Ecological Economics 75 (2012) 152–160

Contents lists available at SciVerse ScienceDirect

Ecological Economics

journal homepage: www.elsevier.com/locate/ecolecon

Analysis

Does household composition matter? The impact of the Grain for Green Program on rural livelihoods in China

Yicheng Liang [a,b,*], Shuzhuo Li [b], Marcus W. Feldman [c], Gretchen C. Daily [a]

[a] Center for conservation Biology, Department of Biology, Stanford University, Stanford, CA 94305, USA
[b] Institute for Population and Development Studies, School of Public Policy and Administration, Xi'an Jiaotong University, Xi'an, Shaanxi Province 710049, China
[c] Department of Biology, Stanford University, Stanford, CA 94305, USA

ARTICLE INFO

Article history:
Received 16 October 2010
Received in revised form 11 January 2012
Accepted 17 January 2012
Available online 6 February 2012

Keywords:
Payment-for-ecosystem-service
Family structure
Sustainable livelihood
Wage-labor supply

ABSTRACT

This research introduces family composition into the sustainable livelihoods framework for policy analysis. We apply this approach to a case study on the Grain for Green Program in western China. Using recent survey data from Zhouzhi County, we show that the impact of the policy on rural livelihoods varies across household compositions. The environmental program neither targets asset-poor households, nor does it necessarily shift the on-farm labor to non-farm sectors, which would improve household incomes (after controlling for the effect of assets). Households with children but without the elderly tend to have lower migration rates and lower incomes after participation in the program. Policy strategies should consider household heterogeneity, particularly household composition in rural China.

1. Introduction

The Grain for Green Program (GFG) (also known as the Sloping Land Conversion Program), is one of the largest payment-for-ecosystem-service (PES) experiments in the world in terms of scale, payment, and duration. Initiated in 1999, the program aimed to increase vegetative cover over 32 million hectares by 2010, of which 14.7 million hectares would be converted from cropland on steep slopes back to forest and grassland. It was intended to have beneficial ecological and socioeconomic effects, immediately or potentially, to China and the world (Caldwell et al., 2007; Groom et al., 2010; Liu et al., 2008; Wang et al., 2007).

A number of studies show that the program may benefit poor participants if they can receive payments more than the opportunity costs of the retired land. Retiring sloping lands may reduce inefficient agriculture, and payments from the program may reduce poverty and negative externality by relaxing local institutional and market constraints (Groom et al., 2010; Uchida et al., 2009). By increasing investment in local infrastructure and developing tourism industries in program areas, policymakers are expecting to see the shift of surplus labor to more sustainable and lucrative activities after the program, and indeed, to improve the economic structure of rural china (Wang et al., 2007; Xu et al., 2004; Ye et al., 2003; Zilberman et al., 2008).

However, it is not necessarily true that PES will benefit all households, even though policy designers were, on average, quite willing to overpay the participants of the program relative to the opportunity costs of the retired land (Bennett, 2008). Economists have provided only weak evidence that the program was benefiting the poor, and that participants began to shift the labor freed by the program to off-farm activities (Uchida et al., 2007). A survey also showed that only 30% of the labor freed by the program in Wuqi County of Shaanxi Province migrated for off-farm work (Xue, 2007). In another survey, 17% of households had lower income after participating in the program, although the author did not explain why (Zhi and Li, 2004).

It is important to take into account household heterogeneity in evaluating the effects of policies on household decision processes. These decision processes are mediated and shaped by other livelihood components, in particular assets, activities, and constraints on labor supply resulting from multiple market imperfections. Our main objective in this study is to address different impacts of the policy on rural households' livelihoods, depending on the households' demographic characteristics, and our particular focus is on household composition. We develop an analytical framework and a simple household model to make hypotheses that households respond differently to the program. We then present the empirical results and a brief discussion concludes the paper.

2. Analytical Approach and Methods

2.1. A Sustainable Livelihood Analysis Framework with Household Composition

Following previous studies (de Sherbinin et al., 2008; Ellis, 2000; Reardon and Vosti, 1995), we use the livelihood approach as an organizing framework to better understand effects of policies (Fig. 1).

* Corresponding author. Tel.: +1 650 521 2289.
E-mail address: liangyicheng2008@gmail.com (Y. Liang).

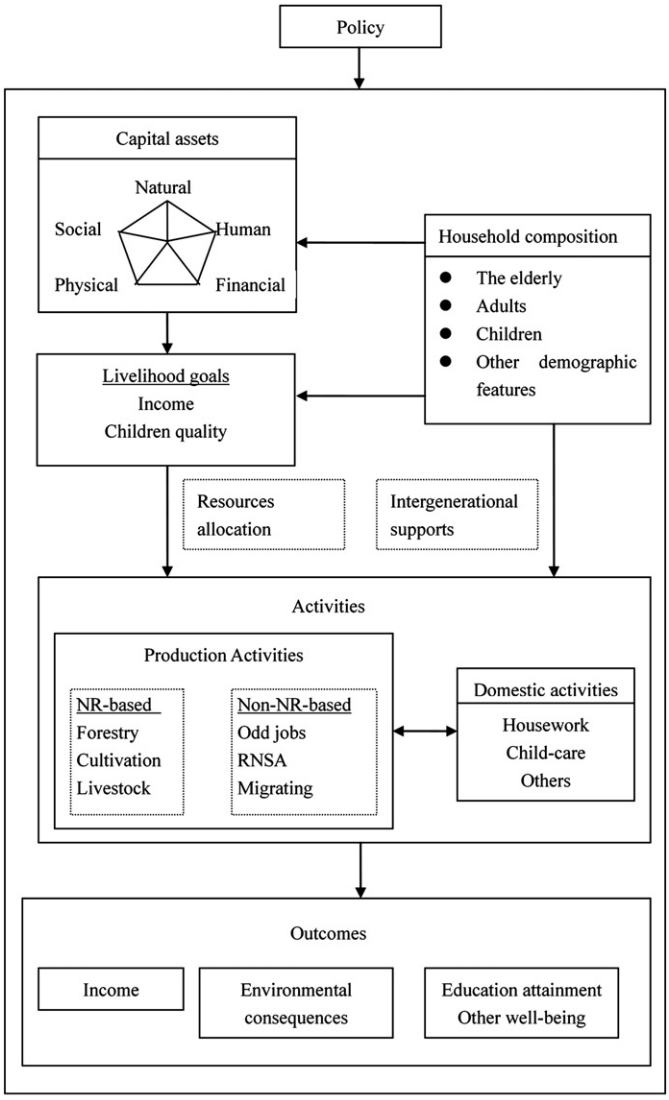
0921-8009/$ – see front matter © 2012 Elsevier B.V. All rights reserved.
doi:10.1016/j.ecolecon.2012.01.019

