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Keywords: Land allocation, shadow prices, non-market values, traditional crops, on-farm conservation, Mexico

JEL classification: O12, O13, Q12, Q39

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SHADOW VS. MARKET PRICES IN EXPLAINING LAND ALLOCATION: SUBSISTENCE MAIZE CULTIVATION IN RURAL MEXICO

ASLIHAN ARSLAN†

Abstract. Economic models of land allocation may lead to expectations for farmer response that "surprisingly" do not materialize, if market prices fail to reflect the value of farmers' product. "Shadow prices" rather than market prices explain resource allocation better for farmers who attach significant non-market values to their own crops. I extend the theoretical model in Arslan and Taylor (2008) to explain why the land allocation of such farmers may not respond to market signals even if transaction costs are not binding. I estimate the proportion of land subsistence maize farmers allocate to traditional versus modern maize varieties using nationally representative rural household data from Mexico – the center of diversity of maize. I conclude that shadow prices explain land allocation better than market prices and discuss the importance of non-market values in understanding both farmers' supply response and on-farm conservation of traditional crops with non-market values.

> "The central place that maize occupies in the culture of Mexico makes it less likely that traditional production methods will be drastically altered by new market forces." — CEC (1999)

The question of how farmers respond to price signals is central for understanding the effects of changing economic conditions on food supply and farmer welfare. The answer to this question becomes more important if farmers' land allocation decisions have implications for the on-farm conservation of crop genetic resources. Most research in economic literature on farmers' land

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allocation decisions focuses on determinants such as portfolio selection, safety-first behaviour or learning and uses market prices to value production (Feder, 1980; Just and Zilberman, 1983; Bellon and Taylor, 1993; Brush et al., 1992; Smale et al., 1994). If, however, market prices fail to reflect the value of farmers' product, economic models may lead to wrong expectations and "surprising" farmer response to price signals. The inelastic supply response of maize farmers in rural Mexico in spite of decreasing maize prices after NAFTA is an example (Nadal, 2000). "Shadow prices" rather than market prices explain farmers' resource allocation better if farmers attach significant non-market values to their own crops (Smale et al., 2001; Dyer Leal and Yunez Naude, 2003). This was suggested (though not explicitly accounted for) by many researchers as one of the underlying reasons for the inelastic supply response of subsistence farmers in Mexico (de Janvry et al., 1995; Dyer Leal and Yunez Naude, 2003; Berthaud and Gepts, 2004).

Mexico is the center of maize domestication and diversity with 59 different races (Dowswell et al., 1996; Turrent and Serratos-Hernandez, 2004). These races represent the largest genetic diversity of maize in the world and are valuable inputs to crop breeding research for maize – the worlds' most widely used food grain (Yunez Naude and Taylor, 2006; Berthaud and Gepts, 2004). Therefore, understanding maize farmers' supply response has implications for the on-farm conservation of this diversity. I explain why some farmers' land allocation decisions may not respond to market signals even if transaction costs (TCs) are not binding by extending the theoretical agricultural household model in Arslan and Taylor (2008). I estimate land allocation decisions between different maize types (traditional and modern) and compare the performance of market prices and shadow prices in explaining this decision using nationally representative household data from rural Mexico. I conclude that shadow prices explain the land allocation decisions of subsistence maize farmers better and discuss the importance of non-market values in understanding both supply response and on-farm conservation. The methods and the policy implications of this paper are applicable to other settings where farmers attach significant non-market values to their crops.

I provide some background on the non-market values modeled in Arslan and Taylor (2008) in the next section. I extend their theoretical model to emphasize the tradeoff between allocating land to the subsistence or the cash crop in section 2. In section 3, I estimate the proportion of maize area allocated to traditional maize varieties using different prices (shadow vs. market) and compare their performance in explaining this allocation. I conclude in section 4 and provide policy implications.

1. Non-market values and land allocation

Farmers' land allocation decisions have long been a subject of economics. Especially those related to high yielding crop varieties have been studied in detail by the technology adoption literature following the Green Revolution (Feder, 1980; Just and Zilberman, 1983; Bellon and Taylor, 1993; Brush et al., 1992; Smale et al., 1994). These studies use market prices to value farmers' output as a determinant of land allocation decision, along with socio-economic and agro-ecological variables. Smale et al. (1994) show that farmers' land allocation to high yielding and traditional crop varieties have multiple explanations such as input fixity, safety first behaviour, learning and portfolio selection. They also value farmers' maize output at market prices in their empirical analysis of maize cultivation in Malawi. While using market prices may not be problematic for some cases, more attention should be paid to shadow prices where farmers attach non-market values to their crops. If some farmers make land allocation decisions based on shadow prices that are different from market prices, we may underestimate (overestimate) the land such farmers will allocate to the crop with high shadow prices (modern crops).

