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Consumption risk, farm characteristics, and soil conservation adoption among low-income farmers in the Philippines

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Abstract

This paper investigates patterns of soil conservation adoption among low-income farmers in the Philippines. A model is presented that focuses attention on the role of assets and consumption risk in influencing soil conservation adoption decisions. Results from a reduced-form probit model of adoption are reported. These econometric findings indicate that patterns of soil conservation adoption reflect relative risk considerations in addition to farm and household characteristics. Farm size, tenure security, labor availability, and land quality all exhibit a positive association with soil conservation adoption. In contrast, controlling on these and other household characteristics, the probability of adoption falls as consumption risk rises. These results underscore a need for greater sensitivity among policymakers to the role of consumption risk in influencing soil conservation decisions in low-income settings. © 1997 Elsevier Science B.V.

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1. Introduction

Land degradation is an important economic and environmental policy problem in developing countries. To maintain farm incomes and reduce externalities associated with erosive agricultural techniques, considerable effort has been directed toward identifying and promoting profitable soil conservation strategies in low-income countries. [1] However, as many observers now recognize, profitability is necessary but rarely sufficient to ensure soil conservation adoption (Barbier and Bishop, 1995; Ervin and Ervin, 1982; López-Pereira et al., 1994). In low-income settings, where asset holdings are modest and borrowing for consumption is difficult, economic constraints can be important determinants of investment patterns (Reardon and Vosti, 1995). The primary thesis of this paper is that the income risk associated with soil conservation measures can discourage adoption by resource-constrained farmers.

To test this thesis, this paper investigates the respective roles of assets and relative risk in explaining patterns of contour hedgerow adoption in the Philippines. Contour hedgerows are permanent vegetative barriers planted across the width of a field and

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[1] Some reviews of soil conservation practices are provided by Lutz et al. (1994) and Sanders et al. (1995). External effects are not explicitly treated here. For a general equilibrium model of agricultural externalities, see Coxhead and Shively (1996).

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spaced 5–10 m apart. The barriers restrict soil and water movement, and enhance nutrient recycling. Annual crops are planted in the areas between the hedgerows. A primary advantage of hedgerows compared with other soil conservation measures such as rock walls and terraces is their relatively low labor and material cost for construction. However, an important drawback with hedgerows is their opportunity cost and impact on traditional agricultural practices. They occupy cultivable space and 5–7 years may be required before their yield-augmenting properties compensate for foregone grain. Despite being profitable in the long run, the initial consumption loss can discourage adoption on small or resource-poor farms.

This paper is empirically oriented. However, it also seeks to extend the framework for studying adoption decisions by presenting a model that focuses specific attention on the role of risk in conditioning adoption. [2] The paper investigates the empirical roles of assets and relative risk in explaining patterns of hedgerow adoption. A reduced form model is estimated using data from a sample of Philippine farms. Econometric findings demonstrate that patterns of soil conservation adoption reflect relative risk considerations in addition to farm and household characteristics. Results underscore a need for greater sensitivity among policymakers to the role of consumption risk in influencing soil conservation decisions in low-income settings.

2. Soil conservation adoption and risk

2.1. Model specification

The potential impact of consumption risk on hedgerow adoption can be illustrated using a simplified model of an agricultural household. The household is assumed to maximize its expected returns from farming, i.e.,:

$$\text{Max } E\left[\sum_{t=0}^{T} \beta^t \pi_t(\theta)\right] \tag{1}$$

subject to the definition of farm income: [3]

$$\pi_t = A[f(S,\theta,x,\varepsilon) - c(\theta,x)] + wL + I \tag{2}$$

and a household-specific safety-first constraint:

$$\Pr(\pi_t < D) \le \alpha \ \forall t. \tag{3}$$

In Eq. (1), β is a per-period discount factor; π_t is per-period net farm income, and $\theta = \{0,1\}$ denotes the use of hedgerows. In Eq. (2), A denotes farm size; $f(S,x,\theta,\varepsilon)$ is a stochastic production function that depends on the soil stock (S), conservation efforts (θ), other inputs (x), and a stochastic shock (ε); and $c(\theta,x)$ is a cost function. Eq. (2) also includes noncrop income which is the combination of nonwage income (I) and labor (L) supplied at the wage rate (w). In Eq. (3), D is a threshold or critical level of income and α denotes a maximum allowable probability of falling below the threshold. Bigman (1996) provides a review of safety-first criteria.

