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The Adoption of Sustainable Management Practices by Mexican Coffee Producers

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Abstract

In order to maintain optimal growing conditions on coffee plots, producers in Mexico are encouraged to renovate their stock of coffee trees, use fertilizer, implement soil conservation measures and manage shade levels. The adoption of these sustainable management practices (SMPs) by smallholder coffee growers has become an important rural development objective, especially as a way to overcome low yields, poverty and land degradation. However, adoption rates for SMPs remain below expected levels, a situation that potentially threatens the long-term viability of the coffee sector in Mexico. To better understand the choices made by producers, a multivariate probit technique was used which modelled the adoption of possibly interrelated SMPs using data from a survey of 119 coffee producers. The analysis reveals that adoption of SMPs is related to the size of coffee holdings, the socio-economic characteristics of producers and the role of social capital, the latter being a key factor in the overall adoption process. Surprisingly, government subsidies to coffee growers were not tied to higher adoption rates, suggesting the need for policy reforms in order to better facilitate the uptake of new practices. The results indicate that efforts aimed at strengthening local institutions and organizing coffee growers into producer associations could increase the adoption of SMPs in smallholder coffee systems.

Keywords: adoption in agriculture, sustainable management practices, coffee

1. Introduction

Coffee production is central to the rural economy of Mexico and is one of the country's principal export crops. In light of its importance, recent studies have tried to explore the relationship between coffee growing and the livelihood strategies of Mexican rural households (Barham, Callenes, Gitter, Lewis & Weber, 2011; Padrón & Burger, 2015). From a development perspective, Mexico's coffee producing regions suffer from high levels of economic and social marginalization with most households continuing to live below the poverty line (CONAPO, 2010). As a result, the sustainability of coffee growing has a direct impact on poverty alleviation, food security and rural development in Mexico.

However, the performance of the coffee sector has failed to live up to expectations, characterized by several decades of stagnation and low yields. In response, Mexico's ministry of agriculture (SAGARPA) has recommended that producers adopt a series of sustainable management practices (SMPs) in order to improve physical conditions on coffee plots (AMECAFE, 2011). Practices considered to be a high priority include renovating coffee tree stocks, applying fertilizer, adopting soil conservation measures and managing shade levels. Depending on a plot's initial physical state, it is estimated that a full renovation cycle requires the implementation of SMPs for between seven and twelve years.

By considering the problem of low yields, the present study seeks to identify the social, economic and institutional factors that influence the adoption of SMPs by coffee growers in Mexico. For this purpose, an empirical application was tested using data from a survey of producers in the southern state of Oaxaca and a multivariate probit model. The study's importance derives from simultaneously modelling the effects of explanatory variables on the adoption of SMPs while taking into account possible correlations among practices.

This theoretical approach offers a new direction for research into smallholder coffee systems in Latin America. Most studies have tended to focus on the economic, social and environmental impact of certification schemes (Bacon, 2005; Valkila, 2009; Beuchelt & Zeller, 2011; Blackman & Naranjo, 2012). However, new research suggests that a greater effort should be made to understand the adoption choices of coffee producers themselves. As several impact studies conducted in Mexico and Peru have demonstrated, revenue differences between certified organic and non-certified coffee producers are largely attributable to differences in yields rather than to the premiums from certification (Barham et al., 2011; Barham & Weber, 2012; Ruben & Fort, 2012). A case can therefore be made that policymakers, NGOs and cooperatives looking to increase the revenues of coffee growing households should focus greater attention on promoting the adoption of better management practices with a view to increasing yields rather than pursuing smallholder certification (Barham et al., 2011). In this respect, a deeper understanding of the adoption choices that producers make could potentially facilitate such a strategy.

2. Method

2.1 Study Area and Sampling Procedure

The data for this study was gathered from a survey of 119 coffee producers in the southern state of Oaxaca. The survey related to activities undertaken during the 2013/2014 coffee season and was conducted in August-September, 2014. Field interviews with producers were carried out face to face using a structured survey questionnaire. During the initial sampling stage, a municipal district - San Agustin Loxicha - was selected (see Figure 1). The area in question was chosen due to its coffee growing potential and because it is located in one of the state's main coffee growing regions.

