we develop in this paper are based on microeconomic theory and are applicable—perhaps after minor adjustments—to other parts of the world and to other types of programs. Thus, our paper contributes to the literature on approaches to the socio-economic assessment of policy interventions in the agricultural sector. In addition, we investigate the impact of SLCP not only before, but also after the policy change, which has—to our best knowledge—not yet been done by other studies.

2 Sloping Land Conversion Program

In response to the drought of the Yellow River in 1997 and the massive floods along the Yangtze River in 1998, the Chinese government initiated in the late 1990s one of the first and most ambitious PES programs (Bennett, 2008). The program aims to reduce soil erosion through reforestation and is exceptional because of its ambitious ecological objective to convert 14.67 million hectares of farmland to forest (4.4 million of which is on land with slopes above 25 degrees) and an additional "soft" goal of afforesting a roughly equal area of denuded mountains and wasteland by 2010 (SFA, 2003). By the end of 2012, 9.26 million hectares of sloping agricultural land had been converted to forest, while the total compensation payments amounted to 326.2 billion CNY (1USD=6.29 CNY, in 2012), which benefited 32 million households spread over 25 provinces.[2] While preventing soil erosion is the primary objective of the SLCP, the State Forestry Administration (SFA, 2003) also explicitly states some socio-economic objectives of the program, e.g. poverty alleviation (Uchida et al., 2007).

The State Forestry Administration (SFA) and provincial and sub-provincial forestry bureaus identified the plots that were eligible to participate in the SLCP using the slope as a single criteria (slopes greater than 15° in the northwest and 25° in the southwest), because these plots tend to experience serious erosion resulting from cultivation. The political elite and the administration pressed farmers to enroll all eligible plots in the SLCP. The contracts with the participating households had a duration of 8 years. The participant households were granted seedlings as well as technical guidance for planting. Local governments were in charge of inspecting the afforested plots, e.g. checking whether the trees' survival rate was at least 70%, which was a condition for receiving the payments. In most cases, the compensation payment exceeded the foregone income of cultivating the (less fertile) sloping land so that—together with the pressure from local governments to participate—participation in SLCP programs has been "quasi voluntary" (Uchida et al., 2009).

In order to account for yield differences between the two river basins, the compensation payment was set to 2100 CNY/ha/year in the Yellow River Basin and to 3150 CNY/ha/year in the Yangtze River Basin. In addition to these compensation payments, the households in both regions received 300 CNY/ha/year for managing and protecting the planted trees. However, in practice, the compensation payments actually received by the participating households were usually lower than the official payment rates. Xu et al. (2010) elaborated two plausible reasons for this shortfall in payments: (a) the local government deducted some money from the compensation payments to make up for expenditure shortfalls and tax arrears, or (b) the government kept some of the funds to compensate themselves for expenditure on seedlings and other costs induced by the SLCP. We observed the same situation in our study, and therefore, the compensation rate not only varies between the different river basins, but also between households within the same river basin.

In 2007, when the first SLCP contracts were about to expire, the Chinese government adjusted the policy in two ways. First, new afforestation of sloping farmland was suspended under the program from 2008 due to the consideration of food security. Second, the government prolonged

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[2] More detailed information about the SLCP can be found in the study by Liu (2013).

the contract with existing participants for another 8 years, but it reduced the compensation payments rates by half (i.e. to 1050 CNY/ha/year in the Yellow River Basin and to 1575 CNY/ha/year in the Yangtze River Basin), while the remuneration for maintaining the trees remained unchanged (300 CNY/ha/year).

3 Theoretical model

In this section, we construct a static agricultural household model[3] that concentrates on the production, consumption and labor supply decisions of agricultural households that participate in the SLCP and are affected by labor market imperfections. Some aspects of the households' decisions will be ignored, notably (price) risk (Finkelshtain and Chalfant, 1991, Fafchamps, 1995) and credit constraints (Chambers and Lopez, 1987). For instance, output price uncertainty may be less relevant for agricultural households that consume a high proportion of their own products, which is also observed in our sample, so that the behavior of the agricultural households in our sample can be approximately modelled by assuming risk neutrality. In addition, financial constraints can be relaxed by internal saving, borrowing, and microcredit, which was available for the households from the Chinese Rural Credit Cooperative and the Postal Saving Bank and which specifically targets purchases of agricultural inputs and services. We assume that the agricultural households maximize utility U from both home-produced and market-purchased goods and leisure subjecting to constraints by the production technology, their time endowment and their (full) income (Singh et al., 1986):

$$max\ U(C_c, C_a, C_m, C_l, z^c), \tag{1}$$

where C_c and C_a are home-produced consumption goods, crop products and animal products, respectively, C_m indicates market-purchased consumption goods and C_l means leisure consumption, while z^c is a vector of household characteristics that influence the household's preferences.

Utility is maximized subject to a production technology:

$$G\left(X_c, X_a, X_v, X_l, R_f, R_s, R_{sp}, z^p\right) = 0, \tag{2}$$

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[3] Most agricultural household models are defined as static models that maximize current utility instead of a discounted future stream of expected utility (Taylor and Adelman, 2003).

where the production technology $G(.)$ is represented by a well-behaved multi-input, multi-output transformation production function (Lau, 1978a), X_c indicates the produced quantity of crop products, X_a indicates the produced quantity of animal products, X_v indicates the quantity of intermediate inputs, X_l indicates the quantity of the on-farm labor input, R_f indicates the size of the flat (non-sloping) land and R_s indicates the size of the sloping land, which includes sloping land used for agricultural production (R_{sa}) and sloping land in the SLCP that has been converted to forest (R_{sp}), where $R_s = R_{sa} + R_{sp}$, and z^p represent the production characteristics of the agricultural household.[4] Given the situation in rural China, we assume that both flat land (R_f) and sloping land (R_s) are quasi-fixed inputs and that the amount of sloping land that is in the SLCP (R_{sp}) is exogenously determined (see section 2 and Uchida et al. 2009).

The agricultural household also faces a time constraint; it cannot allocate more time to on-farm work (X_l), non-farm work (X_l^s) and leisure (C_l) than the total time available to the household (T_l):

$$T_l - X_l - X_l^s - C_l \geq 0 \tag{3}$$

Generally, the pervasive situation in rural China is that most households are involved in off-farm work, but only very few, if any, households hire labor for farming in the peak season. Furthermore, for the few households that hire farm labor, the proportion of hired labor in total farm labor is negligible. Therefore, we do not take hired farm labor into account.

The household also faces a cash income constraint:

$$P_m C_m \leq P_c[(1 - T_c)X_c - C_c] + P_a(X_a - C_a) - P_v X_v + f(X_l^s, z^s) + R_{sp}S_p + \left(R_f + R_s - R_{sp}\right)S_a + E, \tag{4}$$

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[4] The multi-input, multi-output transformation production function $G(.)$ not only depends on the size of the flat and sloping land that is used for agricultural production (R_f and R_{sa}), but also on the size of the (sloping) land that is in the SLCP (R_{sp}), because land in the SLCP requires some labor for maintenance and may contribute a little to the agricultural output through agroforestry. Our model specification, where $G(.)$ depends on R_f, R_s, and R_{sp} is equivalent to a more intuitive model specification, where $G(.)$ depends on R_f, R_{sa}, and R_{sp}, because $R_s = R_{sa} + R_{sp}$. We chose our model specification because it simplifies the comparative static analysis, because only one variable (R_{sp}) is affected by the SLCP in our specification, while two variables (R_{sa} and R_{sp}) are affected by the SLCP in the alternative specification.

where the total expenditures on purchased consumption goods $P_m C_m$ must not exceed the households' monetary income, including 'tax-corrected' crop farming revenue $P_c[(1-T_c)X_c - C_c]$, livestock farming revenue $P_a(X_a - C_a)$, non-farm labor income $f(X_l^s, z^s)$, the SLCP compensation payment $R_{sp}S_p$, the area payment for crop production $\left(R_f + R_s - R_{sp}\right)S_a$, and exogenous income E (e.g. remittances), reduced by the expenditure on intermediate inputs $P_v X_v$, where P_m, P_c, P_a, and P_v, are exogenous market prices of purchased consumption goods, crop products, animal products, and intermediate inputs, respectively, T_c is the tax rate that farmers had to pay on produced crop products until 2002, z^s are factors explaining transaction costs on the labor market and labor heterogeneity, and S_p and S_a are the compensation payment and the subsidy rate that farmers receive per unit of land in the SLCP and per unit of cultivated farm land, respectively. As the variables R_f, R_s, R_{sp}, S_p, and S_a are all exogenously given for the household, we can rewrite the cash income constraint (4) as:

$$P_m C_m \leq P_c[(1-T_c)X_c - C_c] + P_a(X_a - C_a) - P_v X_v + f(X_l^s, z^s) + E^*, \qquad (5)$$

where $E^* = R_{sp}S_p + \left(R_f + R_s - R_{sp}\right)S_a + E$ is the total exogenous income.

We assume that the produced quantities of crop products and animal products are clearly larger than the consumed amounts of these products ($X_c \gg C_c$ and $X_a \gg C_a$) so that the consumption restrictions $C_c \leq X_c$ and $C_a \leq X_a$ are not binding.

Henning and Henningsen (2007) state that household members could receive different non-farm wage rates corresponding to their observable skills. And if all the household labor is homogenous on farm work, then utility maximization implies that the order, in which household members take up non-farm work, corresponds to their (potential) off-farm wage levels so that the marginal non-farm wage is a step-wise decreasing function of non-farm labor supply. This means that household members with a higher (potential) wage level participate in the non-farm labor market first. This would imply that the labor revenue function $f(\cdot)$ is concave, which corresponds to the assumptions of Henning and Henningsen (2007) and Glauben et al. (2012).