While most research in the agricultural household literature uses market prices to value agricultural output, both de Janvry et al. (1991) and Taylor and Adelman (2003) analyze farmer decisions under missing product markets and represent the value of the "constrained" food crop with a shadow price. The constraint in their context is a transaction cost (TC) band that prevents farmers from participating in markets both as a buyer and a seller. One shortcoming of TC based household models is that they cannot account for non-market benefits farmers may derive from producing their own crops, because they assume that market crops are perfect substitutes for the domestic crop in consumption.[1] If the market crop and the domestic crop are perfect substitutes, farmers would not produce a crop at a higher opportunity cost than the market price (controlling for risk and transaction costs). However, if the domestic crop has non-market values that make the "same" crop purchased in the market an imperfect substitute, then some farmers will produce it at high cost even if there is a local market with small or no TCs.[2]

The non-market values of producing and consuming one's own crop may be significant if the crop has cultural or religious connotations (Altieri, 2004). Traditional crops in their centers of domestication (such as maize in Mexico, potatoes in Peruvian highlands, rice in Philippines or wheat in Turkey) have long histories of evolution that are intertwined with the culture of the peoples who grow them.[3] In some cases these crops are used in weddings, funerals and rituals in which purchased crop simply will not do, and are important in determining the farmer's place in the community as a good farmer (Fussell, 1992). Akerlof and Kranton (2000) model "identity" (or the sense of self) as a way to incorporate non-pecuniary motivations into economic behaviour. If a farmer's "identity" depends on the cultivation of such a crop, the market purchased crop cannot provide the same utility as the domestic crop. In this case, the market crop lacks the non-market values and is a poor substitute for the domestic crop in consumption. Consequently, market prices may not reflect the full value of these crops for the farmer. Although I do not model "identity" explicitly as do Akerlof and Kranton (2000), their study provides an intuitive way of thinking about

[1]Throughout this paper I use "domestic crop" to refer to the crop produced by the household.

[2]Besides the prevalence of subsistence farming in spite of lively local markets in developing countries, the imperfect substitutability in consumption can also explain the rationale behind backyard gardening in developed countries. If the non-market value of growing and consuming one's own crop was not important, we would not expect a rational person to grow tomatoes in her backyard for multiple times the cost of buying them in the market.

[3]The term "traditional crop" refers to a landrace, which is a crop cultivar that evolved with and has been genetically improved by traditional agriculturalists, but not by modern breeding practices. All components of landraces are adopted to local climate conditions, cultural practices, diseases and pests (Hoisington et al., 1999; Jarvis et al., 2000).

why some subsistence farmers may produce crops at cash losses when they can buy them in the market.

It is not rare to find that small-scale maize farmers in Mexico incur cash losses when their maize production is valued at the price of maize commercially available in local markets (and not necessarily the same variety) (Smale et al., 2001; Dyer Leal and Yunez Naude, 2003; Brush and Chauvet, 2004). This finding does not reflect the "irrationality" of farmers. On the contrary, it likely reflects the existence of non-market benefits that farmers get from cultivating and consuming their own maize (Dyer Leal et al., 2002). When one takes these non-market values into account, the cash losses may lose significance. It has been argued in the literature that farming in general is a way of life with non-pecuniary benefits (Vincent, 1976; Botterill, 2001). Even in developed countries farmers do not just switch in and out of farming based on monetary incentives because of the "psychic income" they get from farming. Moreover, when the cultural values mentioned above are attached to farming, we can expect that monetary incentives will not be enough to fully explain farmer behaviour.

Dyer Leal (2006) emphasizes the importance of "shadow values" (rather than market prices) in understanding the responses of subsistence maize producers to economic changes in Mexico. Arslan and Taylor (2008) are the first ones to explicitly model and estimate shadow prices by conceptualizing the non-market values with an asymmetric market constraint for the subsistence crop. This constraint is such that the farmer can sell this crop but cannot buy an identical crop in the market. The resulting market is similar in spirit to the "partly absent market" in Strauss (1986), where the separability of the agricultural household model breaks down due commodity heterogeneity. Arslan and Taylor (2008) theoretically analyze how non-market values may lead to shadow prices that are higher than market prices and empirically show that estimated shadow prices of traditional maize are significantly higher than market prices for subsistence farmers. Their empirical analysis also shows that the same is not true for modern maize and the sellers of traditional maize, supporting the non-market values as an underlying determinant of subsistence farmers' decisions.

The theoretical model in Arslan and Taylor (2008) models farmer's resource allocation to the subsistence crop holding the land area constant. I extend their model in the next section by including the decision to allocate the land between a subsistence and a cash crop to discuss the effects of shadow prices on this decision.

2. Theoretical Model

Suppose that a farmer produces a cash crop in addition to a subsistence crop using labor and a fixed amount of land (A). The markets for the cash crop and labor are perfect, hence the farmer can buy and sell these at market prices. The farmer divides his land between the subsistence crop and the cash crop. He also decides how to allocate labor across different crops and activities to maximize his utility.

