DISCUSSION PAPER

December 2008; revised August 2009 ■ RFF DP 08-48-REV

Agroforestry Price Supports as a Conservation Tool

Mexican Shade Coffee

Beatriz Ávalos-Sartorio and Allen Blackman

1616 P St. NW
Washington, DC 20036
202-328-5000 www.rff.org

RESOURCES
FOR THE FUTURE

Agroforestry Price Supports as a Conservation Tool: Mexican Shade Coffee

Beatriz Ávalos-Sartorio and Allen Blackman

Abstract

Economic policies that boost profits from agroforesty, thereby creating financial incentives for land managers to favor these systems over less environmentally friendly land uses, could, in theory, have ancillary environmental benefits. This paper analyzes primary and secondary data to determine whether a voluntary price support program for Mexican coffee—mostly grown in shaded systems that supply important ecosystem services—has had such "win-win" benefits by stemming land-use change in the coffee sector. We find that although the program attracted the types of growers associated with land-use change, it attracted only a relatively small number of them, did not target growing areas hardest hit by conversion to other land uses, and provided subsidies that were probably too small to affect land-use decisions. These results raise serious questions about the ability of an agroforestry price support program with a modest price floor to have a significant conservation impact.

Key Words: agroforestry, shade-grown coffee, Mexico, price supports, land use

JEL Classification Numbers: Q23, Q56, Q57, O13

Contents

Agroforestry Price Supports as a Conservation Tool: Mexican Shade Coffee

Beatriz Ávalos-Sartorio and Allen Blackman*

1. Introduction

Agroforestry systems, in which crops such as coffee, cocoa, and bananas are planted side by side with woody perennials, can provide important ecosystem services. They can harbor biodiversity, sequester carbon, prevent soil erosion, and aid in flood control and aquifer recharge (Daily et al. 2003; Castro et al. 2003; Vandermeer and Perfecto 1997). In addition, they can provide biological corridors between patches of primary forests and help preserve forests by diverting extractive activities, such as hunting and foraging (Gajaseni et al. 1996; Saunders and Hobbs 1991). Hence, policies and programs that boost profits from agroforesty, thereby creating financial incentives for land managers to retain these systems instead of switching to less environmentally friendly land uses, could, in theory, have ancillary environmental benefits.[1] The literature on this link is thin, however. We know little about whether and to what extent economic policies aimed at supporting agroforestry effectively serve double duty as conservation tools, or how they might be designed or modified to enhance such synergies.

To help fill that gap, this paper presents a case study of a historical episode in which a policy aimed at raising profits from an agroforesty system had the potential to generate "win-win" environmental benefits. We examine Mexico's Coffee Stabilization Fund (*Fondo de Estabilizción del Café,* FEC), a voluntary program that guarantees participating growers a set price for their crop. The FEC was established in the 2001–2002 harvest season in response to the coffee crisis—the precipitous decline in world coffee prices during the 1980s and 1990s that culminated in a 100-year low during the 2000–2001 season. In addition to creating economic

---

* Ávalos-Sartorio is director of academic development at the Polytechnic University of Morelos. Blackman (corresponding author) is a senior fellow at Resources for the Future; blackman@rff.org. This research was partially funded by Dr. Ávalos-Sartorio's Gilbert White Fellowship at Resources for the Future. We are grateful to our interviewees in Mexico for sharing insights and providing data. For valuable comments and suggestions, we thank the Associate Editor, an anonymous reviewer, Patrick Heidkamp, and participants at meetings of the Southern Economic Association and the Latin American and Caribbean Environmental Economic Association.

[1] Agroforesty systems typically provide lower levels of ecosystem services than native forest. Therefore, policies and programs that create incentives for land managers to convert native forest to agroforestry can entail environmental costs (Rappole et al. 2002). Our focus is on policies that create incentives for the retention of existing systems.

hardship, the crisis spurred conversion of land on and around coffee farms to cleared land uses, including row crops and pasture. Because the Mexican coffee sector is dominated by densely shaded systems located in particularly biodiverse areas, the end result was significant loss of tree cover along with critical ecosystem services (Moguel and Toledo 1999; Batz et al. 2005; Blackman et al. 2005; Eakin et al. 2006).

In principle, the FEC had the potential to mitigate those environmental damages by creating financial incentives for growers to continue to cultivate shade coffee instead switching to other land uses or abandoning their farms and leaving them vulnerable to encroachment. However, the program could have stemmed tree cover loss only if it changed the behavior of significant number of growers who otherwise would have cleared the tree cover or abandoned their farms. Accordingly, we use detailed census data along with original survey data on coffee growers to address four sets of questions about the FEC:

1. What was the scope of the program? Did it attract a significant percentage of coffee growers and of the total coffee acreage?
2. What types of growers participated? Did the program attract the growers who were responsible for tree cover loss?
3. Where were participating growers located? Were their farms in areas where tree cover loss was most severe?
4. Were the program's subsidies large enough to affect growers' land-use decisions?

To make the analysis manageable, we focus on a limited geographic area and time frame: the Coast and Southern Sierra *(Costa y Sierra Sur)* region of the state of Oaxaca in the 2002–2003 harvest season, the second year of FEC program operation.

We find that although the FEC attracted the types of growers associated with tree cover loss, it attracted only a relatively small number of them, did not target growing areas hardest hit by tree cover loss, and provided subsidies that were probably too small to affect land-use decisions. Taken together, these results suggest that the FEC, by itself, probably did little to stem tree cover loss in Mexico's Coast and Southern Sierra coffee-growing area.

The remainder of the paper is organized as follows. The next section provides background on the Mexican coffee sector, the FEC, and our study area. The third section briefly discusses our data. The fourth section presents an analysis of the four questions listed above. The fifth section presents a summary and conclusion.

2. Background

In Mexico, coffee production represents an important source of income for some 481,000 households that cultivate 665,000 hectares of coffee and hire at least one million laborers annually (CMC 2004a). The lion's share of coffee farms are smaller than 2 hectares each and are concentrated in some of the country's poorest regions (Davidson 2005).

Almost 90 percent of Mexican coffee is cultivated in mixed systems in which coffee bushes are planted alongside trees, and almost 40 percent—including the coffee in our study area—is cultivated in "rustic" and "traditional" systems characterized by relatively dense and diverse tree cover that generates ecosystem services on par with native forest.[2] The biodiversity benefits of Mexican shade coffee are particularly notable. All 14 of Mexico's main coffee-growing regions have been designated biodiversity "hotspots" by the country's national commission on biodiversity (Moguel and Toledo 1999; Perfecto et al. 1996; Davidson 2005).

The coffee crisis had a dramatic effect on Mexico's coffee sector. Between 1990 and 2004, coffee production in Mexico fell 21 percent and exports fell 56 percent (ICO 2005). During the same period, coffee export revenue fell 80 percent, from US$450 million to US$250 million (SourceMex 2004). By the end of the 1990s, prices received by many Mexican growers had dropped to levels below average production costs, severely affecting the economy in coffee-growing areas.

The Mexican federal government responded to the coffee crisis by implementing a series of programs targeting the coffee sector beginning in the 2001–2002 harvest season.[3] The flagship

---

[2] Ecosystem services aside, shaded systems have private advantages and disadvantages for growers. Among the disadvantages, they generally produce yields 10–30% lower than systems with little or no shade (Staver et al. 2001; Campanha et al. 2004; Muschler 2004). Among the advantages, they help conserve soil on steeply sloped land and require lower levels of purchased inputs because tree cover harbors birds that eat pests; generates nitrogen, leaf litter, and other organic matter that serves as fertilizer; and helps retain moisture (Davidson 2005).