We solve the utility maximization problem defined in equations (1) to (3) and (5) by constructing a Lagrangian function:

$$\begin{aligned} L = U(C_c, C_a, C_m, C_l, z^c) + \lambda\{P_c[(1-T_c)X_c - C_c] + P_a(X_a - C_a) - P_m C_m - P_v X_v + \\ f(X_l^s, z^s) + E^*\} + \mu[T_l - X_l - X_l^s - C_l] + \eta\left[G\left(X_c, X_a, X_v, X_l, R_f, R_s, R_{sp}, z^p\right)\right], \quad (6) \end{aligned}$$

where λ, μ and η are Lagrangian multipliers associated with the budget, time and production technology constraints, respectively. From the Lagrangian function, we derive the following first-order conditions (in addition to the production constraint (2), the time constraint (3), and the cash income constraint (4-5):

$$\frac{\partial L}{\partial C_i} = \frac{\partial U(.)}{\partial C_i} - \lambda P_i = 0 \; \forall \; i \in (c, a, m) \tag{7}$$

$$\frac{\partial L}{\partial C_l} = \frac{\partial U(.)}{\partial C_l} - \mu = 0 \tag{8}$$

$$\frac{\partial L}{\partial X_c} = \eta \frac{\partial G(.)}{\partial X_c} + \lambda(1 - T_c)P_c = 0 \tag{9}$$

$$\frac{\partial L}{\partial X_a} = \eta \frac{\partial G(.)}{\partial X_a} + \lambda P_a = 0 \tag{10}$$

$$\frac{\partial L}{\partial X_v} = \eta \frac{\partial G(.)}{\partial X_v} - \lambda P_v = 0 \tag{11}$$

$$\frac{\partial L}{\partial X_l} = \eta \frac{\partial G(.)}{\partial X_l} - \mu = 0 \tag{12}$$

$$\frac{\partial L}{\partial X_l^s} = \lambda \frac{\partial f(.)}{\partial X_l^s} - \mu = 0 \tag{13}$$

As suggested by Henning and Henningsen (2007), we can obtain the unobservable shadow wage as the marginal revenue from off-farm labor, i.e. $P_l^* = \partial f(.)/\partial X_l^s$. By substituting this term into equation (13), we derive $P_l^* = \mu/\lambda$, where λ is the marginal utility of cash and μ is the marginal utility of time endowment, which shows that the shadow wage P_l^* depends on factors from both the cash income constraint and the time constraint.

4 Comparative static analysis

The main objective for building and applying an agricultural household model is often to assess the effects of policies and other exogenous shocks on agricultural household behavior based on comparative statics or empirical models. A comparative static analysis helps to understand the mechanisms and attempts to determine the directions of the effects of policies and other exogenous shocks, and hence, can provide the theoretical basis for hypotheses for empirical studies. However, difficulties in the analysis due to its complexity are a hallmark of agricultural household models (Taylor and Adelman, 2003).

In order to facilitate the comparative statics analysis, we use duality results to express the primal decision problem (Diewert, 1982, Singh et al., 1986), while we make the usual assumptions about the curvature properties of profit functions and expenditure functions. The expenditure function indicates the minimum expenditure required to achieve a fixed utility level, i.e. $e(p^c, U^O, z^c) = \min_c\{p^{c\prime} c | U(c, z^c) \geq U^O\}$, where $c = (C_c, C_a, C_m, C_l)'$ is the vector of all consumed quantities and $p^c = (P_c, P_a, P_m, P_l^*)'$ is the corresponding vector of consumer prices. Shepard's lemma gives the relationship between the expenditure function and the Hicksian demand functions, i.e. $C_i^H(p^c, U^O) = \partial e(.)/\partial P_i \ \forall\, i \in \{c, a, m\}$ and $C_l^H(p^c, U^O) = \partial e(.)/\partial P_l^*$. By substituting the indirect utility function $v(p^c, y^*)$ for U^O, the Hicksian demand function at utility level $v(p^c, y^*)$, i.e. $C_i^H\big(p^c, v(p^c, y^*)\big)$, is equivalent to the Marshallian demand function $C_i(p^c, y^*)$ at income level y^*, where the "full" income is given by:

$$y^* = p^{c\prime}c = P_c(1 - T_c)X_c + P_aX_a - P_vX_v + P_l^*(T_l - X_l - X_l^s) + f(X_l^s, z^s) + E^* \qquad (14)$$

The profit function indicates the maximum profit that can be obtained, i.e. $\Pi\big(p^p, R_f, R_s, R_{sp}, z^p\big) \equiv \max_x\big\{P_c^*X_c + P_aX_a - P_vX_v - P_l^*X_l \big| G\big(X_c, X_a, X_v, X_l, R_f, R_s, R_{sp}, z^p\big) = 0\big\}$, where $p^p = (P_c^*, P_a, P_v, P_l^*)'$ is the vector of effective producer prices and $P_c^* = (1 - T_c)P_c$ is the tax-corrected price of crop products. We can use Hotelling's lemma to obtain the output supply functions, i.e. $X_c\big(p^p, R_f, R_s, R_{sp}, z^p\big) = \partial\Pi(.)/\,\partial P_c^*$ and $X_a\big(p^p, R_f, R_s, R_{sp}, z^p\big) = \partial\Pi(.)/\,\partial P_a$, as well as the input demand functions, i.e. $X_v\big(p^p, R_f, R_s, R_{sp}, z^p\big) = -\partial\Pi(.)/\,\partial P_v$ and $X_l\big(p^p, R_f, R_s, R_{sp}, z^p\big) = -\partial\Pi(.)/\,\partial P_l^*$.

In the case of non-separability, the comparative static effects of the conversion of sloping land into forests within the SLCP can be expressed as follows (Taylor and Adelman, 2003):

$$\frac{\partial Z}{\partial R_{sp}} = \left.\frac{\partial Z}{\partial R_{sp}}\right|_{P_l^* = const} + \frac{\partial Z}{\partial P_l^*}\frac{\partial P_l^*}{\partial R_{sp}}\,, \qquad (15)$$

where z can be any endogenous variable of interest including agricultural production, input use, consumption, and the supply of non-farm labor, i.e. $Z \in \{X_c, X_a, X_v, X_l, C_c, C_a, C_m, C_l, X_l^s\}$. The first right-hand term in equation (15) represents the direct effects of the program, while the second terms indicates the indirect effects through its influence on the endogenous shadow price of labor.

To obtain the indirect component of the non-separable model, we derive the shadow price adjustment by applying the implicit function theorem to the time constraint (3) (De Janvry et al., 1991):

$$\frac{\partial P_l^*}{\partial R_{sp}} = -\frac{-\frac{\partial C_l}{\partial R_{sp}}-\frac{\partial X_l}{\partial R_{sp}}}{-\frac{\partial X_l}{\partial P_l^*}-\frac{\partial X_l^s}{\partial P_l^*}-\frac{\partial C_l^H}{\partial P_l^*}} = \frac{\frac{\partial C_l}{\partial y^*}\frac{\partial y^*}{\partial R_{sp}}+\frac{\partial X_l}{\partial R_{sp}}}{-\frac{\partial X_l}{\partial P_l^*}-\frac{\partial X_l^s}{\partial P_l^*}-\frac{\partial C_l^H}{\partial P_l^*}} \qquad (16)$$

The denominator of (16) indicates the change in the time allocation induced by changes in the internal wage rate. Given the convexity of $\Pi(.)$ in p^p and the concavity of $e(.)$ in p^c, and given the concavity of $f(.)$ in marketed non-farm labor, we can obtain $\partial X_l/\partial P_l^* < 0$, $\partial C_l^H/\partial P_l^* < 0$, and $\partial X_l^s/\partial P_l^* < 0$, respectively, which shows that the denominator is expected to be positive. The sign of the numerator is theoretically undetermined. The effect of "full" income on leisure time is expected to be positive, as leisure is unlikely to be an inferior consumption good. The effect of participating in the SLCP on the "full" income $\partial y^*/\partial R_{sp} = \partial \Pi(.)/\partial R_{sp} + S_p - S_a$[5] could theoretically be negative or positive, but the Chinese government set the SLCP compensation payments (S_p) so high that it usually overcompensates the loss in profit due to reduced production $\left(\partial \Pi(.)/\partial R_{sp}\,|_{P_l^*=constant}\right)$ and reduced area payments for crop production (S_a) so that the *ceteris paribus* effect of participation in the SLCP on leisure time, i.e. $\partial C_l/\partial R_{sp} = (\partial C_l/\partial y^*)(\partial y^*/\partial R_{sp})|_{P_l^*=constant}$, is expected to be positive. In contrast, it is expected that the term $\partial X_l/\partial R_{sp}\,|_{P_l^*=constant}$ is negative, because converting some of the sloping farmland into forest likely reduces the optimal labor use on the farm. In almost all agricultural households in our data set that participated in the SLCP, we found decreased farming labor and increased non-farm labor when the SLCP was introduced, which means that the reduction in the farming labor that occurred when the SLCP was introduced was larger than the increase in leisure. Although these observed total effects are not identical to the *ceteris paribus* effects, it is reasonable to assume that the sign of the numerator is negative, which also subsequently infers that SLCP *ceteris paribus* results in a decline in the shadow price of labor. Based on this result and the properties of the above-defined profit, expenditure, and labor revenue functions, we

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[5] Please note that the full income can be represented by $y^* = \Pi\left(p^p, R_f, R_s, R_{sp}, z^p\right) + P_l^*(T_l - X_l^s) + f(X_l^s, z^s) + R_{sp}S_p + \left(R_f + R_s - R_{sp}\right)S_a + E$.

derive the directions of the household’s consumption, production and labor market responses to participation in the SLCP (Table 1).