Chambers and Conway (1992) proposed a now-popular definition of the livelihood to comprise "the capabilities, assets (including both material and social resources) and activities required for a means of living. A livelihood is sustainable when it can cope with and recover from stresses and choices, maintain or enhance its capabilities and assets, while not undermining the natural resource base." Subsequent studies identified five main categories of capital: natural capital, physical capital, human capital, financial capital, and social capital. Although some of these categories do not conform to the orthodox economic definitions of capital, all five types of assets are useful in understanding rural livelihoods (Ellis, 2000).

In the framework presented in Fig. 1, we highlight the role of household demographic characteristics; in particular, household composition, as a key to understanding household heterogeneity in the livelihood analysis. Aside from the direct influence on human capital and other household assets, household composition may have effects on the objectives of the household. As the basic unit of production and reproduction in most rural areas of the developing world, households allocate and organize their resources into a variety of activities to pursue a livelihood strategy (de Sherbinin et al., 2008).

In Fig. 1, we also highlight the elderly as a labor supplier instead of a burden to a household, especially for those households living in poor areas without formal institutional sources of support. Several models (e.g., the exchange model, the altruism/corporate group model) can explain the support that the elderly give to their children, especially in those Asian countries that are characterized by strong Confucian norms; most older persons are involved in caring for grandchildren, and receive financial support from children (Agree et al., 2005; Li et al., 2004; Zhang and Li, 2004). In one survey, almost all the healthy elderly (95.6%) worked formally, and their health status could be the main reason for them to leave the work force; the elderly are more likely to work if a child migrates for work (Pang et al., 2004).

Although information about multiple generations in a household and the relationship between household members would be valuable, our study identifies household composition in a simple way. We first partition household members into three groups by age: children (<15), adults (15≤65), and the elderly (>65), and then divide households into four types: H(A, E) are households with elderly and adults; H(A) are households with only adults; H(C, A) are households with children but without the elderly; H(C, A, E) are households with members in all three groups. This division helps us to concentrate on activities engaged in by all or by some family members. For example, in rural China the elderly usually do on-farm work as well as work at home to care for children, until they can no longer work (Pang et al., 2004). Due to laws and a traditional emphasis on education, children are primarily in school. Migrating workers are mostly adults.



Source: adapted from Scoones (1998:4), Ellis (2000: 30), Reardon (1995)
NR: Natural resources. NRSA: Non-farm rural self-employment activities.

Fig. 1. A livelihood framework with household composition.

2.2. A Household Analytical Model

We develop a household model (in Appendix A) for the household decision process, and use it to estimate the impact of the GFG program on household activities and livelihood outcomes. Here, we focus on H(C, A), namely households that have children but no elderly.

In general, given the adult members, there are two ways household composition influences the household non-farm labor supply and total income. One is non-farm constraints related to total labor time spent by the adult and the elderly; the other is the substitution of home time for labor time after the household participates in the GFG, due to the presence of children. It is more likely for H(C, A) to be limited in non-farm labor supply due to both market imperfections and relative lack of family labor, while requiring relatively more time at home for child care. As a result, this household may reduce its off-farm labor supply and hence its total income due to market constraints and/or the substitution effect when receiving payments from the program.

Relatively more payments comparing opportunity costs and surplus labor resulting from retired lands do not necessarily shift labor into non-farm sectors. Payments might induce income effects in that households would spend more time to care for children. Non-separability holds for many developing countries (Janvry and Sadoulet, 2006), and households with a labor surplus cannot supply more non-farm labor after some of their lands are retired. On the other hand, households with migrating workers cannot continually adjust their schedule as they desire, thus, some workers just choose to give up migrating work.

2.3. Statistical Issues

In order to test different policy effects depending on various types of household composition, we follow Uchida et al. (2007) and estimate household income as

$$y_{ij} = \beta_0 + \beta_1 \cdot \sum_{1}^{n} x_j + \beta_2 \cdot \sum_{1}^{4} H_j * \text{Participation}_i + \beta_3 \cdot r_i + \varepsilon_i,$$

where, y_{ij} is the income of household i from activities j, β_i are vectors of parameters to be estimated, x_j is type j of household assets, $H_j \cdot Participation_i$ is an interaction term between a household composition dummy (set to 1 if the household belongs to H_j) and

a participation dummy, r_i is a dummy to control unobservable heterogeneity at the community level,[1] and ε_i is the disturbance term. In our case study, we are more concerned with the statistical than theoretical consequences of endogenous household composition, and we wish to test whether the β_2 coefficients for the interaction term between household composition and participation are equal to 0.

Following (DFID, 1999), we developed indicators to measure five types of assets, activities, and livelihood outcomes for local households. Natural capital consists of *areas of croplands and forestlands incorporated in the GFG (in mu; 1 mu = 1/15 ha)*; human capital is composed of *laborer numbers* and households' education, including *average schooling years of the family labor force*, and *schooling years of the family member with the most years of schooling*; physical capital includes *number of rooms* and *the value of the house (in units of 10 thousand yuan)*; financial capital and social capital include a credit access indicator as to *whether the household ever received any loans from formal institutions, including banks, Rural Credit Cooperatives and World Wildlife Fund (WWF) (1 = yes)*, and *the number of family members that have any experience of being a village cadre (leader), formal employee in an enterprise and/or other institutions, or a soldier*. Activities mainly include time allocations of each adult family member, agricultural inputs, migrating and other non-farm activities, etc. We focus on different incomes from households' activities as the outcome of livelihoods.

Although the program may have been "quasi-voluntary" to participants, and some households were "strongly encouraged" by the local officials to participate in the program provided their lands met the slope steepness criteria (≥25°) (Uchida et al., 2009), most participants had the right to choose whether to participate, and could choose not to retire lands. The right is generally protected by SLCP regulations which have been implemented effectively since 2002 (Feng et al., 2005; Ye et al., 2003).

