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Cost-Effectiveness of Payments for Ecosystem Services with Dual Goals of Environment and Poverty Alleviation

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Abstract The goal of this article is to understand strategies by which both the environmental and poverty alleviation objectives of PES programs can be achieved cost effectively. To meet this goal, we first create a conceptual framework to understand the implications of alternative targeting when policy makers have both environmental and poverty alleviation goals. We then use the *Grain for Green* program in China, the largest PES program in the developing world, as a case study. We also use a data set from a survey that we designed and implemented to evaluate the program. Using the data set we first evaluate what factors determined selection of program areas for the *Grain for Green* program. We then demonstrate the heterogeneity of parcels and households and examine the correlations across households and their parcels in terms of their potential environmental benefits, opportunity costs of participating, and the asset levels of households as an indicator of poverty. Finally, we compare five alternative targeting criteria and simulate their performance in terms of cost effectiveness in meeting both the environmental and poverty alleviation goals when given a fixed budget. Based on our simulations, we find that there is a substantial gain in the cost effectiveness of the program by targeting parcels based on the "gold standard," i.e., targeting parcels with low opportunity cost and high environmental benefit managed by poorer households.

Keywords Payments for ecosystem services · Cost effectiveness · Poverty alleviation · *Grain for Green* program · China

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Introduction

In recent years, Payments for Ecosystem Services (PES) initiatives have attracted attention not only for their potential to support enhanced ecosystem services but also as a way that can contribute to poverty alleviation by giving financial support to the rural poor in developing countries (FAO 2007b; Pagiola and others 2005). PES programs offer financial assistance to the "suppliers" of the ecosystem services who in turn can agree to participate by setting aside farmland, adopting habitat protective farming techniques or protecting watershed functions through new technologies. Since most of the world's poor people live in rural areas and depend on agriculture for their livelihoods, many of them in marginal environments, it is often the case that it is the poor who are able to supply these ecosystem services. When officials pay poor farmers to change their production processes to ones that supply more ecosystem services, it is possible to generate "win-win" outcomes for both environmental benefits and poverty alleviation. Accordingly, many PES programs have been designed with dual goals—to generate ecosystem services and to alleviate poverty (FAO 2007b; Pagiola and others 2005).

However, reaching both goals via PES programs is neither automatic nor universal. If the supply of ecosystem services by households is *not* positively correlated with their levels of poverty, tradeoffs may exist between meeting the two objectives. This problem arises partly because parcels with high environmental benefits may not necessarily be managed by the poorest farmers. In Costa Rica, for example, evidence from a PES program in the Virilla watershed shows that landowners receiving payments were relatively wealthy individuals (Grieg-Gran and Bishop 2004). In addition, PES programs may give incentives for rich individuals to "muscle out" poor households (Pagiola and others (2005). If poor households do not own land or are encouraged *not* to participate, then they cannot earn the benefits from the program (Bulte 2005). It is easy to imagine that this situation could occur in a country such as China where the village leader often has the power and the responsibility to allocate parcels to village households.

For a PES program with dual goals, it is critical to address the poverty issue explicitly (Wang and others 2008). Even if those that can supply ecosystem services are the poor, the program manager needs to adopt the right targeting criteria based on limited information to allocate a given budget to achieve both goals cost effectively. Moreover, addressing the poverty issue is also critically important to sustain the environmental benefits of a PES program (Groom and others 2008; Grosjean and Kontoleon 2009). One of the main outstanding questions is: Under what conditions will a targeting approach based solely on the opportunity cost and/or on the level of environmental benefits be consistent with an objective of jointly maximizing the environmental and poverty alleviation benefits? How well would alternative targeting strategies perform compared to the "Golden Rule"?

The overall goal of this article is to understand strategies through which both the environmental and poverty alleviation objectives can be achieved cost effectively. To meet this goal, we have four specific objectives. Our first objective is to develop a conceptual understanding of a cost effective targeting approach for PES programs that have both environmental and poverty alleviation goals. Second, we examine *Grain for Green*, a PES program in China, as a case study for evaluating whether or not environmental benefits, cost factors and poverty alleviation factors have been taken into account during program implementation. Third, we analyze the heterogeneity and correlation among the environmental benefits, opportunity costs and the poverty levels of households and analyze if there are tradeoffs among the three. Finally, we simulate the performance of five alternative targeting instruments when the program manager needs to meet environment and poverty alleviation goals given a fixed budget.

Despite the importance of the poverty dimension, the previous literature has mostly focused on how to target program areas cost effectively when environmental benefit is the only goal (e.g., Alpízar and others 2007; Just and Antle 1990). In a seminal work, Babcock and others (1997) demonstrated that program managers should target land from the highest environmental benefit-to-cost ratio to achieve its environmental goals cost effectively. Most studies that examine targeting issues of PES programs in developing economies also only consider the environmental benefits. These include studies that are evaluating China's *Grain for Green* program (Uchida and others 2005; Wang and others 2008; Weyerhaeuser and others 2005; Xu and others 2004). For example, Weyerhaeuser and others (2005) conducted a case study in a 40 km^2 watershed in Yunnan Province using GIS data and found that comparing the selected areas with the distributions of slopes, the target areas were not necessarily aimed at sites prone to the highest erosion and/or with the steepest slopes. Studies on other PES programs in developing economies also focus on the environmental goal (e.g., Alix-Garcia and others 2008; Wünscher and others 2006; Wunder 2007). For example, Wünscher and others (2006) analyzed the potential efficiency gains from improved targeting for the Costa Rica program and showed that, given a fixed budget, selecting sites according to their service delivery potential increases the amount of contracted services supplied.

This manuscript has two main contributions. Our conceptual model incorporates a poverty alleviation goal in the model by including an additional constraint, which is a relatively straightforward extension of Babcock and others (1996). Empirically, this article is the first study in the PES literature to simulate and compare the cost effectiveness of a program given alternative targeting strategies when there are two goals—poverty alleviation and environmental goals. Our major finding is that the gain would be significant in the case of China's *Grain for Green* program. This is an important finding given that the budget outlay of the program has not increased as much as it was initially planned at the outset of the program. Moreover, the methodology also allows practitioners to compare the degree of heterogeneity across attributes of regions, which would inform program managers who are operating under a fixed budget, into which variable they should make more investment to collect information to form the basis of a more cost-effective targeting approach.