Let Q_i denote the quantity produced of crop i, where $i = s,\ c$ identifying the subsistence and the cash crop, respectively. X_m and X_l are, respectively, the amount of market goods and leisure consumed. He also consumes part or all of his subsistence crop denoted by X_s^h, where the superscript h indicates that the only source of consumption of X_s is home production. Under the assumption of a perfect labor market, the farmer can hire out his own labor and hire in as much labor as he likes at the market wage, w. Output is certain and the farmer's decisions are: what proportion of land to cultivate with the subsistence crop (θ); how much labor to allocate to the production of each crop and to off-farm work; how much of his subsistence crop to sell (X_s^s); and how much to consume of all goods. The farmer's problem is given by:

$$\max U(X_s^h, X_m, X_l; Z)$$

subject to full income, production, and nonnegativity constraints;

$$p_m X_m + w X_l \leq p_s X_s^s + p_c Q_c - w(L_s + L_c) + W \tag{1}$$

$$Q_s = g(L_s, A\theta) \tag{2}$$

$$Q_c = h(L_c, A(1-\theta)) \tag{3}$$

$$X_s^h + X_s^s \leq Q_s \tag{4}$$

$$X_s^s, X_s^h, X_m, L_s, L_c \geq 0. \tag{5}$$

Where θ satisfies $0 \leq \theta \leq 1$; p_j denotes the market prices of consumption goods and the cash crop identified with subscripts $j = s, m, c$; L_i denotes the amount of labor used to produce the crop i, and W denotes exogenous transfers. *U(.)* is a continuously differentiable and strictly quasi-concave utility function and *g(.)* and *h(.)* are, respectively, quasi-convex production functions for the subsistence and cash crops.

The Lagrangean of this problem is:

$$\max_{X_l, X_m, X_s^h, X_s^s, \theta, L_i, \lambda, \mu_n} \mathscr{L} = U(X_s^h, X_m, X_l; Z)$$

$$+\lambda[p_s X_s^s + p_c h(L_c, A(1-\theta)) + W + w(\bar{T} - L_s - L_c - X_l) - p_m X_m]$$

$$+\mu_1[g(L_s, A\theta) - X_s^s - X_s^h] + \mu_2 X_s^s + \mu_3 X_s^h + \mu_4 X_m + \mu_5 \theta + \mu_6(1-\theta) + \mu_7 L_s + \mu_8 L_c$$

$$i = s, c$$

$$n = 1, ..., 8$$

As shown in Arslan and Taylor (2008), the shadow price of the subsistence crop can be expressed as:

$$\rho \equiv \frac{\mu_1}{\lambda} = \frac{w}{MPL_s}, \tag{6}$$

and estimated using the marginal product of labor in subsistence crop production. The shadow price is higher than the market price for farmers constrained by the asymmetric market constraint (i.e., do not sell any subsistence crop) (Arslan and Taylor, 2008). The optimality condition for land allocation is different from the standard optimality conditions for these farmers. The first order condition for θ is:

$$p_c MPA_c = \frac{\mu_1}{\lambda} MPA_s, \text{when } \theta > 0. \tag{7}$$

The farmer sets the value of marginal product of land (*VMPA*) cultivated with the cash crop equal to the "shadow value of marginal product" of land cultivated with the subsistence crop.

Figure 1 shows the land allocation conditions between the cash crop and the subsistence crop.[4] Under perfect markets – in which the market prices reflect the true value of crops to farmers – the farmer sets the value of marginal product of land equal to each other for all crops, which corresponds to the point θ^* in Figure 1. However, if the farmer's decision price, i.e. shadow price (ρ), is different from the market price, the observed land allocation will be different from what would be observed under the perfect markets scenario. He will allocate more land to the subsistence crop (point θ^0 in Figure 1), which satisfies the equation 7. These farmers will not respond to changes in the market price of subsistence crop as expected, unless the price change is big enough to offset the difference between the two value measures.

Farmers who are trapped in a TC band as defined in de Janvry et al. (1991) will exhibit a similar sluggish response to price signals. However, in their model, farmers would be indifferent between producing the cash crop and the subsistence crop as long as the TC are not binding. The current model and the empirical application in the next section provide an explanation for why land allocation may not respond to price signals even in the absence of TCs by accounting for non-market values. In the next section, I econometrically analyze subsistence maize farmers'

[4] Total land cultivated is set to unity for simplification.

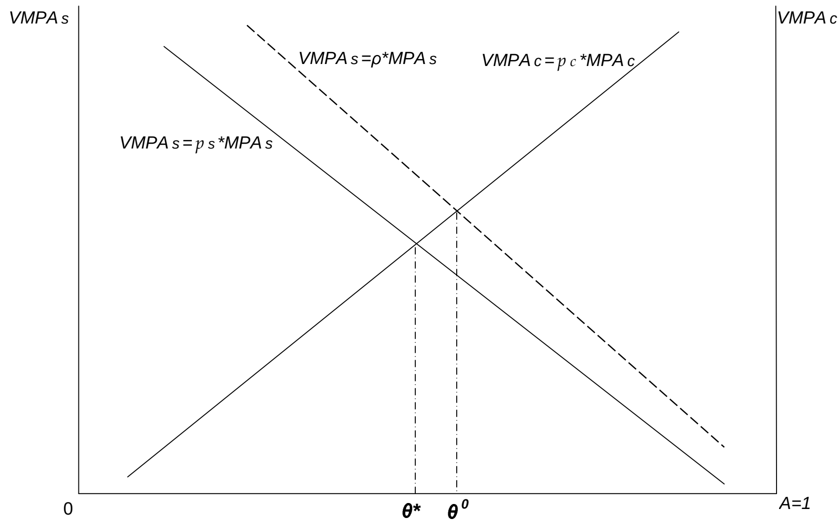

Figure 1. Optimal land allocation using market prices vs. shadow prices. θ^* is the proportion of land that would be allocated to the subsistence crop using the market prices (p_s and p_c) and θ^0 is the proportion of land that is allocated to the subsistence crop using the shadow price (ρ) of the subsistence crop. The distance between the value of marginal product line and the shadow value of marginal product line is decreasing with θ to reflect the decreasing marginal utility from the consumption of subsistence crop valued at ρ.