Endogenous selection bias may occur when participants are not assigned randomly, for instance, when households' participating decisions are determined by some unobservable factors. However, in our case, only households in assigned areas have the right to choose whether to participate in the program voluntarily.

SLCP regulations emphasized "comprehensive planning" and "policy encouragement" in the implementation process. In addition, the government required in general that the retired lands be contiguous so that the scope was fit for tree planting and supervising.

Although it is possible for some households with connections to local officials to take the advantage of participation in the program regarding land measurement and payment calculation, few households own a contiguous land large enough to be retired separately. Thus, it was hard for households to cheat if the slope steepness is a large degree less than the criteria. Generally, local governments decided which areas should be included primarily in the program according to geographic and ecological conditions (for example, whether these areas suffer from soil erosion and desertification). Conclusively then, land owners in these areas would be given the right to decide whether to participate in the program. As a result, most retired lands met the slope steepness and are located in planning areas designed by the government. Thus we treat participants as being assigned randomly although they could choose voluntarily not to retire their lands.

2.4. The Household Survey

2.4.1. Study Area and the GFG

We selected four towns in the mountainous area in Zhouzhi County, Shaanxi Province as the survey site. The county has a total area of 2949 km^2, most of which is located in the Qinling Mountains, a natural boundary between northern and southern China, and home to the Qinling Panda and the Golden Snub-nosed Monkey.

Zhouzhi County is one of the poorest counties in Shaanxi province, with 3023 Yuan average per capita income in 2005. A number of environmental protection policies have been implemented in mountainous areas, including the GFG, Natural Forest Protection Project, and the approval system for timber logging. These ecological and environmental protection policies are often compulsory and implemented by the central government from the top down. Industry is forbidden and arable land is scarce in the Qinling Mountains. Also there is hardly any transfer of land in these villages. Cultivation of crops is common, although the production is not enough to satisfy family needs. Most forestry production from *Cornus* (a genus of fruit-bearing plants), walnuts, and peppers is sold to small retailers who come to the villages at specific times of the year. Walnuts and peppers are expected to generate income within three years, while *Cornus* generate income about five years after being planted.

Zhouzhi County is also a project site of World Wildlife Fund's (WWF's) Qinling Conservation and Development program. WWF supplied loans at low interest rates to a small number of qualified households for the purpose of engaging in some off-farm activities, while local cadres (leaders) played an important role in the process. Although loans from relatives and friends often carry no interest charges, the amounts of such loans are so small that some households in great need of cash have to rely on usurious loans.

In 2002, Zhouzhi County introduced the GFG in the mountain towns. Households enrolled in the program did not cultivate sloping cropland but planted mainly "economic trees" instead, including *Cornus*, walnuts, and pepper. The government provided participants with free seedlings at the beginning of the program.

2.4.2. Data Collection

We administered household questionnaires and conducted interviews in these locations in April of 2008. Although we knew the lack of panel data (before and after the program) might prevent policy analysis, we decided not to risk collecting data that households should have to recall about their livelihoods six years earlier. Due to the government's rapid decision to implement the program, it is also difficult to conduct a household survey that can cover in a representative way potential participants at the program's onset (Uchida et al., 2005). As a substitute, the survey covered both participating and non-participating households with a variety of detailed information on demographic characteristics, production and consumption activities, incomes and other livelihood outcomes, as well as some basic information on each family member. In particular, the questionnaire addressed households' assets that did not change much even after households participated in the program. This information was sought for comparative analysis in order to help overcome the lack of panel data.

Multiple level cluster sampling was adopted as the questionnaire survey method. We selected the survey villages according to the communities' economic and geographical conditions. At the household level, cluster sampling was used for the questionnaire survey in 20

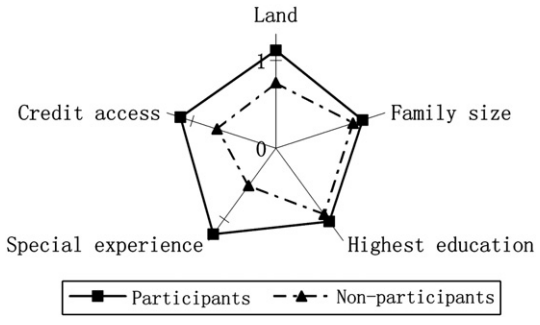


Fig. 2. Selected assets by participation.

[1] Since there is not a clear boundary between villages, and local residents are scattered over the mountainous areas, we use the household location (whether close to a road) as the representation of the heterogeneity level.

Table 1
Assets by household composition (unweighted data).

Capital	Natural	Human				Social	Financial	Physical	
	Land areas	Family size	Laborer numbers	Highest education	Average education	Special experience	credit access	Rooms	House value
H(A E)	21.01	4.02	2.80	8.55	7.55	0.48	0.11	3.98	2.58
N = 127	(2.07)	(0.11)	(0.11)	(0.33)	(0.35)	(0.09)	(0.02)	(0.13)	(0.18)
H(A)	16.74	3.31	3.31	9.06	6.43	0.58	0.15	3.74	2.40
N = 442	(0.99)	(0.06)	(0.06)	(0.17)	(0.14)	(0.05)	(0.02)	(0.07)	(0.08)
H(C, A)	16.94	4.31	2.87	8.41	8.87	0.52	0.15	3.56	2.32
N = 366	(0.75)	(0.06)	(0.05)	(0.12)	(0.19)	(0.06)	(0.02)	(0.08)	(0.10)
H(C, A, E)	24.45	5.43	2.78	8.79	9.99	0.65	0.14	4.02	2.33
N = 132	(3.52)	(0.10)	(0.09)	(0.22)	(0.37)	(0.12)	(0.03)	(0.13)	(0.16)
Total	18.25	3.99	3.01	8.72	7.82	0.56	0.14	3.73	2.38
N = 1073	(0.70)	(0.04)	(0.04)	(0.10)	(0.11)	(0.03)	(0.01)	(0.05)	(0.06)

Note: Standard errors in parentheses.

villages from the four selected towns. 1078 questionnaires were completed for a response rate of 72.6%. Five of these completed questionnaires were excluded from our analysis due to data problems. In addition, a total of 35 persons were involved in focus group and individual interviews.

