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Planting Hybrids, Keeping Landraces: Agricultural Modernization and Tradition Among Small-Scale Maize Farmers in Chiapas, Mexico

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Summary. — This paper examines how agricultural modernization and tradition interact among small-scale commercially-oriented maize farmers by studying shifts in area and number of farmers planting hybrids and landraces. Results show substantial yield increases but reductions in production and area planted, associated with widespread hybrid adoption and landrace abandonment. Agricultural government programs have played an important role fostering commercialization and hybrid adoption. Cultural preferences, and possibly an anti-poverty program coupled with women's empowerment, have fostered landrace retention. Hybrids and landraces have overlapping functions in farmers' livelihoods influenced by interdependent production and consumption decisions, cultural preferences, and imperfect markets even under agricultural modernization.

Key words — government programs, NAFTA, Oportunidades, Mexico, Latin America

1. INTRODUCTION

Maize is the most important crop cultivated in Mexico, and is central to the diets of both urban and rural consumers, particularly the poor. It occupies the largest area planted to any crop in the country, and many small-scale farmers are engaged in its production (Barkin, 2002), mostly in rain-fed areas producing for self-consumption as well as for the market to varying degrees (de Janvry, Sadoulet, & de Anda, 1995). The country is the center of domestication and diversity for maize, which is grown in a variety of environments and plays multiple functions in farmers' livelihoods, such as a source of food, income, cultural identity, social status, and as part of a safety net (Bellon, 1996; Bellon & Brush, 1994; Perales, Benz, & Brush, 2005). Although there has historically been strong government support to the maize sector, such support has changed dramatically in the last three decades. Government policies have shifted from promoting a protected and almost insular maize sector to supporting trade liberalization and a more open, efficient, and competitive sector, while at the same time trying to mitigate the adverse effects of these changes on smallholder farmers (Avalos-Sartorio, 2006; Yunes-Naude, 2006). Government policies have sought to increase productivity and market participation while at the same time freeing up land and labor from the peasant sector and transferring them to supposedly more efficient uses (Avalos-Sartorio, 2006; Levy & van Wijnbergen, 1992).

Changes in the Mexican maize sector induced by trade liberalization have received a great deal of attention, particularly the potential and actual impacts on small-scale maize farmers (e.g., de Janvry *et al.*, 1995; Dyer, Boucher, & Taylor, 2006; Levy & van Wijnbergen, 1992; Nadal & Wise, 2004; Yunes-Naude, 2006). Recognizing that there is an important structural heterogeneity in the link between small-scale maize producers and the market, de Janvry *et al.* (1995) predicted highly differentiated impacts caused by the reduction in maize prices associated with trade liberalization and the implementation of the North American Free Trade Agreement (NAFTA). They identified traditional producers oriented to the market as those most vulnerable to these changes and agricultural modernization as the best way to respond. Several studies have looked at how small-scale subsistence-oriented farmers have responded to trade liberalization and agricultural modernization (Dyer *et al.*, 2006; Taylor, Dyer, & Yunes-Naude, 2005), but there is a lack of understanding of how small-scale commercially-oriented farmers have responded to these changes.

In this paper we present the case of commercially-oriented small-scale maize farmers in the La Frailesca region of Chiapas. This region is well-endowed area for maize production, producing important surpluses, and has benefited historically from government support policies. We document and analyze changes in maize farming over a seven-year period (2001–07) using secondary data, a panel of household-level data from four villages in the region and qualitative information. We examine how agricultural modernization and tradition interact among these farmers by studying shifts in the area and number of farmers planting hybrids and landraces. Hybrids represent increased productivity and agricultural modernization, while landraces are related to the traditional subsistence and cultural roles of maize among Mexican farmers. We address the hypothesis that these two types of germplasm play two distinct functions in farmers' livelihoods: a commercial one to generate

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income, driven by market considerations (hybrids) and a subsistence one, driven by food security and cultural concerns (landraces), and that due to market participation and government policies there has been a shift in favor of the commercial function. The idea of crop multi-functionality in farmers' livelihood has been used to understand the dynamics of planting diverse varieties on-farm (Bellon 1996; Brush 2004) and we use this as a framework for our analysis.

The paper is organized as follows. First we present the methods used. Then the study area is described, followed by a synopsis of the government policy changes that have occurred both in Mexico and in La Frailesca. Results from secondary data on trends in production, area planted, and yields are then shown and, finally, results from the household panel data and qualitative data are presented, followed by the discussion.

2. METHODS

This study is based on three types of data: (1) secondary data, (2) surveys and (3) qualitative data. Secondary data on production, area planted, yields and prices for the municipalities that comprise La Frailesca were obtained from the *Sistema de Información y Estadística Agroalimentaria y Pesquera* (National Information and Statistical System for Food, Agriculture and Fisheries, http://www.siap.gob.mx/). Three household surveys were carried out in 2001, 2005 and 2007 with a panel of maize farmers (the surveys captured farming characteristics of the 2001, 2004 and 2006 spring-summer growing seasons, respectively). They were carried out with a random sample of farmers in four villages in La Frailesca. The villages were selected to represent different degrees of marginality and poverty in the region (see Bellon, Adato, Becerril, and Mindek (2006) for details). Sample sizes and actual farmers interviewed varied slightly per year. The 2001 and 2005 surveys were similar and elicited information on household characteristics, labor allocation, agricultural assets, and maize production, particularly maize varieties planted. Maize varieties were classified into five types of germplasm: hybrids, recycled hybrids, open-pollinated improved varieties (OPVs), creolized varieties (originally improved varieties that have been under farmer selection for several generations), and landraces following the criteria described by Bellon *et al.* (2006). The 2007 survey was more limited in scope, but paid particular attention to the maize types farmers grew, the area planted to them, and farmers' participation in government programs. Qualitative research was carried out in 2004, to characterize the formal seed system in the region. Different actors were interviewed, such as representatives of major seed companies and local cooperatives, government officials, local extension agencies known as *despachos*, and retailers of agricultural products. Further qualitative research based on a market mapping approach (Hellin, Griffith, & Albu, 2005), was conducted in 2006 and 2007 with key informants along the maize seed input and grain output chains.

