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Policy options promoting market participation of smallholder livestock producers: A case study from The Philippines

International Livestock Research Institute

Socio-economics and Policy Research

Policy options promoting market participation of smallholder livestock producers: A case study from The Philippines

Socio-economics and Policy Research Working Paper 47

M.L. Lapar, G. Holloway and S. Ehui

ILRI
INTERNATIONAL LIVESTOCK RESEARCH INSTITUTE

International Livestock Research Institute
P.O. Box 30709, Nairobi, Kenya

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Authors' affiliations

Ma Lucila Lapar, International Livestock Research Institute (ILRI), DAPO Box 7777, Metro Manila, The Philippines

Garth Holloway, University of Reading, Department of Agricultural and Food Economics, 4 Earley Gate, Whiteknights Road, P.O. Box 237, Reading RG6 6AR, UK

Simeon Ehui, ILRI, P.O. Box 5689, Addis Ababa, Ethiopia

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Executive summary

The population growth, urbanisation and income growth that fuelled the increase in meat and milk consumption during the last two decades are expected to continue in the future, creating a veritable Livestock Revolution. This revolution presents new and expanding market opportunities for smallholder livestock producers. Inappropriate policies and misallocation of investment resources could, however, skew the distribution of the benefits and opportunities away from those smallholders who would potentially gain the most from this revolution. In this context, a search for policies designed to enhance the benefits to smallholders seems appropriate.

This study provides an empirical basis for identifying options to increase the participation of smallholders in livestock markets in The Philippines. We present a model of household entry into markets where smallholders make decisions about participation (whether to sell quantities of products) and supply (how much of the various quantities to sell). The theory is implemented using probit and Tobit techniques that exploit Gibbs-sampling and data-augmentation. Application to a sample of Philippine smallholders reveals important insights about the competing influences of transactions costs, labour mobility, capital formation and credit use on the market participation and supply decisions. The offsetting impacts of conflicting factors complicate the roles for policy in the context of expanding the density of participation in the study site.

1 Introduction

In a recent study, Delgado et al. (1999) reported that from the early 1970s to the mid-1990s, consumption of meat and milk in the developing countries increased by 175 million tonnes, more than twice the increase that occurred in developed countries. For the year 1990, they calculated that the market value of that increase in meat and milk consumption totals approximately US$ 155 billion, more than twice the market value of increases in cereals consumption under the Green Revolution. They argue that population growth, urbanisation and income growth that fuel the increase in meat and milk consumption are expected to continue over the next several decades, creating a veritable livestock revolution. This revolution presents new and expanding market opportunities for smallholder livestock producers. Delgado et al. (1999) projected that per capita consumption of meat and milk will increase by about 50% from 1993 to 2020, and that developing countries, where at least three-fourths of livestock production come from smallholder/backyard producers, will produce about 60% of all meat products and 52% of all milk products. Inappropriate policies and misallocation of investment resources could, however, skew the distribution of the benefits and opportunities away from the smallholders who would potentially gain the most from this revolution. In this context, a search for policies designed to effect benefits to smallholders seems appropriate and this is one main objective of this paper.

Improving access to markets to benefit from the rapidly growing demand for livestock products is one option that policy-makers must consider. However, its consideration is complicated by the potentially offsetting effects of transactions costs, labour mobility, opportunities for off-farm employment and the competing impacts that physical, financial and intellectual capital accumulation may have when diverse opportunities for resource allocation are present. For example, smallholders generally have inadequate capital resources—including, physical and financial resources, and also intellectual capital resources such as experience, education and extension—that limit their ability to diversify farm activities. When an increase in the capital stock arises, for example, through an increase in education levels, and alternative employment opportunities exist, it is unclear what the impacts of the increased capital stock will be on participation and supply in livestock markets. Similar arguments exist in the context of examining increases in incomes from alternative sources, such as remittances and other farm activities. When alternative employment opportunities exist it is unclear what the allocation towards the market will be. In short, alternative employment prospects complicate policy analysis about market participation and supply decisions.

Additional issues further complicate policy design. For example, the inability of smallholder producers to take advantage of economies of scale in production and marketing is a significant impediment to participation. Because large producers are better able to take advantage of scale effects, blanket policies such as price supports are often biased towards them because such policies often favour physically and financially capital-intensive production systems. In addition, smallholders are often disadvantaged due to poor access to information and market-precipitating services such as visits by extension agents and credit assistance and these impediments often give rise to low rates of adoption of improved technologies that could potentially increase productivity. Likewise, poor infrastructure often increases the transactions costs of smallholder market participation and is an open question as to the design of appropriate policies in this context.

This study provides an empirical basis for identifying options to increase the participation of smallholders in livestock markets in The Philippines. Our sub-national focus is prompted by the availability of detailed data on transactions costs, labour mobility and capital formation across a set of households, some of which participate in livestock production and marketing activities and some, which do not. In this context we provide precise evidence on the offsetting impacts of competing factors on the joint decisions to participate in a market and furnish positive supply. While the policy prescriptions have, arguably, a narrower purview, the methodologies employed have broader implications for market participation and supply analysis in the context of household production data.

Section 2 of this paper presents a simple framework for investigating market participation and supply decisions that lends itself to traditional probit and Tobit estimation. Section 3 briefly discusses a multivariate extension of the basic model and presents the estimation algorism. Section 4 introduces the empirical application; and Section 5 presents results. Conclusions are offered in Section 6.