Table 1 *Agricultural household's consumption, production and labor market responses to SLCP*

		Direct effect	Indirect effect	Total effect
Shadow price of labor	P_l^*	$\frac{\partial P_l^*}{\partial R_{sp}} \leq 0^{1,2,3,6}$	—	< 0
Production	X_c	$\frac{\partial X_c}{\partial R_{sp}} \leq 0^7$	$\frac{\partial X_c}{\partial P_l^*}\frac{\partial P_l^*}{\partial R_{sp}} \gtrless 0$	$\leq 0^9$
	X_a	$\frac{\partial X_a}{\partial R_{sp}} \approx 0^7$	$\frac{\partial X_a}{\partial P_l^*}\frac{\partial P_l^*}{\partial R_{sp}} \gtrless 0$	?
	X_v	$\frac{\partial X_v}{\partial R_{sp}} \leq 0^8$	$\frac{\partial X_v}{\partial P_l^*}\frac{\partial P_l^*}{\partial R_{sp}} \gtrless 0$	$\leq 0^9$
	X_l	$\frac{\partial X_l}{\partial R_{sp}} \leq 0^8$	$\frac{\partial X_l}{\partial P_l^*}\frac{\partial P_l^*}{\partial R_{sp}} \geq 0^2$	$\leq 0^9$
Consumption	C_c	$\frac{\partial C_c}{\partial y^*}\frac{\partial y^*}{\partial R_{sp}} \geq 0^{4,5}$	$\frac{\partial C_c}{\partial P_l^*}\frac{\partial P_l^*}{\partial R_{sp}} \gtrless 0$	$\geq 0^9$
	C_a	$\frac{\partial C_a}{\partial y^*}\frac{\partial y^*}{\partial R_{sp}} \geq 0^{4,5}$	$\frac{\partial C_a}{\partial P_l^*}\frac{\partial P_l^*}{\partial R_{sp}} \gtrless 0$	$\geq 0^9$
	C_m	$\frac{\partial C_v}{\partial y^*}\frac{\partial y^*}{\partial R_{sp}} \geq 0^{4,5}$	$\frac{\partial C_m}{\partial P_l^*}\frac{\partial P_l^*}{\partial R_{sp}} \gtrless 0$	$\geq 0^9$
	C_l	$\frac{\partial C_l}{\partial y^*}\frac{\partial y^*}{\partial R_{sp}} \geq 0^{4,5}$	$\frac{\partial C_l}{\partial P_l^*}\frac{\partial P_l^*}{\partial R_{sp}} \geq 0^1$	≥ 0
Non-farm labor	X_l^s	—	$\frac{\partial X_l^s}{\partial P_l^*}\frac{\partial P_l^*}{\partial R_{sp}} \geq 0^3$	≥ 0

Notes: the theoretical analysis is based on the following assumptions: 1. concavity of $e(\cdot)$ in p^c; 2. convexity of $\Pi(\cdot)$ in p^p; 3. concavity of $f(\cdot)$ in X_l^s; 4. C_c, C_a, C_m and C_l are normal goods; 5. the SLCP increases full income; 6. the increase in leisure due to the SLCP is smaller than the decrease in farm labor due to the SLCP, i.e. $\partial \mathrm{C_l}/\partial R_{sp} + \partial \mathrm{X_l}/\partial R_{sp} < 0$; 7. the sloping land is used for crop production and not for animal production; 8. labor and intermediate inputs are complements to (sloping) land; 9 the direct effect is larger (in absolute terms) than the indirect effect. (Glauben et al., 2012) assume that labor and intermediate inputs are complements, i.e. $\partial^2\Pi(.)/(\partial \mathrm{P_l^*}\ \partial \mathrm{P_v}) = -\partial \mathrm{X_l}(.)/\partial \mathrm{P_v} = -\partial \mathrm{X_v}(.)/\partial \mathrm{P_l^*} > 0$, and that all (physical) consumption goods are net-substitutes of leisure, i.e. $\partial^2 \mathrm{e}(.)/(\partial \mathrm{P_l^*}\ \partial \mathrm{P_i}) = \partial \mathrm{C_l}(.)/\partial \mathrm{P_i} = \partial \mathrm{C_i}(.)/\partial \mathrm{P_l^*} > 0$, but we think that these assumptions are unrealistic in our case, e.g. because a higher (shadow) price of labor could encourage farmers to do less hand-weeding and instead use more pesticides (i.e. more intermediate inputs) and/or a higher (shadow) price of leisure (with full income remaining constant) may not only decrease leisure time, but also decrease the expenditure on leisure activities (i.e. less market-purchased consumption goods).

A comparative static analysis based on standard microeconomic assumptions (i.e. concavity of $e(\cdot)$ in p^c and convexity of $\Pi(\cdot)$ in p^p) suggests that all allocation effects of the SLCP are theoretically ambiguous. However, after making some reasonable additional assumptions regarding the household's preferences, the production technology, the labor revenue function, and the height of the SLCP compensation payment (assumptions 3-9 below Table 1), the directions of most consumption, production, and non-farm labor adjustments become clear. As it is assumed that the SLCP increases full income and all consumption goods are normal goods, the SLCP *directly* leads to an increased consumption of all consumption goods. The reduction of cultivated farmland by converting sloping farmland into forest most likely *directly* reduces the use of labor and intermediate inputs (e.g. fertilizers) and the production of crop products. The production of animal products is probably not significantly affected, because the sloping land was rarely used for animal production (e.g. grazing or forage production). In case of labor market imperfections, the consumption and production decisions are additionally affected by a change in the shadow price of labor. A decline in the shadow price of leisure / labor caused by the SLCP stimulates the leisure consumption and increases the use of labor in the production, but the effect on other consumption goods, intermediate inputs and the agricultural outputs is unclear. The SLCP does not directly affect non-farm labor, but the SLCP-induced reduction of the shadow price (opportunity costs) of labor, results in an increase in non-farm activities. Assuming that the (clear) direct effects are larger (in absolutes terms) than the (mostly ambiguous) indirect effects, we conclude that the SLCP reduces production activities (except for animal production) and increases consumption and non-farm activities.

5 Empirical model and data

The econometric estimation of non-separable household models usually implies the simultaneous estimation of all structural equations, i.e. consumption, production, and (labor) market activities, whereas the explicit expression of the full set of structural equations requires the use of non-observable implicit (shadow) prices (Sadoulet and de Janvry, 1995). This makes the econometric estimation of the structural equations of non-separable household models very complex. Therefore, in most empirical studies that are based on non-separable household models, reduced-form equations are derived from the structural model and these reduced-form equations, rather than the full set of structural equations, are estimated (Lopez, 1984, Benjamin, 1992). The disadvantage of this approach is that it is usually not possible to analytically derive the reduced-form equations from the structural equations. Consequently, it is not possible to fully exploit the economic theory, e.g. by imposing and testing (parameter) constraints derived from economic theory. However, when the goal of the analysis is to investigate policy effects, the estimation of reduced-form equations may be appropriate (Singh et al., 1986).

5.1 Reduced-form model

The reduced form of our non-separable household model can be derived from the first order conditions (equations 2-3, 5, and 6-12). The production decisions depend on the effective producer prices, the quasi-fixed production inputs, and the production characteristics z^p.

$$X_i = X_i\left(P_c^*, P_a, P_v, P_l^*, R_f, R_s, R_{sp}, z^p\right) \forall\, i \in \{c, a, v, l\} \tag{17}$$

On the consumption side, the household behaves as if it were maximizing utility using the exogenous prices P_c , P_a, and P_m, shadow price P_l^* and “full” income y^* and given its consumer characteristics z^c:

$$C_i = C_i(P_c, P_a, P_m, P_l^*, y^*, z^c) \forall\, i \in \{c, a, m, l\} \tag{18}$$

The optimal use of labor for non-farm activities depends on the shadow price of labor and labor market characteristics:

$$X_l^s = X_l^s(P_l^*, z^s) \tag{19}$$

In the non-separable case, the first-order conditions clearly show that the shadow price of labor ($P_l^* = \mu/\lambda$,) depends on all exogenous variables of the relevant optimization problem, because the Lagrangian multipliers λ and μ are determined by these variables:[6]

$$P_l^* = P_l^*\left(P_c, P_a, P_v, P_m, R_f, R_s, R_{sp}, T_c, T_l, E^*, z^p, z^c, z^s\right) \tag{20}$$

Replacing P_l^* in equations (17) and (19) with the right-hand side of equation (20), we obtain the reduced-form equations for the optimal agricultural input quantities, agricultural output quantities, and non-farm labor:

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[6] Alternatively, we could write that the shadow price of labor depends on the effective producer price of crop products P_c^* and the effective consumer price of crop products P_c, where the latter is identical to the market price of crop products and the former is $P_c^* = (1 - T_c)P_c$. We find it more straightforward to write that the shadow price of labor depends on the market price of crop products P_c and the tax rate on crop products T_c. As one of the three variables P_c^*, P_c, and T_c can be obtained from the other two variables, both approaches are equivalent (particularly as we do not assume a specific functional form).

$$X_i = X_i\left(P_c, P_a, P_v, P_m, R_f, R_s, R_{sp}, T_c, T_l, E^*, z^p, z^c, z^s\right)\ \forall\ i\ \in\ \{c, a, v, l\} \quad (21)$$

$$X_l^s = X_l^s\left(P_c, P_a, P_v, P_m, R_f, R_s, R_{sp}, T_c, T_l, E^*, z^p, z^c, z^s\right) \quad (22)$$

Replacing y^* in equation (18 with the right-hand of equation (14) and then replacing P_l^*, $X_i \forall\ i\ \in \{c, a, v, l\}$, and X_l^s with the right-hand sides of equations (20), (21), and (22), respectively, we obtain the reduced-form equations for the optimal consumption quantities:

$$C_i = C_i\left(P_c, P_a, P_v, P_m, R_f, R_s, R_{sp}, T_c, T_l, E^*, z^p, z^c, z^s\right) \forall\ i\ \in\ \{c, a, m, l\} \quad (23)$$

Thus, all endogenous variables depend on all exogenous variables.