As indicated above, the benefits associated with hedgerows appear with a delay. For example, if f_0 denotes production without soil conservation and f_1 denotes production with soil conservation, it may be the case that $f_0 > f_1$ early in the planning horizon and $f_1 > f_0$ in later years. An initial 'negative flow' is typical for investments in soil conservation, and may be particularly important to resource-constrained farmers operating near their threshold income level.

The inclusion of the safety-first constraint in the farmer's problem means that the decision maker must evaluate expected returns in terms of a probability distribution for minimum income. This distribution will depend on the income-earning capacity of the household. Although restrictions could be used to specify a closed form for the conditional probability distribution of returns, a more general approach is to re-express the safety-first constraint as:

$$\pi_t(\theta) + F^{-1}(\alpha)\sigma_\pi \ge D \ \forall t \tag{3'}$$

[2] In this study, adoption is framed as a binary choice. For an analysis of two-stage adoption decisions (i.e., a yes/no decision followed by an acreage decision) see Lohr and Park (1995).

[3] Optimal control models based on Eqs. (1) and (2) are typically maximized subject to an equation of motion for the soil stock (e.g., Barbier, 1988; Barrett, 1991; LaFrance, 1992).

where $F^{-1}(\alpha)\sigma_{\pi}$ is the inverse of the distribution function of returns and σ_{π} is a measure of spread (Boussard, 1979).

Maximization of Eq. (1) subject to Eqs. (2) and (3′) leads to an optimum where in each period

$$(A-\lambda)\left(\frac{\partial f}{\partial\theta}-\frac{\partial c}{\partial\theta}\right)=\lambda\frac{\partial F^{-1}}{\partial\theta} \quad (4)$$

or

$$\frac{\partial f}{\partial\theta}=\frac{\partial c}{\partial\theta}+\frac{\lambda}{(A-\lambda)}\frac{\partial F^{-1}}{\partial\theta} \quad (5)$$

Eq. (5) is a marginal benefit–marginal cost condition for adoption that explicitly accounts for the cost of adoption in terms of its impact on the safety-first constraint in each period. If this constraint is binding (i.e., if $\lambda > 0$), adoption decisions will not be based solely on a comparison of net benefit flows between techniques, but will also depend on farm size, non-farm income, and the impact of adoption on the probability of consumption shortfall.

2.2. The adoption decision

Inverting Eq. (5) leads to a demand function for soil conservation investments of the form:

$$\theta=\phi\left(A,c,E\left\{F^{-1}(\alpha)\sigma_{\pi}\mid A,w,L,I\right\}\right) \quad (6)$$

Eq. (6) says that the decision regarding soil conservation adoption will depend on farm size, the cost of adoption, and the shape of the expected probability distribution associated with the safety-first constraint. The probability distribution is conditioned on the income-earning capacity of the household. Given the probabilistic nature of the safety-first constraint, expectations will clearly influence adoption decisions. Furthermore, by influencing technology performance or adoption cost, farm-specific attributes such as land quality or slope may also influence adoption decisions. Including the safety-first constraint in the adoption problem underscores the point that when technology adoption is costly, it has the potential to push a low-income household below its disaster level. One would therefore expect adoption decisions to be influenced by (and explained by) the productive capacity of the household. Eq. (6) therefore serves as the basis for the reduced-form empirical model investigated below.

3. Sample description

3.1. Description of data and study site

Data used to estimate the model are drawn from a 1994–1995 farm survey of 115 corn producers in an upland area near Bansalan, in the Philippine province of Davao del Sur. The site is described in Garcia et al. (1995). Farms are located at elevations of 1000–1500 m above sea level. A majority of sample farms lie at or above 18% slope, and annual rates of soil erosion in the area have been estimated at 100 t/ha (Latada et al., 1994). The combination of land degradation, small farm sizes (< 3 ha), low yields (1350 kg/ha), and low incomes (US$600 per household) means that many families in the area cannot reliably maintain household food security.