In the following stage, two villages within the municipality were randomly selected as field sites and the survey was pre-tested in a third village. Proportionate random sampling was carried out using a database of coffee producers in each village. The sample size was determined based on a reasonable estimate of the number of producers who could be interviewed during the field research period. Similar sample sizes have also been used in previous adoption studies (Boahene, Snijders & Folmer, 1999; Cramb, 2005; Ali et al., 2007). In addition, during field visits, semi-structured interviews were conducted with two groups of producers to obtain supplementary information on local issues related to coffee growing.

Figure 1. Map of surveyed area in Mexico

2.2 SMP Categories

Producers were asked a series of questions related to their use of SMPs. The practices mentioned in the survey are regarded as a high priority for all coffee growing regions in Mexico (AMECAFE, 2011). They are:

1) Renovating coffee tree stocks

- Replanting coffee trees
- Pruning branches

- Cutting off trunks

2) Applying fertilizer
   - Organic fertilizer usage
   - Chemical fertilizer usage
3) Implementing soil conservation measures
   - Constructing terraces
   - Building drainage ditches
   - Building contour barriers
   - Planting *Inga* trees or shrubs
4) Managing shade levels on coffee plots
   - Pruning surrounding trees or shrubs
   - Thinning sections of plot

For each of the four categories of SMPs, a producer was considered an adopter if at least one of the recommendations had been implemented. The first category lists three possible options producers have for improving coffee tree stocks. These include replanting plots by removing old or damaged trees, pruning branches (*podar*) or cutting off trunks (*recepar*) in order to stimulate new growth. Typically, coffee trees begin to produce berries three years after planting with peak production attained between the fifth and sixth year, after which, in the absence of pruning or cutting, yields begin to decline. The type of measure required depends on both the physical condition and age of the tree. For the second category of SMPs, both organic and chemical fertilizer adoption was accounted for although in Mexico coffee producers rarely use the latter (AMECAFE, 2011). Examples of organic fertilizer used in coffee production include chicken and cow manure, coffee pulp and household compost material.

The third category of SMPs outlines ways that producers can minimize soil erosion due to water runoff. Measures include building terraces, creating drainage ditches and erecting contour barriers. In addition, producers are encouraged to plant leguminous trees and shrubs of the genus *Inga*. Conservation strategies are vital since coffee is mostly cultivated in the river basins of the Pacific Ocean and the Gulf of Mexico. Given the mountainous topography of these regions, coffee plots are often vulnerable to soil erosion in addition to other environmental stressors caused by climate change (Castellanos et al., 2013).

Given that most coffee in Mexico is shade grown (Moguel & Toledo, 1999) adequate shade control measures are considered necessary. Excessive shading can create unfavourable phytosanitary conditions and negatively affect yields. Coffee farmers are advised to prune surrounding trees and shrubs, remove dead branches or thin out plot sections as needed (category 4).

The survey data indicates that SMP adoption varies considerably from one category to the next. For example, the number of producers who had renovated their stock of coffee trees was relatively high: 74% of those surveyed had followed at least one of the recommendations. By contrast, only 34% of producers had applied fertilizer and with one exception all of the adopters had used organic materials. Regarding soil conservation strategies, 58% of producers had implemented at least one measure while less than half (48%) of respondents had chosen to manage shade levels.