2 Modelling participation and supply decisions

We consider the participation and supply decisions in the context of traditional probit and Tobit models applied to household production data. For each household, i, i = 1, 2, ..., N, assume that the decision to participate, $y_i = 1$ (if participation is observed and $y_i = 0$ otherwise) is conditioned by a vector of household-specific covariates, x_i, so that the decision rule is to participate when the utility of doing so, say, $U_i(x_i)$ exceeds the utility of not doing so, say, $V_i(x_i)$, which is also the utility reaped in return for resources x_i (a k-vector of household characteristics) allocated to some alternative, feasible, enterprise. Taking Taylor-series expansions of these two utility functions around the point $x_i = 0$, yields the linear model, $y_i = 1$ if $x_i \gamma \geq x_i \delta$, $y_i = 0$ if $x_i \gamma < x_i \delta$, where γ and δ are k-vectors of first-order effects depicting the impacts on the two utilities of changes in the levels of the various resources. Subtracting the left-hand-side from both sides of the inequalities, equating the result to a latent variable, z_i, and permitting the equality to hold with error, u_i, we are left with the expression:

$$z_i = x_i \alpha + u_i \qquad z_i \geq 0 \text{ if } y_i = 1,\ z_i < 0, \text{ otherwise} \tag{1}$$

Here $\alpha \equiv \gamma - \delta$ measures the difference in allocating resources to either enterprise. By assuming that the errors are normally distributed, $u_i \sim N(0,1)$, the familiar probit specification evolves as a reasonable, linear representation of the participation decision. Here, the error variance is constrained to equal one to overcome an identification problem arising due to the fact that the latent-variable specification in equation (1) is neither scale nor location independent.

Supply decisions are modelled in a similar way. We assume that the quantity supplied on the market is a linear function of another set of household characteristics, which may be the same as the set represented by the covariates x_i, above. Specifically, using v_i, i = 1, 2, ..., N to denote quantities, supply is specified as:

$$q_i = x_i \beta + u_i \tag{2}$$

Unlike the latent specification in the probit model, the dependent variable in (2) takes on positive and zero values. When a zero value is observed, we assume this to imply that the household in question, rather than possessing an excess of the marketable product, actually has a *demand* for the commodity (that is, a negative supply). Hence, sales quantities are left-censored at zero. This simple observation is developed further in Figure 1.

Figure 1 depicts the utility-maximising household-supply decision. Utility (which is latent or unobservable) is depicted on the vertical axis and the potential sales quantity is depicted on the horizontal axis. For two households (households i and j) one household maximises utility by producing a positive sales quantity (q_j) whereas the second finds utility maximised in the negative quadrant over the supply quantity (q_i). Unlike the first household, the second household's implicit supply quantity is unobserved and latent. The quantity v_i, in Figure 1, is used to represent this latent value. This value is very important for policy purposes because it provides a simple and highly intuitive quantity with which to measure a household's distance from market (δ_i). As such, the values, $v_i = \delta_i$, for $i \in$ (the censor set) $c \equiv \{i \mid q_i = 0\}$, are an important part of the estimation exercise. In the section that follows we show how they can be used to simplify the estimation problems arising due to censoring in the sales data and latency arising in the probit regression.

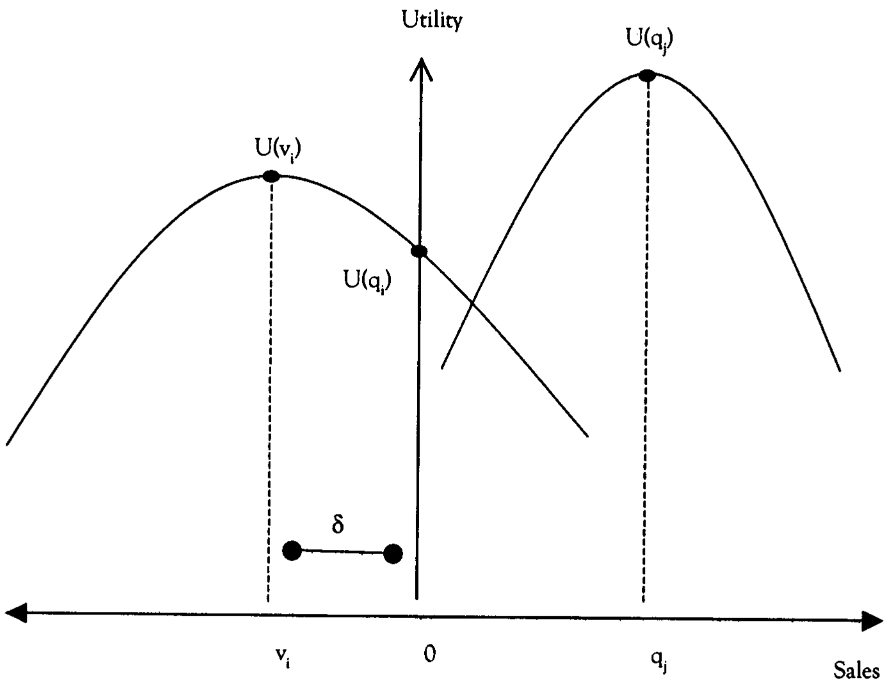

Figure 1. *Utility-maximising sales values and distance-to-market latency.*

3 Estimation

We consider independent estimation of the two equations and, subsequently, discuss joint estimation. Following Albert and Chib (1993), Bayes estimates of the probit model, equation (1), are simplified considerably by exploiting the restrictions on the latent dependent variable, $z \equiv (z_1, z_2, \ldots, z_n)'$. The equations depicting participation across the N households can be arranged in matrix form into the system as:

$$z = x\alpha + u \qquad (3)$$

where $z \equiv (z_1, z_2, \ldots, z_N)'$ is a vector of latent effects constrained to the relevant quadrant (positive if the corresponding element of $y \equiv (y_1, y_2, \ldots, y_n)'$ equals one and negative if the corresponding element is zero; $x \equiv (x_1', x_2', .., x_N')'$ is an $N \times k$ matrix of household-specific covariates; $\alpha \equiv (\alpha_1, \alpha_2, \ldots, \alpha_k)'$ is the vector depicting impacts of the covariates on the latent effects; and vector $u \equiv (u_1, u_2, .., u_N)'$ contains the random errors. Assuming independence across households, each element of u has a normal distribution with mean zero and variance (due to identification) constrained to equal one. With these details at hand, estimation difficulties (arising from the need to evaluate integrals appearing in the likelihood function) are easily overcome by following developments in Albert and Chib (1993). Specifically, by noting that, although the joint distribution of the unknown quantities z and α is intractable, the full conditional distributions comprising the posterior have well known forms. Moreover, these well-known forms are easy to sample from and, hence, a Gibbs-sampling, data-augmentation algorism can be constructed for the purpose of simulating draws from the joint posterior. A detailed description of the estimation algorism is presented in Annex I.

With the probit specification at hand, Tobit estimation can be outlined easily with respect to the matrix model in equation (3) and the algorism in (4) (Annex I). In terms of equation (3), z now contains observed and censored sales data; x contains covariates and α contains the effects of the covariates on the sales quantities. Obviously, and important for policy making, the components of x affecting the sales decision may be different from the covariates affecting the participation decision, and the magnitudes of the effects of α in each case will, in general, also differ.

In the censored regression framework the econometrician observes x and, for $i = 1, 2, \ldots, N$, the maximum of zero or y_i. This model is investigated in detail in Chib (1992). As noted by Chib (1992), censoring implies complications for both maximum-likelihood and traditional Bayesian approaches to estimation. However, when the observed data y are augmented by the latent data z, the estimation task is simplified because no censoring is involved in the latter formulation. The latent quantities appearing in z are the distance measures appearing in Figure 1 as δ. As such, they are important for deriving estimates of the extent to which the households are deficient in sales quantities and, as such, provide important measures for policy formation. However, our main interest presently is the impact that these latent values have on the estimation problem. Developments in Chib (1992) show that these quantities considerably simplify estimation. In fact, the algorism for Tobit estimation of the supply decision has a very similar structure to the algorism for probit estimation of the participation decision, as described in Annex I. In fact, only two changes are required in the notation applied in (4). In step 2, the draws for the latent components of the vector z, namely z_i for each $i \in c \in \{i \mid y_i = 0\}$, are constrained to be negative. The second modification permits estimation of the nuisance parameter σ, which arises due to the fact that, unlike the error variance in the probit model, no such restriction is required in the context of Tobit estimation. A detailed description of the estimation algorism for the Tobit model is presented in Annex I.

Finally, with the probit and Tobit algorisms at hand, it seems natural to discuss a third specification which relies on the idea that the participation and sales decisions, although they may depend on different covariates, are intimately related. In particular, it is natural to presuppose that errors in the two latent specifications (equations (1) and (2)) will be correlated. Where these correlations may be important it seems natural, albeit prudent, to take account of this potentially important feature of the decision-making process. Hence, we now consider the construction of a model in which errors about participation are linked to errors in supply of the livestock products. This issue can now be handled almost trivially in terms of the matrix equations (4) and the algorism in (5) described in Annex I, and with the aid of a little additional notation. Now, let $z \equiv (z_p, z_t)'$, $z_p \equiv (z_{p1}, z_{p2}, \ldots, z_{pN})'$, $z_t \equiv (z_{t1}, z_{t2}, \ldots, z_{tN})'$ denote an $N \times 2$ matrix of observations on the dependent variables in the probit and Tobit models (equations (1) and (2)). In addition, in (3), assume that the same set of covariates are used across both equations but permit the impacts to be different so that $\alpha \equiv (\alpha_p', \alpha_t)'$, $\alpha_p \equiv (\alpha_{p1}, \alpha_{p2}, \ldots, \alpha_{pk})'$, $\alpha_t \equiv (\alpha_{t1}, \alpha_{t2}, \ldots, \alpha_{tk})'$ denotes a $k \times 2$ matrix of effects and the corresponding $N \times 2$ error matrix $u \equiv (u_p, u_t)$, $u_p \equiv (u_{p1}, u_{p2}, \ldots, u_{pN})'$, $u_t \equiv (u_{t1}, u_{t2}, \ldots, u_{tN})'$ is assumed to have a multivariate normal distribution with mean the 2N null vector 0_{2N} and covariance $\Sigma \otimes I_N$. The parameters of the 2×2 covariance matrix Σ are important because they are these parameters that indicate the extent to which the participation and sales decisions will be correlated.