The *Grain for Green* Program

China's *Grain for Green* program began as a pilot set aside program in 1999. Since then, it has grown into one of the most important initiatives to develop the western inland regions of China (Feng and others 2005; Wang and others 2007b; Xu and others 2004). The program was primarily designed to set aside cropland in order to increase forest cover and prevent soil erosion on sloped cropland (Uchida and others 2007).

By the end of 2001, China's leaders had added 20 provinces to the program and 1.16 million hectares of cropland had been converted (Uchida and others 2005). In the first four years alone, 15 million farmers in more than 2000 counties in 25 provinces and municipalities in China had participated (Uchida and others 2007; Xu and others 2004). Based on the public announcement in fall 2007, leaders plan to set aside 15 million hectares of cropland by 2025, an area that is roughly equivalent to the U.S. Conservation Reserve Program (Guowuyuan 2007).

Based on the guidelines for the *Grain for Green* program, participating households are each compensated with three forms of payments: an annual compensation of grain (which later was converted to cash compensation), cash compensation and free seedlings (Uchida and others 2007; Xu and others 2004). Under the rules of the program, farmers receive 1500 to 2250 kilograms of grain per hectare per year. Farmers in the upper and middle reaches of the Yangtze River Basin receive higher payments than those farmers in the upper reaches of the Yellow River Basin. The program makes cash payments to farmers of 300 yuan (per hectare, per year) as well as providing free seedlings (from forestry agencies) at the beginning of their participation in the conversion program.

As described above, the two objectives of China's program are to restore the nation's forests and grasslands to prevent soil erosion and to alleviate poverty in some of China's poorest regions (SFA 2002). Specifically, in addition to conserving soil and water in China's ecologically fragile areas, the program aims to restructure the rural economy so participating farmers can gradually shift into more environmentally and economically sustainable activities (Xu and others 2004).

To accomplish these goals, the steepness of the slope of the parcels has been the main selection criterion of the program (Uchida and others 2007). Parcels with slopes greater than 25 degrees are targeted in southwest China. Parcels with slopes greater than 15 degrees are targeted in the northwest. In fact, research indicates that 12% of the program area has a slope between 15 and 25 degrees; 77% of the program has a slope greater than 25 degrees (Bennett and Xu 2005).

Unfortunately, as described above, simply targeting parcels based on their slope and other environmental benefits may not automatically be effective to meet its second goal of poverty alleviation. In this article, we attempt to examine if targeting solely based on environmental benefits can also achieve a program's poverty alleviation goal.

Cost Effectiveness of the *Grain for Green* Program

The cost effectiveness of China's *Grain for Green* program from an environmental perspective has been called into question since a period of time early in its implementation (Bennett and Xu 2005; Uchida and others 2005; Wang and others 2007a; Xu and Cao 2002; Xu and others 2004). Research has found that in some cases, productive, low sloped parcels have been included in the program while in other cases less productive, high sloped parcels were not (Uchida and others 2005; Xu and others 2004). For example, Xu and others (2004) showed that while parcels with higher slopes and lower productivity were targeted in general, in Gansu Province almost 19% of converted area was low sloped and high to medium productivity (38% being low sloped area in general). In Shaanxi province almost 10% of converted parcels and in Sichuan almost 11% of converted parcels had a slope that was less than 15 degrees. Uchida and others (2005) also found that almost 17% of low sloped cropland was converted under the *Grain for Green* program. Of equal importance, 32% of high sloped cropland was not converted. All these studies indicate that the program's cost effectiveness may have been compromised by enrolling productive, low sloping parcels when high sloped parcels with low to medium productivity were available for conversion. Both studies conclude that although the program has succeeded in enrolling many parcels with high slopes (or those with more environmental benefit) and low opportunity costs, the gains of the program could have been increased by better targeting parcels with high slope and low opportunity cost that exist in the program area.

There are several plausible explanations for the observed environmental inefficiencies. Mistargeting may have arisen because the program expanded and converted land too quickly. Program officers may not have had sufficient information or time to target the most environmental sensitive parcels in a cost effective manner. For example, program managers may not have had sufficiently detailed information on either the erodibility of the soil or the level of poverty of the households in the region. Other factors also could have influenced the program's ability to target environmentally sensitive parcels. It could have been that in some regions parcels were given higher priority because they were closer to a road instead of being chosen on the basis of their steepness (Heilig and others 2005; Xu and Cao

2002). A criterion that considered the proximity of a plot to a road could have facilitated easier inspections and monitoring. Targeting also could have been compromised by the desire of program managers to lower program implementation costs by requiring program parcels to be contiguous (CCICED 2002; Zuo 2001). Political economy considerations also could have overridden the explicit goals of the *Grain for Green* program. For example, program managers inside villages may have wanted to enroll their own parcels in order to obtain the additional income from their own land that was available from the program (Wang and Pei 2004).

Although the studies came to these slightly different conclusions, they had one element in common: all of the studies examined the cost effectiveness of program implementation from an environmental perspective (that is, the studies assumed that the only (or at least main) goal of an effective program was to maximize the environmental benefits of the program). None of these studies considered the poverty alleviation goals of the program as being an important consideration (relative to the program's environmental benefits). In fact, given the twin goals of the program, we believe it is important that the *Grain for Green* program also is evaluated in terms of how well it has been targeted towards its poverty alleviation goals.

Modeling Framework

To understand the properties of a cost effective targeting approach for a PES program when there are dual goals of environmental benefit and poverty alleviation, we extend a model developed by Babcock and others (1996). To do so, we analyze a setting in which a program manager faces a budget constraints and needs to select parcels of cultivated land for retirement for a PES program that has two goals. In this model, we assume that there are N parcels in the program area, $n = 1,\ldots,N$. Parcels differ according to their opportunity costs per unit of land (c_n), the levels of environmental benefits per unit of land (e_n) and the initial wealth (i.e., wealth prior to the program) of the households that manage the nth parcel (w_n). For simplicity, we assume that the program manager pays each household its opportunity cost as the program compensation. The program manager's objective is to maximize the environmental benefit of setting aside the land subject to a wealth level constraint, a program budget constraint and a land constraint:

$$\max_{x_n} \sum_{n=1}^{N} x_n e_n \quad (1)$$

$$s.t.\, x_n c_n + w_n \geq \bar{W}, n = 1, \ldots, N$$

$$\sum_{n=1}^{N} x_n c_n \leq B \quad (2)$$

$$\sum_{n=1}^{N} x_n \leq L \sum_{n=1}^{N} x_n \leq L \quad (3)$$

$$x_n \leq l_n, n = 1, \ldots, N \quad (4)$$

where x_n is the parcel n chosen as the program area, $\bar{W}$ defines the poverty line for the society, B is the program budget, and L is the total land area available for the program . Let δ_n and λ denote the Lagrange multipliers for the wealth and budget constraints. Given this setup of the model, the first order condition for an interior solution for the last parcel in the program is given by $\frac{e_n}{c_n} + \delta_n = \lambda$.