[3] In Mexico, coffee is harvested from October to March. In addition to the FEC, the main government programs that support the coffee sector are (i) the Market Promotion Program *(Programa de Promoción de Mercado),* aimed at improving coffee marketing; (ii) the Program of Withholding Inferior Quality Coffee *(Programa de Retiro de Café de Calidades Inferiores),* which exhorts producers not to sell poor-quality coffee; (iii) the Program to Promote Coffee Production *(Programa de Impulso a la Producción de Café),* which provides subsidies to producers for investments that increase per hectare yields; (iv) the Plan of Producer Support to Promote Crop Production *(Esquema de Apoyo a la Producción y para Fomentar la Realización de la Cosecha),* in which registered producers received a one-time payment of US$95 per hectare to support harvesting costs in 2000–2001, and (v) the Productivity Promotion Program *(Fondo de Fomento Productivo)* which consists of per hectare payments for all registered producers and also encourages growers with plots below 600 meters above sea level to plant fruit or wood trees in their coffee plots.

initiative was the FEC, a US$80 million permanent fund that provides price supports to coffee growers when international prices drop below an established floor of US$85 per hundredweight (cwt, 100 pounds) of green coffee (CMC 2001).[4] Operated by the Mexican Ministry of Agriculture, the FEC provides a maximum subsidy of US$20 per cwt of Arabica coffee for up to 20 cwt per participating producer.[5] To participate, coffee producers must be registered in the National Coffee Census *(Padrón Nacional Cafetalero),* must sell their coffee to registered buyers, and must pick up their subsidy checks in person at the designated local government office. FEC rules establish a mechanism for maintaining the US$80 million fund: participating producers commit to accepting a discounted price when the international price of coffee exceeds US$85, and the amount of the discount is used to replenish the FEC fund.[6]

This case study focuses on the Coast and Southern Sierra region in the state of Oaxaca, which produces about one-fifth of Mexico's coffee (Figure 1). According to the most recent census, in this region, 33,000 producers grow coffee on 87,000 hectares (ASERCA 2004). Three-quarters of the region's coffee acreage is managed by poor, small-scale growers (Nestel 1995). Section 4.2 below provides more information about these farms' socioeconomic and basic geophysical characteristics (altitude and distance to roads).

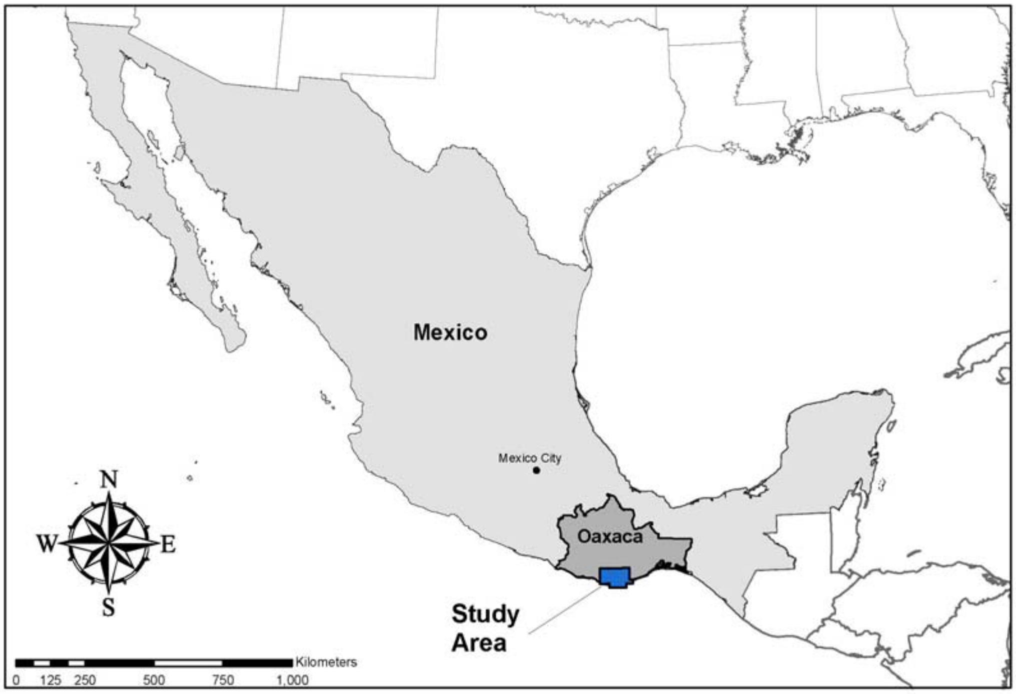
---

[4] In its first year, the FEC was operated by the Mexican Coffee Council (*Consejo Mexicano del Café,* CMC). It is now managed directly by the Ministry of Agriculture's Rural Alliance *(Alianza para el Campo)* program.

[5] The price compensation for *robusta* coffee, a species rarely grown in Mexico, is up to US$10 per cwt for up to 15 cwt per participating producer.

[6] The discount varies from US$3 per cwt when the international price is between US$85 and US$89.5 per cwt, to US$20 when the international price is US$140 or more. To be continuously eligible to participate, producers must demonstrate that they have participated in the FEC's replenishment in years when international prices have exceeded the price ceiling. Starting in 2005–2006, discounts are triggered only when the international price is greater than US$100 (AMECAFE 2008). International prices remained below the US$85 per cwt international "trigger price" for FEC subsidies well into 2004. As a result, the FEC provided subsides in the 2003–2004 harvest season. However, during the fourth quarter of 2004, international prices surpassed $85 per cwt and have remained above it ever since. Between November 2004 and November 2006, the FEC accumulated US$25 million from reimbursements, roughly half the funds assigned to the FEC in the 2006 federal budget. International prices rose above the new US$100 trigger price in the fourth quarter of 2008 and have remained above it ever since. Although the FEC has not received funds from the federal budget since 2007, it continues growing because of reimbursements (Comisión Especial del Café 2006; Pérez 2006).

Figure 1. Location of Study Area



In terms of agroecology, the typical household in our study area manages a mixed production system that includes shade coffee, shifting row agriculture (primarily maize), a home garden, fallow land, and natural forest used for hunting and foraging. Coffee is grown in densely shaded, highly biodiverse "rustic" and "traditional" systems in which the canopy comprises native or seminative trees and the understory includes a variety of wild and domesticated useful species in addition to coffee (Aguilar-Støen et al. In Press; Asteggiano 2008).[7] The most abundant canopy species are *Inga oesterdiana* Benth., *Alchornea latifolia* Swartz, and *Cupania glabra* Swartz, and the understory is dominated by *Musa* sp. (bananas), *Chamaedorea* sp. (palm), and *Theobroma cacao* L. (cacao) (Asteggiano 2008).

According to local stakeholders, during the coffee crisis, most tree cover loss in the Coast and Southern Sierra coffee region resulted from logging and shifting agriculture (Ávalos-Sartorio 2005). During the coffee crisis, when cash income from coffee declined, households cleared

---

[7] There is no sun coffee in our study region. The coffee varieties grown are not compatible with the direct sunlight, relatively low humidity, and relatively high temperatures on full-sun plantations.

small plots of natural forest and/or shade coffee in order to sell the timber and grow row crops. However, the poor soils on these plots—which are typically steeply sloped—were quickly eroded by rainfall. As a result, households cleared new plots within a few years. In principle, such clearing was regulated under Mexican law, which requires all persons wishing to clear forested land to obtain a federal permit and in some cases a local permit, regardless of the scale of the clearing (NACEC 2003). In practice, however, persons clearing small plots for shifting agriculture generally ignored these requirements. Enforcement of forestry laws mainly depended on citizen denunciations of violators and was consequently haphazard, especially in remote areas.