Finally, to complete the outline of the estimation, it remains to determine the form of the joint posterior for the parameters α (a $k \times 2$ matrix of unknown quantities) and the unknown or latent components of the dependent data matrix z (which has dimensions $N \times 2$). As above, the joint distribution is complicated, but its component conditional distributions have the same well-known forms that appear in the single-equation specifications. Relegating the full definitions until later, the fully conditional distributions for the latent components of the first column in matrix z are normal with mean Ez_p and variance Vz_p dependent on α and with truncation corresponding to the observed participation data (binary, zero or one). The latent components of the second column in matrix z are normally distributed $N(Ez_t, Vz_t)$ truncated to the negative quadrant. The parameter matrix α has a multivariate-normal distribution $N(E\alpha, V\alpha)$ and the variance–covariance matrix Σ has an inverse-Wishart distribution $iW(W, v)$

(Zellner 1971, pp. 395–396). These distributions depend, in turn, on the parameters, $Ez_p \equiv x\,\alpha_p + \Sigma_{pt}\,\Sigma_{tt}^{-1}\,(z_t - x\,\alpha_t)$, $Vz_p \equiv \Sigma_{pp} - \Sigma_{pt}\,\Sigma_{tt}^{-1}\Sigma_{tp}$; $Ez_t \equiv x\,\alpha_t + \Sigma_{tp}\,\Sigma_{pp}^{-1}\,(z_p - x\,\alpha_p)$, $Vz_t \equiv \Sigma_{tt} - \Sigma_{tp}\,\Sigma_{pp}^{-1}\Sigma_{pt}$; $E\alpha \equiv (x'x)^{-1}z$, $V\alpha \equiv \Sigma \otimes (x'x)^{-1}$; $W \equiv (z - x\alpha)'(z - x\alpha)$, $v \equiv N - k + m + 1$; and the 2×2 matrix Σ has (scalar) components Σ_{pp}, Σ_{pt}, Σ_{tp} and Σ_{tt}. Consequently, simulations from the joint posterior can be undertaken by applying the algorism described in Annex I.

4 Application

The model and estimation algorisms, obtained from a household survey that was conducted in Don Montano, the study site of the Crop-Animal Systems Research Project (CASREN), were applied to data from a crop-livestock producing village in The Philippines.[1] The CASREN project is aimed at generating technology and policy options to increase the productivity and economic viability of smallholder crop-animal systems in rainfed areas. The study of policy options has focused on identifying ways to improve the market participation of smallholder livestock producers in the area.

Don Montano is one of 58 Barangays[2] in the Municipality of Umingan in the province of Pangasinan, within the northern Luzon island of The Philippine archipelago. It used to be a wide tract of land owned by a Spanish Haciendero,[3] named Don Montano Castillo, who donated part of his land to the municipality to become what is presently the Barangay named after him. Don Montano is characterised by farmlands situated at the foot of the partly denuded Caraballo Mountain. It has a total land area of 297 ha, two-thirds of which is rainfed lowland. It has a Type I climate with distinct wet and dry seasons (wet from May to October, and dry from November to April) and sandy loam soil. There are 329 households in Don Montano consisting of a total population of 1738 persons, or an average household size of 5–6 members. Ninety per cent of the residents are farmers with an average land holding of 1.5 ha. The major crops grown in the area are rice, corn, onion, peanut, mungbean and vegetables. The animal species that are commonly raised by smallholder farmers include beef cattle, buffalo, goat, pig and poultry.

Structured questionnaires were designed to collect primary data from a sample of smallholder livestock producers and non-producers. These include both combined and separate questionnaires for producers and non-producers, a questionnaire on technology adoption, and a survey form recording daily food consumption during a one-week period.[4] A total of 110 households (consisting of 75 smallholder/backyard livestock producers and 35 non-producers) were interviewed by a team of hired enumerators from Central Luzon State University under the supervision of International Livestock Research Institute (ILRI) staff. The respondents were randomly picked from a list of households that was generated from a census to determine the sample population. The complete interview was executed in two rounds. This allowed the collection of information for two time periods. The first round took place in April–May 2001, covering information about livestock production and sales activities for the year 2000 and the second round took place in August 2001, covering information about the same items for the first six months of year 2001. The survey primarily aimed at generating information on general house-

1. This study is one component of the project that is being funded by the Asian Development Bank under a Regional Technical Assisstance (RETA) grant.
2. A Barangay is the smallest political unit in The Philppines.
3. A Spanish term for a rich-landed farmer.
4. The survey forms on consumption and technology adoption were administered during the second round of data collection.

hold characteristics, production, consumption, sales, transactions costs, credit, technology adoption and perceptions about livestock production.

Table 1 shows the descriptive statistics of variables that characterised the sample households in the study site. It is shown that livestock producers are slightly older, more educated, have access to more family labour, have higher household income, have more assets (including residential buildings, vehicles, farm equipment, furniture, household appliances), and have larger farm size than non-producers. Livestock producers are also predominantly farmers producing rice and onion. Both livestock producers and non-producers obtain at least half of their household income from non-farm sources, with non-producers having a larger share than livestock producers. Among livestock producers, slightly less than half sold livestock in 2000, and slightly less than one-fourth did during the first half of 2001.