The properties of the first order condition are straightforward. How much both the environmental and poverty alleviation goals can be achieved, given a fixed budget, depends on the degree of the tradeoff between the gain in the two benefits by retiring parcel n. If environmental and poverty alleviation benefits involve tradeoffs, the program manager will be required to decide how much weight to give environmental benefit relative to its poverty alleviation benefits. The implication of this key tradeoff is that utilizing a targeting approach that is suitable for reaching a program's environmental goals does not necessarily allow the program to simultaneously reach its poverty alleviation goals. In contrast, if there is not a sharp tradeoff between the two goals, then retiring parcel n which has a high environmental benefit would also further the programs poverty alleviation goals. Specifically, in the case of the *Grain for Green* program, if the poorer households are the ones that manage cultivated land that have the most potential for reducing soil erosion (or have high environmental benefits of retirement—e.g., their parcels are on highly sloped land) then there should be little tradeoff between the program's environmental and poverty alleviation goals. In this case, using a targeting approach suitable for the environmental goal would also enable the program to also meet its poverty alleviation goal (and vice versa).

The economic logic of the conceptual framework motivates our empirical strategy for testing the cost effectiveness of the *Grain for Green* program. There are three steps in our approach. First, we econometrically examine what factors affect parcel selection in our study areas. Based on the econometric findings, we can test whether or not the environmental benefits, the opportunity cost and/or the poverty levels of the households were (solely or jointly) considered. Next, we will use parcel-level data to graphically examine the heterogeneity across our study areas in terms of the environmental benefits, the opportunity cost and the poverty levels of the households in our sample. We also examine the correlations among these three factors.

In the last step, we compare the potential performance of five alternative targeting approaches. The first three were developed in Babcock and others (1996): (1) selecting parcels with the highest environmental benefit–opportunity cost ratio first, which would be the most cost effective targeting strategy if the program manager were only seeking to maximize the environmental benefits given a fixed budget; (2) selecting parcels with lowest opportunity cost first, which would maximize the acreage in the program; and (3) selecting parcels that have the highest environmental benefits first, which would select the most environmentally sensitive land. We compare the results of programs designed to achieve these three criteria to two other programs using targeting strategies that consider the poverty alleviation goal: (d) selecting parcels that belong to the poorest households first, which would be the most pro-poor strategy; and (e) selecting parcels that maximize jointly both the environmental and poverty alleviation benefits. Given the dual goals of the program, the fifth approach should be considered the "gold standard." Through simulation analysis, we will examine the gains by adopting the gold standard and the costs of not doing so.

Data

To evaluate the cost effectiveness of China's *Grain for Green* program, this study combines two data sets. The first data set was collected through household surveys that we designed and implemented in 2003, approximately three years after the start of the program. China's State Forest Administration commissioned this independent study in order to evaluate the success of the nation's program (Uchida and others 2007; Xu and others 2004). We interviewed a total of 359 households in three provinces (Sichuan, Shaanxi, and Gansu), six counties (two for each province), 18 townships (three per county) and 36 villages (two for every township). Ten households within each village were randomly selected. According to our design, 75 percent of the households participated in the *Grain for Green* program. At least one participating household was sampled in every village. In two out of the 36 villages, all of the sampled households were participants of the program.

The survey asked respondents for information regarding their situation prior to entering the program (1999) as well as after the program (2002). Information was collected at both the household and parcel levels, including detailed information on each household's total asset holdings, its demographic makeup and other income earning activities. We acknowledge the potential recall bias in the 1999 variables. However, we chose to use the survey data since there is no data available from the period prior to program implementation due to the government's quick decision to implement the program. Moreover, we designed the survey carefully and trained and monitored the enumerators to minimize recall bias and ensure that the best account of past amounts and activities was given by the respondents (Uchida and others 2007).

We utilize the household-level part of our data to create an indicator of each household's wealth. Instead of using income as the indicator, which is often subject to substantial measurement error, this study uses the level of a household's total asset holdings in 1999. In other words we assume that the level of assets prior to the start of the program measures each household's pre-program wealth. A household's total asset is calculated as the sum of the value of each family's house in 1999, the total value of 18 consumer durables (e.g., bicycle, motorcycle, radio) and the total value of 18 fixed productive assets (e.g., car, tractor, farm equipments).

We also utilize parcel-level information from the survey to develop an indicator of the opportunity cost of setting aside each parcel. Using the definition adopted by Uchida and others (2005), the opportunity cost of participating in the program is calculated as the net revenue of the parcel one year prior to entering the program. We assume that the net revenue per mu (where one mu is defined as 1/15th of a hectare) is equal to the gross revenue per mu (price of crop times its yield) minus the plot's variable costs per mu, which includes expenditure on fertilizer, pesticide, plastic sheeting and hired labor. The cost does not account for the value of household labor. We also use parcel-specific variables for land area (in mu), the distance to the house (in km) and an index of slope (1 = less than 15 degrees, 2 = 15 to 25 degrees and 3 = more than 25 degrees).

Finally, our measure of the environmental benefits of retiring cultivated land attempts to capture the potential reduction in soil erosion by combining information from our survey on parcel-specific slope and information from a national database on soil erosion. To create the variable we start with a measure of the erodibility of the soil (due to water, rainfall, etc.). The index is part of a national database on erodibility developed by the Chinese Academy of Science's Data Center for Resources and Environmental Sciences in 1995–1996 (Wang and others 2001). The *water erodibility index* has five levels of intensity, ranging from light to extremely severe. The index is calculated by taking into account multiple factors, including land use, topology, slope, vegetation cover, soil surface substances and information from other data sources on the type of soil erosion in a certain area and its severity. The index is available in spatially explicit, GIS format for all parcels nationwide at the scale of 1:100000. Since we did not have the precise coordinates for our surveyed households (and their plots), we first georeferenced the location of each of the 18 township seats in our study area. Next, we drew an 8 km buffer around each point using ArcGIS and calculated the average *water erodibility index* within each buffer. This method produced a total of 18 unique values of water erodibility for all the townships in our sample.