3. Results

3.1. Assets

There were substantial differences in all five key assets described in Fig. 2 between participants and non-participants. Participating households own relatively more assets in all categories, especially in terms of credit access and social capital.

In explaining the difference between these two groups of households, an argument may be raised as to whether the policy has already changed the levels of household assets. Among these five types of assets, land area and family size (the number of family numbers) are not likely to change due to participation in the program; the program changed only the land utilization, not land area. Social capital is measured by the number of family members with special experience, and highest education is measured by years of schooling of the family member with the most years of schooling, so the policy is unlikely to have changed these to any degree in 6 years. It is more likely for the policy to have changed credit access due to payments by the program, while payments may have reduced financial demand for credit. In general, we suggest that the difference between participants and non-participants may be explained as policy targeting and planning problems rather than policy effects on assets. Given the retired areas assigned by the government, households with more lands are more likely to be involved in the program.

There are no notable differences in five of the categories of assets for different household groups (Table 1). H(A) and H(C, A) have relatively less land, although H(C, A) has the largest family size. Family size does not vary much across households due to Chinese population policies, and large family size does not imply more family laborers. Nor is there a big difference in the numbers of laborers between household groups, when we define the family laborers as family members between 15 and 65 years old. However, in rural China the elderly still tend to work on-farm until they leave the labor force, although they no longer tend to migrate for work. If we take the elders into account, H(C, A) may have relatively less adults available to work, given that most children are in school. Therefore, family composition may play a larger role in production and other activities than family size or number of family laborers in our study.

3.2. Time Allocation

We concentrate only on H(C, A) in comparing time allocated to on-farm and non-farm activities between participants and non-participants.

For H(C, A), participants allocate less time on crops, but more time on forests than non-participants; on average they spend more time on on-farm activities than do non-participants[2] (Fig. 3). As the household model shows (in the appendix), and although some households may reduce on-farm work supplies once some lands have been converted into forests, those households with children, but without any elderly, are more likely to face non-farm market constraints, in addition they cannot continually adjust their non-farm working time. They may as a result, reduce migrating work and spend more time performing on-farm work and taking care of their children as well. According to the interview, households now tend to work on forestry more than they did in the beginning years when they converted the crop lands into forest lands.

In sharp contrast, H(C, A) participants allocate less time to wage-labor than non-participants.[3] In addition, they tend to supply more local wage labor and less migrating wage labor than non-participants[4] (Fig. 4).

3.3. Income

The income portfolio is consistent with households' income-generating activities (Fig. 5). H(C, A) participants have relatively more local wage income,[5] and less migrating wage income[6]; on-farm income is almost the same for the two groups,[7] because participants have less crop income but more forestry income after some lands have been converted. Payments from the program are included in other income, since, on average, payments are more than the opportunity costs of the retired land, so that participants have slightly more income than non-participants[8] (Fig. 5).

We estimate the impact of the GFG and household composition on different kinds of the household income as our last step in examining the program's effect on livelihoods. The estimation is based on the livelihood framework we introduced above, where household assets are the key to understanding their outcomes.

We also focus on the H(C, A) households namely those that have children but no elderly. H(C, A)*participation is the interaction term

[2] The *t* test shows that the difference of on-farm labor input between participants and non-participants is significant at the level 5%.
[3] The *t* test shows that the difference of wage-labor supply between participants and non-participants is significant at the level 1%.
[4] The *t* test shows that the difference of migrating wage labor supply between participants and non-participants is significant at the level 5%.
[5] The *t* test shows that the difference of local wage income between participants and non-participants is significant at the level 5%.
[6] The *t* test shows that the difference migrating wage income between participants and non-participants is not significant at the level 10%.
[7] The *t* test shows that the difference of on-farm income between participants and non-participants is significant at the level 5%.
[8] The *t* test shows that the difference of income between participants and non-participants is not significant at the level 10%.

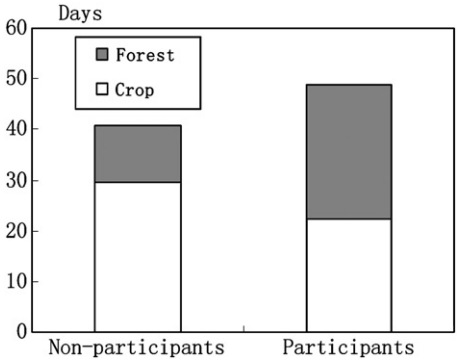


Fig. 3. On-farm labor input in 2007, for H(C, A).

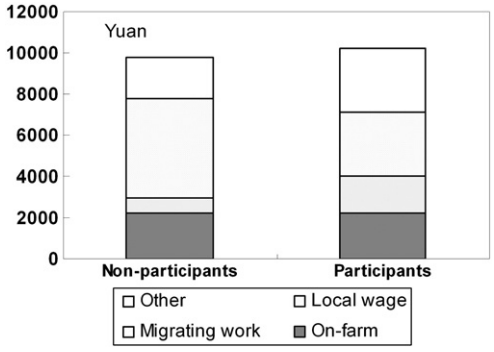


Fig. 5. Mean household income portfolios in 2007, for H(C, A).

between participating in the program and H(C, A). The result (Table 2) shows clearly that this interaction term has significant effects on all kinds of household income only for H(C, A) households, implying that the policy is more likely to affect this type of household. Notwithstanding significant positive effects on household local wage income, participating in the program has negative effects on on-farm income, as well as migrating income. The interaction term has a significant negative effect on total income. These households are more likely to face non-farm constraints, and most migrating workers would either work full time or return home. They cannot adjust their working time after being employed, and payments from the program may reduce its level of migration rather than the amount of time worked (see Appendix A). As a result, the migrating income and the total income would decrease more than households would desire, and as a substitute, local wage labor supply would increase, although local income is still less than migrating income.

Estimation of the income without payments (see Table 2) shows that H(C, A) households rely relatively more on payments from GFG, which can also shed light on which types of household will be most affected by cessations of payments from the program.