Table 1. *Characteristics of livestock producers and non-producers in Barangay Don Montano, Umingan, Pangasinan, The Philippines.*

Characteristic	Livestock producers (N = 75)	Non-producers (N = 35)
Age		
Household head	47 (13.9)	45 (17.2)
Spouse	43 (13.1)	38 (13.7)
Educational attainment		
Household head	9 (3.0)	8 (3.0)
Spouse	9 (2.5)	10 (3.3)
Gender (household head, %)		
Male	71 (95)	30 (86)
Female	4 (5)	5 (14)
Household members	5 (1.73)	4 (2.09)
Available family (aged between 15-69 years old)	2.97 (1.38)	2.66 (1.33)
Main occupation (%)		
Farmer	80	26
Farm labourer	4	30
Housekeeper	3	9
Government employee	5	3
Private employee	8	20
Overseas worker	0	6
None	0	6
Household income (peso)* percent from:	55,094 (54,628)	60,903 (91,104)
Crop production	29	3
Sale of livestock	6	0
Farm labour	3	4
Non-farm	53	76
Remittances	9	17
Household assets (peso)	33,109 (69,711)	26,874 (53,568)
Farm size (ha)	0.99 (0.88)	0.63 (0.32)
Cropping proportions (frequency)		
Rice	62	12
Onion	39	5
Corn	4	-
Sweet potato	1	-
No. of producers with livestock sales (frequency)		
For 2000 (January to December)	35	
For 2001 (January to June)	17	

* US$ 1 = Pesos 50.
Numbers in parentheses are standard errors.
Data are from the survey enacted for the project 'Policy options for improving the market participation of smallholder livestock producers', April–May 2001.

5 Results

Table 2 shows the descriptive statistics of the explanatory variables in the regression models. Table 3 reports results of the three Gibbs-sampling, data augmentation algorisms applied to the participation and sales data. The first column of Table 3 reports definitions of the covariates used in the various regression models and the second to fifth columns report, respectively, results from the single-equation probit model, results from the single-equation Tobit specification; and results from the two-equations probit and results from the two-equations Tobit specification. The dependent variable in the Tobit equations is livestock sales revenues in Philippine pesos. Livestock sales refer to sales of live animals only. The covariates are ordered in blocks corresponding, respectively, to the categories transactions costs, mobility, intellectual capital, financial capital, physical capital, credit and other excluded covariates. The focus on these groups is motivated as follows.

Table 2. *Descriptive statistics of the explanatory variables used in the model.*

Variable	Mean	Standard deviation
Transaction costs		
Distance	2.44	0.70
Members	2.87	1.37
Mobility		
Otheremp	7.57	11.35
Intellectual capital		
Education	17.03	6.00
Farmex	13.15	16.12
Otherex	7.75	5.91
Extension	0.24	0.54
Financial capital		
Otherinc	20,750	33,713
Remitinc	2261	13,058
Memberinc	48,224	41,281
Cropinc	5713	12,279
Physical capital		
Cattle	2.64	1.85
Buffalo	1.57	0.74
Goat	2.86	2.03
Pig	3.00	2.69
Chicken	17.80	17.73
Debt		
Credit	6622	8473

Table 3. *Estimation of market participation and sales of livestock in Don Montano, Umingan, Pangasinan, The Philippines.*

	Model			
	Single-equation formulations		Two-equations formulations	
	Probit	Tobit	Probit	Tobit
Transactions costs				
Distance	-0.07	-1773.65	-0.09	-1655.70
	(-0.40)	(-0.78)	(-0.52)	(-1.04)
Members	-0.39	-3102.93	-0.44	-2262.50
	(-2.76)	(-1.95)	(-2.97)	(-2.00)
Mobility				
Otheremp	-0.02	-116.69	-0.02	-78.59
	(-1.11)	(-0.63)	(-1.22)	(-0.59)
Intellectual capital				
Education	-0.08	-493.45	-0.09	-290.49
	(-2.35)	(-1.24)	(-2.58)	(-1.03)
Farmex	0.00	81.45	0.00	81.13
	(0.03)	(0.62)	(-0.02)	(0.82)
Otherex	-0.15	-1900.16	-0.13	-1503.83
	(-0.94)	(-0.99)	(-0.92)	(-1.04)
Extension	0.54	4447.76	0.56	3363.55
	(2.06)	(1.38)	(1.93)	(1.49)
Financial capital				
Otherinc	0.97	0.12	1.06	0.09
	(1.79)	(1.78)	(1.80)	(1.95)
Remitinc	1.25	0.14	1.42	0.11
	(1.99)	(2.03)	(2.14)	(2.29)
Memberinc	0.86	0.09	0.93	0.07
	(1.83)	(1.63)	(1.81)	(1.81)
Cropinc	-1.59	-0.17	-1.71	-0.14
	(-1.85)	(-1.68)	(-1.97)	(-1.87)
Physical capital				
Cattle	0.40	4610.76	0.44	3727.98
	(5.23)	(4.78)	(5.27)	(5.22)
Buffalo	0.42	4500.57	0.49	3461.19
	(2.55)	(2.17)	(2.67)	(2.22)
Goat	-0.09	-276.78	-0.08	-183.13
	(-1.01)	(-0.29)	(-0.82)	(-0.28)
Pig	0.53	4381.77	0.56	3521.94
	(3.77)	(3.93)	(3.87)	(4.35)
Chicken	0.05	438.21	0.05	341.60
	(4.70)	(3.98)	(4.76)	(4.37)
Debt				

(cont...)