2.3 Econometric Strategy

A multivariate probit model (MVP) employs a system of simultaneous equations in order to determine the effect that explanatory variables have on adoption. The framework is based on the assumption that a producer's decision on whether or not to adopt a new practice is likely to be correlated with other adoption choices. By contrast, many studies develop univariate models to test which variables influence the adoption of a single agricultural practice. Such an approach however can be problematic since it fails to consider potential correlations among practices (Feder, Just, & Zilberman, 1985; Teklewold, Kassie, & Shiferaw, 2013). In many cases, adoption choices are interdependent meaning producers adopt new practices simultaneously or sequentially either as complements or substitutes. When adoption choices are correlated, a univariate model carries the risk of over or underestimating the significance of explanatory variables. By contrast, the MVP approach considers any potential correlations between the unobserved errors in the adoption equations as well as the relationship among adoption choices (Rodríguez-Entrena & Arriaza, 2013).

Formally, it is assumed that producers will evaluate a series of practices and choose the bundle that maximizes their expected utility. Following Teklewold et al. (2013), we consider the i^{th} coffee producer confronted with a decision on whether to adopt a new practice. Let U_0 denote the benefits derived from traditional management practices and let U_n represent the benefits of adopting the n^{th} practice. In our case, n denotes one of the four categories of SMPs. The producer chooses to adopt if $Y^*_{in} = U_n - U_0 > 0$. The net benefits (Y^*_{in}) from adoption is a latent variable determined by a vector of household and farm characteristics (X_{in}) as a well as non-observable disturbances captured by the error term ε_{in}:

$$Y^*_{in} = \beta_n \cdot X_{in} + \varepsilon_{in} \tag{1}$$

In this equation, the term β_n represents the vector of parameters to be estimated. By using the indicator function, we can derive an observed binary equation from the unobserved preferences in equation (1). Specifically, a producer will adopt a SMP ($Y_{in}=1$) if $Y^*_{in} > 0$ but will forego adoption ($Y_{in}=0$) when $Y^*_{in} < 0$. Since the MVP model takes into account the possibility of multiple adoptions, the error terms of the equations jointly follow a multivariate normal distribution. Estimates are obtained using the maximum likelihood approach and the model captures any correlations among the stochastic elements of the SMPs. As a result, the observed binary equation will jointly represent the choice to adopt a new practice. When SMPs are interdependent, the MVP solution allows for greater efficiency in estimating the parameters of interest.

2.4 Explanatory Variables

The explanatory variables (X_{in}) included in the model as well as their hypothesized effect on the adoption of SMPs are discussed below. Table 1 presents the descriptive statistics from the survey relating to the variables of interest.

Table 1. Definitions of variables and descriptive statistics

Dependant Variables	Name	Mean	Std. Err
Renovating coffee tree stock (1= yes; 0 = no)		0.74	0.04
Applying fertilizer (1= yes; 0 = no)		0.34	0.04
Implementing soil conservation measures (1= yes; 0 = no)		0.58	0.05
Controlling shade levels on coffee plots (1= yes; 0 = no)		0.48	0.05
Explanatory Variables			
Farm and Management Characteristics			
Total farm size (hectares)	Hectares	2.58	0.27
Producer has multiple plots (1= yes; 0 = no)	Mult_Plot	0.43	0.05
Average plot distance from home (minutes)	Plot_Dist	32.94	3.00
Producer uses hired labour (1= yes; 0 = no)	Hired_Lab	0.45	0.05
Producer receives coffee subsidies (1= yes; 0 = no)	Coff_Subs	0.42	0.05
Socio-economic Profile			
Age of producer (years)	Age	48.04	1.39
Producer is male (1= yes; 0 = no)	Gender	0.75	0.04
Education level of producer (years of schooling)	Education	4.72	0.33
Total family size (number)	House_Size	4.84	0.23
Household member has salaried employment (1= yes; 0 = no)	Off_Farm_Emp	0.23	0.04
Social Capital			
Membership in farmers' group or association (1= yes; 0 = no)	Farm_Member	0.25	0.04
Number of adult relatives in the village	King_Ties	7.71	0.60
Village Dummy			
Village of Chilapa (1= yes; 0 = no)	Village_Dum	0.63	