4. Discussion

As a critical component of demographic characteristics, household composition is very important in the analysis of separability features of the household model (Benjamin, 1992; Singh et al., 1986). Under the assumption of non-separability in the agricultural household model (AHM) due to market imperfections in developing countries, household composition may have significant effects on on-farm labor allocation, market participation, and other household behaviors (Janvry and Sadoulet, 2006). These studies on household composition aimed to examine the separability feature of the (AHM) as well as market imperfections. In this paper, however, we focus more on the detailed effects of demographic features on household livelihoods.

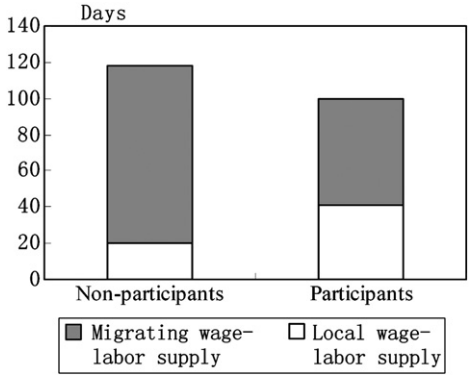


Fig. 4. Wage-labor supply in 2007, for H(C, A).

In many cases, the existence of a "mother substitute," namely a provider of child care, may increase the labor force participation and the labor supply of females with young children (Gong and Soest, 2002; Lokshin, et al., 2000; Wong and Levine, 1992). Even in the developed farm sector, family composition may influence household decisions on time allocation (Kimhi, 2004).

In the survey villages, schools have poor standards and are not able to offer complete courses for all grades. As a result, an increasing number of parents choose to send their children to towns for education, which incurs more expenses and home time for child care in downtown areas, far away from home, thus reducing time allocated to production activities.

There was also evidence that compensation payments may reduce off-farm labor supply due to income effects of the compensation or increased value of at-home time, and the increase in off-farm work of farmers may just reflect the long-term trend toward greater reliance on off-farm work by farm households (Ahearn et al., 2006), or risk-coping effects (Key et al., 2006), rather than the policy effect.

Unlike some areas where households can increase income from livestock activities and other types of assets after they participate in the GFG (e.g. Uchida et al., 2007), in our survey villages ecological policies have been intensively implemented and households' activities are strongly restricted. For the H(C, A) group, which is heavily reliant on payments, if we take payments away from total income, the participants may face a more serious income loss than other groups.[9] Previous studies (Uchida et al., 2005; Xu et al., 2004) also found that, on average, increased income for participating farmers in Guizhou and Ningxia, was due mainly to program payments (Wang et al., 2007). Comparing these studies with earlier information on the policy effects (Uchida et al., 2007), our more recent survey data can help to detect livelihood changes over a longer period.

Non-farm participation or labor supply may not be as sensitive to the program as policy designers thought; some participants may decrease their income either due to the income effect of the compensation or market restrictions on non-farm labor supplies. Although we cannot tell exactly which effect matters more for different participating households due to the cross-sectional nature of the data, it is helpful to take into account demographic heterogeneity as a key to integrating labor supply with other activities, including intergenerational supports and child care, which will in turn affect household livelihood outcomes as a whole.

Another explanation for the income loss from the program for participating H(C, A) is that the household took the subsidies as a risk-coping strategy under the assumption of risk-aversion, or the household over-anticipated the possibility of engaging in alternative

[9] We conducted some interviews on June, 2009, one year after the formal survey, and compensation payments are supposed to cease after this year, although the government is considering continuing payments as a result of bad economic situations for some participants.

Table 2
Estimated impact of the Grain for Green Program and household composition on income.

Dependent variables: household income					
	Total income[a]	On-farm income[b]	Income Without payments[c]	Migrating wage-income[d]	Local wage-income [e]
Land	−7.31	8.165**	−16.28	−80.89 **	−22.41
Highest education	400.38***	44.74*	400.29***	819.22 ***	−6.68
Social capital	233.30	18.91	214.8	32.40	719.64*
Credit access	172.43	−527.84**	215.49	2323.46	5.21
Laborers number	2505.42***	380.78***	2376.97***	5079.91***	363.31
Rooms	−134.02	178.80***	−68.58	−196.70	−119.12
House value	824.271***	159.098***	770.24***	−498.362	224.67
Close to a road	2670.78***	30.83	2453.76***	943.86	1511.97
H1*participating	−270.51	−123.5	−1636.11	867.67	2594.41
H2*participation	−743.39	−347.76*	−1862.29**	−276.77	2354.03
H3*participation	−1895.91**	−568.75***	−3329.07***	−6946.50***	5859.25***
H4*participation	278.57	280.76	−1304.99	−2403.46	2985.06
Constant	−791.01	136.29	−431.47	−23181.51***	−14301.66***
Adjusted R square	0.15	0.11	0.14		
F	16.54***	11.45***	15.42***		
Log likelihood				−4990.28***	−2532.28***
LR hi2(12)				149.36***	30.57***

Note: *, **, *** indicate significance at 10%, 5% and 1% levels, respectively.
a, b, c: Coefficients are estimated by OLS. Total income includes on-farm income, wage-labor income, rural self-employment non-farm income, payments from participating in the GFG, and all other income. On-farm income includes income from crops and forests (fruits from trees).
c: The dependent variable is the total household income not including payments from the GFG.
d, e: Coefficients are estimated by Tobit, because there is no local and/or migrating wage-labor income for some households. Migrating wage-income is the income from migrating work outside of local villages and towns; local wage-income is income from working in the villages and towns.

income generating activities, aside the compensation or the substitution of home time for income.

Policymakers might desire to see the transition of the surplus labor force from the agriculture sector to the industrial sector, and that the GFG would help some households to relax local constraints on off-farm labor markets (Groom et al., 2010). However, those households exposed to market imperfections and lack of institutional infrastructure (such as local schools), still cannot reallocate their labor to other activities, particularly migrating work.

We suggest that policy analysis should take into account the heterogeneity of participants and their labor allocation decisions (Grosjean and Kontoleon, 2009), and payments should target constrained households (Groom et al., 2010). Furthermore, we highlight this heterogeneity in terms of demographic characteristics, and expand consideration of constraints from market imperfections to lack of assets and other institutional failures. We also emphasize the context of multiple market imperfections, and lack of livelihood assets; both may prevent those households with a labor surplus from engaging in non-farm activities, even though they do not demand more home time after participation in the program.