Next, to exploit the parcel-specific information from our survey data in conjunction with the township-level water erodibility index, we transformed the township-level water erodibility index by multiplying it by each parcel's slope index (1, 2, or 3) to arrive at a parcel-specific environmental benefit indicator. Higher values of the composite index indicate greater potential for reduction in water erosion on or near the specific parcel. We believe that the composite index is a more accurate indicator of environmental benefit compared to using only the slope information from the survey, which was used in previous studies (e.g., Uchida and others 2005).

We acknowledge four shortcomings of using the composite index as an indicator of the environmental benefits associated with the program. In the article we restrict our analysis to examining the reduction of soil erosion, which is (importantly) the overall environmental goal of the program. It is possible that there may be other environmental benefits of retiring cultivated land on steep slopes. In addition, the index is based on data that were not measured directly in the field. The water erodibility index was developed based on remote sensing data; the parcel-specific slope index is based on information given by the survey respondent (usually the household head.) Although an environmental benefit index based on direct field measurements may be more accurate, collecting such data for a wide region would be costly. Moreover, the slope index is not a continuous variable but instead is composed of three categorical dummy variables which each represent a different range of slope steepness. This inherently may make the distribution of the composite index homogeneous and limits the precision of the composite index. Finally, although we only incorporate information on slope and soil erodibility to construct the index, parcel size and the connectivity of the parcels are also important factors in assessing the reduction of soil erosion. Unfortunately, we do not have information on these other concepts; therefore it is impossible to incorporate them into our analysis. Readers may refer to case studies which make use of more sophisticated models to project the runoff reductions in the context of the *Grain for Green* program (e.g., Bennett and others 2008).

Targeting of the *Grain for Green* Program

Descriptive Statistics

Based on the descriptive statistics, both the opportunity cost of retiring the parcel and the environmental benefit of land retirement appear to have been factored into targeting (Table 1). The mean of the opportunity cost for program

Table 1 Descriptive statistics of parcel and household characteristics, 1999

Parcel characteristics	Program parcels	Non-program parcels of participating households	Parcels of non-participating households
Opportunity cost	112.6[a] (12.67)	380.86 (24.97)	347.76 (32.38)
Environmental benefit	33.05[a] (0.46)	21.97[b] (0.36)	24.73 (0.59)
Slope (1,2,3)	2.53[a] (0.03)	1.67[b] (0.03)	1.88 (0.05)
Distance to house (km)	1233.34[a] (55.19)	764.13 (29.03)	681.63 (47.44)
Area (mu)	3.19[a] (0.13)	1.91 (0.06)	1.92 (0.13)
N (# of parcels)	549	1025	433
Household characteristics		**Participating households**	**Non-participating households**
Asset value in 1999 (1000 yuan)		2.60 (0.24)	2.57 (0.45)
Land area (mu)		3.09[c] (0.13)	2.55 (0.27)
Individuals in household		4.89[d] (0.11)	4.47 (0.14)
N (# of households)		262	81

Source: Authors' survey

[a] Indicates that the mean between program parcels and non-program parcels is statistically significantly different from 0 at the 1% significance level

[b] Indicates that the mean of non-program parcels coming from participating and non-participating households is statistically significantly different from 0 at the 1% significance level

[c] Indicates that the mean of participating households and non-participating households is statistically significantly different from 0 at the 10% significance level

[d] Indicates that the mean of participating households and non-participating households is statistically significantly different from 0 at the 5% significance level

parcels was less than one third that of the non-program parcels (row 1). The average environmental benefits of the program parcels were statistically significantly higher than those of the non-program parcels either based on our composite index or just slope (row 2). In addition we found that program parcels tended to have larger areas and were further from each respondent's house (rows 4 and 5). These overall trends continue to hold up when comparing the characteristics of parcels of nonparticipating households and nonprogram parcels of participating household. We find that the nonprogram parcels of participating households would have had lower environmental benefits than those parcels from nonparticipating households. Interestingly, when comparing the mean asset levels of participants and nonparticipants, we found that they were not statistically significantly different (row 6). Combined, these findings suggest that environmental benefit and cost factors were considered explicitly when officials were deciding who was allowed to participate in the program. However, the descriptive data do not appear to support the finding that level of poverty of the households was considered.

When we graph the asset levels of the households against plot-specific opportunity costs, it is also clear that selection could have been better in terms of targeting parcels belonging to poor households with lower opportunity costs (Fig. 1a). There are many parcels managed by poor households that have low opportunity costs that were not in the program (lower left hand quadrant.) The parcels having low opportunity costs managed by poor households are the ideal parcels to retire if program mangers want to maximize the program's poverty alleviation goal given a fixed budget. This finding implies that to improve the cost effectiveness of the program from the perspective of reaching its poverty alleviation goal, program managers could have included these nonprogram parcels and not included other households.

We also find that targeting was not perfect in terms of targeting parcels with high environmental benefits and low opportunity costs (Fig. 1b). We find that parcels of both