Table 3. cont

	Model			
	Single-equation formulations		Two-equations formulations	
	Probit	Tobit	Probit	Tobit
Credit	-2.69	-0.24	-3.12	-0.16
	(-1.11)	(-0.83)	(-1.14)	(-0.71)
Other excluded				
Constant	-0.28	-11,891.84	-0.17	-10,031.83
	(-0.34)	(-1.16)	(-0.21)	(-1.37)
	Covariance			
Participation	1.00	13,427.01	1.00	4249.24
		(6.80)		(4.54)
Sales			(symmetric)	89,981,399.69
				(2.29)
	Auxiliary statistics			
	Participants			
Positive predictions	30	20	30	26
Negative predictions	22	32	22	26
	Non-participants			
Positive predictions	16	6	16	10
Negative predictions	150	160	150	156

Implied t statistics are reported in parentheses.

First, we consider that transactions costs are likely to play a major role impeding entry by subsistence households into emerging markets. The problems of ensuring adequate demand, locating and negotiating a sale and transporting goods to market are anticipated to feature prominently in the household decision-making process. For these reasons and in the absence of precise information concerning the likely ranges of these costs, we use two proxies—return-time distance to market 'distance' and household labour availability or number of household members 'members'—as principal determinants of these costs. We assume that transactions costs increase with greater distance to market but may be reduced with increased labour abundance and the lower opportunity costs that this may imply. Consequently, for both participation and selling decisions we presume that the impacts of these two covariates are, respectively, negative and positive.

Second, because the transition to the new occupation in local markets requires freeing-up other resources, we desire some measure of the extent to which households in question may be more or less mobile than others. This degree is represented by the variable 'otheremp' which, in turn, measures the number of years that the household head devoted to non-farm employment activities in his/her current and previous occupations. In the absence of more precise information concerning previous employment prospects and the household's propensity to change occupations in response to these incentives, we use the covariate 'otheremp' as a proxy for mobility. The larger the value of 'otheremp', the more likely the household is to participate in markets. We do not have strong a priori expectations about the effect of 'otheremp' on sales.

Third, we assume that the level of intellectual capital stock in the household is positively related to the participation decision. However, this stock level may be related in a contradictory fashion when other employment activities are available, particularly when those employment opportunities require skill. In this way, a greater degree of intellectual capital—measured in terms of the number of years of formal schooling by both the household head and the spouse 'education', the number of years of farming experience 'farmex', farm experience by other household members 'otherex' and exposure to extension agents last year ('extension' = 1 if the household had contact with an extension agent, = 0 otherwise) may each exert a positive impact on the participation and selling decisions; although the precise impact of the non-farm specialist covariates ('education' in particular) are complicated by their opportunity costs in alternative enterprises. For this reason, unlike the farm-specific variables 'experience' and 'extension', we do not have strong prior beliefs about the likely sign of the coefficient of 'education'.

Fourth, we include measures of income[5] derived from both farm and non-farm sources. The definitions of the variables are, respectively, income (in 100 thousand pesos (US$ 1 = Pesos 50) from sources other than farming 'otherinc', income from remittances 'remitinc', income from other household members 'memberinc' and income from crops 'cropinc'. Where the income relates to livestock enterprises we consider that this has a positive impact on participation and selling, but where the income relates to other farm activities and to other non-farm activities we consider that the impact will be negative. In the case of income earned by other household members, we assume that this diversification may lead to risk reduction in household decision-making and, with it, a likely increased propensity to undertake higher-risk activities, notably selling livestock. While this phenomenon may also explain a likelihood that returns from crop income may be positive, this sign is compounded by the fact that increased revenues from crop production may signal incentives to re-allocate away from livestock production and selling activities.

A more distinct, less diffuse set of prior beliefs are maintained with respect to the physical capital variables representing numbers of relevant livestock on the farm—cattle, buffalo, goat, chicken and pig. Each is expected to exert a positive impact on both the likelihood that participation will occur and the amount of selling that will be undertaken once the decision to participate has been made.

In the remaining category of debt, we expect the covariate 'credit' (representing the amount of indebtedness in 100 thousand pesos) to have ambiguous impacts on the participation and selling decisions. This is because debt can be interpreted in two ways. The first way pertains to the fact that increased debt in other activities may lead to lack of free collateral to secure loans for market selling activities. In this case, the sign of the coefficient of 'credit' is expected to be negative. In the second case, existing debt may be

5. A Hausman test was performed to test for endogeneity across the four income variables, namely, otherinc, remitinc, memberinc and cropinc. The test results indicated that these are endogenous with respect to the variables age of the household head, age of the spouse, value of assets, farm size, other livestock numbers, and gender of the household head (Chi-squared = 4.1459, 4 d.f.). However, these covariates are not included in the set of covariates used in the estimation of the model. Hence, the issue of endogeneity need not be a concern in this case.

the result of previous borrowing that has occurred for the production and selling decisions and may, therefore signal greater propensity to sell. In this case, we expect the coefficient of 'credit' to be positive.

Finally, we have no reason to expect the impacts of other excluded factors 'constant' to be positive or negative.

Regarding the results reported in Table 3, three observations are apparent and important. First, with the exceptions of a few covariates, the participation and selling decisions are mostly affected by the same factors. Second, responses across the single-equation probit and Tobit specifications are slightly improved by moving to the multivariate specification in the sense that most of the marginal significance levels of each of the covariates is increased. Third, there is very strong evidence that the errors in the two equations are positively correlated. This observation is important because it suggests that it is most appropriate to consider the participation and selling decisions simultaneously. Hence, policy recommendations concerning market access, provision of infrastructure and estimates of minimum resource levels required to effect entry should be based on the two-equation formulation.