land allocation decisions using both market and shadow prices to test the empirical validity of the hypothesis that shadow prices explain these decisions better than market prices.

3. Do shadow prices explain land allocation better?

I use agricultural household data from the Mexican National Rural Household Survey (ENHRUM) that was collected in January-February 2003. The sample covers 1782 households in 16 villages of each of the 5 geographic regions in Mexico and was designed by the National Institute of Statistics, Geography and Informatics (INEGI) to be nationally representative of rural Mexico. The survey data include household demographics; plot level information on inputs and output of all crops; marketing and consumption of agricultural and livestock products; and maize seed varieties and their origins. They also include information about migration and work histories, off-farm income sources, credit market participation and household assets.[5]

[5]See `http://precesam.colmex.mx` for detailed information about the ENHRUM data, and Arslan (2007) for more descriptive statistics.

Arslan and Taylor (2008) show that the shadow prices of traditional maize varieties (TVs) are significantly higher than market prices for subsistence maize farmers in the ENHRUM data. The same is not true for modern maize varieties (MV) and the sellers of traditional maize, therefore market prices can be used to reflect the value of maize for these farmers. Understanding the land allocation decisions of subsistence farmers of TVs, however, calls for an understanding of farmers' shadow prices as well as other variables that affect land allocation. Based on these results the TVs and MVs correspond, respectively, to the subsistence and the cash crop modeled in the theoretical model above.

The classification of maize into different groups is based on farmers' response to the question of whether the seed they used was "criollo" (TV) or "híbrido" (MV) as in Arslan and Taylor (2008). Given their conclusion that shadow prices are significantly different from market prices only for subsistence farmers of TVs, I use the subsample of ENHRUM data that only includes these farmers. Out of 280 farmers in this subsample around 75% are in the South-Southeast and Central Regions. Table 1 shows the proportion of land allocated to TVs, the shadow prices estimated by Arslan and Taylor (2008) and market prices. The proportion of land farmers allocate to TVs is largest in the South-Southeast and the Central regions. These two regions and the Western Central Region are also the ones where the estimated shadow prices are the highest. Given these shadow prices, market prices can not explain subsistence farmers' land allocation to TVs, because they underestimate the subjective value of TVs for these farmers. I test this hypothesis by econometrically estimating the proportion of land subsistence farmers allocate to TVs using both market prices and shadow prices.[6]

Two econometric issues arise when doing this analysis: First, shadow prices are not observed, but estimated with error. This introduces an additional source of variance to the standard errors of the area share regressions, which will bias the results if not taken into account (Dumont et al.,

[6]The analysis of area share is done at the household level. Given the plot-level data, I use the area weighted averages for shadow prices, soil quality and slope variables for this analysis.

Table 1. Regional averages for area share of TVs, shadow prices and market prices

Regions	**TVshare**	**Shadow p.**	**Market p.**
South-Southeast	0.70	87.75	2.34
Central	0.76	31.60	1.72
Western Cent.	0.61	57.35	1.51
Northwest	0.29	0.18	2.28
Northeast	0.73	24.69	1.30

2005). I use bootstrapping to address this issue following Cameron and Trivedi (2005). Second, the dependent variable is bounded from below and above (i.e., between 0-100%), which makes it likely that an OLS specification will result in predicted values that lie outside of this interval. I use tobit and fractional logit specifications to address the problems caused by the bounded(fractional) nature of the dependent variable in the area share regressions (Tobin, 1958; Papke and Wooldridge, 1996).

The theoretical model discussed here does not include risk. Technology adoption literature shows that risk is an important determinant of farmers' crop choices (Feder, 1980; Feder et al., 1985; Just and Zilberman, 1983). The ENHRUM data do not include a variable that represents the production or price risks farmers may face, however, they include detailed migration histories for all household members for each year since 1980. Munshi (2003) uses rainfall as an instrument for the size of the migrant networks in the destination cities. He shows that there is a strong correlation between the past rainfall in the community and migration. The intuition is that communities where most farmers rely on rain-fed agriculture will have more migrants as the variation in rainfall increases. Big variations in rainfall translate into variations in income, and migrant remittances can provide a steady source of income and hedge against risk. I use the standard error of the migration prevalence in each community over the period of 1980-2002 as a proxy for risk reversing the argument in Munshi (2003).[7] As in Munshi's sample, rain-fed agriculture is dominant in the ENHRUM sample to support the use of the variation in historical migration prevalence as a proxy

[7]When analyzed at the community level, this variable (along with the availability of irrigation) is significantly correlated with the percentage of plots cultivated with TVs.

for risk.[8] To control for risk attitudes, I use a wealth index that captures risk attitudes to the extent that farmers' risk aversion decreases with wealth.[9]

Farmers' yield expectations also play a role in land allocation (Smale et al., 1994). The ENHRUM questionnaire asked farmers the average yield they would expect to get from maize production on each plot in a normal year. I use the ratio of the village level average expected yield for TVs and MVs to control for the effect of yield expectations on land allocation.