Policymakers need to develop more lucrative opportunities (such as truism industry), and provide more training programmers to support participating households engaging in non-farm activates (Uchida et al., 2009). Increasing the investment in local infrastructure (such as local schools) can also help households to break down institutional and market constraints, achieving win-win objectives.

Acknowledgments

This work is jointly supported by Programs for Changjiang Scholars and Innovative Research Team (IRT0855) in Universities of the Ministry of Education of China, the 985-3 Project of Xi'an Jiaotong University, the National Natural Science Foundation of China (70773094), the Natural Capital Project (a partnership among TNC, WWF, and Stanford University), and the Morrison Institute for Population and Resource Studies at Stanford University. We thank the reviewers for their valuable comments. Yicheng Liang thanks Karin Meiswinkel for her support.

Appendix A

We develop a household model for the household decision process based on the framework in Fig. 1.

The household utility is a function of total income y, and quality of children q:

$$U = U(y, q).$$

We assume that the quality of children is a function of home time L_h for children and household income y, $q = y \cdot L_h$. $L_h = 0$ when $n = 0$, n is the number of children. The utility function takes the form:

$$U = y + y \cdot L_h = y(1 + L_h) \tag{1}$$

subject to

$$y = y_o + y_s + \bar{y}_p \cdot E_p + \tilde{y} \tag{2}$$

$$y_o = L_o^r \cdot (E - E_P)^{1-r} \tag{3}$$

$$y_s = L_s \cdot w \tag{4}$$

$$L_o + L_s + L_h = T(L_a, L_e) \tag{5}$$

$$T = L_a + L_e \tag{6}$$

$$L_h \geq \bar{L}_h \tag{7}$$

$$L_s \leq \bar{L}_s = \beta \cdot (T - \bar{L}_h) \tag{8}$$

$$0 \leq \beta \leq 1, \quad 0 \leq r \leq 1, \tag{9}$$

$$L_o, L_s, \bar{L}_h, L_h, n, w, E_p \geq 0. \tag{10}$$

Total household income is composed of: (1) on-farm income, y_o, which is a function of the time allocated to on-farm work (L_o), land inputs ($E - E_P$), and the elasticity coefficient (r); (2) labor supply income, y_s, which is a function of the time allocated to non-farm work (L_s) and wage rates (w); (3) payments from the GFG, $\bar{y}_p \cdot E_p$, where $\bar{y}_p$ represents average payments per land area conserved after participating in the

GFG, and E_p are total conserved land areas enrolled in the program, $E_p>0$ when the household participates in the program; E is total land; (4) other income $\tilde{y}$.

L_h is the home time, and $\bar{L}_h$ are minimum levels of home time spent on children. $\bar{L}_s$ is the maximum amount of time that can be allocated to non-farm work and it equals $\beta\cdot(T-\bar{L}_h)$, where β represents percentage of the labor time that can be allocated to non-farm activities, and may relate to the level of education, skills and other household characteristics.

T is total time endowment of the household, L_a is time endowment of adult laborers, and L_e is time endowment of the elderly.

The linkage of household composition variables and non-farm constraints is indicated in functions (6) and (8).

1. Case $n=0$, the household has no children, so that $L_h=0$.
   When constraint (8) is not binding, $L_s<\bar{L}_s$, the household can allocate its time to both on-farm and non-farm activities without constraints (Benjamin, 1992). We can form the Lagrangian for the problem:

$$\Lambda = U(L_o, L_s, L_h) + \lambda(T-L_o-L_s-L_h)$$

   where $T=L_a+L_e$, and is exogenous. λ is the Lagrange multiplier. Plugging Eq. (2) into Eq. (1), we rewrite the utility function

$$U = \left(y_o + y_s + \bar{y}_p\cdot E_p + \tilde{y}\right)(1+L_h). \tag{1'}$$

   Then the necessary condition for a maximum is

$$\frac{\partial U}{\partial L_o} = \frac{\partial U}{\partial L_s} = \lambda. \tag{11}$$

   According to Eqs. (1'), (3), and (4), we have

$$\frac{\partial U}{\partial L_o} = (1+L_h)\cdot(\partial y_o/\partial L_o) = (1+L_h)\cdot r\cdot[L_o/(E-E_P)]^{r-1}$$
$$\frac{\partial U}{\partial L_s} = (1+L_h)\cdot(\partial y_s/\partial L_s) = (1+L_h)\cdot w$$

   so that

$$L_o = (w/r)^{1/(r-1)}\cdot(E-E_P) \tag{12}$$

$$y_o = (w/r)^{r/(r-1)}\cdot(E-E_P). \tag{13}$$

   Plugging Eq. (12) into Eq. (5) yields

$$L_s = T-L_0-L_h = T-(w/r)^{1/(r-1)}\cdot(E-E_P)-L_h, \tag{14}$$

   so that

$$L_s'(E_P|n=0) = \partial L_s/\partial E_P = (w/r)^{\frac{1}{r-1}} \geq 0. \tag{15}$$

   Differentiating Eqs. (13), (4), and (2) with respect to E_P yields

$$y_o'(E_P) = -(w/r)^{r/(r-1)} \tag{16}$$

$$y_s'(E_P) = w\cdot L_s'(E_P) \tag{17}$$

$$y'(E_P) = y_o'(E_P) + y_s'(E_P) + \bar{y}_p. \tag{18}$$

   Given Eq. (15), we also have $y_s'(E_P)\geq 0$ according to Eq. (17). If payments from the program are no less than the opportunity costs of retired lands, we assume

$$\bar{y}_p \geq \left|y'_o(E_P)\right| = (w/r)^{r/(r-1)}, \tag{19}$$

   so that $y'(E_P)\geq 0$ according to Eq. (18), implying that when there is no constraint on non-farm labor supply, the program will have a positive impact on the household's non-farm supply and in turn, on its total income.
   However, when Eq. (8) is binding, $L_s=\bar{L}_s$, the household cannot supply more off-farm labor even after it participates in the program that saves the on-farm labor due to the retired land, implying $L_s'(E_P)=0$. In this case, if $\bar{y}_p=(w/r)^{r/(r-1)}$, then $y'(E_P)=0$, participation in the program does not change total income.
2. Case $n>0$, so that $L_h>0$.
   (1) Non-farm constraint (8) is not binding.
   The necessary condition for a maximum of the utility function (1) is

$$\frac{\partial U}{\partial L_o} = \frac{\partial U}{\partial L_s} = \frac{\partial U}{\partial L_h} = \lambda.$$