Regarding the impacts of the various covariates on participation, number of household members 'members', education levels of the head and spouse 'education', visits by extension agent 'extension', and the livestock assets—cattle, buffalo, pigs and chicken—are each highly significant. Each of the coefficient estimates of these factors has marginal significance levels in excess of 5% (that is, the 95% Bayesian highest posterior density regions corresponding to these coefficients do not contain zero). Propensity to participate declines with number of household members, education, and income from cropping, but increases with respect to increases in each of the other covariates. Distance to market 'distance', mobility 'otheremp', experience in farming by the household head, and other family members 'farmex' and 'otherex', respectively, indebtedness 'credit', and goat livestock numbers 'goat' are not significant determinants of participation. There is marginal significance of some of the income variables. Income from other sources 'otherinc', income from remittances 'remitinc' and income from other household members 'memberinc' have a positive influence on the participation decision, whereas increased crop revenues 'cropinc' lowers the likelihood of livestock-market participation. These results conform to prior expectations that income diversity lowers risk and, with it, the likelihood that (potentially risky) market development will occur, and that improved alternative production and marketing opportunities in other farm enterprises such as cropping may weaken participation incentives. However, perhaps the most interesting result is the strong negative impact that education exerts on the participation decision. When alternative employment opportunities exist, an increase in skills that resulted by increased education lowers the likelihood that market participation arises.

This last observation is confirmed somewhat by examining the impacts of education on sales in the single-equation Tobit regression (column three of Table 3). The effect of increased education on sales is insignificant, suggesting that the influence of education is more important in market entry than in market supply. Among the remaining covariates, all have the same signs of effects as those in the probit equation. However, the marginal significance levels are significantly lower than in the probit specification.

This difference is most dramatic with respect to the extension covariate. Whereas in the probit equation this covariate was highly significant; in the Tobit equation it is not. Hence, extension activities appear to play an important role, but only in the set-up of market operations. Finally, most of the remaining covariates share significant levels that are similar to those in the probit model and, once again, indebtedness, farm experience and mobility do not appear to be significant factors explaining supply decisions.

The estimates pertaining to the two-equation model (columns four and five of Table 3) confirm two conjectures. The first conjecture is that the participation and sales decisions are strongly positively correlated. This fact is supported by the cross-equation error covariance reported in the lower part of Table 2. The implied t-statistic (4.54) corresponding to the covariance estimate (4249.24) suggests that the covariance is not close to zero. In other words, the probit and Tobit equations estimates are not independent. The second conjecture is that the inclusion of covariance information in the two-equation system significantly affects inferences about the participation and supply decisions; in this case, making considerably more precise derived statistical inferences.

6 Conclusion

There is a strong potential for growth in livestock production and consumption, particularly in developing countries, as indicated by recent global trends in the livestock sector (Delgado et al. 1999). The critical policy question is whether smallholders are able to participate and compete in the domestic and global markets. This study has examined the competing effects of transaction costs, labour mobility, (intellectual, financial and physical), and capital formation and indebtedness on smallholders' market participation and selling decisions. The important role of policy in providing an enabling environment for improving the productivity of smallholder livestock production systems is suggested by the strong effect of animal numbers in the participation and selling decisions of farmers. Technology and policy options that will enhance incentives to increase production will have a large, though indirect, impact on motivating market participation. Social prescriptions that increase education will, however, divert smallholder attentions elsewhere and this finding appears to be in marked contrast to other studies (e.g. Holloway et al. 2000) that find a strong participatory impact from education. Whether this difference stems from externalities arising from differences in off-farm employment opportunities; differences in risks associated with different commodities; or, perhaps, climatic variability, remains an open research question. In addition, potentially important insights for policy appear possible in comparison of results at different locations. For example, such comparisons may uncover additional factors explaining differences in results attributable to infrastructure, especially the quality of roads, communication and transport systems. Presently we find that 'distance' (the return time to transport goods to market) is neither a significant determinant of participation nor sales. However, the companion transactions-costs proxy 'members' (the total number of members of the household) appears to significantly affect both the participation and sales decisions. Thus, we suggest that this impact may be due to increased responsibilities for risk bearing which greater household numbers engender.

The availability of alternative occupation opportunities affects significantly the potency of social and economic prescriptions, and policymakers need to be mindful of these results when targeting objectives for smallholders. In addition, the emergence of capital stock variables, especially remittances, as a positive influence on market participation, suggests the importance of financial security in enabling smallholders to cope with risks as well as meet their subsistence requirements. This also points to the more important and general issue of farmers' capacities to bear risks as a critical determinant of market entry, and how this can be addressed through appropriate policy interventions that can facilitate risk-bearing. Improving farm-specific skills through visits by extension agents' appears important in precipitating entry, but not supply. Here, animal productivity-improving technologies appear to be, perhaps, the most lucrative of all policies.