3.2. Farm characteristics and the opportunity cost of soil conservation

Estimates of the labor and opportunity costs of hedgerow construction are summarized in Table 1. The consumption risk embodied in soil conservation adoption is directly related to the opportunity cost of hedgerows. This opportunity cost can be calculated in terms of the foregone grain associated with the area occupied by hedgerows. The estimate of opportunity cost for each parcel is based on recommended hedgerow spacing for observed field slope, and was converted to a grain-equivalent measure using the sample average yield. The opportunity cost of adoption on a parcel is measured as a ratio. The numerator is the cumulative amount of grain that would have been foregone if hedgerows had been constructed at the recommended intensity on the parcel; the denominator is the total household corn harvest of the previous year. Based on extension estimates, labor required for establishment was assumed to be 40 days/ha. This value was converted to grain equivalents using the local agricultural wage (50 pesos/day) and the prevailing wholesale market price of corn (5 pesos/kg).

The entries in Table 1 suggest that per-hectare labor requirements for hedgerow adoption were rather

Table 1
Household resources and hedgerow establishment costs

Farm size quintile	Farm size (ha)	Field slope (°)	Labor availability (man-days)	Corn production (kg)	Annual income (pesos)[a]	Average cost		
						Labor required/ labor available	Cumulative grain/ annual production	Cost/ annual income
1	0.81	30	658	404	7300	0.06	0.82	0.55
2	1.34	28	663	1336	14444	0.06	0.25	0.28
3	2.05	26	577	1346	12685	0.07	0.25	0.32
4	3.30	23	790	1568	25186	0.05	0.21	0.16
5	7.09	23	895	2300	21144	0.04	0.14	0.19

[a] Including imputed value of retained home consumption. The 1995 exchange rate was US$1.00 = 25 Pesos.

low, typically on the order of 4–7% of available household labor. Conversely, the opportunity cost of land used for hedgerows was quite high, especially for small farms on steep fields (where greater hedgerow intensity is required to reduce erosion). As the entries in Table 1 indicate, in the initial years of adoption the cumulative amount of grain foregone due to hedgerow construction on a parcel was about 80% of the annual available supply for a household in the lowest farm-size quintile, and about 15% for a household in the highest farm-size quintile. These high measures of opportunity cost reflect three facts. First, the output gap between traditional and hedgerow plots can be as much as 25% of output during the initial years of hedgerow establishment. Second, it typically takes 5–7 years for the yield augmenting properties of hedgerows to erase this gap. And third, small farms typically rely on a single parcel of land to meet food production needs while large farms spread production over several parcels. The opportunity cost of adopting hedgerows on any single parcel therefore tends to be higher on small farms than on large farms. The overall cost (in terms of labor, land, and materials) of establishing hedgerows ranged from 16 to 55% of total annual income on average. At the time of the survey, 60% of sample farmers had adopted contour hedgerows on one or more parcels.

3.3. Farm characteristics

Table 2 reports average values observed for variables considered in this analysis. The first three columns in Table 2 correspond to values for the full household sample of adopters and non-adopters; the last three columns correspond to a subsample of plots (both with and without hedgerows) for which detailed plot-level information was available. [4] Independent variables are presented in four groups: (A) assets; (B) off-farm income; (C) farmer characteristics; and (D) plot characteristics.

3.3.1. Assets

Assets considered in this study include farm size, tenure security, and labor quantity and quality. As a factor of production and store of wealth, land is probably the most important asset influencing adoption. Land provides collateral and is one of the few sources of credit and liquidity for low-income households. For these reasons, one might expect a household's willingness or capacity to invest in soil conservation to be positively correlated with farm size. For example, models of technology adoption that explicitly account for farm size and risk predict higher adoption rates on large farms (Feder and O'Mara, 1981; Just and Zilberman, 1983; Feder et al., 1985). Similarly, empirical studies from LDCs have indicated that agroforestry adoption rates are higher on large farms (Scherr, 1995), and that farmers regard small farm size as a barrier to investing in soil conservation (Fujisaka, 1993). [5] In the regressions, farm size is expressed as area per adult-equivalent unit.