   According to the utility function (1) and income functions (2)–(4), we have

$$\partial U/\partial L_h = y \text{ and } \partial U/\partial L_s = (\partial U/\partial y)\cdot(\partial y/\partial L_s) = (1+L_h)\cdot w,$$

   so that $(1+L_h)\cdot w=y$. Combining Eqs. (2)–(5) yields:

$$(1+T-L_o-L_s)\cdot w = y_o + y_s + \bar{y}_p\cdot E_p + \tilde{y}. \tag{20}$$

   Given family composition and other exogenous variables in the short run, we derive comparative results concerning a change in the land retired and the household income. Differentiating the condition (20) with respect to E_P, and combining Eqs. (12), (16), and (17) yields

$$L_s'(E_P|n>0) = \partial L_s/\partial E_P = (1/2)\cdot\left[(1/w)(w/r)^{\frac{r}{r-1}} - (1/w)\bar{y}_p + (w/r)^{\frac{1}{r-1}}\right]. \tag{21}$$

   Since the policy designers tended to overpay the participant, we also assume Eq. (19), and furthermore, when

$$\bar{y}_p \geq (w/r)^{\frac{r}{r-1}} + w(w/r)^{\frac{1}{r-1}}, \tag{22}$$

   we have $L_s'(E_P|n>0)\leq 0$, and $y_s'(E_P)\leq 0$ according to Eq. (17). Combining Eqs. (16)–(18) and (21), we have

$$y'(E_P) = (1/2)\left[\bar{y}_p + w(w/r)^{\frac{1}{r-1}} - (w/r)^{\frac{r}{r-1}}\right]. \tag{23}$$

   Given the assumption (22), we have $y'(E_P)\geq 0$, which implies that participation in the program will increase total income when non-farm constraint is not binding.
   (2). Non-farm constraint (8) is binding.
   Given time endowment of adult laborers L_a and the parameter β, households with children and without the elderly, $L_e=0$ and $n>0$, are more likely to face a binding non-farm constraint (8), $L_s=\bar{L}_s=\beta\cdot(T-\bar{L}_h)$, implying $L_s'(E_P|n\geq 1)=\partial L_s/\partial E_p\leq 0$.
   Then the change of total income, Δy, is composed by the change of income from on-farm work, Δy_o, the change of migrating work, Δy_s, and compensation from the program, $\bar{y}_p\cdot E_p$.

$$\Delta y = y_{t+1}-y_t = \Delta y_o + \Delta y_s + \bar{y}_p\cdot E_p \tag{24}$$

   y_{t+1} and y_t are total income after and before participation in the program. Generally, the majority of migrating workers hold full time employment, and they cannot adjust their work time after being employed (Cahuc and Zylberberg, 2004; Hansen, 1985). Under this assumption, when the household receives payments from the program, it will reduce

its level of migration rather than the amount of time worked. For example, the only migrating worker of the household may return home after receiving the payments, so that $|\Delta y_s| = \left|\Delta y_o + \bar{y}_p \cdot E_p\right|$, but the desired migrating working time is more than 0 if the household can continually adjust it. As a result, the total income will decrease, $y'(E_P)<0$.

(3). Considering the link between on-farm work and home time for childcare.

Most migrating workers have to work in cities far away from their family; while farming on their own lands is generally flexible so that the household can spend some home time to take care of their children. For simplicity, we assume

$$L_h = \varepsilon L_o \tag{25}$$

where $0<\varepsilon$.

We can rewrite the utility function and necessary conditions

$$U = y + y \cdot L_h = y(1+\varepsilon L_o) \tag{26}$$

$$\begin{aligned}\frac{\partial U}{\partial L_o} &= (1+\varepsilon L_o)\cdot(\partial y_o/\partial L_o) + y\cdot\varepsilon \\ &= (1+\varepsilon L_o)\cdot r\cdot\left[L_o/(E-E_P)\right]^{r-1} + y\cdot\varepsilon\end{aligned}$$

$$\frac{\partial U}{\partial L_s} = (1+\varepsilon L_o)\cdot(\partial y_s/\partial L_s) = (1+\varepsilon L_o)\cdot w, \tag{27}$$

so that

$$(E-E_P)^{1-r}\left[r(r-1)L_o^{r-2} + r^2\varepsilon L_o^{r-1}\right] = 2w\varepsilon + w\varepsilon^2 \tag{28}$$

$$(E-E_P)\left[r(r-1)L_o^{r-2} + r^2\varepsilon L_o^{r-1}\right]^{1/(1-r)} = \left(2w\varepsilon + w\varepsilon^2\right)^{1/(1-r)}. \tag{29}$$

Differentiating both sides with respect to E_P yields

$$-A + (E-E_P)\left(\frac{1}{1-r}\right)A^{\left[\left(\frac{1}{1-r}\right)-1\right]}\cdot B\frac{\partial L_o}{\partial E_P} = 0$$

where

$$A=r(r-1)L_o^{r-2} + r^2\varepsilon L_o^{r-1}, \text{ and } B=r(r-1)(r-2)L_o^{r-3} + r^2(r-1)\varepsilon L_o^{r-2}, \tag{30}$$

so that

$$\frac{\partial L_O}{\partial E_P} = A\left[(E-E_P)\left(\frac{1}{1-r}\right)A^{\left(\frac{1}{1-r}\right)}B\right]^{-1} = (A/B)(1-r)\left[(E-E_P)A^{\left(\frac{1}{1-r}\right)}\right]^{-1}, \tag{31}$$

so if

$$\frac{2-r}{rL_o} > \varepsilon > \frac{1-r}{rL_o}, \text{ or } \frac{2-r}{r} > L_h > \frac{1-r}{r}. \tag{32}$$

Then we have

$$A > 0 \text{ and } B > 0, \tag{33}$$

so that $\partial L_o/\partial E_P > 0$, and given T, we have $\partial L_s/\partial E_P<0$ according to Eqs. (5) and (25), no matter if non-farm constraint (8) is binding.

References

Agree, E.M., Biddlecom, A.E., Valente, T.W., 2005. Intergenerational transfers of resources between older persons and extended kin in Taiwan and the Philippines. Population Studies 59, 181–195.