In addition to these variables, I use the following explanatory variables in the econometric analysis: the market price of maize in the village, household size to account for consumption requirements, total number of adults (ages 15-60) in the household representing household labor availability, age, education, a dummy variable indicating farmers that use saved seed, area weighted soil quality and slope, a dummy variable indicating farmers with access to irrigation, proportion of farmers that have off-farm income and credit in the same village (both excluding the farmer himself), total area owned by the farmer, and regional dummy variables.[10] Table 2 demonstrates the sample means and standard deviations of these variables.

Subsistence farmers, on average, allocate 71% of their maize area to TVs and belong to households with 5.11 members with 2.6 working age adults. Forty-six percent of subsistence farmers use their own seed saved from previous harvests and only 13% have access to irrigation. The average expected yield of TVs is 84% of that of MVs, and farmers own 7 hectares of land on average. The average farmer lives in a community where around 40% of households have off-farm income and some kind of credit.

I use three different specifications to estimate the area share of TVs using tobit and fractional logit models (Table 3). The first specification (Columns 1 and 4) uses only market prices to test

[8]Rain-fed plots account for around 85% of the plots both in the whole sample and the subsample used here.
[9]The wealth index is created using Principal Components Analysis based on the characteristics of households' primary residence, access to utilities, and ownership of a television and refrigerator.
[10]I do not include indigenous identity as an explanatory variable. The effect of this variable is captured by the shadow prices given that indigenous identity is one of the most important determinants of shadow prices (Arslan and Taylor, 2008). Inclusion of this variable does not change the results presented here.

TABLE 2. Summary of variables used in econometric analysis

Variable	**Definition**	**Mean**	**Std. Dev.**
TVshare	Proportion of land in TVs	0.71	0.37
mktprice	Market price of maize	1.90	0.75
rho	Shadow price of TVs	46.94	43.07
hhsize	Household size	5.11	2.47
adults	Number of adults (ages 15-60)	2.64	1.55
age	Farmer's age	50.26	14.65
educ	Farmer's education (yrs.)	3.69	3.12
oldseedD	Dummy variable (=1 if farmer uses own seed)	0.46	0.50
wtsoilq	Weighted soil quality (1: Bad, 2: Regular, 3: Good)	2.29	0.58
wtslope	Weighted slope (1: Plain, 2: Sloped, 3: Very steep)	1.59	0.60
irrigD	Irrigation dummy	0.13	0.33
sdmig	Standard deviation of community migration prevalence between 1980-2002	3.82	2.58
expyield	Ratio of expected yields (TV/MV)	0.84	1.14
totown	Total area owned (ha.)	7.04	30.75
wealth	Wealth index	1.62	0.65
othersoffD	Proportion of farmers with off-farm income in the village	0.45	0.23
otherscredit	Proportion of farmers with credit in the village	0.39	0.31
N	Number of observations	280	

how well we can explain land allocation for subsistence farmers if we ignore shadow prices. The second specification (Columns 2 and 5) uses only shadow prices, and the third (Columns 3 and 6) uses both. The regression standard errors are clustered at the Rural Development District (DDR) level to correct for potential error correlation due to unobserved agro-ecological conditions that are common to all households within a DDR.[11] The Akaike and Bayesian Information Criteria (AIC and BIC) are also reported to compare the fit of different specifications.All regressions with shadow prices as an explanatory variable are bootstrapped to account for the fact that this variable is estimated with error.

A Box-Cox regression shows that a logarithmic transformation for the shadow prices improves the fit of the model. Market prices, on the other hand, provide better fit without any transformation.

[11]Rural Development Districts are districts defined by SAGARPA (Secretary of Agriculture, Ranching, Rural Development, Fisheries, and Food Supply) as having similar agro-ecological conditions and production potential.