The adoption of agricultural innovations in developing countries has long attracted the attention of researchers (Feder et al., 1985; Doss, 2006). For the purposes of empirical analysis, studies have generally distinguished between farm and aggregate level adoption. At the farm level, the decision process is usually modelled as a series of intrinsic and extrinsic factors that determine individual adoption behaviour (Meijer, Catacutan, Ajayi, Sileshi, & Nieuwenhuis, 2015). A macro level approach by contrast measures the aggregate use of a practice within a given population or territory (Feder et al., 1985). Generally, studies seek ways of relating adoption choices to farm and socio-economic factors through the use of econometric models (Knowler & Bradshaw, 2007). While various factors are hypothesized to play a role, results from different studies also indicate that the effect of certain variables is not always uniform.

Among the possible determinants of adoption include factors relating to farm and management characteristics. For instance, having a larger plot can facilitate adoption since larger producers on average tend to have lower fixed costs and can expect higher yields after implementing a new practice (Boahene et al., 1999). On the other hand, producers with larger holdings might choose to practice more extensive forms of agriculture by not adopting intensive farming methods (Kassie, Jaleta, Shiferaw, Mmbando, & Mekuria, 2013). Working multiple plots is expected however to have a positive effect since conditions on different land parcels may increase the need for certain SMPs to be implemented (Nkegbe & Shankar, 2014). Access to hired labour also potentially facilitates the uptake of new practices by enabling producers to overcome workforce related production constraints (Yila & Thapa, 2008). On the other hand, the average distance from household to plot is expected to make adoption less likely due to the transaction costs involved in moving heavy materials and inputs (Bizimana, Nieuwoudt, & Ferrer, 2002). From a policy perspective, government support programs can give producers the confidence to invest in new practices despite uncertainty (Teklewold et al., 2013). The main coffee program in Mexico (*Fomento Productivo*) offers subsidies to producers who are able to document that they marketed coffee during each of the three years prior to applying for benefits. In 2013, 29% of producers were beneficiaries under the program (SAGARPA, 2014).

Studies have also suggested that certain socio-economic characteristics of producers and their households influence adoption choices. For instance, age and education are considered possible determinants although the direction of the effect is not always clear. Older producers or those with higher levels of education will have accumulated a greater stock of information, which could mitigate the risks involved in adopting new practices (Doss, 2006). On the other hand, age is associated with a shorter planning horizon and reduced physical capacities. As well, producers with higher levels of educational attainment often have greater off-farm employment opportunities, potentially limiting the range of plot work they choose to undertake. Several studies have confirmed that education has played a major role in enabling rural households in Mexico to pursue non-agricultural employment (Janvry & Sadoulet, 2001; Yúnez-Naude & Edward Taylor, 2001; Barham et al., 2011).

Family members are often the principal source of labour for smallholders (Netting, 1993). As a result, household size is expected to have a positive effect on the likelihood of adoption. With regard to gender, it has been argued that female producers often have less access to agricultural resources (credit, land, labour, inputs, information…) which could limit their ability to adopt new practices (De Groote & Coulibaly, 1998; Teklewold et al., 2013). In Mexico, 28% of coffee producers are women and female participation rates have increased in recent years (AMECAFE, 2012).

Access to off-farm employment can be a catalyst for adoption especially since coffee producing households in Mexico are increasingly diversifying their sources of income (Barham et al., 2011; Padrón & Burger, 2015). Nonetheless, the anticipated effect of this trend on adoption is ambiguous. Off-farm revenues allow for greater consumption smoothing, thereby reducing the perceived risks associated with implementing new practices. On the other hand, the opportunity cost of undertaking plot work increases.

Finally, different aspects of a producer's endowment in social capital have been shown in various contexts to influence adoption choices (Narayan & Pritchett, 1999; Isham, 2002; Cramb, 2005). In regions where markets and information sources are imperfect, local forms of association enable farmers to exchange knowledge and experiences (Kassie et al., 2013). As such, membership in rural institutions can encourage adoption by giving producers the opportunity to learn about new or unfamiliar practices. In addition, extended families in many developing countries share resources through informal insurance mechanisms which allow households to better manage risk (Fafchamps & Gubert, 2007). Coffee growers with greater kingship ties might therefore be more likely to adopt SMPs. On the other hand, family networks characterized by strong links between members ("bonding social capital") can be closed off to outside ideas in such a way that the adoption of new agricultural practices is discouraged (Warriner & Moul, 1992).