3. Data

We use four complementary quantitative databases to address the four sets of questions listed in Section 1. First, we use a 2001–2004 census of approximately 33,000 coffee growers in the Coast and Southern Sierra region compiled by the Agricultural Marketing Services agency (*Apoyos y Servicios a la Comercialización Agropecuaria,* ASERCA), a Mexican governmental institution. The ASERCA census includes data on farm size, land tenure, and location. Second, we use 1995 township-level data on the socioeconomic characteristics of the Coast and Southern Sierra region compiled by the National Population Council (*Consejo Nacional de Población,* CONAPO), another Mexican government agency. The CONAPO data include socioeconomic indicators and distance to the township center from paved roads for more than 400 townships in this region. Third, we use a 2004 list of the study area's coffee growers who participated in the FEC program in the 2002–2003 harvest season. The list was compiled by the Mexican Coffee Council (*Consejo Mexicano del Café,* CMC). Finally, we use coffee production data provided by local stakeholders during a series of structured face-to-face interviews conducted by the authors in January 2005 (Ávalos-Sartorio 2005). In addition to providing quantitative data, the structured interviews helped frame and guide our analysis.

The interviews were conducted using a checklist of topics to be covered, including the costs of FEC participation, perceived implementation irregularities, the timeliness and amounts of support received, coffee prices, and coffee production costs.[8] We interviewed 30 coffee growers, chosen by first randomly selecting several townships in our study area and then

---

[8] The checklist was developed based on our prior knowledge of the FEC and of coffee growing in the Coast and Southern Sierra region, along with results from preliminary econometric analysis of FEC participation.

randomly selecting growers in these townships from the ASERCA census. In addition to growers, we interviewed two middlemen, the managers of the two largest coffee-exporting companies in our study area (Calvo Export and Becafisa), the government official in charge of the rural development office that manages the FEC in our study area, an official of a government agricultural development bank (*Fideicomisos Instituidos en Relación con la Agricultura en el Banco de México*, FIRA), the manager of a coffee production-marketing cooperative (La Trinidad), and the manager of a local nongovernmental organization *(Fundación Mexicana para el Desarrollo Rural).* Challenges in conducting the interviews included growers' limited education—and in the case of some indigenous growers, limited Spanish proficiency—and difficulty tracking down randomly selected producers in remote locations.

4. Analysis

4.1. Scope of FEC Participation

The ASERCA census lists 33,156 coffee growers in our study region, collectively cultivating 86,956 hectares. Of these growers 27 percent participated in the FEC in the 2002–2003 harvest season. These participants cultivated 24 percent of the total land in coffee. Thus, the FEC's purview in our study area was limited: only approximately a quarter of all growers representing slightly more than a quarter of the land planted in coffee participated in the program. This finding suggests that to be effective as a conservation tool, the FEC would have to have been particularly effective in attracting growers responsible for deforestation.

4.2. What Types of Growers Participated in the FEC?

We use multiple regression analysis to identify the characteristics of the growers who participated in the FEC. To underpin the econometric analysis, Appendix 1 presents a simple analytical model of a coffee grower's decision to participate. The model demonstrates that a grower's decision depends on two general factors: the profits s/he obtains from coffee absent the FEC program, and the transaction costs s/he pays to participate (e.g., the costs of obtaining information about the program, filling out the necessary paperwork, selling to registered buyers, and picking up subsidies in person). Both preprogram profits and participation transaction costs depend on the characteristics of the coffee farm and of the grower. For example, all other things equal, growers at high altitudes produce higher-quality coffee and therefore earn higher profits but pay higher transaction costs because they are farther from FEC offices. The analytical model can be used to demonstrate that as one would expect, growers who earn relatively low preprogram profits and those who pay lower transaction costs are more likely to participate in the program.

4.2.1. Variables

Table 1 lists the farm and grower characteristic variables used in the econometric analysis of program participation (as well as in a second analysis discussed in Section 4.3). The variables are FARM_SIZE, the size of the farm measured in hectares; ALTITUDE, the altitude of the farm measured in meters above sea level (msl); PRIVATE, a dichotomous dummy variable indicating the farm is privately owned (versus communally owned by a *communidad agraria* or an *ejido*); P_INDIGENOUS, the percentage of the population aged five and over in the township where the farm is located who speak an indigenous language instead of Spanish; P_WOMEN, the percentage of the population in the township where the farm is located who are female; and KM_TO_ROAD, the distance from the nearest township center to the nearest paved road.

The data set used to analyze participation in the FEC was created by merging three of the data sets discussed in Section 3 (ASERCA 2004; CONAPO 1998; CMC 2004b). Of the 33,156 coffee growers in our study area listed in the ASERCA census, 23,284 (70 percent) survived this merge. Table 1 presents summary statistics for the full sample (n = 23,284), as well as for participants (n = 5,741) and nonparticipants (n = 17,543). The statistics show that the typical coffee grower in our study area was small-scale, was located at relatively high altitude and more than 10 km from a paved road, was cultivating communally owned land, and was not indigenous.

Table 1. Variables Used in Econometric Analyses

Variable	Explanation	Units	Source	Level	Mean All (n = 23,284)	Mean Participants (n = 5,741)	Mean Non-participants (n =17,543)
Dependent							
PARTICIPATE	Grower participated in FEC ’02–’03 season	0/1	CMC (2004)	farm	0.25	1	0
Independent							
FARM_SIZE	Size farm	ha	ASERCA (2004)	farm	2.86	2.51	2.97
ALTITUDE	Altitude farm	m.s.l.	ASERCA (2004)	farm	1,033.15	1,021.09	1,037.10
PRIVATE	Tenure farm is private	0/1	ASERCA (2004)	farm	0.11	0.09	0.12
P_INDIGENOUS	% town population indigenous	%	CONAPO (1998)	town	16.29	15.84	16.44
P_WOMEN	% town population female	%	CONAPO (1998)	town	50.19	50.07	50.22
KM_TO_ROAD	Distance twn. ctr. to paved rd.	km.	CONAPO (1998)	town	14.38	14.40	14.37
P_CLEAR*	% forest in town cleared ’93–’02	%	Blackman et al. (2005)	town	4.39*	4.54*	4.33*

*Number of observations for P_CLEAR: all farms n = 8193; participants n = 2155; nonparticipants = 6038.

As for our expectations about the effect of grower and farm characteristics on the probability of FEC participation, the variables fall into two categories: those that have unidirectional effects on this probability, and those that have countervailing effects. The first category only includes one variable: ALTITUDE. We expect ALTITUDE to be negatively correlated with the probability of participation. Growers at higher altitudes typically earn a relatively high return on their coffee because they produce better-quality beans that fetch better prices (Avelino et al. 2005). Also, growers located at higher altitudes pay higher transaction costs for participating in the FEC because they have to travel longer distances to FEC offices and banks in the cities of Pochutla and Puerto Escondido, both of which are located on the coastal plain.

We expect the remaining farm characteristic variables—FARM_SIZE, PRIVATE, P_INDIGENOUS, P_WOMEN, and KM_TO_ROAD—to have countervailing effects on the probability of participation. They have one effect through returns to coffee, and an opposite effect through transaction costs; which effect dominates is an empirical issue. As for P_INDIGENOUS, in Mexico, heavily indigenous populations do not have equal access to public sector goods and services, including education, technical extension, agricultural marketing, credit, and infrastructure (Patrinos 2000). As a result, such populations likely pay higher prices for coffee inputs and receive lower prices for their beans. Hence indigenous growers earn relatively low returns on coffee and have relatively strong incentives to participate in the FEC. But on the other hand, indigenous growers also likely incur higher-than-average transaction costs to participate in the program.