TABLE 3. Tobit and GLM (Fractional Logit) models for area share of TVs for subsistence farmers (marginal effects reported)

	Tobit			**GLM (Frac. Logit)**		
	mkt.pr.	**ln(rho)**	**both**	**mkt.pr.**	**ln(rho)**	**both**
TVshare	(1)	(2)	(3)	(4)	(5)	(6)
sellprice	0.16		0.17*	0.06		0.08
ln(rho)		0.24***	0.25***		0.11***	0.11***
hhsize	-0.04*	-0.03	-0.04	-0.02*	-0.01	-0.02
adults	0.00	-0.01	-0.00	-0.00	-0.01	-0.00
age	-0.01*	-0.01**	-0.01***	-0.00	-0.00*	-0.00*
educ	-0.04**	-0.03*	-0.04**	-0.01**	-0.01	-0.01**
oldseedD	0.13*	0.15	0.13	0.07**	0.08**	0.07*
wtsoilq	0.02	0.00	0.02	-0.00	-0.02	-0.01
wtslope	-0.13	-0.17**	-0.20**	-0.05	-0.07*	-0.09
irrigD	0.11	0.31	0.36	0.05	0.12	0.14
sdmig	-0.02	-0.01	-0.00	-0.01	-0.00	-0.00
expyield	-0.06	-0.02	-0.03	-0.03	-0.01	-0.01
totown	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00
wealth	-0.30***	-0.23**	-0.20*	-0.13**	-0.10*	-0.09*
othersoffD	0.27	0.42*	0.35	0.12	0.20	0.15
otherscredit	-0.42	-0.21	-0.27	-0.16	-0.08	-0.11
R1	-0.35	-0.60**	-0.73***	-0.14	-0.27*	-0.34**
R2	-0.07	-0.29	-0.33	-0.03	-0.12	-0.15
R3	-0.12	-0.51**	-0.53**	-0.06	-0.28	-0.30**
R4	-0.76***	-0.63	-0.78	-0.39**	-0.34	-0.48
Intercept	2.57***	1.96***	1.81***	3.80***	3.05***	2.78**
AIC	533.59	497.99	495.56	320.61	298.91	298.24
BIC	609.92	574.32	575.52	393.30	371.61	374.57

Significance levels : $*$: 10% $**$: 5% $***$: 1%

Therefore, I use the log of the shadow prices and non-transformed market prices in the regressions reported in Table 3. The coefficients reported in Table 3 are marginal effects for all models.

Columns 1-3 in Table 3 show the results of area share regressions using a tobit model, and columns 4-6 show the results using the fractional logit model. When used alone, market prices are not significant in explaining the area share of TVs (columns 1 and 4). Shadow prices are highly significant in predicting the land area allocated to TVs (columns 2 and 5), even after controlling for market prices (columns 3 and 6). The specifications only with shadow prices provide the best fit according to the Information Criteria.

The area allocated to TVs is found to be positively correlated with the availability of family labor and negatively correlated with family consumption requirements in other settings (Bellon and Taylor, 1993; Smale et al., 1994). I find that both the household size and the number of adults have negative coefficients, though these are not significant. Older farmers allocate smaller proportions of their maize land to TVs contradicting the finding in Bellon and Taylor (1993), however this coefficient is very small. Farmers with more education allocate smaller shares of land to TVs as found by Bellon and Taylor (1993).

Farmers who save their own seed are more likely to allocate larger shares of their maize area to TVs, reflecting the fact that they carefully manage their seed stocks to ensure the availability of preferred traits embedded in TVs. Farmers in rural Mexico are found to cultivate TVs on poorer soils and shift to MVs as soil quality improves (Bellon and Taylor, 1993). Controlling for other variables, I do not find a significant effect of soil quality in the ENHRUM sample. Surprisingly, slope has a significant and negative coefficient. The steeper the slope of farmers' plots, the smaller the area share of the TVs.

Larger-scale farmers tend to allocate bigger shares of their land to cash crops in general (Fafchamps, 1992). Controlling for farmers' wealth, total area owned by the farmer does not have a significant effect in this sample. I find that more wealthy farmers cultivate a larger share of their maize land with TVs, confirming previous findings (Bellon and Taylor, 1993; Bellon et al., 2006).

Variables that control for farmers' yield expectations and risk exposure are not significantly correlated with land allocation. This is surprising because risk usually affects land allocation in the absence of perfect credit and insurance markets (Fafchamps, 1992; Smale et al., 1994). Traditional crop varieties are perceived to be less vulnerable to risk in many different settings (Smale et al., 2001; Edmeades et al., 2006; Bellon et al., 2006). To the extent that shadow prices reflect the value of the risk reducing characteristics of TVs, my findings may capture the effect of risk on land allocation indirectly through shadow prices.

Two variables represent market access: the percentage of other farmers in the village that have off-farm income and the percentage of other farmers in the village that have some kind of credit. Neither of these variables is significantly correlated with area share of TVs. This is similar to the result in Bellon and Taylor (1993) and indicates that there is not necessarily a tradeoff between market access and cultivation of TVs. If the TVs have significant non-market values, farmers allocate higher proportions of their land to these varieties regardless of the off-farm income and credit market activities in their villages. Perales et al. (2003) has a similar conclusion after observing that farmers in villages that are closer to Mexico city and have better market access did not produce less TVs. On the contrary, TV cultivation was higher in these villages, leading to the conclusion that farmers' variety selection depends on multiple criteria and minor varieties are cultivated for traits other than expected income or yield. This finding is also confirmed by Bellon et al. (2006) in Southeastern Mexico. The traits that affect the cultivation of TVs – mainly non-market values – are captured by shadow prices in the current analysis and help explain resource allocation decisions of subsistence farmers in the national sample.