5.2 Data

The data used in this study were collected by the Economics and Development Research Centre (EDRC) of the State Forestry Administration (SFA) in China through rural household surveys.[7] The survey was conducted in 126 administrative villages, in which the SLCP was implemented. These villages are located in 42 different townships, in 14 different counties and in five different provinces, which are Sichuan, Shaanxi, Guangxi, Hebei and Jiangxi. The first survey was conducted in 2004 and covered 1458 households.

In order to also have data from the pre-implementation phase of the SLCP, the households were asked in the first survey (in 2004) to recall their livelihood and production information back to 1995. In order to minimize the (long-term) recall bias in the years 1995-2001, local government statistics helped the respondents to recollect the past livelihood and production information. The survey was repeated annually or biannually (with only one year or two years of recall, respectively) and is still on-going. The last year, for which the data were entered, checked and made available is 2010. All households that participated in the first survey were interviewed in the following years as long as the household was still involved in agricultural activities (even if the agricultural activities were limited to maintaining land in the SLCP) and it was available for

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[7] The EDRC designed the questionnaire and conducted the household surveys. The surveys were conducted by experienced interviewers from the respective regions, and as far as possible, the same interviewers were used in each year in order to ensure high consistency and quality of the data. These surveys were sponsored and supported by the Asian Development Bank and China's Ministry of Finance. They were conducted in cooperation with local governments, which provided some basic information that was used in the surveys to check the plausibility of the answers from the farmers, e.g. average crop yield, which increased the reliability of the data. These surveys collected detailed household data from 16 consecutive years and generated a large longitudinal socio-economic data set, which is rarely found in developing countries.

interviews (i.e. the household members were still alive and had not moved away). As exiting households were not replaced by new households, the number of households in the survey had reduced to 1263 in 2010. After having removed the observations with missing values, we still had 20,570 observations in our data set in total.

As this data set only includes values, but no prices or quantities of most inputs, outputs, and consumption goods[8], we obtained province-level price indices from the National Bureau of Statistics of China[9]. The price indices for grain and meat (including poultry) are used as approximations of the prices of crop products (P_c) and animal products (P_a), respectively. We calculated the price index of intermediate inputs (P_v) as a weighted average of the price indices of fertilizer, pesticides, and fodder with weights equal to expenditure shares. The general consumer price index is used as an approximation of the price of purchased consumption goods (P_m). We assume that the "law of one price" holds so that all households within a specific province and within a specific year face the same price for the same good and price differences between farms within a province only reflect quality differences (Deaton, 1990, Deaton, 1998). Hence, we can calculate quality-adjusted quantity indices for the inputs, outputs, and consumption goods by dividing the values of these goods by the corresponding province-level price indices.

Our data set does not explicitly separate the total utilized agricultural area $\left(R_f + R_s\right)$ into flat land $\left(R_f\right)$ and sloping land (R_s). We assume that all sloping land and only sloping land participated in the SLCP so that we can obtain the area of the sloping land (R_s) as the area of land in the SLCP $\left(R_{sp}\right)$ for the time after the introduction of the SLCP, i.e. $R_s = R_{sp} \geq 0$. As land transfers were virtually absent, we can obtain the area of the sloping land for the time before the introduction of the SLCP by assuming that R_s is constant over time, i.e. $R_s \geq R_{sp} = 0$.

The tax rates for crop outputs (T_c) are formulated by the township and county governments and hence, differ between townships and counties. We obtain the tax rate on crop production (T_c) by dividing the households' tax payments by the value of crop production. Due to measurement

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[8] It would have been problematic anyway to use household-level price data, because the market prices vary at different places on different days, and even from hour to hour (Gibson and Rozelle, 2005), while using unit values (values divided by quantities) is usually a poor approximation of the market price due to quality differences.

[9] http://www.stats.gov.cn/tjsj/ndsj/

errors, the calculated tax rates (T_c) are not the same for all households within each township as they differ slightly between households in a specific township. In order to avoid biased estimates due to a correlation between individual tax rates (T_c) and the error term, we take the median tax rate in each township as the value of T_c.

As our data set does not include any information about the number of household members of working age, we use the total number of household members as a proxy for total available time (T_l). We operationalize the total exogenous income (E^*) by adding the SLCP payments $(R_{sp}S_p)$[10], the area payment for grain production $\left((R_f + R_s - R_{sp})S_a\right)$[11], and the variable "financial and transfer-payments income," which is income that does not come from agricultural production, employment or business activities and mainly comprises remittances, capital income, and transfers from the government, such as pension payments and other social welfare benefits.

In addition to the above-described variables, our theoretical model includes variables that indicate the household's production conditions (z^p), its consumption preferences (z^c), and its non-farm labor market opportunities (z^s). Temporal differences in z^p, z^c, and z^s are accounted for by a linear and quadratic time trend (t and t^2). Differences between the households consumption preferences (z^c) and labor market opportunities (z^s) are captured by the gender (SEX), age (AGE), and education (EDU) of the household head and the number of household members (NO). In addition, the road condition $(ROAD)$, the distance to the center of township (DIS), and the average non-farm wage in the county $(\bar{P}_l)$ are used as proxies for z^s. Moreover, in rural China, if a household member works for the (local) government, the entire household often has more

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[10] The central government set the standard compensation payment rate for land in the SLCP program to 2100 CNY / ha in the Yellow River Basin and to 3150 CNY / ha in the Yangtze River Basin. However, in practice, the households that participated in the SLCP program usually received lower compensation payments. (Xu and Cao, 2002) elaborated two plausible reasons for this shortfall in receiving payment, either because the local government had reduced the compensation payment, or because the converted sloping land had not yet been fully approved by the program monitoring department. We observed the same situation in our study, and therefore, the compensation rate not only varies between the different river basins, but also between townships and counties within the same river basin.

[11] The grain subsidy was introduced in 2004 in order to motivate rural households to produce grain. The subsidy rate (S_a) has changed over time and differs between townships due to different levels of financial support from townships, counties, and provincial governments. In our theoretical model, we assume that the area payment is paid for all types of crop production, but in our empirical application, the area payment is only paid for grain production. Our data set does not include information on the area that is used for grain production. However, the data on production values indicate that grain production comprises on average 93% of crop production so that the total cultivated area is a suitable proxy for the area that is used for grain production.

connections with agricultural policy and information, and also much easier access to the higher quality land. Hence, we use this variable ($CADRE$) as an additional proxy for z^p.

Microeconomic theory suggests that the output supply and input demand functions (21), the non-farm labor supply function (22), and the consumer demand functions (23), are linearly homogeneous in all variables that are measured in monetary terms, i.e. $P_c, P_a, P_v, P_m, \bar{P}_l$, and E^*. In order to impose linear homogeneity, we have chosen the price of purchased consumption goods (P_m, the consumer price index) as numéraire and deflated all other variables that are measured in monetary terms by dividing them by P_m. Some variables in the data set have a few missing values. It seems that the missing values are randomly distributed and are not missing for some special reason. Hence, we can remove observations with missing values from our sample without introducing a bias, because the random sampling assumption still holds (Wooldridge, 2009). Descriptive statistics of the variables that are used in our empirical analysis are given in Table 2.

5.3 Empirical specification

We operationalize the econometric estimation of the general model specifications in equations (21), (22), and (23) by the following functional form:

$$\begin{aligned} Z_{it}^{*} = {} & \beta_0 + \beta_{Pc} logP_{c,it} + \beta_{Pa} logP_{\mathrm{a},it} + \beta_{Pv} logP_{v,it} + \beta_R \, log\left(R_{f,i} + R_{s,i}\right) + \beta_{Rs} R_{s,i}^{*} + \beta_{\mathrm{Rsp}} R_{sp,it}^{*} \\ & + \beta_{Tc} T_{c,it} + \beta_E E^{*}{}_{it} + \beta_t t_t + \beta_{t2} t^2{}_t + \beta_{SEX} SEX_i + \beta_{AGE} AGE_{it} + \beta_{AGE2} AGE_{it}^2 \\ & + \beta_{EDU} EDU_i + \beta_{NO} logNO_{it} + \beta_{ROAD} ROAD_{it} + \beta_{DIS} \, log\, DIS_i + \beta_{Pl} log\bar{P}_{l,it} \\ & + \beta_{CADRE} CADRE_i + \mu_i + \varepsilon_{it} \qquad (24) \end{aligned}$$

where i indicates the individual household, $t \in \{1, \cdots, 16\}$ indicates the time period, Z^* is some relevant dependent variable, $R_f + R_s$ is total farmland, $R_s^* = R_s/(R_f + R_s)$ is the proportion of sloping land, $R_{sp}^* = R_{sp}/\left(R_f + R_s\right)$ is the proportion of land in the SLCP, μ_i is an error term that accounts for individual unobserved heterogeneity between households due to unobserved explanatory variables such as consumption preferences, production conditions (e.g. soil quality, (micro) climate), and labor heterogeneity (e.g. job training, ability, motivation), and ε_{it} is an idiosyncratic error term.