PRIVATE also has countervailing effects on the probability of participation. Private growers likely earn lower returns on coffee than growers affiliated with a communally owned and operated *communidad* or *ejido* because they do not have the bargaining power to negotiate favorable prices for inputs and outputs. But such growers also pay higher transaction costs of participating in the FEC program because they cannot rely on cooperative institutions to gather relevant information and assist with paperwork and transportation.

As for P_WOMEN, a relatively high percentage of women in the local population reflects outmigration of men seeking nonfarm work; this variable is a proxy for the number of coffee farms headed by women. Because of the prevailing culture of the region, men are often able to negotiate better input and output prices than are women (Ávalos-Sartorio 2005). Thus, one would expect women-headed farms to earn relatively low returns on coffee and have relatively strong incentives to participate in the FEC program. But for the same cultural reasons, women probably also incur higher transaction costs of participating.

FARM_SIZE too is likely to have countervailing effects on the probability of participation. Large growers typically earn higher profits on coffee than small growers because transportation, processing, and marketing of coffee inputs and outputs exhibit economies of scale.[9] But the transaction costs that large growers pay to participate in the FEC are probably lower than those of small growers. Unlike large growers who typically sell to registered buyers as required under FEC rules, small growers tend to sell their coffee to informal middlemen who provide them with working capital (Ávalos-Sartorio 2005). Therefore, small growers would need to identify and switch to new buyers to participate. Just as important, small growers are not able to spread the fixed transaction costs of participating over as many units of output as large growers.

Finally, we also expect KM_TO_ROAD to have countervailing effects on the probability of participation in the FEC program. Growers located far from paved roads obtain lower returns, all other things equal, because of transportation costs. Such growers have relatively strong incentives to join the FEC program but would also pay higher transaction costs to participate.

---

[9] Also, unlike large growers, small growers sometimes sell their coffee at a relatively early stage of processing—as natural (dried whole cherries) or as pergamino (before the paperlike husk covering the bean has been removed)—instead of as green coffee.

4.2.2. Regression results

Table 2 (Model 1) presents the results of a probit regression aimed at explaining participation in the FEC. All the variables are significant except for KM_TO_ROAD. We had unequivocal expectations about the sign of one variable—ALTITUDE and it has the expected negative sign: farms at higher altitudes were less likely to participate in the FEC.

Table 2. Probit Regression Results
(dependent variable = PARTICIPATE)

Variable	**Model 1**		**Model 2**	
	Coefficient (s.e.)	**dF/dX**	**Coefficient** (s.e.)	**dF/dX**
FARM_SIZE	-0.00290** 0.00132)	-0.00091	—	—
ALTITUDE	-0.00007*** (0.00003)	-0.00002	—	—
PRIVATE§	-0.19422*** (0.03254)	-0.05783	—	—
P_INDIGENOUS	-0.00129*** (0.00046)	-0.00041	—	—
P_WOMEN	-0.02242*** 0.00413)	-0.00706	—	—
KM_TO_ROAD	0.00132 (0.00106)	0.00042	—	—
P_CLEAR	—	—	0.0009 (0.0015)	0.0003
CONSTANT	0.53940 (0.20542)	—	-0.6233 (0.0159)	—
No. obs.	23284		8534	
Pseudo R^2	0.0034		0.0000	
LL	-12961.207		-4959.1561	

*** significant at 1% level
** significant at 5% level
* significant at 10% level
§dichotomous dummy variable

Recall that the remaining significant variables—FARM_SIZE, PRIVATE, P_INDIGENOUS, and P_WOMEN—have countervailing effects on the probability of participation, and as a result, we did not have strong expectations about their signs. FARM_SIZE is negative: large farms were less likely to participate than small ones. Hence, for FARM_SIZE, the returns effect dominates the transaction costs effect: the disincentive for large farms to participate because they earned relatively high returns outweighed the incentive due to paying relatively low transaction costs.

For PRIVATE, P_INDIGENOUS, and P_WOMEN the opposite is true. All are negative: growers with privately held land and those who were indigenous and female (to be exact, growers in townships that were disproportionately indigenous and female) were less likely to participate. Hence for PRIVATE, P_INDIGENOUS, and P_WOMEN, the transaction cost effect dominates the returns effect; that is, for growers with privately held land and those who were indigenous and female, the disincentive to participate due to relatively high transaction costs outweighs the positive incentive due to relatively low returns.

To sum up, we find that farms that were small, located at low altitudes, with communal land tenure, and not run by indigenous growers or women were more likely to participate in the FEC program. These results suggest that variations across farms in both preprogram profitability and in transaction costs help explain participation.

What are the implications for deforestation? Previous econometric research (Blackman et al. 2005, 2008a) as well as interview evidence (Ávalos-Sartorio 2005) suggests that in our study area, the coffee farms responsible for deforestation were small, located at low altitudes, and had communal land tenure; that is, for the most part, they had same characteristics as the farms that participated in the FEC program. This is not surprising, since farms earning low returns were more likely to clear tree cover and were also more likely to participate. Hence, the program does appear to have targeted, with reasonable accuracy, the growers most likely to clear tree cover.

4.3. Where Were Participating Growers Located?

The results presented in the previous section suggest that the FEC program attracted the types of growers responsible for deforestation. Presumably, then, these growers were located in areas experiencing the most severe tree cover loss. To test this hypothesis, we analyze spatially explicit township-level data on rates of deforestation. These data were generated by comparing land cover maps derived from LANDSAT satellite images for 1993 and 2001 that cover a portion of the same territory as our study area (for a detailed description of the data and the methodology used to derive them, see Blackman et al. 2005). These data show that 27,000 hectares of land that were forested in 1993 had been cleared by 2001. However, 19,000 hectares of land that were cleared in 1993 had been reforested by 2001.[10] These figures imply a net loss of

---

[10] There have not been any concerted reforestation efforts in our study area. The most probable explanation for reforestation between 1993 and 2001 is that cleared land used for annual crops was abandoned by shifting and conventional farmers and underwent succession to secondary forest.

8,000 hectares of forest cover, representing approximately 3 percent of the area of the land cover maps.[11]

Because we do not know the exact location (latitude and longitude) of the coffee farms in our data set—we only know the townships (*localidades*, the Mexican jurisdictional units that comprise *municipios*) in which they are located—we are not able to analyze the correlation between participation in the FEC program and rates of deforestation at the farm level. Instead, we use township-level data—specifically, data on the percentage of forest cover lost for each of 479 townships in our land cover maps. Next we create a farm household-level variable, P_CLEAR, that associates each farm household with the percentage of forest cover lost in the township where it is located. Because the land cover maps depict only a portion of our study area, the number of farm households in this analysis is roughly a third of that for the econometric analysis of participation. Finally, we use a simple probit regression to determine whether P_CLEAR is correlated with the probability of participation in the FEC program.[12] As discussed in Section 2, virtually all of the land in the townships in our study area is a managed by rural farm households that split their land among shade coffee, natural forest (which they use for hunting and foraging), and shifting agriculture, and that clear their land for shifting agriculture when coffee profits are insufficient to meet subsistence needs. As a result, townships are aggregations of land managed by farm households and should reflect farm-level deforestation rates.