4. Conclusions

This paper shows that by using shadow prices rather than market prices, we can better understand land allocation decisions of subsistence farmers. In the case of maize in Mexico, shadow prices capture various non-market values subsistence farmers attach to traditional maize varieties, hence farmers' real incentives to cultivate them (Arslan and Taylor, 2008). Accounting for these incentives takes part of the "surprise" out of farmers' non-response to decreasing market prices following NAFTA. The non-market values of maize are one of the oft-mentioned underlying reasons for why farmers did not respond to price signals as expected (de Janvry et al., 1995; Dyer Leal and Yunez Naude, 2003; Berthaud and Gepts, 2004). This paper tests the role of non-market values in explaining land allocation by explicitly using shadow prices and comparing their performance to market prices. Research results suggest that market prices fail to explain land allocation decisions for farmers who attach significant non-market values to their crops.

In addition to providing an insight into sluggish supply response of subsistence farmers, these results also have implications for the on-farm conservation of traditional crops. Shadow prices of traditional crops give farmers *de facto* incentives for conservation. Although preferences may change over time, shadow prices create a buffer for sudden losses of genetic diversity on farmers' fields. The regions where subsistence farmers exhibit sluggish supply response can contribute to on-farm conservation of TVs and should be prioritized in targeting of such programs. These results can be applied to other regions and crops where non-market benefits of subsistence crops are significant.

An interesting extension to this paper would be to analyze the effects of the current food price crisis on resource allocation and poverty in rural Mexico. The international prices of basic food commodities have increased significantly in the last couple of years. Dyer Leal (2006) finds that land allocation decisions of maize farmers in rural Mexico are more responsive to price increases than price decreases. Whether the current price increases will be high enough to offset the difference between shadow and market prices and how this will translate into supply response with implications for on-farm conservation is a question left for future research.

References

Akerlof, G. A. and Kranton, R. E. (2000). Economics and Identity. *The Quarterly Journal of Economics*, 115(3):715–753.

Altieri, Miguel, A. (2004). Socio-Cultural Aspects of Native Maize Diversity. In *Maize and Biodiversity: The Effects of Transgenic Maize in Mexico*. Secretariat of the Commission for Environmental Cooperation of North America.

Arslan, A. (2007). *Farmers' Subjective Valuation of Subsistence Crops: The Case of Traditional Maize in Mexico*. PhD thesis, Department of Agricultural and Resource Economics, University of California, Davis. Available at http://ssrn.com/author=354360.

Arslan, A. and Taylor, J. E. (2008). Farmer's Subjective Valuation of Subsistence Crops: The Case of Traditional Maize in Mexico. Kiel Working Papers 1457, Kiel Institute for the World Economy.

Bellon, M. R., Adato, M., Becerril, J., and Mindek, D. (2006). Poor farmers' perceived benefits from different types of maize germplasm: The case of creolization in lowland tropical Mexico. *World Development*, 34(1):113–129.

Bellon, M. R. and Taylor, J. E. (1993). Folk Soil Taxonomy and the Partial Adoption of New Seed Varieties. *Economic Development and Cultural Change*, 41(4):763–786.

Berthaud, J. and Gepts, P. (2004). Assessment of Effects on Genetic Diversity. In *Maize and Biodiversity: The Effects of Transgenic Maize in Mexico*. Secretariat of the Commission for Environmental Cooperation of North America.

Botterill, L. C. (2001). Rural Policy Assumptions and Policy Failure: The Case of the Re-establishment Grant. *Australian Journal of Public Administration*, 60(4):9–16.

Brush, Stephen, B. and Chauvet, M. (2004). Assessment of Social and Cultural Effects Associated with Transgenic Maize Poduction. In *Maize and Biodiversity: The Effects of Transgenic Maize in Mexico*. Secretariat of the Commission for Environmental Cooperation of North America.

Brush, Stephen, B., Taylor, J. E., and Bellon, Mauricio, R. (1992). Technology Adoption and Biological Diversity in Andean Potato Agriculture. *Journal of Development Economics*, 39:365–387.

Cameron, A., C. and Trivedi, P. K. (2005). *Microeconometrics: Methods and Applications*, pages 357–382. Cambridge University Press, New York.

CEC (1999). Assessing environmental effects of the north american free trade agreement (nafta): An analytic framework (phase ii). Technical report, Commission for Environmental Cooperation, Montreal: Communications Commission for Economic Cooperation Secretariat.

de Janvry, A., Fafchamps, M., and Sadoulet, E. (1991). Peasant Household Behaviour with Missing Markets: Some Paradoxes Explained. *The Economic Journal*, 101:1400–1417.

de Janvry, A., Sadoulet, E., and Gordillo de Anda, G. (1995). NAFTA and Mexico's Maize Producers. *World Development*, 23:1349–1362.

Dowswell, Christopher, R., Paliwall, R., L., and Cantrell, Ronald, P. (1996). *Maize in the Third World*. Westview Press.

Dumont, M., Rayp, G., Thass, O., and Willeme, P. (2005). Correcting Standard Errors in Two-stage Estimation Procedures with Generated Regressands. *Oxford Bulletin of Economics and Statistics*, 67(3):421–433.