Land ownership is also likely to be an important determinant of adoption. Tenure security can influence access to credit, the length of a household's planning horizon, or a household's willingness to invest. Although investments in soil conservation have been found to be lower on rented land than owned land (e.g., Clay and Reardon, 1994), ambiguity can sometimes arise regarding the role of tenure security in influencing adoption. For example, while tenure security may be a precondition for investments in maintaining land productivity, in some settings investments may help farmers to obtain de facto if not de jure land rights (Russell, 1986). This logic applies to some extent in the study area for this investigation. Most farms lie within Mt. Apo National Park on what is legally classified as public land. Although this might be viewed as a situation of tenure insecurity, farmers covered by traditional tenure regimes nevertheless see agricultural investments as a way to legitimize their claim to the land, and local authorities tend to officially recognize tra-

[4] Plot-level data are a subset of the farm-level data and contain a larger proportion of second-season harvests. Farmers who planted corn during the second cropping season had larger farms, more non-agricultural income, and higher first-season yields than their cohorts.

[5] However, as a reviewer has pointed out, a large farm size may also allow longer rotations, which could reduce returns from conservation and undermine incentives for soil conservation investments.

Table 2
Selected characteristics of Bansalan farms, 1994–1995

Variable	Farm level			Plot level		
	Non-adopters	Adopters	All	Without hedgerows	With hedgerows	All
(A) Assets						
Farm size (ha)	2.3	3.5	2.9	3.4	3.6	3.5
Per capita farm size (ha per adult equivalent)	0.50	0.88	0.72	0.75	0.85	0.79
Tenure security (proportion of area with secure tenure)	0.56	0.85	0.75	0.89	0.93	0.90
Labor availability (adult male equivalents)	1.94	1.96	1.95	1.80	1.83	1.81
Labor availability per hectare (man-days per ha)	690	348	485	135	224	171
Education of household head (yr)	4.4	4.6	4.5	4.7	4.2	4.5
(B) Off-farm income						
Non-agricultural, non-wage income (1994 pesos)	2646	656	1450	5749	2727	4525
Wage income (1994 pesos)	550	1075	950	1184	679	975
Non-agricultural, non-wage income per adult equivalent (1994 pesos)	705	150	370	1210	511	930
Wage income per adult equivalent (1994 pesos)	134	268	234	332	161	263
(C) Farmer characteristics						
Baptist household {0,1}	0.15	0.48	0.30	0.60	0.75	0.66
Hedgerow attitude index (-10 to $+10$; centered and scaled)	-0.64	0.39	0.00	0.09	0.19	0.01
Subjective estimate of hedgerow yield (ratio of hedgerow to traditional yield)	1.18	1.16	1.17	1.16	1.14	1.15
(D) Plot characteristics						
Plot size (ha)	–	–	–	0.56	0.38	0.40
Soil depth on plot (mm)	–	–	–	839	867	850
Period of continuous cropping on plot (months)	–	–	–	90	73	83
Plot slope (°)	–	–	–	25	27	26
Ratio of cumulative cost of adoption on plot to annual production	–	–	–	0.66	0.51	0.60
Number of observations	46	69	115	53	36	89

ditional forms of tenure when good land-use practices are observed. For this reason, both traditional land claims and titled ownership are classified as secure tenure in this study. Rented land is classified as insecure tenure. By this definition, approximately 75% of sample farms had secure tenure at the time of the survey.

Labor requirements are widely regarded as a critical element influencing adoption of soil conservation (Fujisaka, 1993; Harper and El-Swaify, 1988; Clay and Reardon, 1994). Measures of both labor quantity and labor quality are included in this study. Households had an average of two adult-male equivalent workers and average labor capacity of approximately 500 days per year. In the regressions, labor availability is measured as man days per hectare. Land quality is measured as educational attainment (in years) among household heads.

3.3.2. Off-farm income

Results from previous studies suggest an ambiguous role for off-farm income in influencing soil conservation adoption. A negative relationship may reflect labor competition between off-farm activities and farming, or may signal a shift in household interests away from farming as a primary livelihood. For example, in a previous study of soil conservation adoption in the Philippines, de los Angeles (1986) reported a negative correlation between the level of non-farm income in a household, and the probability of conservation adoption, and concluded that households without off-farm income had greater incentives to maintain on-farm resources. In contrast, other authors have argued that off-farm income provides cash for investments in conservation, especially when labor or materials must be acquired (e.g., Reardon and Vosti, 1995). Two off-farm income variables are used in this analysis. The first measures non-agricultural, nonwage income. The second measures wage income. In both cases, the variable entered in the regressions is expressed in pesos per adult-equivalent unit.