Table 2 (Model 2) presents the probit regression results. P_CLEAR is not significant. Hence, FEC program participation is not any more likely in townships with high historical deforestation rates than in townships with low rates. That is, our data suggest that the FEC does not appear to geographically target the "right" areas from a forest conservation perspective.

---

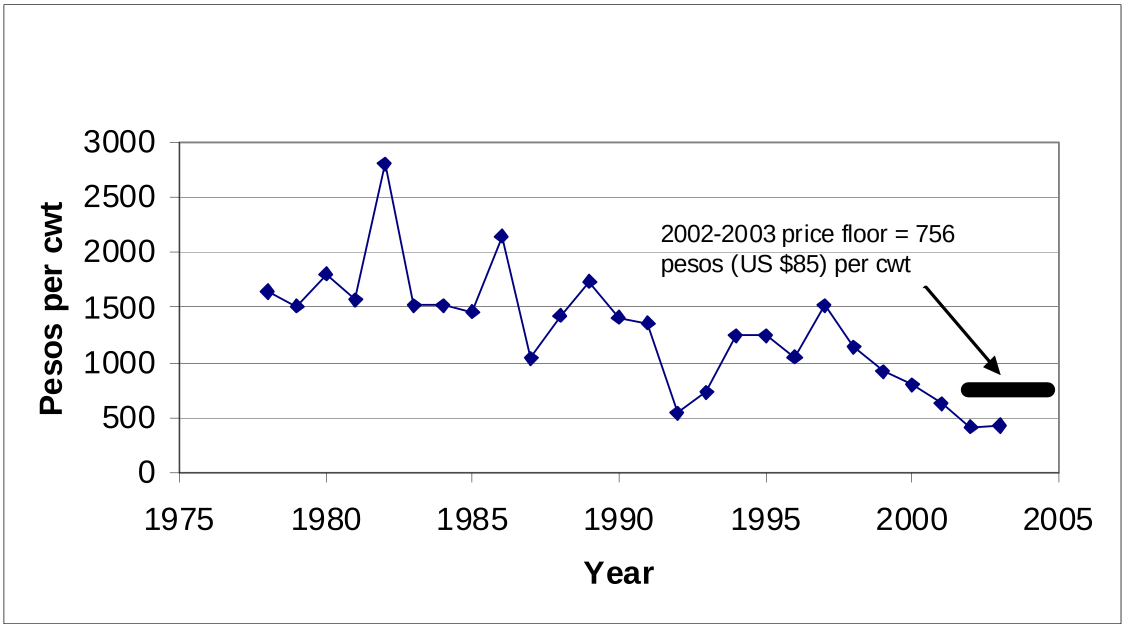
[11] Equivalently, the area experienced a 0.4% average annual deforestation rate between 1993 and 2001.

[12] Ideally, we could develop a simultaneous equation econometric model that explains both participation in the FEC program and deforestation. Both phenomena are driven by the same factors (ALTITUDE, FARM_SIZE, etc.) that determine the coffee growers' profits. Unfortunately, however, we do not have the requisite data. Specifically, our deforestation data are at the town level, not the farm level, and they predate our participation data by one year. Hence, the goal of our analysis is modest. We simply want to determine whether participation is more likely in areas where past deforestation has been most intense.

4.4. Were FEC Subsidies Large Enough to Affect Land-Use Decisions?

The 2002–2003 FEC price floor (US$85, or 756 pesos per cwt) was well below average coffee prices during the 1980s and 1990s (Figure 2). This fact begs the question of whether the FEC subsidies were sufficiently large to affect growers' land-use decisions. To help answer this question, we constructed a simple linear model of a representative coffee farm household and used it to develop back-of-the-envelope estimates of the percentage of the coffee farm's subsistence needs that were met with income from coffee production, assuming alternatively that the farm did, and did not, participate in the FEC. We developed a range of such estimates for farms of various sizes.

Figure 2. Average Pergamino Coffee Prices per Hundredweight (cwt), Pochutla, Oaxaca, 1978–2003, in 2000 pesos



Source: Authors' calculations, based on "C" contract quotes from the New York Board of Trade (http://www.nybot.com/), exchange rate data from the Chicago Mercantile Exchange (http://www.cme.com), inflation data from the Banco de México (www.banxico.org.mx/), and data on local transportation costs gathered by the authors.

We did not explicitly model the link between deforestation and the percentage of a coffee farm's subsistence needs that were met with coffee profits. However, as discussed in Section 2, previous research as well as plentiful anecdotal evidence suggests that most of the deforestation in our study area occurs when coffee farms—particularly small ones—are not able to meet their subsistence needs and turn to selling timber and shifting subsistence agriculture to help fill the gap (Blackman et al. 2005).[13]

The simulation model is parameterized with data culled from official statistics as well as interviews with local stakeholders (Ávalos-Sartorio 2005). To the extent possible, we assume average prices, yields, and costs for the 2002–2003 growing season. To ensure that our modeling assumptions are not driving our conclusion that FEC subsidies did not significantly improve most growers' ability to meet their subsistence needs, we make relatively conservative assumptions about parameter values; that is, the assumptions bias upward our estimate of the percentage change in subsistence needs attributable to the FEC.

The equations and parameters for the simulation model are detailed in Appendix 2. We summarize the major assumptions here. We assume that growers obtain an average yield of 4.3 cwt of pergamino coffee per hectare; this is the region's average yield according to a 1991 coffee grower census (the most recent yield data available), which is likely a significant overestimate for the 2002–2003 harvest season.[14] We assume that growers who did not participate in the FEC program received the 2002–2003 average market price of 430 pesos per cwt of pergamino and that growers who did participate received 756 pesos per cwt, equivalent to the price floor of US$85 dollars per cwt. As for costs, we assume that the grower carried out the bare minimum level of maintenance activities: two weedings and harvesting. Furthermore, we assume that these activities could be carried out at zero opportunity cost using family labor only, as long as the farm was no larger than 5 hectares. Finally, we make the conservative assumption that coffee households' minimum subsistence needs are 28,800 pesos per year (approximately US$3,000), the annual wage of an unskilled male adult who works in the local construction sector.

Figure 3 shows the model's estimated coffee profits as a share of household subsistence needs by farm size and FEC participation. Several features of the figure are notable. First, the