Table 2 *Descriptive statistics of the variables in our empirical model*

		Yangtze River Basin					**Yellow River Basin**				
Variable	**Descriptions**	**Mean**	**S.D.**	**Min**	**Max**	**Zeros**	**Mean**	**S.D.**	**Min**	**Max**	**Zeros**
$X_c + X_a$	Total agricultural outputs (CNY 1994)	3587.9	3769.7	0.00	137746.0	328	2283.1	3225.8	0.0	92390.6	188
X_c	Crop production (CNY 1994)	1551.4	2032.6	0.00	120107.4	610	1705.1	2381.7	0.0	89077.5	253
X_v	Intermediate inputs (CNY 1994)	1152.4	1978.6	0.00	93424.9	446	840.1	2952.4	0.0	131579.9	81
X_l	Working days on the farm	259.5	179.4	0.00	1373.0	516	137.5	121.0	0.0	1373.0	538
X_l^s	Working days on non-farm jobs	232.5	248.4	0.00	1830.0	2427	153.7	163.2	0.0	1680.0	1223
$C_c + C_a + C_m$	Total consumption (CNY 1994)	5545.3	5395.1	151.1	255803.4	--	4584.7	4633.4	40.3	60512.9	--
$C_c + C_a$	Consumption of self-produced agricultural products (CNY 1994)	2111.6	2481.5	0.0	144954.7	536	834.4	792.8	0.0	8985.2	685
P_c/P_m	Province-level price index of crop products (1994 = 1)	0.57	0.11	0.45	0.89	--	0.65	0.14	0.51	1.09	--
P_a/P_m	Province-level price index of animal products (1994 = 1)	0.70	0.10	0.47	0.92	--	0.85	0.14	0.67	1.21	--
P_v/P_m	Province-level Price index of intermediate inputs (1994 = 1)	0.97	0.11	0.80	1.33	--	1.01	0.09	0.82	1.20	--
R_f	Total flat land (mu = 0.067 hectare)	7.93	7.32	0.00	60.50	28	9.48	10.23	0.00	77.00	59
R_s	Total sloping land (mu = 0.067 hectare)	2.67	5.28	0.00	49.00	7189	22.45	25.06	0.89	164.30	485
$R_f + R_s$	Total cultivated land (mu = 0.067 hectare)	10.60	9.09	1.00	61.80	--	22.45	25.06	0.89	164.30	--
$R_s^* = R_s/(R_f + R_s)$	Share of sloping land	0.20	0.25	0.00	1.00	7189	0.46	0.26	0.00	1.00	485
$R_{sp}^* = R_{sp}/\left(R_f + R_s\right)$	Share of land in the SLCP program	0.08	0.17	0.00	1.00	10838	0.19	0.24	0.00	1.00	2852
	-- only for the 6880 observations with $R_{sp} > 0$	0.41	0.22	0.02	1.00	--	0.52	0.23	0.03	1.00	--
$R_{sp}S_p/P_m$	SLCP compensation payments (CNY 1994)	167.97	527.19	0.00	8796.3	10838	555.76	1159.27	0.00	16799.0	2852
	-- only for the 6880 observations with $R_{sp} > 0$	677.32	880.84	3.18	8796.3	--	1035.19	1416.74	6.64	16799.0	--
$\left(R_f + R_s - R_{sp}\right)S_a/P_m$	Grain subsidy (CNY 1994)	35.80	98.04	0.00	1913.9	10351	41.28	264.02	0.00	10945.0	4403
	-- only years 2004 - 2010	126.22	146.26	0.67	1913.9	--	144.96	479.50	0.76	10945.0	--
T_c	Agricultural tax rate on crop production	0.01	0.03	0.00	0.21	4593	0.01	0.02	0.00	0.19	4637
	-- only years 1995-2002	0.02	0.03	0.00	0.21	10889	0.02	0.02	0.00	0.19	
E/P_m	Exogenous income (mainly remittance) (CNY 1994)	202.53	1444.01	0.00	48545.4	13405	193.17	1255.44	0.00	44326.2	5638
E^*/P_m	Total exogenous income (CNY 1994)	465.51	1630.84	0.00	49882.4	8122	824.54	1896.15	0.00	45624.1	2665
T	Time trend variable for 1995 (*t*=1) to 2010 (*t*=16)	8.21	4.50	1.00	16.00	--	8.21	4.53	1.00	16.00	--
SEX	Gender of household head (0 = female, 1 = male)	0.93	0.25	0.00	1.00	1005	0.98	0.15	0.00	1.00	140
AGE	The age of household head in years	45.27	11.75	20.00	86.00	--	45.24	11.40	20.00	87.00	--
EDU	Education years of household head	6.15	2.66	0.00	14.00	1170	6.80	2.86	0.00	14.00	425
NO	Number of persons living in the household	4.13	1.40	1.00	9.00	--	3.63	1.22	1.00	8.00	--
$ROAD$	Type of road to the household (0=soft surface, 1=hard surface)	0.35	0.44	0.00	1.00	8152	0.47	0.44	0.00	1.00	2143
DIS	Distance to the center of township (km)	7.89	7.54	0.00	65.00	337	9.04	5.80	0.50	25.00	--
$\bar{P}_l/P_m$	County-level wage rate of off-farm labor (CNY 1994/day)	16.84	4.77	9.17	34.19	--	19.93	5.87	10.17	37.64	--
$CADRE$	A household member working at the government (0=no, 1=yes)	0.09	0.29	0.00	1.00	13109	0.09	0.29	0.00	1.00	5599

Note: all the household data information is from surveys by the Economics and Development Research Centre (EDRC), State Forestry Administration (SFA) in China, while all price indices are from the national statistics yearbook. We take the price in 1994 as the base price.

We consider the following endogenous model variables as being particularly relevant and we use them as dependent variables in our empirical estimations: the total agricultural production ($X_c + X_a$), the production of crop products (X_c), the use of intermediate farm inputs (X_v), the labor input of the farm (X_l), the supply of non-farm labor (X_l^s), total consumption ($C_c + C_a + C_m$), and consumption of self-produced food products ($C_c + C_a$).

We take the logarithm of the numeric dependent and explanatory variables that have positive values at almost all observations and we express some other variables in terms of shares (R_s^*, R_{sp}^*, T_c), because the values of most of these variables are strongly right-skewed (which is typical for farm household surveys) so that taking the logarithms or shares results in much more equally distributed variables. This has several econometric advantages, e.g. it fulfills the assumptions of the classical linear regression model more often, and it mitigates the heteroskedasticity problem (Wooldridge, 2009).

Since the time trend t and variable AGE are perfectly collinear for almost all households (i.e. households with the same household head in the sampling period), and equation (24) includes quadratic terms of these two variables, we use an transformed variable $t - AGE_{it}$ which is the household head's year of birth or the year thereafter (depending on whether the household head's birthday is before or after the survey) instead of variable AGE as explanatory variable in the econometric estimation:

$$\begin{aligned} Z_{it}^* = {} & \beta_0 + \beta_{Pc} logP_{c,it} + \beta_{Pa} logP_{\mathrm{a},it} + \beta_{Pv} logP_{v,it} + \beta_R \, log\left(R_{f,i} + R_{s,i}\right) + \beta_{Rs} R_{s,i}^* \\ & + \beta_{\mathrm{Rsp}} R_{sp,it}^* + \beta_{Tc} T_{c,it} + \beta_E E^*{}_{it} + \beta_t^* t_t + \beta_{t2}^* t^2{}_t + \beta_{SEX} SEX_i \\ & + \beta_{AGE}^* (t_t - AGE_{it}) \qquad + \beta_{AGE2}^* (t_t - AGE_{it})^2 + \beta_{EDU} EDU_i + \beta_{NO} logNO_{it} \\ & + \beta_{ROAD} ROAD_{it} + \beta_{DIS} \, log \, DIS_i + \beta_{Pl} log\bar{P}_{l,it} + \beta_{CADRE} CADRE_i + \mu_i \\ & + \varepsilon_{it} \qquad\qquad (25) \end{aligned}$$

where $\beta_t^* = \beta_t + \beta_{AGE}$, $\beta_{t2}^* = \beta_{t2} + \beta_{AGE2}$, $\beta_{AGE}^* = -\beta_{AGE}$, and $\beta_{AGE2}^* = \beta_{AGE2}$. Based on the estimated parameters $\hat{\beta}_t^*$, $\hat{\beta}_{AGE}^*$, $\hat{\beta}_{t2}^*$ and $\hat{\beta}_{AGE2}^*$, the estimates of the parameters β_t, β_{AGE}, β_{t2} and β_{AGE2} of the reduced-form equation (25) can be obtained by $\hat{\beta}_t = \hat{\beta}_t^* + \hat{\beta}_{AGE}^*$, $\hat{\beta}_{AGE} = -\hat{\beta}_{AGE}^*$, $\hat{\beta}_{t2} = \hat{\beta}_{t2}^* + \hat{\beta}_{AGE2}^*$ and $\hat{\beta}_{AGE2} = \hat{\beta}_{AGE2}^*$. For the nearly time-invariant explanatory variables in equation (25), we use household-specific average values of these variables in all time periods so that all of our explanatory variables are either completely time-invariant for all households or clearly time-varying.