3.3.3. Farmer characteristics

Farmer characteristics incorporated in the analysis include an indicator of religious affiliation, a measure of attitudes toward hedgerows, and a subjective estimate of hedgerow yields. Approximately 30% of farmers in the sample reported membership in the local Baptist church, a factor that is important for this study because of a church-based extension program that promoted hedgerows in the area. An attitude measure is included because previous studies have shown that farmer attitudes are important determinants of new technology adoption (e.g., Adesina and Zinnah, 1993). An index of a decision maker's attitude toward hedgerows is used. This index was constructed using responses from a series of 10 questions regarding positive and negative aspects of hedgerows. For each question a negative response was recorded as -1, a positive response was recorded as $+1$, and indifference was recorded as 0. The index, computed as the sum across the 10 questions, was centered and scaled so that it is positive for decision makers who judge hedgerows more favorably than average, and is negative for decision makers who judge hedgerows less favorably than average. The regressions also include a measure of a farmer's estimate of the impact of hedgerows on corn yields. Construction of this subjective yield estimate is described in Appendix A. The variable is a ratio computed as the farmer's yield estimate for a hedgerow plot divided by his yield estimate for a traditional plot. As constructed, this ratio exceeds 1 for farmers who consider hedgerows superior to traditional methods of growing corn, falls below 1 for farmers who consider hedgerows relatively inferior to traditional techniques, and equals 1 for farmers who regard yields under the two techniques as essentially similar. On average, both adopters and non-adopters judged hedgerows as relatively more productive than traditional techniques.

3.3.4. Plot characteristics

Plot characteristics used in the analysis include parcel size, measures of land quality, and an estimate of the opportunity cost of adoption. Two variables represent land quality: soil depth and duration of use. Soil depth on each parcel was imputed using data from a recent soil survey. The duration of use variable is measured in months and was computed as the total length of time since the parcel was first cropped, minus any intervening periods of fallow. Both characteristics could be expected to influence adoption because returns to soil conservation can be lower on degraded land. Parcel slope is also included in the analysis under the assumption that greater slope increases the cost of hedgerow adoption. As the entries in Table 1 indicate, small farms tend to occupy steeper land, a pattern that would suggest systematically higher costs of adoption on small farms.

Finally, in order to assess whether the fixed cost of adopting hedgerows on a particular plot might contribute to overall consumption risk in a household, a measure of the opportunity cost of adoption is employed. This variable is measured as a ratio. The numerator is the cumulative amount of forgone grain associated with hedgerow construction on the parcel. The denominator is the total annual corn harvest for the household from all parcels. [6] A small value indicates that adoption would have reduced the household corn supply by a small proportion. A large value indicates that adoption would have required a farm to forgo an amount of grain that was a relatively large proportion of its typical corn harvest.

4. Model estimation and results

A reduced-form model was used to relate hedgerow adoption to variables outlined in Section 3. Analysis was conducted at both the farm level and the plot level. In the farm-level regressions, adoption is registered as a binary variable equal to 1 if the household adopted contour hedgerows anywhere on the farm, and 0 otherwise. In the plot-level regressions, adoption is registered as a binary variable equal to 1 if the household adopted contour hedgerows on a specific plot and 0 otherwise. A probit model was used under the assumptions that an underlying (but unobserved) response variable describes a household's probability of technology adoption, and that unobserved disturbances are normally distributed. [7]

Table 3 contains results from four probit regressions. Regressions A1 and A2 were conducted at the farm level; regressions B1 and B2 were conducted at the plot level. All regressions contain measures of assets and off-farm income. Model A2 adds to model A1 the set of farmer-specific variables. Model B2 contains both farmer-specific variables and plot-specific variables. The farm-level dataset contains 115 observations; the plot-level dataset contains 89 observations. Overall, the models predict farm-level adoption patterns somewhat better than plot-level adoption patterns, attaining an 86% success rate in model A2.