Certain variables of interest were not considered during the final analysis. For instance, tenure arrangements were not taken into account since households in the sampled area are governed by a communal land resources committee, an institution independent of the municipality. Under this system, producers hold usufruct rights over their coffee parcels. While a 1991 amendment to the Mexican constitution made the privatization of communal lands (*ejidos*) possible, it remains the dominant type of ownership, especially in the rural areas of the south (Brown, 2004).

In addition, the survey data indicated a perfect correlation between membership in a producer association and participation in extension training. Respondents who were members of an organization all belonged to organic coffee cooperatives and no other type of producer group was present in the area. Producers who were selected to participate in the semi-structured interviews confirmed that independent growers had not received technical assistance during the 2013/2014 coffee season. Generally speaking, outside of cooperatives, the availability of technical support depends largely on government funding. However, since 2009, public spending earmarked for the coffee sector has been declining (FUNDAR, 2015) and in 2013 no funds were allocated for the provision of extension services. Given the perfect correlation between participation in extension training and membership in a producer organization, it was decided that only the latter variable would be retained.

3. Results and Discussion

3.1 General Performance of the Model

The MVP model was used to estimate the effects of explanatory variables on adoption behaviour. The natural logarithm of certain variables was taken in order to correct for skewed distributions and allow for a better model fit. In addition, we tested for the presence of multicollinearity by running the variance inflation factors (VIF). The results of the test (VIF <2.30) did not suggest any potential bias. The Wald test [chi-square (56) =98.570***] also indicates that the data fit of our model performs reasonably well. In addition, a likelihood ratio test was carried out in order to compare four univariate probit models to the multivariate solution (Table 2). The test result was statistically meaningful [chi-square (6) =14.216**] indicating that the error correlations between practices are jointly significant. This justifies our use of the MVP model rather than separate probit regressions and supports the hypothesis that SMP adoption choices are interrelated. Specifically, coffee producers who used fertilizer were more likely to adopt soil conservation measures (rho =0.642***) as well as manage shade levels (rho = 0.359*). However, renovating coffee tree stocks was not correlated with other categories of SMPs and can therefore be considered a ‘stand-alone’ practice.

Table 2. Correlation coefficients for MVP adoption equations

Equations	Coefficients (rho)	Standard error	t-value
Renovating coffee tree stock vs Applying fertilizer	0.171	0.242	0.710
Renovating coffee tree stocks vs Implementing soil conservation measures	0.202	0.196	1.030
Renovating coffee tree stock vs Managing shade levels	0.217	0.204	1.060
Applying fertilizer vs Implementing soil conservation measures	0.642	0.244	2.630***
Applying fertilizer vs Managing shade levels	0.359	0.214	1.680*
Implementing soil conservation measures vs Managing shade levels	−0.015	0.187	−0.080
Likelihood ratio test chi-square (6) =14.216**			

*p**** <0.01, *p*** <0.05, *p** <0.10.

3.2 Farm Characteristics and Management Practices

Tables 3 summarizes the MVP estimates obtained for the four categories of SMPs. The results indicate that larger coffee producers are less likely to use fertilizer or manage shade levels. With one exception, surveyed producers who adopted fertilizer had chosen to use organic materials. However, this result is not unusual given that coffee growers in Mexico tend not to use chemical fertilizer due to its perceived high cost (AMECAFE, 2011). While organic fertilizer can be more cost-effective, its availability depends crucially on local materials. This makes it difficult for producers to increase the amounts that can be obtained over a certain threshold (Valkila, 2009). As a result, fertilizer use will be more attractive to smaller producers since the application of relatively limited levels of organic fertilizer will have a greater positive impact on soil fertility than what larger producers can achieve.