5.4 Hausman-Taylor (HT) Estimator

The usual approach to control for unobserved heterogeneity in a panel data regression is the fixed effects (FE) model, which has the attractive virtue that it is—in contrast to the random-effects estimator—robust against a correlation between the observed explanatory variables and the unobserved individual effects (μ_i). However, the fixed effects (within-group) estimator has two important defects: (1) the effects of the time-invariant explanatory variables cannot be identified[12] and (2) it is not fully efficient since it neglects variation across individuals in the sample. Therefore, Hausman and Taylor (1981) introduced an instrumental-variables method, the so-called Hausman-Taylor (HT) estimator, which can efficiently account for time-varying and time-invariant explanatory variables, while relaxing the assumption of the random effects estimator about the independence between the explanatory variables and the unobserved individual effects. Halaby (2004) has shown that the HT estimator is more efficient than the FE estimator when the time means of the time-varying explanatory variables are used as instruments to identify the parameters of the time-invariant regressors that are correlated with the unobserved individual effects. Besides, the HT method gives a significant improvement over blindly assuming that all explanatory variables are uncorrelated with the individual effects (μ_i) (Halaby, 2004). The HT instrumental-variable procedure distinguishes four groups of explanatory variables: time-varying variables X_1 and time-invariant variables W_1 that are uncorrelated with the unobserved individual effects (μ_i) and time-varying variables X_2 and time-invariant variables W_2 that are potentially correlated with the unobserved individual effects (μ_i):

$$Z_{it} = X_{1it}\beta_1 + X_{2it}\beta_2 + W_{1i}\alpha_1 + W_{2i}\alpha_2 + \mu_i + \varepsilon_{it} \tag{26}$$

The first step of the HT procedure is a traditional fixed-effects panel data estimation using the "within" transformation:

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[12] The so-called "fixed-effects vector decomposition" (FEVD) procedure (Plümper and Troeger, 2011) is an extension of the FE estimator that can identify the effects of time-invariant variables. Breusch et al. (2011) show that this estimator is a special case of the Hausman-Taylor (HT) estimator and Greene (2011) shows that the FEVD estimator may be biased in the case of slowly changing explanatory variables.

$$(Z_{it} - \bar{Z}_i) = (X_{1it} - \bar{X}_{1i})\beta_1 + (X_{2it} - \bar{X}_{2i})\beta_2 + (\varepsilon_{it} - \bar{\varepsilon}_i), \qquad (27)$$

where $\bar{Z}_i$, $\bar{X}_{1i}$, $\bar{X}_{2i}$, and $\bar{\varepsilon}_i$ are the temporal mean values of Z_{it}, X_{1it}, X_{2it}, and ε_{it}, respectively. This model specification consistently estimates the coefficients of X_1 and X_2, i.e. β_1 and β_2. Then, the temporal means of the residuals from the within estimation are calculated by $\bar{e}_i = T^{-1}\sum_{t=1}^{T}\hat{e}_{it}$, where $\hat{e}_{it} = \widehat{\varepsilon_{it} - \bar{\varepsilon}_i}$ are the residuals from the within estimation.

The second step is a conventional 2SLS instrumental-variable estimation of the within residuals $\bar{e}_i$ on the time-invariant variables W_{1i} and W_{2i} using X_{1it} and W_{1i} as instruments:

$$\bar{e}_i = \alpha_1 W_{1i} + \alpha_2 W_{2i} + \epsilon_i \qquad (28)$$

Thirdly, the two sets of residuals from step one and two are used to estimate the variance components of model (26). Finally, these variance components are used to conduct a GLS transformation of the variables in equation (26), which then can be estimated by a FGLS IV regression.

In our empirical application, the variables $R_f + R_s$, R_s^*, SEX, , $(t - AGE)$, $(t - AGE)^2$, EDU, DIS, and $CADRE$ are time-invariant for (nearly) all households and the variables E^*, $logNO$, and $CADRE$ are potentially correlated with the unobserved individual effects (μ_i), because they depend on the decisions of each individual household.

The two River Basins that are included in our study have some distinct differences. For instance, they have different staple crops, i.e. rural households in the Yellow River Basin cultivate wheat and corn, while rice is much more popular in the Yangtze River Basin. Furthermore, the two river basins have different limitation on the markets, different developments of local institutions, and different infrastructure, which may lead to significant heterogeneity between the two regions, e.g. regarding opportunities for off-farm labor. Therefore, we test for heterogeneity between the Yangtze River Basin and the Yellow River Basin by adding interaction terms between all explanatory variables (including the constant) in equation (25) and a dummy variable for the river basin.[13] For all models (dependent variables), t-tests show that the effects of many explanatory

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[13] In a simple FE regression, this specification would be equivalent to estimating two separate models (one for the Yangtze River basin and one for the Yellow River basin). However, in our HT estimation, the estimated coefficients of this specification and of the estimated coefficients of two separate estimations for the two river basins are slightly different, because the joint estimation with dummy variables still assumes

variables differ between the two river basins and F-tests clearly reject the joint models for the two river basins. Therefore, we separately estimate equation (25) for the two river basins.

5.5 Semiparametric censored regression

The potential problem in the above estimation is that almost all dependent variables have some zero values (see Table 2), which indicates that the variables are left-censored at zero. While the production and consumption variables have a relatively low proportion of zero values, the non-farm labor supply is zero for 34.5% of the observations, which means that this variable is clearly left-censored so that ignoring the censoring will result in regressors that understate the effect of the explanatory variables (MaCurdy, 1981). Therefore, the estimation of the labor supply function should be done by a censored regression model. Traditionally, censored regression models are estimated by the maximum likelihood (ML) method, but the maximum likelihood estimation of censored regression models with fixed effects generally gives inconsistent estimates for a fixed number of time periods (Honoré, 1992) and the estimation of censored regression models with random effects gives inconsistent estimates if the explanatory variables are correlated with the unobserved individual effects (μ_i). Furthermore, the maximum likelihood estimation of censored regression models requires the specification of the error distribution and the homoscedasticity assumption. Chamberlain (1984) develops estimators for censored regression with panel data with a specified parametric form of the disturbances, and Manski (1987) proposes a conditional maximum score estimator for the same model. The parametric specification of the conditional error distributions in these estimators can be problematic in practice, and the estimation is still inconsistent even when the parametric form of the conditional error distribution is correctly specified (Arabmazar and Schmidt, 1982, Chay and Powell, 2001). In order to avoid these problems, a number of semiparametric alternatives for censored regression have been proposed, which neither assume a parametric form for the disturbances nor homoskedasticity across individuals. In our study, we use the semiparametric estimator for censored regression developed by Honoré (1992), which is based upon (unconditional) moment restrictions derived from a conditional moment restriction.

We estimate the following censored regression model for non-farm labor supply with individual fixed effects:

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that the variance components are the same for the two river basins, while the separate estimations do not have this restriction.

$$X_{l,it}^{s*} = a_i + \beta_{Pc} logP_{c,it} + \beta_{Pa} logP_{\mathrm{a},it} + \beta_{Pv} logP_{v,it} + \beta_{Rsp} R_{sp,it}^{*} + \beta_{Tc} T_{c,it} + \beta_E E^{*} + \beta_t^{*} t + \beta_{t2}^{*} t^2$$

$$+\beta_{NO} logNO_{it} + \beta_{ROAD} ROAD_{it} + \beta_{Pl} log\bar{P}_{l,it} + \varepsilon_{it}\ , X_{l,it}^{s} = max\{0, X_{l,it}^{s*}\}, \quad (29)$$

where $X_{l,it}^{s}$ is the observed non-farm labor supply, $X_{l,it}^{s*}$ represents an unobserved latent variable, and the explanatory variables are kept the same as in equation (25). We estimate the effects of the time-invariant variables in a second step by a standard 2SLS regression of equation (28). These two estimations correspond to the first two steps of the Hausman-Taylor (HT) procedure. The fourth step of the HT procedure would be a semiparametric FGLS censored regression with instrumental variables, which—to the best of our knowledge—has not yet been developed. However, the first two steps of the HT procedure still give consistent estimates.

5.6 Marginal Effects

Based on the model specification in equation (24), we derive the marginal effects of the proportion of land in the SLCP by:

$$\frac{\partial Z}{\partial R_{sp}^{*}} = \beta_{Rsp} + \ \beta_E (R_f + R_s)(S_p - S_a) \quad (30)$$

We calculate these marginal effects at the average values of S_p, S_a, and $R_f + R_s$ for the observations at which the household participates in the first phase and the second phase of the SLCP. Hence, these marginal effects can be interpreted as the treatment effect on an average treated household in the respective phase of the program.

We calculate the marginal effects of the compensation payment rate (S_p) using logarithms in order to simplify the interpretation by:

$$\frac{\partial Z}{\partial \log S_p} = \beta_E R_{sp} S_p, \quad (31)$$

where we calculate these marginal effects at the average values of $R_{sp} S_p$ for the observations at which the household participates in the SLCP.

6 Estimation results and discussion

We estimate the model defined in equation (25) for the dependent variables $Z \in \{\log(X_c + X_a)$, $\log X_c$, $\log X_v$, $\log X_l$, $\log(C_c + C_a + C_m)$, $\log(C_c + C_a)\}$ using the STATA routine “xthtaylor.” Furthermore, we estimate the model for non-farm labor (X_l^s) defined in equations (29) and (28) using the STATA routines “Pantob” (Honoré 1992) and “ivregress,” respectively. The standard errors of the not directly estimated coefficients (β_t, β_{AGE}, β_{t2} and β_{AGE2}) and of the marginal effects of participation in the SLCP ($\partial Z/\partial R_{sp}^*$) and of the compensation payment rates ($\partial Z/\partial S_p$) have been calculated with the delta method using the STATA routine "nlcom."