4.1. Assets

Results from all reported models indicate that after controlling other factors, hedgerow adoption was more likely on large farms. These results are consistent with previous Philippine research on soil conservation adoption (de los Angeles, 1986). Results suggest that farm size may be a proxy for lower risk exposure, fewer liquidity constraints, or improved access to resources. In elasticity terms, a 1% increase in per-capita farm size is associated with a 0.15% increase in the probability of adoption at the mean. In the farm-level regressions (models A1 and A2), the probability of adoption is positively and significantly correlated with the proportion of a household's holdings that are securely held (either formally or informally). This relationship is somewhat weaker in the plot level regressions (models B1 and B2). In contrast, in the farm-level regressions (models A1 and A2) the correlation between labor availability and adoption is weak in the farm-level regressions, but per hectare labor availability is positively correlated with hedgerow adoption at a 95% confidence level in the plot-level regressions. Education of the household head exhibits a positive but statistically weak correlation with adoption in all models. The statistical weakness likely reflects the

[6] This ratio generally increases as farm size falls, although it need not, since a large plot on a large farm may have a larger ratio than a small plot on a small farm. The denominator of this measure is an endogenous function of the adoption decision, but the bias introduced in the regressions is in favor of a positive coefficient on the regressor. Given the large and statistically strong negative sign on the estimated coefficient, this statistical bias is not of great concern.

[7] The results of the probit models do not differ markedly from those of logit models (in which disturbances are assumed to be log-normally distributed).

Table 3
Probit results for models of soil conservation adoption

Independent variable	Farm level		Plot level	
	A1	A2	B1	B2
Constant	−0.4482 (0.4704)	0.8369 (1.1383)	−1.0181 (0.8471)	1.6823 (2.8560)
Per capita farm size (ha per adult equivalent)	0.3100 (0.1372)	0.2479 (0.1320)	0.3407 (0.1232)	1.2824 (0.4553)
Labor availability per hectare (man-days per ha)	−0.0030 (0.0040)	−0.0083 (0.0054)	0.0018 (0.0008)	0.0033 (0.0014)
Tenure security (proportion of cultivated area with secure tenure)	0.9165 (0.3213)	1.1007 (0.4004)	0.1647 (0.6848)	0.7979 (1.1391)
Education of household head (yr)	0.0189 (0.0414)	0.0257 (0.0506)	0.0354 (0.0601)	0.0167 (0.0877)
Non-agricultural, non-wage income per adult equivalent[b] (1994 pesos)	−0.0008 (0.0005)	−0.0005 (0.0006)	−0.0001 (0.0001)	−0.0001 (0.0001)
Wage income per adult equivalent (1994 pesos)[b]	0.0010 (0.0008)	0.0006 (0.0010)	0.0002 (0.0002)	0.0003 (0.0004)
Baptist {0,1}	–	1.3386 (0.4108)	–	0.4418 (0.4949)
Attitude index (mean 0)		−0.7892 (0.1696)		−0.2713 (0.2993)
Subjective estimate of hedgerow yield (ratio of hedgerow to traditional)	–	−1.1257 (0.8415)	–	−0.0611 (0.0974)
Plot size (ha)	–	–	–	−0.8714 (0.4899)
Soil depth of plot (mm)	–	–	–	−0.0035 (0.0018)
Period of continuous cropping on plot (months)	–	–	–	−0.0234 (0.0116)
Plot slope (°)	–	–	–	−0.0027 (0.0166)
Ratio of cost of adoption on plot to annual production	–	–	–	−0.8384 (0.2639)
Value of log-likelihood function[c]	−58.66	−45.51	−50.49	−43.94
Percentage correct predictions	0.77	0.86	0.71	0.72
Number of observations	115	115	89	89

[a]Asymptotic standard errors are presented in parentheses.
[b]Variables have been replaced by instrumented values; see Appendix B for details.
[c]Likelihood ratio tests for regressions with a constant term only are: −77.4 for the farm-level models and −60.1 for the plot-level models.

fact that educational attainments in the sample were uniformly low.

4.2. Off-farm income

Including measures of off-farm income presents an econometric challenge because decisions regarding soil conservation investments and off-farm labor supply are often simultaneously determined. The possible endogeneity of off-farm income is a feature that complicates efforts to include measures of off-farm income in any adoption study. Here, the null hypothesis that off-farm income is exogenous to adoption is tested, rather than assumed. The testing method follows the procedure of Smith and Blundell (1986) for testing exogeneity in a Tobit regression. Formally, the procedure consists of testing whether $c = 0$ in the regression $y = ax + bm + c\hat{v} + \varepsilon$, where y is the adoption variable, m is the off-farm income variable, and $\hat{v}$ is the predicted residual from a regression of m on a set of instrumental variables. For this study, tests were conducted on both measures of off-farm income. Results suggest that only the measure of per-capita wages strictly fails the test of exogeneity. [8] Nevertheless, given the likely endogeneity of both measures of off-farm income, each has been replaced by its instrumented value. The regressions used for computing instruments are reported in Appendix B.