From a policy perspective, these results suggest that smallholder coffee growing does not in itself represent a barrier to the adoption of SMPs. Smaller-scale coffee producers have greater facility implementing certain practices by utilizing their own resources as compared to larger producers who are more likely to require access to off-farm inputs before making a decision to adopt. When the markets for these inputs (credit, labour, fertilizer…) are imperfect, larger producers will face greater constraints in terms of their ability to implement SMPs. Viewed in this light, targeted policy reforms aimed at increasing the efficiency of agricultural input markets could indirectly facilitate the adoption process for producers with larger coffee plots.

Table 3. Coefficient estimates of the MVP model

	Renovating coffee tree stocks			Fertilizer use		
Variables	Coefficients	Standard error	t-value	Coefficients	Standard error	t-value
Hectares (log)	−0.246	0.265	−0.930	−0.609	0.265	−2.300**
Mult_Plot	0.023	0.363	0.060	0.069	0.406	0.170
Plot_Dist (log)	−0.078	0.110	−0.710	0.032	0.116	0.270
Hired_Lab	0.498	0.409	1.220	0.478	0.414	1.150
Coff_Subs	0.127	0.345	0.370	−0.436	0.391	−1.120
Age	−0.198	0.079	−2.490**	0.136	0.085	1.610
Age (squared)	0.002	0.001	2.520**	−0.001	0.001	−1.300
Gender	−0.717	0.459	−1.560	0.868	0.467	1.860*
Education (log)	−0.070	0.295	−0.240	0.108	0.272	0.400
House_Size (log)	0.433	0.427	1.010	−0.489	0.419	−1.170
Salar_Emp	0.101	0.403	0.250	0.283	0.464	0.610
Farm_Member	1.858	0.649	2.860***	2.780	0.481	5.780***
King_Ties (log)	0.570	0.249	2.290**	0.578	0.261	2.220**
Village_Dum	−0.144	0.471	−0.310	−0.455	0.462	−0.980
Constant	4.010	2.122	1.890*	−5.703	2.194	−2.600***
	Soil conservation measures			**Managing shade levels**		
Variables	Coefficients	Standard error	t-value	Coefficients	Standard error	t-value
Hectares (log)	−0.183	0.230	−0.800	−0.402	0.219	−1.830*
Mult_Plot	0.341	0.347	0.980	0.017	0.317	0.050
Plot_Dist (log)	0.122	0.104	1.180	−0.091	0.098	−0.930
Hired_Lab	0.466	0.361	1.290	−0.273	0.351	−0.780
Coff_Subs	0.009	0.324	0.030	0.084	0.314	0.270
Age	0.136	0.073	1.860*	−0.108	0.068	−1.590
Age (squared)	−0.002	0.001	−2.070**	0.001	0.001	1.660*
Gender	0.225	0.400	0.560	0.362	0.357	1.010
Education (log)	−0.482	0.293	−1.650*	−0.329	0.244	−1.350
House_Size (log)	−1.032	0.394	−2.620***	−0.886	0.370	−2.390**
Salar_Emp	0.309	0.386	0.800	0.599	0.386	1.550
Farm_Member	2.085	0.543	3.840***	1.051	0.359	2.930***
King_Ties (log)	0.404	0.228	1.770*	0.252	0.204	1.230
Village_Dum	−0.337	0.433	−0.780	−0.154	0.406	−0.380
Constant	−1.790	1.889	−0.950	3.917	1.901	2.060**
Wald chi-square (56)	98.570***					
Log pseudo-likelihood	−213.394					
Number of observations	119					

p*** <0.01, p** <0.05, p* <0.10.