The directly and indirectly estimated coefficients of equations (25), as well as the marginal effects of participation in the SLCP ($\partial Z/\partial R_{sp}^*$) and of the compensation payment rates ($\partial Z/\partial S_p$) for the Yellow River basin and the Yangtze River Basin are presented in Tables 3 and 4, respectively. These two tables provide many interesting insights into how the exogenous variables affect the production, consumption, and off-farm labor supply decisions of rural households in the Yangtze River Basin and the Yellow River Basin. As most results in Tables 3 and 4 can be easily interpreted without further explanation, we only comment on the results regarding the main research question of our paper, i.e. the effects of the SLCP. As predicted by our theoretical model (see Table 1), the SLCP (first phase) significantly decreases agricultural production activities. For each percent of the total land area that enters the SLCP, farming labor is reduced by 0.62 percent and 0.39 percent, intermediate inputs are reduced by 0.32 percent and 0.18 percent, total farm output is reduced by 0.54 percent and 0.27 percent, and crop production is reduced by 0.50 percent and 0.52 percent for the Yellow River basin and the Yangtze River Basin, respectively. The marginal effects on crop production are significantly lower than one (in absolute terms), which means that the reduction in crop production is smaller than the reduction in the land area that is used for crop production. This could be caused by the lower productivity of the sloping land compared to flat land (which is also confirmed by the negative coefficient β_{Rs} in the model for X_c, while the coefficient only shows significant in the Yangtze River Basin) or by the intensification of production on flat land as a reaction to the cessation of production on sloping land. As around 36% of the total land in our sample enters the SLCP and our econometric analysis indicates that the crop production decreases by around 0.5% for each percent of land that enters the SLCP (see Table 3), the total effect of the SLCP is a reduction in crop production of around 18% in our sample. However, as farmers who participate in the SLCP are over-represented in our sample, the negative effect of the SLCP on local crop production is definitely smaller. In fact, land in the SLCP only accounts for 5.67% of China's total land that is used for grain production, so the effect of the SLCP on grain production is only a reduction of around 2.8% at the national level. This also confirms the results of Feng et al. (2005) who show that the SLCP reduced grain production in the range of 2-3%.

As predicted by our theoretical model (see Table 1), our empirical results suggest that participation in the SLCP (first phase) increases non-farm work, but this effect is only statistically significant in the Yellow River Basin, whereas the positive effect in the Yangtze River Basin is insignificant. (Yao et al., 2010, Kelly and Huo, 2013) and (Uchida et al., 2009) also found that participation in the SLCP increased the likelihood of non-farm employment, but they did not consider regional differences. The extent of the marginal effects of the SLCP on non-farm labor cannot be directly interpreted, because marginal effects derived from the (semiparametric) censored regression model consist of two effects; one is the effect on the mean value of non-farm work, while the other is the effect on the probability that the household supplies off-farm labor, which depends on the distribution assumed for the censoring model (Long, 1997). The lack of statistical significance of the effect on non-farm labor for the Yangtze River Basin could be caused by a lack of non-farm employment opportunities in this region.

In contrast to our theoretical analysis, our empirical analysis indicates that the SLCP significantly reduces the consumption of self-produced crop and animal products. This could indicate that some of the assumptions of our theoretical model are wrong, e.g. it could be that the consumption restrictions ($C_c \leq X_c$ and $C_a \leq X_a$) are binding for a significant number of households (indeed at around 8.5% of the observations, the households consume more than 90% of the produced crop or animal products) or that the self-produced goods are absolute inferior goods ($\partial C_c/\partial Y^* < 0$, $\partial C_a/\partial Y^* < 0$). Our theoretical results regarding the effect of the SLCP (first phase) on total consumption are partly confirmed in the empirical analysis: the effect is close to zero (-0.04) in the Yangtze River Basin, but positive and statistically significant (0.13) in the Yellow River basin. The effect on total consumption shows that the SLCP did not significantly reduce the real income of participating agricultural households in the Yangtze River Basin, and it even increased the real income of participating agricultural households in the Yellow River Basin, which indicates that one objective of the SLCP—the alleviation of poverty by increasing rural incomes—has probably not been achieved in the Yangtze River Basin, but has been achieved in the Yellow River basin. Given the significant decrease in the consumption of self-produced products and the unchanged or increased total consumption, it can be easily concluded that the SLCP increased the consumption of purchased consumption goods in both regions. Moreover, the effect on total consumption might be partly derived from the higher income from non-farm labor which is used for purchased products.

One relevant research question that has not yet been analyzed before is the effect of reducing the compensation payment rate (S_p) by less than 50% for plots that have been in the SLCP for more than 8 years.[14] In the Yellow river basin, the reduction of the compensation payment rate (S_p) has negligible effects on the agricultural production so that the effect of the SLCP on agricultural production in the second phase is about the same as in the first phase of the program. However, the reduction of the compensation payment rate (S_p)—as expected—significantly decreases the consumption of purchased goods so that it has a negative effect on total consumption in spite of a slightly positive effect on the consumption of self-produced goods. However, even with the reduced compensation payment rates (S_p) in the second phase, the SLCP still has a positive—although somewhat lower—effect on total consumption (0.10). In the Yangtze River basin, the reduction of the compensation payment rate (S_p) makes farmers put more effort into agricultural production so that the reduction of the income from the SLCP is compensated by higher income from agricultural production leaving the total consumption approximately unchanged. As a result, the effect of the SLCP on agricultural production is slightly less negative in the second phase than in the first phase of the program, while the effect on total consumption remains close to zero.

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[14] The compensation payment rates received by the households that were in the second phase of the SLCP were on average 21% and 30% lower than the compensation payment rates of the households that were in the first phase of the SLCP in the Yellow River basin and the Yangtze River basin, respectively. The compensation payment rates were reduced by almost 50% for two reasons. First, the reduction did not include the cash subsidy for managing and protecting the planted trees. Second, as discussed above, some local governments kept some funds to compensate themselves for the cost of the seedlings in the first phase of the program.

Table 3 *Estimation results of Yellow River Basin*

Coefficient	**(1)** $X_a + X_c$	**(2)** X_c	**(3)** X_v	**(4)** X_l	**(5)** X_l^s	**(6)** $C_a + C_c + C_m$	**(7)** $C_a + C_c$
β_{Pc}	0.999***	1.023***	-0.355**	0.402***	-50.422	0.205*	0.324*
	(0.139)	(0.134)	(0.123)	(0.111)	(43.032)	(0.089)	(0.141)
β_{Pa}	1.293***	0.983***	-0.586***	0.004	-249.208***	-0.245***	0.837***
	(0.113)	(0.110)	(0.095)	(0.090)	(56.691)	(0.071)	(0.114)
β_{Pv}	-0.867***	-0.631***	-0.860***	0.411**	-16.631	-0.007	-0.536**
	(0.184)	(0.177)	(0.161)	(0.146)	(48.563)	(0.117)	(0.180)
β_{Rsp}	-0.535***	-0.494***	-0.329***	-0.640***	68.753*	0.050	-0.291***
	(0.069)	(0.068)	(0.060)	(0.055)	(28.561)	(0.043)	(0.070)
β_{Tc}	-2.588***	-0.314	-1.107*	-0.623	313.470	-1.489***	-5.759***
	(0.623)	(0.610)	(0.552)	(0.498)	(231.154)	(0.405)	(0.634)
β_t	0.181***	0.162***	-0.105**	-0.058*	-32.401***	0.006	0.219***
	(0.031)	(0.042)	(0.035)	(0.028)	(1.655)	(0.037)	(0.028)
β_{t2}	-0.014***	-0.014***	0.011***	0.0001	3.316***	0.003**	-0.015***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.020)	(0.001)	(0.002)
β_{ROAD}	0.014	0.057	0.157***	0.048	27.032	0.049*	-0.031
	(0.036)	(0.038)	(0.033)	(0.030)	(22.348)	(0.025)	(0.042)
β_{Pl}	0.666***	0.706***	-0.288***	0.447***	-198.766***	-0.197***	0.177*
	(0.079)	(0.079)	(0.069)	(0.061)	(32.607)	(0.050)	(0.080)
β_E (10^3)	0.002	0.004	0.003	0.009	2.544	0.027***	0.019**
	(0.006)	(0.006)	(0.005)	(0.005)	(4.643)	(0.004)	(0.007)
β_{NO}	0.140**	0.152***	0.197***	0.111**	22.092***	0.471***	0.211***
	(0.051)	(0.049)	(0.044)	(0.039)	(36.786)	(0.032)	(0.056)
β_R	0.332***	0.371***	0.063	0.478***	-106.348***	-0.117	0.021
	(0.050)	(0.080)	(0.064)	(0.046)	(4.308)	(0.074)	(0.107)
β_{Rs}	-0.348*	-0.352	-0.546**	-0.527***	24.454*	-0.145	0.099
	(0.152)	(0.258)	(0.200)	(0.149)	(17.626)	(0.246)	(0.324)
β_{SEX}	-0.019	0.368	-0.423	-0.213	-77.214***	-0.476	-0.775
	(0.207)	(0.354)	(0.274)	(0.202)	(15.873)	(0.337)	(0.446)
β_{Birth}	0.023	0.041	0.013	0.021	0.814	0.018	-0.014
	(0.021)	(0.035)	(0.027)	(0.020)	(1.655)	(0.033)	(0.046)
β_{Brith2}(10^3)	-0.307	-0.517	0.174	-0.191	-14.325	0.295	0.193
	(0.255)	(0.436)	(0.338)	(0.249)	(20.304)	(0.413)	(0.563)
β_{EDU}	0.004	0.028	0.018	-0.007	-5.845	0.023	-0.016
	(0.015)	(0.025)	(0.020)	(0.014)	(2.778)	(0.024)	(0.035)
β_{DIS}	-0.057	-0.008	-0.007	0.071	9.877***	-0.027	0.038
	(0.041)	(0.021)	(0.055)	(0.014)	(2.987)	(0.068)	(0.089)
β_{CADRE}	-0.089	-1.255	0.261	-0.217	526.523***	1.211	1.074
	(0.617)	(1.032)	(0.835)	(0.513)	(80.226)	(0.934)	(1.676)
Marginal Effect							
$\partial Z/\partial R_{sp}^*$	-0.541***	-0.504***	-0.322***	-0.616***	75.939**	0.125**	-0.346***
phase 1	(0.067)	(0.066)	(0.059)	(0.054)	(26.741)	(0.042)	(0.068)
$\partial Z/\partial R_{sp}^*$	-0.539***	-0.501***	-0.325***	-0.625***	73.287**	0.097*	-0.326***
phase 2	(0.068)	(0.066)	(0.059)	(0.054)	(26.687)	(0.042)	(0.068)
$\partial Z/\partial S_p$	-0.002	-0.004	0.003	0.009	2.634	0.028***	-0.020**
	(0.006)	(0.006)	(0.006)	(0.005)	(4.807)	(0.004)	(0.007)
Observ.	5659	5594	5766	5610	5847	5847	5259