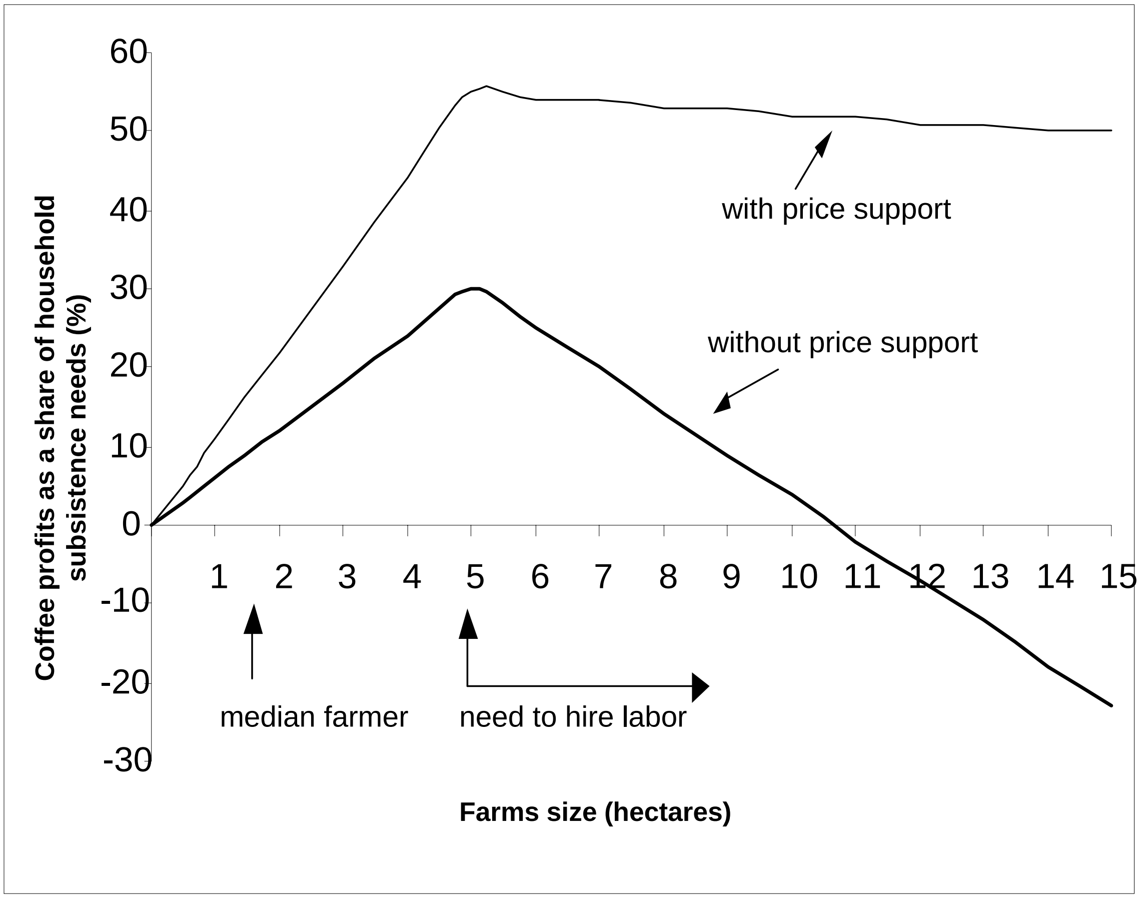
---

[13] Large growers, by contrast, are less frequently associated with deforestation. Stakeholder interviews suggest that their response to falling returns has most often been to completely abandon their farms, not to clear them for alternative land uses. Moreover, large growers have evidently been successful at preventing encroachment on abandoned farms by loggers, ranchers, and conventional farmers, presumably because they have the requisite political power (Ávalos-Sartorio 2005).

[14] The 1991 average yield is likely well above the 2002–2003 average. In the low-price years preceding the 2002–2003 harvest season, growers cut back on "discretionary" weeding and crop maintenance, which has a lasting adverse effect on yield.

share of annual subsistence needs met by coffee production is increasing in farm size up to 5 hectares because as farm size increases, revenues increase proportionately while labor costs do not change. After 5 hectares, however, the share of subsistence needs met by coffee declines because the farm must hire external labor. Second, for any given farm size, the share of annual subsistence needs met by coffee is higher if the farm participates in the FEC program because in this case, it receives higher per hectare revenues.

Figure 3. Coffee Profits as Share of Household Subsistence Needs, by Farm Size and FEC Participation



Source: Authors' calculations, based on Ávalos-Sartorio (2005)

Hence, in our model, a farm of 5 hectares meets the greatest percentage of its subsistence needs. The model suggests that in the 2002–2003 crop season, such a farm would meet 30 percent of its subsistence needs if it did not participate in the FEC program, and 55 percent of its subsistence needs if it did participate. However, the median farm size in our study area was just 1.5 hectares. Such a farm would meet just 10 percent of its subsistence needs if it did not participate in the FEC program, and 20 percent of its subsistence needs if it did participate. Note that the model suggests that the FEC program enabled otherwise unprofitable large farms to earn profits from coffee production. Farms larger than 11 hectares lose money from coffee production if they do not participate, but with the program, farms up to 115 hectares generate profits.

Hence, our back-of-the envelope calculations suggest that the FEC program did not significantly improve the ability of *small* growers to meet their subsistence needs. This was due to two factors. First, the program paid a per hectare subsidy, not a per household subsidy, which implied that small farms received less financial assistance than large ones. Second, the FEC program established a per hectare price floor that was simply too low to enable the average household to meet subsistence needs.

5. Conclusion

We have used both primary and secondary data to evaluate the potential for Mexico's FEC to stem rapid deforestation in the Coast and Southern Sierra region, one of the country's main shade-coffee areas in the early 2000s. We found that the program attracted the types of coffee farms that tended to earn low returns and that were associated with deforestation: those that were relatively small, those located at low altitudes, and those with communal land tenure. However, we found that the program's reach was limited. In 2002–2003, only approximately a quarter of all growers in our study area representing approximately a quarter of the land planted in coffee participated in the program. Moreover, the FEC did not target the "right" locations: program participation was not any more likely in townships with high historical deforestation rates than in townships with low rates. Finally, we estimated that participation in the FEC did not significantly improve the ability of the average small coffee-farm household in our study area to meet its subsistence needs. Taken together, these results suggest that the FEC, by itself, probably did little to stem tree cover loss in Mexico's Coast and Southern Sierra coffee-growing area.

How could the FEC and programs like it be modified to make them more effective as conservation tools? One obvious option would be to raise the price floor to attract more growers responsible for land-use change and provide them with sufficiently strong financial incentives to retain their land in shade coffee. A second option would be to complement price support programs with other initiatives, including those that provide lump-sum payments to help cover harvesting costs, technical assistance for improved quality and marketing, and payments for environmental services provided by shade-coffee. However, large increases in government expenditure in the coffee sector may not be politically or economically feasible. Most coffee growers are small in scale and poorly organized (Davidson 2005). The average Mexican is not aware of the social, much less the ecological, importance of coffee production in Mexico. Even for agricultural authorities, coffee is not considered a "basic crop" (like maize, beans, sorghum, and oilseeds), and coffee exports no longer represent a leading source of foreign exchange (Ávalos-Sartorio 2009).

A third option would be to use existing fiscal resources devoted to the program more strategically. The aim would be to reduce the transaction costs of program participation for precisely the types of growers responsible for deforestation in geographic areas where deforestation risk is highest—that is, to target program outreach at a subpopulation of growers. This could be accomplished by, for example, funding more branch offices in certain areas, developing subsidy payment mechanisms that do not require participants to travel to distant program offices, and reducing red tape. In addition to helping stem tree cover loss, such strategies also could further the FEC's stated objective of softening the economic impact of the coffee crisis, since in our study region, the small-scale, disadvantaged growers responsible for deforestation were also those most affected economically by the price shocks.

Although our analysis suggests that such targeting would be likely to enhance the conservation benefits of price support programs like the FEC, it does not guarantee that the effect will be significant. Unfortunately, overall, our analysis raises serious questions about the ability of an agroforestry price support program with a modest price floor—that is, one that is well below historical average prices—to have a significant conservation impact. Alternative approaches like shade coffee certification (ecolabeling) and simple command-and-control land-use restrictions may be more effective (Heidkamp et al. 2008; Blackman et al. 2008b).

References

Aguilar-Støen, M., S.R. Moe, and L. Montalvo-Espinosa. In press. On Farm Tree Management in Coffee Forest Gardens in Oaxaca, Mexico: A Socio-Ecological System Approach. *Ecology and Society*.

Apoyos y Servicios a la Comercialización Agropecuaria (ASERCA). 2004. Padrón Nacional Cafetalero. www.cmcafe.org.mx.