Apart from the total size of coffee holdings, the farm and management variables included in the model were not significant. For instance, the number of plots as well as average distance did not have any noticeable effect on adoption rates. In addition, access to labour was not a determining factor. Producers who responded to the semi-structured interviews explained that workers are normally hired to help during the coffee harvest. Since plot improvement work is undertaken earlier in the season this explains why access to non-household labour did not translate into higher adoption rates. Moreover, hired labourers tend to come from neighbouring rural areas where coffee is not grown due to lower altitudes. During the pre-harvest period, these workers usually cultivate their own agricultural plots meaning the supply of available labour to coffee producers is highly seasonal.

Also of note is the fact that producers who benefited from government subsidies did not have higher adoption rates in any of the SMP categories. The absence of noticeable results derives from a general policy failure in Mexico to implement stable coffee support programs for producers. As a case in point, since 2003 there have been four major changes to the largest subsidy program (*Fomento Productivo*) in terms of both eligibility and funding criteria. Funding allocated to the coffee sector is also renegotiated on an annual basis and tends to fluctuate sharply (Fundar, 2015). The resulting uncertainty around subsidies makes it challenging for producers to plan their coffee investment strategies around the level of government support they can expect to receive. This in turn reduces their incentive to adopt SMPs. The question of whether or not non market incentives should be used to support coffee production remains of course a matter open to debate. However, the lack of results suggests that coffee policies in Mexico have not encouraged the uptake of SMPs and that producers seem to be passive beneficiaries of current programs.

3.3 Producers' Socio-Economic Profile

The results indicate that age is a determining factor although the effect is not uniform. Older producers are less likely to renovate their stock of coffee trees. This preference for drawing down capital stocks could be the result of shorter planning horizons associated with age. It might also reflect recent transformations in the Mexican economy, notably the increasing returns from education and off-farm employment over coffee as highlighted by Barham et al. (2011). Specifically, older producers might not renovate their stocks if they expect that younger household members will rely less on coffee growing for their livelihood. Such an expectation would reduce the incentive to improve coffee tree stocks since the benefits in terms of improved yields would only materialize over the long run. In this respect, new policies designed to promote the efficient sale and transfer of landholdings could encourage older producers to maintain their coffee trees. In contrast, the MVP model reveals that age is positively correlated with the adoption of soil conservation practices. This outcome is likely due to the fact that older producers on average have accumulated a greater stock of information on the importance and proper implementation of such measures.

The variable for gender indicated that male coffee producers are more likely to use fertilizer. As previous studies have shown, male producers often have social advantages when it comes to accessing agricultural inputs (Udry, 1996; De Groote & Coulibaly, 1998). The result might therefore indicate that women coffee growers have fewer resources for making fertilizer. Other factors might also be relevant such as the possibility that female producers face greater difficulties when it comes to transporting inputs and materials. Given the growing number of female coffee producers in Mexico, initiatives should focus on removing the constraints that women face when making adoption choices.

The results also indicate that a producer's level of education negatively influences the adoption of soil conservation measures. While education is generally regarded as helpful to adoption, producers with more schooling often have better opportunities for off-farm work and may limit the number of practices they choose to implement (Umatsu & Mishra, 2010). Moreover, several of the soil conservation recommendations in particular the building of ditches, terraces and contour barriers are especially labour-intensive. On average, the opportunity costs of implementing these measures will be greater for producers with higher levels of educational attainment.

Also of note is the fact that household size is negatively correlated with the adoption of soil conservation and shade control measures. In smallholder systems it is generally assumed that household size has a positive effect on adoption since it can be interpreted as a proxy for available farm labour (Netting, 1993). However, while household labour used to be an important factor of production, the growth in returns to education in Mexico over the last two decades has increased both school attendance and retention rates. Comparing the investments made by rural households in education and coffee production can provide some insight into the negative relationship observed between household size and adoption. In a study by Barham et al. (2011), the average educational costs (both direct and opportunity costs) per child for a coffee producing household were compared with the daily opportunity cost of making capital improvements to coffee plots. Due to the comparatively higher returns from schooling, it was estimated that rural households in Mexico invest on average twice as much in education as they do in coffee production. The MVP results appear to confirm this trade-off and suggest that larger households (with generally more children) tend to invest more in education and less in plot improvement work.