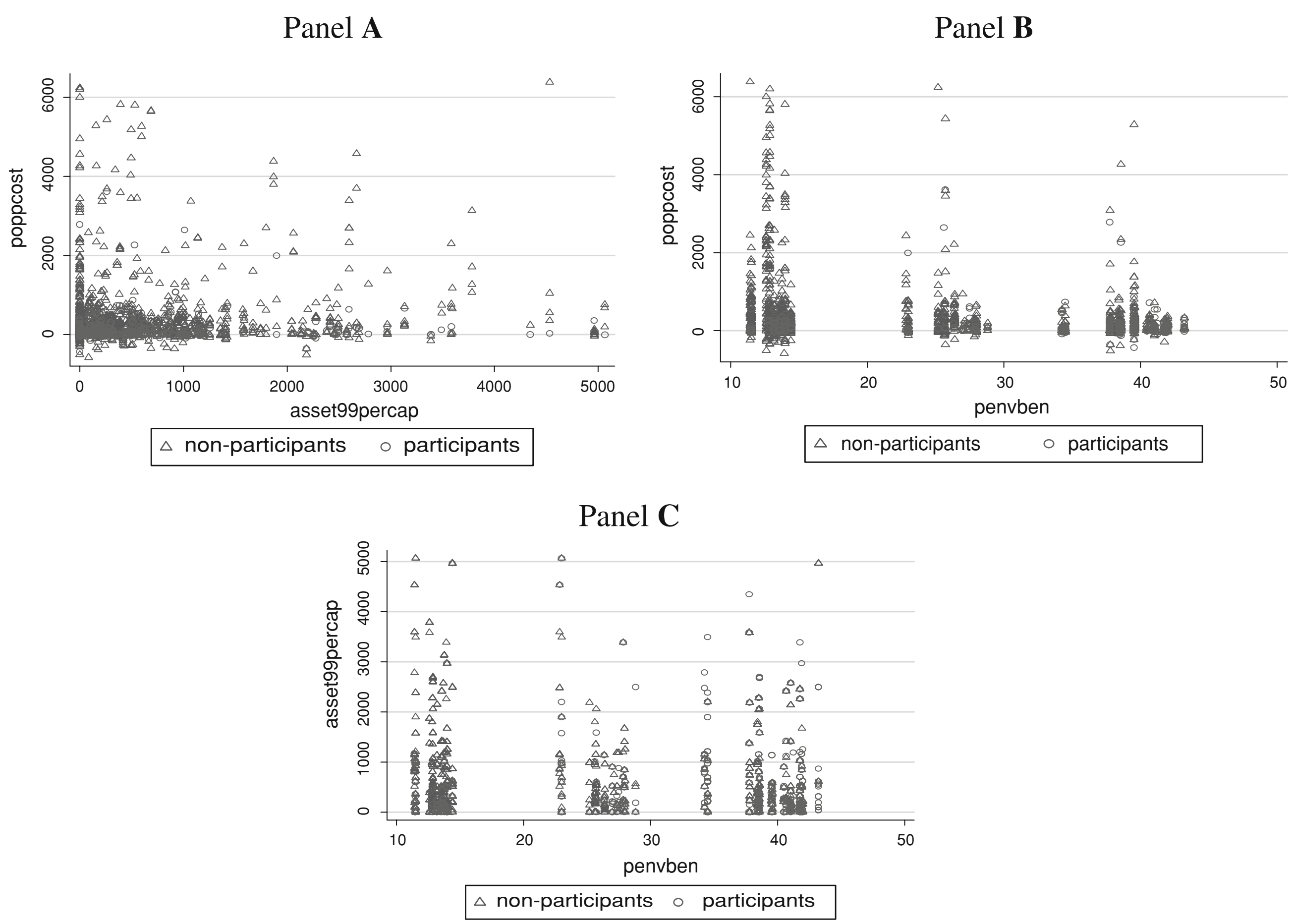

Fig. 1 Scatter parcels: **a** asset level per capita versus opportunity cost of each parcel that is enrolled and not enrolled in the program, 2002; **b** parcel environmental benefit versus opportunity cost of each parcel that is enrolled and not enrolled in the program, 2002; **c** asset level per capita versus environmental benefit of each parcel that is enrolled and not enrolled in the program. *Triangles* represent the non-participants' plots and *circles* represent the program participants' plots. *Source*: Author's data

high and low environmental benefits have been selected to participate in the program, suggesting that there are numerous parcels with high environmental benefits and low opportunity costs that could be enrolled in the program, but were not selected. To improve targeting, program managers could have enrolled these parcels in the place of parcels with low environmental benefit and high opportunity cost. In addition, we see that program managers could have selected parcels with higher environmental benefit that were managed by poorer households in order to better meet both the goals of the program simultaneously (Fig. 1c). In both Fig. 1b and c, the clustered nature of the environmental benefits may be driven by several features of the data: (1) the national erodibility index is common across all plots within each county; and (2) the plot-specific slope data are measured on a scale of one to three (no slope; moderate slope; high slope). In sum, these graphs illustrate that the program could have improved its cost effectiveness by increasing program areas with higher environmental benefits and including parcels with lower opportunity costs that were managed by poorer households.

Econometric Analysis

Since the descriptive statistics and the graphical approach only give us a descriptive view of how well the program was targeted to meet its goals, in this section we examine the marginal effect of the three factors—environmental benefits, opportunity costs and poverty levels–on program participation. Specifically, we use a discrete choice linear probit model to investigate whether or not information on these three factors were taken into account in selecting parcels for the *Grain for Green* program, holding other household and parcel characteristics in the model constant.

From the conceptual model, the reduced form for x_n, the area of a parcel n chosen as the program area, is given by $x_n = f(c_n, w_n, e_n)$. In our empirical model, we focus on the intensive margin of participation and measure x_n using a discrete variable, which equals one if the parcel is selected into the program and zero otherwise. Consistent with the reduced form model, the key explanatory variables of interest are: (1) the pre-program asset level of the household that manages the parcel as an indicator of the household's level of poverty (w_n); (2) the opportunity cost of retiring the parcel (c_n); and (3) an indicator of the environmental benefit of retiring the plot which is measured using three dummy variables (e_n). Each dummy variable takes on a value of one for each of the parcel's slope index (1, 2, or 3). In the regression the first category (the slope index is equal to 1) is the base category. In the second model we also control for the size of the parcel (measured in mu), the log of the distance (in km) from the parcel to the farmer's house and the size of the household (measured in terms of the number of members). The third regression includes a set of dummy variables for each village to account for village-level fixed effects in order to control for all, non-time varying unobservable village characteristics that may affect program selection.

When we examine the regression results, we find that overall the signs and magnitudes of the estimated coefficients are stable across the three models (Table 2). The discrete choice models without village fixed effects has a pseudo R-square value of 0.15 (column 1) and 0.19 (column 2) with and without the control variables, respectively. The model which account for the village fixed effects performed significantly better with a pseudo R-squared value of 0.30 (column 3). With the exception of the household's asset level and the household size, the coefficients are significant at the one percent significance level.

The results clearly demonstrate that parcels with lower opportunity costs and higher slopes were more likely to be selected for the *Grain for Green* program, holding all other variables in the model constant (Table 2). Specifically, we find positive and highly significant coefficients on both of the slope dummies. The coefficient for the dummy variable representing the third category (that is, the highest slope) had a larger coefficient than those that represented the lower sloped parcels. These results indicate that the parcels with higher slopes (and, hence, higher environmental benefits) were more likely to be selected for the program. The negative coefficients on opportunity cost variables likewise imply that parcels with higher opportunity costs were less likely to be enrolled in the program. In contrast, however, the coefficient on the asset value variable—although negative—was very small; the coefficient also was significant only at the 10 percent level (column 3). This finding suggests that *Grain for Green* program managers in our sample areas were only (at most) marginally considering the poverty levels of the households when they were enrolling plots. In sum, the results suggest that, at the margin, the program managers for the *Grain for Green* program selected parcels that provided significant environmental benefit and were retired at a relatively low opportunity cost, but did not base their decisions on the poverty levels of the households.