Dyer Leal, G. (2006). Crop Valuation and Farmer Response to Change: Implications for In-situ Conservation of Maize in Mexico. In Smale, M., editor, *Valuing Crop Biodiversity: On-Farm Genetic Resources and Economic Change*, pages 17–32. CABI Publishing, Cambridge, MA.

Dyer Leal, G., Taylor, J. E., and Boucher, S. (2002). Rethinking the Supply Response to Market Reforms in Agriculture: Household Heterogeneity in Village General Equilibrium Analysis from Mexico. UCD ARE Working Paper.

Dyer Leal, G. and Yunez Naude, A. (2003). NAFTA and Conservation of Maize Diversity in Mexico. Paper for the Program for Commission for Environmental Cooperation.

Edmeades, S., Smale, M., and Karamura, D. (2006). Demand for Cultivar Attributes and the Biodiversity of Bananas on Farms in Uganda. In Smale, M., editor, *Valuing Crop Biodiversity: On-Farm Genetic Resources and Economic Change*, pages 1–16. CABI Publishing, Cambridge, MA.

Fafchamps, M. (1992). Cash Crop Production, Food Price Volatility, and Rural Market Integration in the Third World. *American Journal of Agricultural Economics*, 74(1):90–99.

Feder, G. (1980). Farm Size, Risk Aversion and the Adoption of New Technology Under Uncertainty. *Oxford Economic Papers*, 32(2):263–283.

Feder, G., Just, R., and Zilberman, D. (1985). Adoption of Agricultural Innovations in Developing Countries: A Survey. *Economic Development and Cultural Change*, 33(2):255–298.

Fussell, B. (1992). The language of ceremony. In *The Story of Corn*, pages 281–300. Alfred A. Knopf, Inc.

Hoisington, D., Khairallah, M., Reeves, T., Ribaut, J., Skovmand, B., Taba, S., and Warburton, M. (1999). Plant Genetic Resources: What can they contribute toward increased crop productivity? *Proceedings of National Academy of Science*, 96:5937–5943. U.S.A., Colloquium Paper.

Jarvis, D., Meyer, L., Klemick, H., Guarino, L., Smale, M., Brown, A., Sadiki, M., B., S., and Hodgkin, T. (2000). *A Training Guide for In Situ Conservation On-farm*. IPGRI, Rome, Italy.

Just, R. and Zilberman, D. (1983). Stochastic Structure, Farm Size and Technology Adoption in Developing Agriculture. *Oxford Economic Papers, New Series*, 35(2):307–328.

Munshi, K. (2003). Networks in the Modern Economy: Mexican Migrants in the U.S. Labor Market. *The Quarterly Journal of Economics*, 118(2):549–599. available at http://ideas.repec.org/a/tpr/qjecon/v118y2003i2p549-599.html.

Nadal, A. (2000). The Environmental and Social Impacts of Economic Liberalization on Corn Production in Mexico. Report to Oxfam and World Wildlife Fund International.

Papke, L. E. and Wooldridge, J. M. (1996). Econometric methods for fractional response variables with an application to 401(k) plan participation rates. *Journal of Applied Econometrics*, 11(6):619 – 632.

Perales, Hugo, R., Brush, S. B., and Qualset, C. (2003). Landraces of Maize in Central Mexico: An Altitudinal Transect. *Economic Botany*, 51(1):7–20.

Smale, M., Bellon, M. R., and Aguirre Gomez, J. A. (2001). Maize Diversity, Variety Attributes, and Farmers' Choices in Southeastern Guanajuato, Mexico. *Economic Development and Cultural Change*, 50:201–225.

Smale, M., Just, R., and Leathers, H. (1994). Land Allocation in HYV Adoption Models: An Investigation of Alternative Explanations. *American Journal of Agricultural Economics*, 76:535–546.

Strauss, J. (1986). The Theory and Comparative Statics of Agricultural Household Models: A General Approach (Appendix to Part 1). In Singh, I. J., Squire, L., and Strauss, J., editors, *Agricultural Household Models: Extensions, Applications, and Policy*, pages 71–91. The Johns Hopkins University Press, World Bank Research Publication, Baltimore.

Taylor, J. E. and Adelman, I. (2003). Agricultural Household Models: Genesis, Evolution and Extensions. *Review of Economics of the Household*, 1(1):33–58.

Tobin, J. (1958). Estimation of relationships for limited dependent variables. *Econometrica*, 26(1):24–36.

Turrent, A. I. and Serratos-Hernandez, J. A. (2004). Context and Background on Wild and Cultivated Maize in Mexico. In *Maize and Biodiversity: The Effects of Transgenic Maize in Mexico*. Secretariat of the Commission for Environmental Cooperation of North America.

Vincent, D. (1976). Economic Aspects of Farm Poverty. *Australian Journal of Agricultural Economics*, 20:103–118.

Yunez Naude, A. and Taylor, Edward, J. (2006). La biodiversidad genetica del maiz en Mexico. Programa de Estudios del Cambio Economico y la Sustentabilidad del Agro Mexicano, Folletin Informativo No. 3.