Note: ***, ** and * denote significance at 0.1%, 1% and 5%, respectively.

Table 4 *Estimation results of Yangtze River Basin*

Coefficient	**(1)** $X_a + X_c$	**(2)** X_c	**(3)** X_v	**(4)** X_l	**(5)** X_l^s	**(6)** $C_a + C_c + C_m$	**(7)** $C_a + C_c$
β_{Pc}	0.419^{***}	0.111	-0.121	0.551^{***}	-172.779^{***}	0.080	0.539^{***}
	(0.092)	(0.093)	(0.091)	(0.086)	(39. 781)	(0.064)	(0.079)
β_{Pa}	0.597^{***}	0.017	-0.400^{***}	-0.099^{*}	-38.627	0.037	-0.551^{***}
	(0.055)	(0.057)	(0.055)	(0.052)	(35.541)	(0.038)	(0.048)
β_{Pv}	-0.595^{***}	0.199^{*}	-1.641^{***}	-0.629^{***}	165.489^{**}	-0.548^{***}	-0.132^{*}
	(0.085)	(0.087)	(0.084)	(0.078)	(52.749)	(0.058)	(0.073)
β_{Rsp}	-0.225^{***}	-0.493^{***}	-0.175^{***}	-0.389^{***}	61.229	-0.035	-0.207^{***}
	(0.042)	(0.044)	(0.042)	(0.039)	(33.936)	(0.029)	(0.036)
β_{Tc}	-0.887^{**}	-2.573^{***}	-0.655^{**}	-1.061^{***}	-111.704	0.039	-0.273
	(0.277)	(0.280)	(0.272)	(0.257)	(297.030)	(0.190)	(0.235)
β_{t}	0.107^{***}	0.089^{***}	-0.058^{*}	0.036^{*}	0.688	0.043	0.124^{***}
	(0.029)	(0.021)	(0.024)	(0.022)	(3.590)	(0.014)	(0.016)
β_{t2}	-0.004^{***}	-0.007^{***}	0.008^{***}	0.003^{***}	-1.060^{***}	0.004^{***}	-0.008^{***}
	(0.001)	(0.001)	(0.001)	(0.001)	(0.044)	(0.001)	(0.001)
β_{ROAD}	-0.059^{*}	-0.020	0.005	-0.011	68.598^{*}	0.052^{**}	0.002
	(0.025)	(0.025)	(0.024)	(0.023)	(29.417)	(0.016)	(0.021)
β_{Pl}	-0.226^{***}	-0.190^{***}	-0.129^{***}	-0.058^{*}	-3.076	0.022	-0.055^{*}
	(0.029)	(0.030)	(0.029)	(0.027)	(27.545)	(0.020)	(0.025)
β_E (10^3)	0.023^{***}	-0.017^{***}	0.002	0.002	-7.276	0.001	0.015^{***}
	(0.003)	(0.003)	(0.003)	(0.003)	(4.355)	(0.002)	(0.003)
β_{NO}	0.213^{***}	0.301^{***}	0.217^{***}	0.168^{***}	269.528^{***}	0.367^{***}	0.275^{***}
	(0.025)	(0.026)	(0.025)	(0.023)	(27.123)	(0.017)	(0.022)
β_R	0.152^{*}	0.169^{***}	0.156^{**}	0.191^{***}	-21.184^{**}	0.079^{**}	0.231^{***}
	(0.064)	(0.044)	(0.053)	(0.048)	(7.433)	(0.027)	(0.031)
β_{Rs}	-0.391^{**}	-0.520^{***}	-0.308^{*}	0.002	90.205^{***}	-0.016	-0.067
	(0.149)	(0.105)	(0.122)	(0.123)	(12.312)	(0.063)	(0.076)
β_{SEX}	-0.036	-0.056	-0.023	0.074	-47.201^{***}	-0.040	0.021
	(0.138)	(0.098)	(0.114)	(0.116)	(10.637)	(0.058)	(0.070)
β_{Birth}	-0.010	0.025	-0.014	-0.007	318.231	0.031^{**}	0.037^{**}
	(0.027)	(0.018)	(0.022)	(0.019)	(44.528)	(0.012)	(0.013)
$\beta_{Brith2}(10^3)$	0.159	-0.220	0.227	0.111	362.349	0.408^{**}	0.422^{*}
	(0.351)	(0.236)	(0.279)	(0.250)	(49.452)	(0.151)	(0.167)
β_{EDU}	-0.037	0.017	-0.010	-0.033^{*}	26.300^{***}	0.046^{***}	0.028^{*}
	(0.026)	(0.017)	(0.021)	(0.017)	(3.653)	(0.011)	(0.012)
β_{DIS}	0.021	0.014	0.006	0.055	2.241	0.002	0.030
	(0.035)	(0.025)	(0.029)	(0.030)	(2.724)	(0.015)	(0.018)
β_{CADRE}	2.881^{*}	0.969	2.416^{*}	1.041	-954.594^{***}	-0.527	-1.277^{*}
	(1.178)	(0.760)	(0.939)	(0.650)	(185.354)	(0.499)	(0.531)
Marginal Effect							
$\partial Z/\partial R_{sp}^*$	-0.265^{***}	-0.523^{***}	-0.178^{***}	-0.393^{***}	48. 270	-0.037	-0.235^{***}
phase 1	(0.041)	(0.042)	(0.041)	(0.038)	(32.583)	(0.029)	(0.036)
$\partial Z/\partial R_{sp}^*$	-0.244^{***}	-0.507^{***}	-0.176^{***}	-0.391^{***}	55. 006	-0.036	-0.221^{***}
phase 2	(0.042)	(0.043)	(0.041)	(0.038)	(33.053)	(0.029)	(0.036)
$\partial Z/\partial S_p$	-0.015^{***}	-0.011^{***}	-0.001	-0.001	-4.928	-0.001	-0.010^{***}
	(0.002)	(0.002)	(0.002)	(0.002)	(2.950)	(0.002)	(0.002)
Observ.	13736	13498	13641	13896	14412	14075	13570

Note: ***, ** and * denote significance at 0.1%, 1% and 5%, respectively.

7 Conclusion

Our paper has examined the effects of the world's largest 'Payments for Environmental Services' (PES) programme, i.e. China's Sloping Land Conversion Programme (SLCP), on rural agricultural households. Using a theoretical comparative static analysis and an econometric estimation with a large panel data set, our study consistently finds that the SLCP significantly reduces agricultural production activities and the consumption of self-produced products, which could reduce food security at the local level. However, the negative impact of the SLCP on agricultural production at the national level is rather small (around -2.8%). The program has reduced poverty in the Yellow River basin by increasing the income of participating households through the compensation payment and shifting the labor force from farm activities to non-farm work. However, in the Yangtze River basin, the SLCP does not significantly increase non-farm work and total consumption, which could be caused by lower off-farm work opportunities in the Yangtze River basin than in the Yellow River basin. Thus, measures that facilitate the households' access to the non-farm labor market–including employment training and information services–could strengthen the positive socio-economic effects of the SLCP, particularly in the Yangtze River basin.

The reduction of the compensation payment rates by less than 50% in the second phase of the SLCP results in a minor reduction of total consumption—which can be seen as a proxy for real income—of the participating agricultural households in the Yellow River Basin, while this effect is insignificant in the Yangtze River basin. This suggests that the large reduction of the compensation payment rates does not have any severely negative impacts on the participating households, which indicates that the SLCP program has become more cost effective in the second phase, which enhances its long-term viability. In contrast to other studies of the SLCP, our study is built upon a thorough microeconomic framework for the participating and non-participating households. Furthermore, it utilizes more years of the panel data set, which is a significant advantage, because it may have taken some time for the households to adjust to the policy. Given the thorough microeconomic background and the large spatial and longitudinal dimension of our data set, we consider our results to be very reliable and accurate. From a policy perspective, our study significantly contributes to the on-going debate about the effects of the SLCP, such as grain production, poverty alleviation, and non-farm labor supply. Furthermore, we develop a microeconomic framework and suggest an empirical econometric specification that can be used for integrated socio-economic assessments of the treatment effects of agricultural and environmental policies such as ‘Payments for Environmental Services’ (PES) programs in other developing countries.

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