Regression results indicate that neither off-farm income variable is correlated with adoption at standard significance levels. Nevertheless, the patterns exhibited in the regressions help to explain previous contradictions in empirical findings in two ways. First, the probability of adoption is negatively correlated with non-agricultural, non-wage income. This may reflect reduced interest in farming among households with non-agricultural income, some of whom had started small businesses that competed with farming for capital investments. Second, households with wage income appear to have invested in hedgerows at a higher rate than those without. Far from indicating a tendency to invest wage earnings in soil conservation, however, this more likely represents a greater reliance on annual crop income by wage earners, who tended to have below-average incomes.

4.3. Farmer characteristics

Membership in the local Baptist church and participation in agricultural training workshops run by the church are highly correlated in the sample. Not surprisingly, therefore, data indicate that households identified as Baptist tended to adopt hedgerows at a higher rate than their non-Baptist cohorts. Model A2 indicates that hedgerow adopters generally exhibit a more favorable attitude toward hedgerows than non-adopters. While such a pattern might not itself be surprising, what is surprising is that adding this subjective measure does not diminish the explanatory power of farm-level characteristics. Model A2 also includes farmer estimates of the impact of hedgerows on yields. On average, both adopters and non-adopters judged hedgerows as relatively more productive than traditional techniques. However, regression results indicate that adopters were likely to judge them less favorably than non-adopters. This pattern is unexpected, but may indicate that adopters were more accurate in their estimate of impacts than non-adopters (since lower corn output was observed on hedgerow plots).

4.4. Plot characteristics

The results of the plot-level regressions indicate that adoption was less likely on large parcels than on small parcels (model B2). This pattern is consistent with research from Africa that shows large farms tend to invest less per hectare in soil conservation than small farms (e.g., Clay and Reardon, 1994). However, causality could run the other way as well: if parcels are large because soil quality is poor, then the returns to soil conservation investments on large parcels might be low, and therefore incentives to adopt may be weaker than on smaller parcels.

The estimated coefficients on the land quality variables are negative and significantly different from

[8] Specific t-statistics for the tests are as follows: for per-capita non-agricultural, non-wage income: $t = 1.31$, and for per-capita wage income: $t = 2.11$.

zero at a 95% confidence level. Parcels with greater soil depth were less likely to receive investments in soil conservation, and older parcels were also less likely to receive investments. Since older parcels are likely to have experienced greater cumulative soil loss, these results suggest a nonlinear impact of land quality on adoption. Farmers may postpone conservation on parcels that have remaining productive potential, but refrain from investing on parcels that are very old and, presumably, exhausted. Although a conceptual link between parcel slope and cost of adoption is clear, this explanation for lower adoption rates on small farms is not fully borne out by the data. In the regressions, greater slope is negatively correlated with adoption, but not at statistically significant levels.

Finally, to assess whether the opportunity cost of adopting hedgerows on a particular plot discouraged adoption, a measure of the opportunity cost of adoption is included in model B2. The estimated coefficient is negative and significantly different from zero at a 95% confidence level. This pattern indicates that as the opportunity cost of adoption on a plot rises, the probability of adoption falls. Greater consumption risk, as reflected by a higher opportunity cost of soil conservation adoption on a plot, appears to be negatively correlated with the probability of adopting hedgerows. [9]

5. Conclusions

This paper examined the respective roles of farm characteristics and relative risk in explaining patterns of soil conservation adoption by a group of low-income farmers in the Philippines. A conceptual model based on a safety-first criterion was presented. The model highlighted the importance of consumption risk in influencing adoption decisions. A reduced-form model of hedgerow adoption was estimated using probit analysis. Among the empirical findings observed were that land- and labor-poor households are less likely to invest in soil conservation. Larger farm size, greater tenure security, and higher labor availability were all correlated with higher probability of adoption on sample farms. Higher adoption probability was also positively correlated with wage income, but was negatively correlated with other forms of off-farm income.