Asociación Mexicana del Sistema Producto Café (AMECAFE). 2008. Sistema Producto Café. Reglas de Operación del Fondo de Estabilización del Café: Ciclo 2001–2002, Ciclo 2002–2003, Ciclo 2003–2004, Ciclo 2004–2005, Ciclo 2005–2006. http://www.spcafe.org.mx/wb3/wb/spc/spc_reglas_de_operacion.

Asteggiano, L. 2008. Woody Species Diversity and Vegetation Structure in Managed and Abandoned Shade Coffee Systems in Coastal Oaxaca. Masters Thesis, Department of International Environment and Development Studies, Noragric, Norwegian University of Life Sciences.

Ávalos-Sartorio, B. 2005. Unpublished Field Survey Notes for Oaxaca. January.

Ávalos-Sartorio, B. 2009. Coffee, Policy and Stability in Mexico. In P. Pinstrup-Andersen and F. Cheng (eds.) *Case Studies in Food Policy for Developing Countries, Volume I, Policies for Health, Nutrition, Food Consumption, and Poverty*. Ithaca, NY: Cornell University Press.

Avelino, J., B. Barboza, J. C. Araya, C. Fonseca, F. Davrieux, B. Guyot, and C. Cilas. 2005. Effects of Slope Exposure, Altitude and Yield on Coffee Quality in Two Altitude Terroirs of Costa Rica, Orosi, and Santa María de Dota. *Journal of the Science of Food and Agriculture* 85(11): 1869–76.

Banco de México. 2005. Inflation data. www.banxico.org.mx.

Batz, M., H. Albers, B. Ávalos-Sartorio, and A. Blackman. 2005. Shade-Grown Coffee: Simulation and Policy Analysis for Coastal Oaxaca, Mexico. Discussion Paper 05-61. Washington, DC: Resources for the Future. http://www.rff.org/documents/RFF-DP-05-61.pdf.

Blackman, A., H. J. Albers, B. Ávalos-Sartorio, and L. Crooks. 2005. Deforestation and Shade-Coffee in Oaxaca, Mexico: Key Research Findings. Discussion Paper 05-39. Washington, DC: Resources for the Future. http://www.rff.org/Documents/RFF-DP-05-39.pdf.

Blackman, A., H.J. Albers, B. Ávalos-Sartorio, and L. Murphy. 2008a. Land Cover in a Managed Forest Ecosystem: Mexican Shade Coffee. *American Journal of Agricultural Economics* 90(1): 216–31.

Blackman, A. B. Ávalos-Sartorio, and J. Chow. 2008b. Land Cover Change in Mixed Agroforestry: Shade Coffee in El Salvador. Discussion Paper 08-25. Washington, DC: Resources for the Future. http://www.rff.org/RFF/Documents/EfD-DP-08-25.pdf.

Campanha, M., R. Santos, G. de Freitas, H. Martinez, S. Garcia, and F. Finger. 2004. Growth and Yield of Coffee Plants in Agroforestry and Monoculture Systems in Minas Gerais, Brazil. *Agroforestry Systems* 63: 75–82.

Castro, K., G. Sanchez, and B. Rivard. 2003. Monitoring Secondary Tropical Forests Using Space Borne Data: Implications for Central America. *International Journal of Remote Sensing* 24(9): 1853–94.

Chicago Mercantile Exchange. 1998–2005. Quotes for Mexican peso futures. www.cme.com.

Comisión Especial del Café. 2006. *Boletín de la Cámara de Diputados 2691*. February 25.

Consejo Mexicano del Café (CMC). 2001. Reglas de Operación del Fondo de Estabilización Precios del Café. Unpublished document.

———. 2004a. Fondo de Estabilización de Precios del Café. Sistema de Administración. Unpublished document.

———. 2004b. Fondo de Estabilización de Precios del Café. Beneficiarios 2002–2003. www.cmcafe.org.mx

Consejo Nacional de Población (CONAPO). 1998. Índices de Marginación en México, 1995. CONAPO, Mexico City.

Daily, G., G. Ceballos, J. Pacheco, G. Suzán, and A. Sánchez-Azofeifa. 2003. Countryside Biogeography of Neotropical Mammals: Conservation Opportunities in Agricultural Landscapes of Costa Rica. *Conservation Biology* 117(6): 1814–26.

Davidson, S. 2005. Shade Coffee Agro-Ecosystems in Mexico: A Synopsis of the Environmental Services and Socio-Economic Considerations. *Journal of Sustainable Forestry* 21(1): 81–95.

Eakin, H., C. Tucker, and E. Castellanos. 2006. Responding to the Coffee Crisis: A Pilot Study of Farmers' Adaptations in Mexico, Guatemala, and Honduras. *The Geographical Journal* 172: 156–71.

Gajaseni, J., R. Matta-Machado, and C. Jordan. 1996. Diversified Agroforestry Systems: Buffers for Biodiversity Reserves, and Landbridges for Fragmented Habitats in the Tropics. In R. Szaro and D. Johnston (eds.), *Biodiversity in Managed Landscapes.* New York: Oxford University Press, 506–13.

Heidkamp, P., D. Hanink, and R. Cromley. 2008. A Land Use Model of the Effects of Eco-labeling in Coffee Markets. *The Annals of Regional Science* 42: 725-46.

International Coffee Organization (ICO). 2005. Historical coffee data. http://www.ico.org/historical.asp.

Moguel, P., and V. Toledo. 1999. Biodiversity Conservation in Traditional Coffee Systems of Mexico. *Conservation Biology* 13(1): 1–21.

Muschler, R. 2004. Shade Management and Its Effects on Coffee Growth and Quality. In J. Wintegens (ed.) *Coffee: Growing, Processing, Sustainable Production. A Guidebook for Growers, Processors, Traders and Researchers*. Weinheim, Germany: Wiley-VCH, 391–415.

Nestel, D. 1995. Coffee in Mexico: International Market, Agricultural Landscape and Ecology. *Ecological Economics* 15: 165–78.

New York Board of Trade. 1998-2005. Quotes for contract "C" futures. http://www.nybot.com.

North American Commission for Environmental Cooperation (NACEC). 2003. Mexican law governing forests and forest management. www.cec.org/pubs_info_resources/law_treat_agree/summary_enviro_law

Patrinos, H.A. 2000. The Cost of Discrimination in Latin America. *Studies in Comparative International Development* 35(2): 3–17.

Pérez, M. 2006. Fondo Cafetalero Acumula 246 millones en Dos Años. *La Jornada* November 26.

Perfecto, I., R. Rice, R. Greenberg, and M. Van Der Voort. 1996. Shade Coffee: A Disappearing Refuge for Biodiversity. *Bioscience* 46(8): 598–608.

Rappole, J., D. King, and J. Vega Rivera. 2002. Coffee and Conservation. *Conservation Biology* 17(1): 334–36.

Saunders, D., and R. Hobbs. 1991. The Role of Corridors in Conservation: What Do We Know and Where Do We Go? In D. Saunders and R. Hobbs (eds.), *The Role of Corridors*. Surrey, UK: Beaty and Sons.

SourceMex. 2004. Agriculture Organizations Propose New Programs to Address Crisis among Coffee Growers. October 27. http://retanet.unm.edu/LADB-articles/25803.html.

Staver, C., F. Guharay, D. Monterroso, and R. Muschler, 2001. Designing Pest Suppressive Multistrata Perennial Crop Systems: Shade Grown Coffee in Central America. *Agroforestry Systems* 53: 151–70.

Vandermeer, J., and I. Perfecto. 1997. The Agroecosystem: The Need for the Conservationist's Lens. *Conservation Biology* 11(3): 591–92.