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Annex I. Description of Gibbs-sampling data-augmentation algorism used in the estimation of the models

Estimation of the probit model

More formally, with the usual, non-informative prior over the unknown quantities, $\pi(z, \alpha) \propto$ constant, the full conditional distributions of the two vector blocks z and α are easily established. Respectively, the conditional distribution of z given α is normal with mean the prediction vector $Ez \equiv x\alpha$ and covariance the $N \times N$ identity matrix $Vz \equiv I_N$. The conditional distribution of α given z is also normal, but with mean the k-vector $E\alpha \equiv (x'x)^{-1}x'z$ and covariance $V\alpha \equiv (x'x)^{-1}$. Accordingly, a Gibbs-sampling, data-augmentation algorism can be constructed to simulate draws from the joint posterior distribution $\pi(z, \alpha \mid y)$. There are five sequential steps:

Step 1: Select starting values $\alpha^{(s)}$.
Step 2: Draw $z^{(s)}$ from the multivariate normal distribution $N(x\alpha^{(s)}, I_N)$, where $\alpha^{(s)}$ implies conditioning on $\alpha^{(s)}$ from Step 1 and the draws are made such that $z_i \geq 0$ when $y = 1$ is observed, and $z_i < 0$ otherwise.
Step 3: Draw $\alpha^{(s+1)}$ from the multivariate normal distribution $N((x'x)^{-1}x'z^{(s)}, (x'x)^{-1})$, where $z^{(s)}$ denotes conditioning on $z^{(s)}$ from step 2 (4)
Step 4: Repeat steps 1–3 many times, S^1, until convergence is attained.
Step 5: Repeat steps 1–3 many times, S^2, and collect samples $\{z^{(s)}\ s = 1, 2, ..., S\}$ and $\{\alpha^{(s)}\ s = 1, 2, ..., S\}$.

The draws in the last step can be used to compute means, standard errors or, indeed, to plot histograms of any characteristic of interest in the posterior (Gelman et al. 1995). In the reports of the empirical results that follow, the algorism is run for a burn-in phase of $S^1 = 5000$ observations followed by a collection phase of $S^2 = 5000$ and means and implied standard errors are used to infer confidence intervals. The procedures are implemented on a DELL™ LATITUDE™ laptop machine running a Pentium™ III processor at 600 megahertz with commands executed in MATLAB™ version 5.1.0.421. All computer codes are available upon request.

Estimation of the Tobit model

In comparison with the algorism in (4) above, Tobit estimation is executed through the following steps:

Step 1: Select starting values $\alpha^{(s)}$ and $z^{(s)}$.

Step 2: Draw $\sigma^{(s)}$, a scalar, from the inverse-gamma distribution ig(s^2, v) (Zellner 1971, pp. 371–373), with $s^2 \equiv (z^{(s)} - x\,\alpha^{(s)})'(z^{(s)} - x\,\alpha^{(s)})/v$, $v \equiv N - k$ and where $z^{(s)}$ and $\alpha^{(s)}$ denote conditioning on $z^{(s)}$ and $\alpha^{(s)}$ from Step 1.

Step 3: Construct $z^{(s)}$ by combining the observed, positive sales quantities with a draw for the latent quantities z_c from the normal distribution $N(x_c\alpha^{(s)}, \sigma^{(s)}I_N)$, where $\alpha^{(s)}$ and $\sigma^{(s)}$ denote conditioning on $\alpha^{(s)}$ from Step 1 and $\sigma^{(s)}$ from step 2 and the draws $z^{(s)}$ are made such that $z_i < 0$ when $y = 0$ is observed (5)

Step 4: Draw $\alpha^{(s+1)}$ from the multivariate normal distribution $N((x'x)^{-1}x'z^{(s)}, \sigma^{(s)}(x'x)^{-1})$, where $z^{(s)}$ denotes conditioning on $z^{(s)}$ from step 3 and $\sigma^{(s)}$ implies conditioning on $\sigma^{(s)}$ from step 2.

Step 5: Repeat steps 1–4 many times, S^1, until convergence is attained.

Step 6: Repeat steps 1–4 many times, S^2, and collect samples $\{z^{(s)}\ s = 1, 2, ..., S\}$ and $\{\alpha^{(s)}\ s = 1, 2, ..., S\}$.

Estimation of the probit–Tobit model

Step 1: Select starting values $\alpha^{(s)}$ and $z^{(s)}$.

Step 2: Draw $\Sigma^{(s)}$, (a 2 × 2 square, symmetric, positive definite matrix), from the inverse-gamma distribution iW(W, v) (Zellner 1971, pp. 371–373), with $W \equiv (z^{(s)} - x\,\alpha^{(s)})'(z^{(s)} - x\,\alpha^{(s)})/v$, $v \equiv N + m + k + 1$ and where $z^{(s)}$ and $\alpha^{(s)}$ denote conditioning on $z^{(s)}$ and $\alpha^{(s)}$ from Step 1.

Step 3: Construct the latent components $z^{(s)}$ by combining the observed, positive sales quantities with draws for the censored observations and draws for the latent data in the probit equation, as in steps 2 and 3 in the algorisms (4) and (5) above, respectively (6)

Step 4: Draw $\alpha^{(s+1)}$ from the multivariate normal distribution $N((x'x)^{-1}x'z^{(s)}, \sigma^{(s)}(x'x)^{-1})$, where $z^{(s)}$ denotes conditioning on $z^{(s)}$ from step 3 and $\sigma^{(s)}$ implies conditioning on $\sigma^{(s)}$ from step 2.

Step 5: Repeat steps 1–4 many times, S^1, until convergence is attained.

Step 6: Repeat steps 1–4 many times, S^2, and collect samples $\{z^{(s)}\ s = 1, 2, ..., S\}$ and $\{\alpha^{(s)}\ s = 1, 2, ..., S\}$.

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