Heterogeneity and Correlation Among Opportunity Cost, Environmental Benefits, and Asset Levels

In this section we aim to accomplish two tasks. First, we examine why program managers appear to have been selecting areas, households and parcels based on opportunity costs and environmental benefits, but not poverty. To do so, we examine the heterogeneity of plots in our sample in terms of their environmental benefits, the poverty levels

Table 2 Regression results of impact of parcel and household characteristics on participation in China's *Grain for Green* program

Independent variable	Dependent variable: 1 = Parcel in Program, 0 = Otherwise		
	(1) Probit	(2) Probit	(3) Probit with village fixed effects
Asset value in 1999 (1000 Yuan)	−0.005 (0.51)	−0.009 (0.94)	−0.018 (1.67)[a]
Parcel opportunity cost (1000 Yuan)	−0.555 (5.48)[b]	−0.368 (3.83)[b]	−0.295 (3.07)[b]
Slope dummy 2	0.460 (4.66)[b]	0.452 (4.46)[b]	0.606 (5.17)[b]
Slope dummy 3	1.061 (14.90)[b]	0.974 (13.10)[b]	1.196 (12.84)[b]
Environmental benefit	–	–	–
Land area	–	0.052 (4.34)[b]	0.058 (3.81)[b]
Log of distance to house	–	0.247 (8.32)[b]	0.307 (8.75)[b]
Household size	–	0.007 (0.36)	0.020 (0.87)
Constant	−1.024 (16.58)[b]	−2.743 (12.32)[b]	−3.384 (9.98)[b]
Number of parcels	2021	2021	2021
Pseudo R-squared	0.15	0.19	0.30
Log-likelihood	−1011.52	−959.73	−827.89
Village fixed effects	No	No	Yes

Source: Author's data

The reported coefficients are calculated marginal values. Absolute value of z statistics in parentheses

[a] Significant at 10%

[b] Significant at 1%

of the households that control the plots and the opportunity cost of retiring the plots. The logic is that when households or parcels are more homogeneous, then (1) ranking among them may be less meaningful and (2) the choices among them will be less important for cost effective targeting and the value of information will be small. Conversely, when households or parcels are more heterogeneous, then (1) ranking among them is likely to be more reliable and (2) choices among them will be more important and the value of information will be larger. This approach is consistent with Just and Antle (1990) and Babcock and others (1996) who point out that agricultural heterogeneity greatly increases the importance of obtaining good measures of parcel characteristics to facilitate proper targeting (Babcock and others1996). Following this, we believe that the variables that are more heterogeneous are also the ones for which information would produce the greatest gains to the program managers in terms of helping them make cost effective program selections.

In addition to the distribution of these variables, we also examine the correlation among them. If the parcels with high environmental benefit and low opportunity costs are also the ones managed by poor households, the program can "kill two birds with one stone." However, if they are not highly correlated, there may be a tradeoff between meeting the environmental and poverty alleviation goals. If that is the case, the cost effectiveness of the program would be sensitive to the targeting strategy. A low correlation among the factors would also suggest that the program manager would need to collect more information on both the ecosystem services of the plots and the poverty levels of the households if they wanted to achieve a more optimal output in terms of the program's twin goals.

To examine the correlations among the variables, we begin by following Babcock and others (1996), using the Lorenz curve to measure heterogeneity in environmental benefits, the level poverty and the opportunity cost of the plots in the program area. Lorenz curves traditionally have been used to understand the distributions of income of some population. In plotting Lorenz curves a 45-degree line, starting at the origin, represents perfectly equal income distribution. In addition, the greater the distance between the Lorenz curve and the 45-degree line, the larger the income inequality. In our case, when we use Lorenz curves to examine the distribution of the environmental benefits, opportunity costs and asset levels of the plots and their owners, the further the distance between the Lorenz curve for a variable and the 45-degree line means that that there is more heterogeneity in that variable in our sample.

Results

Examining the difference curves, we find that the degree of heterogeneity differs across the three variables (Fig. 2). The opportunity cost of retiring a parcel is the most heterogeneous, followed by the distribution of asset levels of the households. The parcels are the least heterogeneous (or the most homogeneous) in terms of their environmental

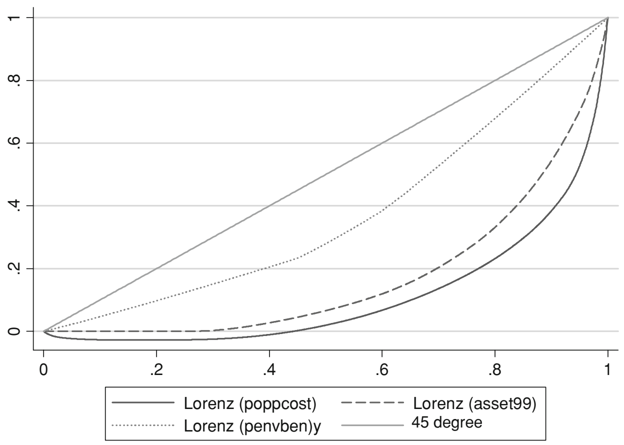

Fig. 2 Proportion of parcels' opportunity cost, asset level, or environmental benefit achieved given proportion of parcels, 2002. The curves indicate the Lorenz curves for opportunity cost per unit area (*poppcost*); environmental benefit (*penvben*); and household asset per capita in 1999 (*asset99*). The straight line indicates a 45-degree line

benefit. For example, 60 percent of the parcels (in area) captures nearly 40 percent of the total environmental benefit but less than 15 percent of total household assets and less than 10 percent of total opportunity cost of retiring. This result suggests that if better targeting is desired, the program manager would need to collect information on the relatively unevenly distributed variables—the opportunity cost of retiring the plot and the asset level of the owner of the plot. However, we recognize that the homogeneous nature of the environmental benefits (relative to the other two factors) may again be driven by two features of the environmental benefit index: (1) the national erodibility index is common across all plots within each county; and (2) the plot-specific slope index is a discrete measure (measuring one of three levels).