Factors that helped explain patterns of adoption at the plot level include land quality and risk exposure. Adoption was seen to be less likely when land quality was high, or when plots were old. In the case of risk exposure, results supported the main hypothesis tested in the paper, namely that after controlling asset holdings, household characteristics, and subjective factors, consumption risk influences conservation adoption. As the consumption risk specific to adoption increased, as measured here by the opportunity cost of conservation adoption on a plot, the probability of adoption fell.

Focusing on the change in predicted probability of hedgerow adoption associated with changes in available labor and land, the results show that individually, labor is relatively less important than land. This pattern is consistent with the modest labor requirements for hedgerow establishment (e.g., 40 days/ha compared with up to 500 days/ha for bench terraces). In contrast, per-capita farm size was positively and significantly correlated with the probability of adoption. Larger farms, of course, have both greater productive capacity and greater liquidity, both of which translate into lower consumption risk.

From a policy perspective, these patterns underscore the importance of risk management in promoting soil conservation technologies to resource-constrained farmers. Future work should focus on three related areas of research: first, investigating the extent to which risk considerations influence soil conservation decisions in other settings; second, assessing the degree to which specific soil conservation strategies influence consumption risk; and third, separating the impact of adoption on consumption risk from the possible impact of adoption on production risk. A better understanding of these factors will likely contribute to efforts directed at the twin goals

[9] As a reviewer pointed out, a change in opportunity cost could shift the distribution of profits and thereby lead to a change in the level of production risk. Therefore, in some cases the proxy measure of consumption risk used in the regressions could also be picking-up the impact of higher production risk on adoption. Obviously, an increase in either production risk or consumption risk could discourage adoption.

of reversing land degradation and alleviating poverty in low-income countries.

Appendix A. Subjective yield estimates and the method of triangulation

A two-moment analysis was used to elicit subjective yield distributions based on the relative ease with which a triangular distribution could be implemented empirically (Anderson et al., 1977; Pingali, 1982). During the survey, each decision maker was asked to guess the most likely (m), lowest (a), and highest (b) corn harvest he thought possible, with and without soil conservation, on a specific parcel of land. Parcels used for the estimates were subsequently measured, and the individual's yield estimates were computed for minimum, modal, and maximum values under both scenarios. Probability density functions were then estimated as:

$$f(y) = \frac{2(y-a)}{(b-a)(m-a)}\ \forall\, a < y < m \text{ and}$$

$$f(y) = \frac{2(b-y)}{(b-a)(b-m)}\ \forall\, m < y < b$$

Subjective means and variances were computed in each scenario by integrating over the CDF:

$$\mu_y = \int_{-\infty}^{\infty} y f(y)\,\mathrm{d}x \text{ and}$$

$$\sigma_y^2 = \int_{-\infty}^{\infty} y^2 f(y)\,\mathrm{d}x - \mu_y^2$$

Farmers tended to provide higher estimates for mean yields and variances with hedgerows than without hedgerows. Paired comparison tests between adopters and non-adopters indicate that the difference between true and subjective estimates of means were slightly higher for adopters and that the difference between true and subjective estimates of variances did not differ across farmer groups. This suggests that adopters tend to be somewhat more optimistic regarding hedgerows than non-adopters. An alternative interpretation is that the measure serves as a proxy for farmer skill: better farmers might have a lower estimation error; hence, a ratio closer to the true value, in this case, α approximately 0.90.

Appendix B. Instrumenting regressions for off-farm income variables

Independent variable	Non-agricultural, non-wage income per capita (pesos per adult equivalent	Wage income per capita (pesos per adult equivalent
Constant	1599.4 (694.8)	540.6 (334.2)
Farm size (hectares)	−33.82 (48.69)	−12.45 (23.42)
Household size (number of adults equivalent	−57.58 (54.67)	−46.51 (26.30)
Age of household head (years)	−3.05 (10.01)	−5.64 (4.82)
Ethnicity (1 = indigenous, 0 = other)	−99.34 (249.2)	92.29 (119.9)
Livestock ownership (0/1)	−704.4 (396.0)	229.0 (190.5)
R^2	0.05	0.06
Number of observations	115	115

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