Appendix 1. Analytical Model of Coffee Grower's FEC Participation Decision

This appendix presents a simple analytical model of a coffee grower's decision to participate in the FEC. We assume that growers maximize the following profit function each harvest season:

$$\max_{(q_i,i)} \Pi_i = P_i(Z)q_i(Z) - C(q_i|Z) - T_i(Z) \qquad i = (r,o) \qquad (1.1)$$

where

Π ≡ expected profit
i ≡ an index of participation (r) or nonparticipation (o)
P ≡ price of coffee
Z ≡ a vector of farm characteristics
q ≡ coffee quantity
C ≡ a production cost function
T ≡ transaction costs associated with participation in the FEC program

Thus, growers maximize profit by choosing an output quantity and by deciding whether to participate in the FEC. Each component of the profit function depends on farm characteristics, Z, and some of these components depend on whether the grower participates in the FEC. Coffee price, P, depends on farm characteristics because, for example, farms at higher altitudes are able to grow higher-quality coffee, which fetches a higher price than bulk coffee grown at low altitudes. In years when average coffee prices are below the FEC price floor, price can depend on whether the grower participates in the program. Output, $q(\cdot)$, depends on farm characteristics because, for example, farms at higher altitudes typically have higher coffee yields per hectare. Output also depends on participation in the FEC because growers who participate and obtain price subsidies may choose to harvest more of their crop than they otherwise would. Production costs, $C(\cdot)$, depend on farm characteristics because, for example, large farms are able to negotiate better input prices with suppliers. Finally, growers who participate in the FEC pay transaction costs to do so. These include costs of obtaining information about the program, filling out the necessary paperwork, selling to registered buyers, and picking up subsidies in person. Transaction costs depend on farm characteristics because, for example, larger farms are able to spread these fixed costs over more output, and because non-Spanish-speaking indigenous growers incur greater informational and administrative costs.

Growers decide whether to participate in the FEC by comparing the maximum profit that can be obtained from participating, $\Pi^*_r(Z)$, with the maximum profit that can be obtained by not participating, $\Pi^*_o(Z)$. Equivalently, the grower calculates

$$I^* = \Pi^*_r(Z) - \Pi^*_o(Z) \tag{1.2}$$

and will participate as long as $I^* > 0$. Using this simple framework, it is easy to see that growers who obtain relatively low profits absent the FEC program, $\Pi^*_o(Z)$, are more likely to participate in the program. For example, absent the program, growers at low altitudes obtain inferior prices for their coffee and are therefore more likely to participate. Also, growers who pay lower transaction costs to participate in the program are more likely to do so. Our econometric model is a reduced form of equation 1.2:

$$I_j^* = f(Z_j) \tag{1.3}$$

where j indexes individual growers. Although I^* is latent and unobserved, we do observe an indicator variable, I_j, which takes the value of one if the grower participates and zero otherwise; that is, we observe,

$$I_j = 1 \text{ if } I_j^* > 0$$

$$I_j = 0 \text{ if } I_j^* \leq 0.$$

Using I_j as our dependent variable, we estimate equation 1.3 as a simple probit.

Appendix 2. Simulation Model of a Representative Coffee Farm

The following equations constitute a simple linear model of a representative coffee farm in the Coast and Southern Sierra region of Oaxaca, Mexico, that we use to generate a back-of-the-envelope estimate of the percentage of the farm household's subsistence needs met by income from coffee production. Uppercase letters represent linear functions of parameters, and lowercase italic letters represent parameters.

$$\Pi = \mathrm{PY}f - \mathrm{C}f \qquad (2.1)$$

Total profits from coffee, Π, are equal to total revenues minus total costs. Total revenues, in turn, are equal to P, the price per hundredweight (cwt) of pergamino coffee, times Y, the yield per hectare in cwt pergamino coffee, times *f*, the farm size in hectares. Total costs are equal to C, total variable costs per hectare, times *f*. Note that we ignore transaction costs of participating in the FEC (to conservatively bias upward our estimate of the percentage of subsistence covered by coffee income and because data on these costs are not available).

$$\mathrm{P} = p + s \qquad (2.2)$$

P, the price per cwt of pergamino coffee is equal to *p*, the market price per cwt plus *s*, the FEC subsidy per cwt.

$$\mathrm{Y} = tn \qquad (2.3)$$

Y, the yield per hectare in cwt pergamino is equal to *t*, the number of cwts of pergamino produced by each coffee plant, times *n*, the number of coffee plants per hectare.

$$\mathrm{C} = \mathrm{W1} + \mathrm{W2} + \mathrm{H} + \mathrm{R} + d \qquad (2.4)$$

C, total variable cost per hectare, is equal to W1, the cost per hectare of the first weeding, plus W2, the cost per hectare of the second weeding, plus H, the cost per hectare of harvesting coffee cherries, plus R, the cost per hectare of processing coffee cherries into pergamino, plus *d*, the cost per hectare of transporting coffee to a processing center.

$$\mathrm{W1} = \mathrm{W2} = c_w n \mathrm{L} \tag{2.5}$$

W1 and W2, the cost per hectare of the first and second weeding, are equal to c_w, the cost per plant of weeding, times *n*, the number of plants per hectare, times L, the percentage of total labor that is hired (versus provided by farm household members).

$$\begin{aligned} &\mathrm{L} = 0 && \forall \quad f \in \{0,5\} \\ &\mathrm{L} = 1 - (5/f) && \forall \quad f \in \{5,\infty\} \end{aligned} \tag{2.6}$$

L, the percentage of total labor that is hired, is zero for farms 5 hectares and smaller and is an increasing function of farm size for larger farms.

$$\mathrm{H} = \mathrm{Y} r c_n \mathrm{L} \tag{2.7}$$

H, the cost per hectare of harvesting coffee cherries, is equal to Y, the yield of pergamino coffee per hectare in cwt, times *r*, the number of cherry cans needed to harvest each cwt of pergamino, times c_n, the labor cost per cherry can harvested, times L, the percentage of total labor that is hired.

$$\mathrm{R} = mw\mathrm{YL} \tag{2.7}$$

Finally, R, the cost per hectare of processing coffee cherries into pergamino, is equal to *m*, the number of person-days of labor needed to process one cwt, times *w*, the daily wage paid to laborers, times Y, the per hectare yield, times *l*, the percentage of total labor that is hired. Below, we provide the actual values for each parameter and, for convenience, repeat the definition of each function and parameter.

C = total variable cost per hectare, in pesos
c_n= labor cost per cherry can harvested (20 pesos)
c_w = labor cost per plant of weeding (0.25 pesos per plant)
d = cost per hectare of transporting coffee to processing center, in pesos
f = size of farm, in hectares (simulated for different sizes)
H = cost per hectare of harvesting coffee cherries, in pesos
L = percentage of total labor for activity that is hired
m= person-days labor per cwt needed for processing (1.26 days)
n = plants per hectare (2,850 plants)
p = market price per hundredweight (cwt) of pergamino coffee, in pesos (430 pesos)
r = cherry cans per cwt (18 cans)
R = cost per hectare of processing coffee cherries into pergamino, in pesos
s = FEC subsidy per cwt pergamino coffee (326 pesos)
t = cwt of pergamino per plant (0.0015 cwt)
w = daily wage paid to processing laborers (60 pesos)
$W1$ = cost per hectare of first weeding, in pesos
$W2$ = cost per hectare of second weeding, in pesos
Y = yield per hectare, in cwt pergamino coffee
Π = total farm profits, in pesos