Furthermore, we find there are important differences in heterogeneity across provinces (Fig. 3). First, the degree of heterogeneity in asset levels and environmental benefits are relatively similar across the three provinces in our study

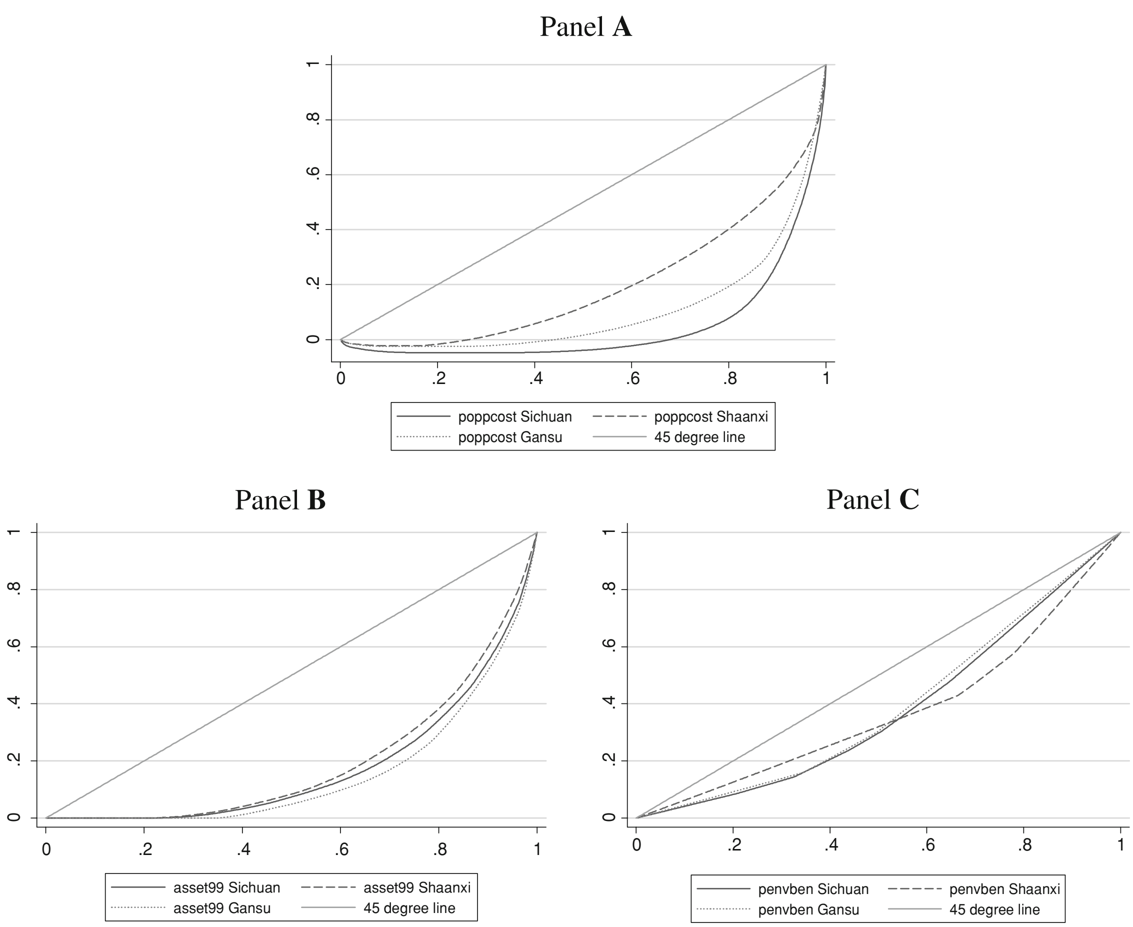

Fig. 3 Lorenz Curves: **a** proportion of parcels' opportunity cost, achieved given proportion of parcels; **b** proportion of households' asset level, achieved given proportion of parcels; **c** proportion of parcels' environmental benefit, achieved given proportion of parcels. The curves indicate the Lorenz curves for opportunity cost per unit area (*poppcost*); environmental benefit (*penvben*); and value of household asset per capita in 1999 (*asset99*). The straight line indicates a 45-degree line. *Source*: Author's data

area. In other words, the level of assets of households is unevenly distributed in all three provinces and the environmental benefits are more evenly distributed in all three provinces. However, the degree of heterogeneity differs in terms of opportunity cost—Shaanxi has a more homogeneous distribution of opportunity cost, followed by Gansu and lastly Sichuan. Second, Sichuan province and Gansu province are generally more heterogeneous in all three variables than Shaanxi province. Overall, these graphs indicate that in order to make a more cost effective program selection, there needs to be (and there will be more gain by) a more careful targeting done in terms of the level of assets of households and the opportunity cost of retiring a plot (especially in Sichuan and Gansu).

Comparison of Alternative Targeting Approaches

In the final part of our analysis we seek to examine whether or not there is a significant gain in the cost effectiveness of the program by adopting a targeting approach that not only takes into account of the environmental benefits and the opportunity costs but also the poverty levels of the households. To meet this objective, we simulate and compare the cost effectiveness of the five alternative targeting instruments described above. In order to simulate targeting approach (5), we first standardize the inverse of the asset variable (as an indicator of poverty level), environmental benefit and opportunity cost separately. We then calculate the ratio:

$$\phi = (\text{standardized score of } 1/\text{asset} + \text{standardized score of environmental benefit}) / \text{standardized score of opportunity cost.}$$

Finally, we rank the parcels in descending order of this ratio. This procedure implicitly gives an equal weight to both the environmental benefit and poverty level. The performances of the five alternative targeting approaches are compared based on the level of the environmental and poverty alleviation goals achieved given the level of program budget.

Results

Figure 4 presents curves corresponding to the five targeting criteria in environmental benefit-budget space, demonstrating the level of environmental benefit that can be achieved for a given budget under each of the five targeting criteria. When the program manger had the single goal of maximizing the environmental benefit subject to a project budget constraint, targeting approach (1) is the most cost effective approach (Fig. 4). The gain over other approaches, especially over approaches (2), (3) and (4), is substantial.

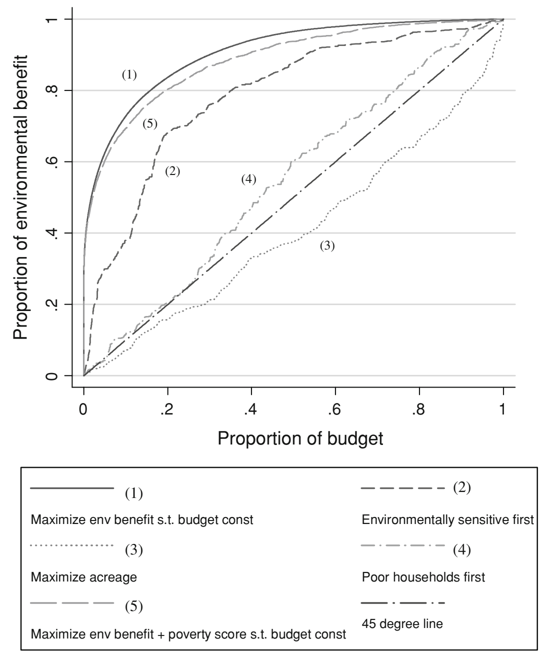

Fig. 4 Proportion of potential environmental benefit given proportion of budget, 1999. Number in parentheses indicates the targeting approach number corresponding to the text. *Source*: Author's data