3.4 Social Capital

Finally, the estimates reveal that the adoption of SMPs depends crucially on different aspects of a producer's endowment in social capital. For every SMP category, membership in a local producer association increased the likelihood of adoption. As was previously mentioned, the only institutions present in the area visited were organic coffee cooperatives and all surveyed members had benefited from some form of extension support provided by the cooperative to which they belonged. The results therefore indicate that training provisions have a positive effect on the accumulation of coffee-related knowledge by producers and facilitate the adoption of new practices. Furthermore, coffee cooperatives arrange frequent member meetings, giving producers the opportunity to access information and share experiences that sensitize non-adopters to the benefits of SMPs. One of the main obstacles to adoption is that the costs of implementing new practices usually exceed the short-term profits, despite yielding important benefits over the long-term. In this respect, the social function of local institutions such as cooperatives is to provide a venue through which producers can learn from others during the adoption phase. These results corroborate what previous studies have highlighted regarding the impact of social capital on adoption choices in sustainable agriculture (Warriner & Moul, 1992; Swinton, 2000; Cramb, 2005; Rodríguez-Entrena & Arriaza, 2013).

In addition, the number of adult relatives in the village was positively correlated with the renovation of coffee tree stocks, fertilizer use and soil conservation measures. The evidence suggests that informal support mechanisms among family members allow producers to mitigate the risks they face when implementing SMPs. Additionally, in many coffee growing regions of Mexico, extended families participate in collaborative work exchanges (Lewis, 2005) which effectively increase the supply of labour available to producers. These exchanges seem to confer advantages on producers with greater kinship ties since they allow extended families to "self-exploit" their own labour in the sense of the term as used by Chayanov (1986). Given the communal land ownership system, it is also possible that producers with extended kinship networks face greater social pressures to adequately maintain their land holdings. As well, improving the productive state of coffee plots by adopting SMPs could confer on adopters a higher social status with the benefits derived being greater for producers with larger kinship ties.

4. Conclusion

Improving physical conditions on coffee plots through the adoption of SMPs is vital for increasing yields, reducing rural household poverty and ensuring the long-term sustainability of the coffee sector in Mexico. In this study, we analyzed the probability of adopting multiple SMPs by coffee producers using data obtained from field survey interviews. An MVP model was used to jointly analyze the adoption of multiple practices while accounting for possible correlations between them.

The results showed a relationship between the adoption of SMPs and the total size of coffee holdings, socio-economic variables (age, gender, education, household size) and a producer's endowment in social capital (association membership, kinship ties) the latter revealing itself to be a key factor in the overall adoption process. This confirms what previous studies have highlighted, namely that direct forms interaction among producers are one of the principal driving forces behind the adoption of sustainable agricultural practices. We therefore conclude that policy efforts aimed at encouraging coffee growers to adopt SMPs must account for the crucial role that social capital plays in smallholder coffee systems. From a development perspective, this implies strengthening the institutions that producers use for interacting with each other as well as encouraging greater organization at the local level. Additionally, since government subsidies had no effect on adoption rates, current coffee programs should be reformed with a view to encouraging the uptake of SMPs.

Regarding the limits of the model, it should be noted that the use of binary variables for classifying producers as adopters has been criticized as it leaves aside the issue of adoption *intensity*. In addition, the results obtained must account for the limited geographical coverage of the area sampled. While the model did capture certain trends, it is often the case with microstudies that variations between households with regard to the explanatory variables are not sufficiently large to produce meaningful results.

One promising option for further research would be to study the perceptions of coffee farmers as they relate to the adoption of SMPs. Indeed, a variety of methods could be drawn upon in order to identify and analyze which factors producers regard as being the principal barriers to adoption. Additional research in this area could contribute to further understanding the livelihood strategies of rural households and inform the design of more effective coffee policies in Mexico.

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