Ahearn, M.C., El-Osta, H., Dewbre, J., 2006. The impact of coupled and decoupled government subsidies on off-farm labor participation of U.S. farm operators. American Journal of Agricultural Economics 88, 393–408.

Benjamin, D., 1992. Household composition, labor-markets, and labor demand — testing for separation in agricultural household models. Econometrica 60, 287–322.

Bennett, M.T., 2008. China's Sloping Land Conversion Program: institutional innovation or business as usual? Ecological Economics 65, 699–711.

Cahuc, P., Zylberberg, A., 2004. Labour Economics. MIT Press.

Caldwell, I.M., Maclaren, V.W., Chen, J.M., Ju, W.M., Zhou, S., Yin, Y., Boland, A., 2007. An integrated assessment model of carbon sequestration benefits: a case study of Liping County, China. Journal of Environmental Management 85, 757–773.

Chambers, R., Conway, G.R., 1992. Sustainable Rural Livelihoods: Practical Concepts for the 21st Century, IDS Discussion Paper 296.

de Sherbinin, A., VanWey, L.K., McSweeney, K., Aggarwal, R., Barbieri, A., Henry, S., Hunter, L.M., Twine, W., Walker, R., 2008. Rural household demographics, livelihoods and the environment. Global Environmental Change 18, 38–53.

DFID, 1999. Sustainable Livelihoods Guidance Sheets. Department for International Development, UK.

Ellis, F., 2000. Rural Livelihoods and Diversity in Developing Countries. Oxford University Press, New York.

Feng, Z., Yang, Y., Zhang, Y., Zhang, P., Li, Y., 2005. Grain-for-green policy and its impacts on grain supply in West China. Land Use Policy 22, 301–312.

Gong, X., Soest, A.v., 2002. Family structure and female labor supply in Mexico City. The Journal of Human Resources 37, 163–191.

Groom, B., Grosjean, P., Kontoleon, A., Swanson, T., Zhang, S., 2010. Relaxing rural constraints: a 'win–win' policy for poverty and environment in China? Oxford Economic Papers 62, 132–156.

Grosjean, P., Kontoleon, A., 2009. How Sustainable are Sustainable Development Programs? The Case of the Sloping Land Conversion Program in China. World Development 37, 268–285.

Hansen, G.D., 1985. Indivisible labor and the business cycle. Journal of Monetary Economics 16, 309–327.

Janvry, A.d., Sadoulet, E., 2006. Progress in the modeling of rural households' behavior under market failures. In: Janvry, A.d., Kanbur, R. (Eds.), Poverty, Inequality and Development: Essay in Honor of Erik Thorbecks. Springer, New York.

Key, N., Roberts, M.J., O'Donoghue, E., 2006. Risk and farm operator labour supply. Applied Economics 38, 573–586.

Kimhi, A., 2004. Family composition and off-farm participation decisions in Israeli farm households. American Journal of Agricultural Economics 86, 502–512.

Li, S., Feldman, M.W., Jin, X., 2004. Children, marriage form, and family support for the elderly in contemporary rural China: the case of Songzi. Research on Aging 26, 352–384.

Liu, J., Li, S., Ouyang, Z., Tam, C., Chen, X., 2008. Ecological and socioeconomic effects of China's policies for ecosystem services. Proceedings of the National Academy of Sciences of the United States of America 105, 9477–9482.

Lokshin, M., Glinskayai, E., Garcia, M., 2000. The effect of early childhood development programs on women's labor force participation and older children's schooling in Kenya. World Bank Policy Research Working Paper No. 2376. World Bank — Development Research Group (DECRG).

Pang, L., de Brauw, A., Rozelle, S., 2004. Working until Dropping: Employment Behavior of the Elderly in Rural China, Working Papers — University of Michigan Department of Economics, pp. 1–36.

Reardon, T., Vosti, S.A., 1995. Links between rural poverty and the environment in developing countries: asset categories and investment poverty. World Development 23, 1495–1506.

Singh, I., Squire, l., Strauss, J., 1986. Agricultural Household Model—Extensions, Applications, and Policy. The Johns Hopkins University Press, Baltimore and London.

Uchida, E., Jintao, X., Rozelle, S., 2005. Grain for Green: cost-effectiveness and sustainability of China's Conservation Set-Aside Program. Land Economics 81, 247–264.

Uchida, E., Jintao, X.U., Zhigang, X.U., Scott, R., 2007. Are the poor benefiting from China's land conservation program? Environment and Development Economics 12, 593–620.

Uchida, E., Rozelle, S., Xu, J., 2009. Conservation payments, liquidity constraints, and off-farm labor: impact of the Grain-for-Green Program on rural households in China. American Journal of Agricultural Economics 91, 70–86.

Wang, C., Ouyang, H., Maclaren, V., Yin, Y., Shao, B., Boland, A., Tian, Y., 2007. Evaluation of the economic and environmental impact of converting cropland to forest: a case study in Dunhua County, China. Journal of Environmental Management 85, 746–756.

Wong, R., Levine, R.E., 1992. The effect of household structure on women's economic activity and fertility: evidence from recent mothers in urban Mexico. Economic Development and Cultural Change 41, 89.

Xu, Z., Bennett, M.T., Tao, R., Xu, J., 2004. China's Sloping Land Conversion Program four years on: current situation and pending issues. International Forestry Review 6, 317–326.

Xue, z., 2007. On difficulties and counter measures for constructing new socialist countryside in mountainous counties: a case study of Wuqi County as an example for Converting Farmland into Woodland. Forestry Economics 41–43 (in Chinese).

Ye, Y., Chen, G., Fan, H., 2003. Impacts of the Grain for Green project on rural communities in the upper Min River Basin, Sichuan, China. Mountain Research and Development 23, 345–352.
Zhang, W., Li, S., 2004. The intergenerational support of the elderly in rural China. Statistical Research 33–37 (in Chinese).
Zhi, L., Li, N., 2004. A discussion on the economic compensation system for conversion of cropland to forestland in the western China. Forestry Economics 40, 2–8 (in Chinese).
Zilberman, D., Lipper, L., McCarthy, N., 2008. When could payments for environmental services benefit the poor? Environment and Development Economics 13, 255–278.