For example, targeting approach (1) would achieve more than 80 percent of the environmental benefit with 20 percent of the budget (or 20 percent of the total opportunity cost in the study area.) Prioritizing on parcels with high environmental benefit and high poverty level with low opportunity cost (targeting approach [5]) would do almost just as well in the environmental benefit budget space, which reflects the relatively high correlation between environmental benefits and asset levels. The next best is to enroll parcels with high environmental benefit first (targeting approach [2]). Although this approach would not perform as well in the environmental benefit budget space, it still would achieve 70 percent of the benefit given 20 percent of the budget, reflecting the negative correlation between environmental benefit and opportunity cost. The other two criteria (enrolling poorest households' parcels first, or enrolling parcels with lowest opportunity cost first) do not perform as well as other criteria.

The ranking of the five targeting instruments changes when we examine the cost effectiveness in meeting *both* the environmental and poverty alleviation goals (Fig. 5). When the program manger must meet two goals—maximizing the environmental benefit of retiring a plot and the level of poverty alleviation that is achieved when the household's plot is retired, targeting approach (5) is the most cost effective approach. The gain over other approaches, especially over approaches (2) and (3), is substantial. Depending on the tightness of the budget constraint, the second and third best approaches are when

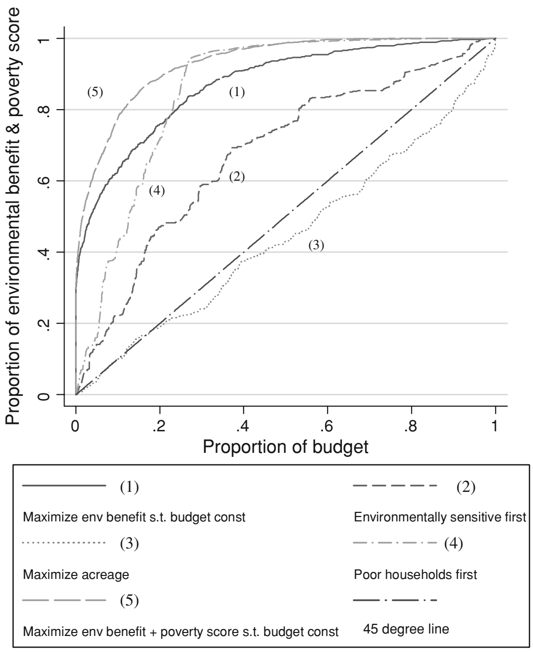

Fig. 5 Proportion of potential environmental and poverty alleviation benefits given proportion of budget, 1999. Number in parentheses indicates the targeting approach corresponding to the text

the program uses targeting instruments (1) and (4). Maximizing on environmental benefit subject to a budget constraint (targeting approach [1]) outperforms targeting poor farmers first (targeting approach [4]) for smaller budgets. The order of performance reverses as the program's budget rises. As expected, maximizing the area (targeting approach [3]) and prioritizing on environmentally sensitive land first (targeting approach [2]) do not perform well in achieving the dual goals. An important finding, however, is that while the first best approach is one which takes into account of both environmental benefit and poverty score, the second best instruments also perform decently. This result from our data set is in part driven by the positive correlation between the two variables (the correlation coefficient for the two variables is 0.1).

Discussion and Conclusion

This study examined the cost effectiveness of China's *Grain for Green* program, a PES program that has the dual goals of environmental benefit and poverty alleviation. Using parcel-specific information from a household survey combined with data on soil erosion from a national set of secondary data, the results indicate that, at the margin, parcels were selected for participation by placing a priority on those with higher environmental benefit and lower opportunity costs but not the poverty level of the households. The program could make a significant improvement in its cost effectiveness even from the environmental perspective by swapping the current program parcels with those with higher environmental benefit and lower opportunity cost. Moreover, the program would be able to better meet the poverty alleviation goal by taking into account of the poverty level of the households explicitly. In sum, these results indicate that the program would have had a substantial gain in meeting its dual goals more cost effectively by targeting the parcels using the gold standard, i.e., prioritizing on parcels that have high environmental benefits, lower opportunity costs that managed by poorer households. This is an important finding for the *Grain for Green* program given that the program's budget outlay has not increased as much as it was initially planned at the outset of the program. To implement such a targeting strategy, the program managers of the *Grain for Green* program will need to collect information on the properties that affect the production of ecosystem service, the opportunity cost and the economic characteristics of the households.

Implementing the "golden rule," however, may be particularly challenging in developing countries (like China) because there are such poor data and institutional capacity often is low. Ultimately, the optimal level of targeting depends on the tradeoffs between the cost and the tolerable degree of errors of exclusion and inclusion (the reduction of which is the benefit of targeting) and is constrained by administrative capacity (FAO 2007a). The program manager will have to be strategic in determining where to put its effort. Our results found that since the environmental benefit of a plot appears to be the most homogeneous of the targeting variables, the program manager under a fixed budget would gain more by making an effort to collect information on the other two targeting variables: the opportunity cost of taking the parcel out of production and the asset values of the owners of the plots. By comparing the heterogeneity across provinces, we found that a program manager could gain greater benefits by carefully targeting these opportunity costs and asset levels particularly in Sichuan and Gansu provinces. Finally, our simulations found that a program's cost effectiveness is sensitive to its targeting approach because of the large amount of heterogeneity that exists. If a PES program has two goals, it would be more cost effective to adopt a targeting strategy which takes into account both types of information. These results, however, may be in part driven by the way we measure the three dimensions of the program. Future research could improve these measurements, especially the measure of environmental benefit, perhaps by using more spatially-detailed and precise data with eco-hydrological modeling.

At the same time, an important implication from our results is that if the tradeoff between targeting areas with high environmental benefit and high poverty level is minimal, a program can achieve a decent performance in cost effectiveness if targeting is based on either the environmental benefit or the poverty level information. Since collecting parcel specific information may be costly, program planners may save resources by examining the correlation between the multiple objectives using an aggregated secondary data, and then concentrate the efforts on collecting information that have more heterogeneity. These findings and the empirical methodologies of this study are applicable to many other PES programs, especially those in developing economies that have dual goals of environment and poverty alleviation and that are operating under a fixed budget.

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