3. THE STUDY AREA: ECOGEOGRAPHIC, SOCIO-ECONOMIC AND AGRICULTURAL SETTING

La Frailesca is a region in the southern state of Chiapas that occupies an area of 2631 km^2 (Erenstein, Cadena, de la Piedra, & Lopez, 1998), situated in a valley at an altitude of 600 m but with surrounding mountains reaching 2000 m. It includes four municipalities: Angel Albino Corzo, La Concordia, Villa Corzo, and Villa Flores (Figure 1). Maize is the dominant crop and the region exports maize surpluses to other parts of Mexico. Maize production is dominated by small-scale farmers producing for the market and self-consumption. There has been a long history of support from the state and federal governments in terms of access to credit, inputs, and marketing facilities. Average yields have been substantially higher than state averages for the last 25 years (Keleman, Hellin, & Bellon, 2009) and farmers' use of fertilizer and improved maize varieties have been common since the 1980s (Erenstein *et al.*, 1998). The cattle and poultry industries are complementary activities that have grown rapidly in the last 15 years (Keleman *et al.*, 2009). In spite of the favorable environmental conditions, relative high maize productivity and government support, 49.8% of the total population in the four municipalities were classified as being in extreme poverty in 2005 (though this proportion varied between 38.9% and 62% depending on the municipality) (CONEVAL, 2007). However, there is also evidence that hybrid adoption has contributed to reduced poverty (Becerril & Abdulai, 2010).

Farmers in the panel are mostly Spanish-speaking *mestizo* (mixed Spanish and indigenous heritage) households with relatively large agricultural landholdings for smallholders in Mexico (Table 1). Maize occupies between half and two-thirds of the total agricultural area. Most farmers sell maize and produce surpluses. Almost all also produce for self-consumption, with very few producing less than what they consume. Family labor is the main source for maize production though hired labor is also used. Migration and remittances are increasing in importance among households. Participation in government, agricultural, and social programs is widespread.

4. MAIZE POLICIES AND GOVERNMENT SUPPORT PROGRAMS

Government support for the maize sector has changed dramatically over the last thirty years, particularly since the ratification of NAFTA in 1994 (Avalos-Sartorio, 2006; Yunez-Naude, 2006). From the mid-1990s, new government programs and policies were created in support of trade liberalization and to mitigate its potential adverse effects. These included (i) the *Apoyos y Servicios a la Comercialización Agropecuaria* (ASERCA), which provides support to commercial producers of maize and crops in surplus-producing regions of the country (Yunez-Naude, 2006); (ii) the *Programa de Apoyos Directos al Campo* (PROCAMPO) which provides a per-hectare subsidy on a yearly basis for maize and other se-

Figure 1. *Map of Mexico, Chiapas and La Frailesca.*

Table 1. *Key characteristics of panel of farming households*

	2001	2004	2006
Household size (persons)	5.5	4.8	4.8
Only Spanish is spoken (%)	90	90	90
Age household head (years)	46.4	49.8	51.5
Education (years)	3.4	3.4	3.5
Agricultural landholding (ha)	8.45	8.3	7.47
Maize production			
Area planted to maize (ha)	5.43	4.9	3.67
Produced for self consumption (%)	98.1	99.2	98.3
Households selling maize (%)	99.1	96.7	92.5
Surplus households (%)	100	85.8	90.8
Equilibrium households (%)	0	13.3	5.8
Deficit households (%)	0	0.9	3.3
Use family labor for production (%)	81.8	96.6	Nd
Households with migrants (%)			
National	0	0.8	6.7
International	1.7	2.5	13.3
Receive remittances	1.7	3.3	14.2
Government programs (%)			
PROCAMPO[a]	87.5	86.6	21.7
Seed subsidy	56.7	62.2	60
Fertilizer subsidy	Na	22.7	90
Marketing support	56.7	59.7	36.7
Oportunidades	61.7	65.6	80.8

Nd: no data, this information was not collected in the 2007 survey.
Na: not applicable since the subsidy only started in 2004.
[a] The reduction in participation in PROCAMPO was due to conversion to PROCAMPO *Capitaliza* as explained in the text.

lected basic crops; and (c) *Alianza para el Campo*, whose main objective is to increase agricultural productivity and to capitalize farmers' investments for their better integration into food chains. The operation of the latter program is decentralized with control vested in the states.

In La Frailesca, all of these government programs have been implemented. An additional important phenomenon in La Frailesca was the establishment of subsidized albeit private extension agents, known locally as *despachos*, which provided technical assistance to smallholder farmers and facilitated farmers' access to government programs, particularly those providing credit and seed. The number of *despachos* has fallen since the mid-1990s and it remains unclear whether this public/private extension provision will continue.

(a) *Programa de Apoyos Directos al Campo (PROCAMPO)*

PROCAMPO makes a fixed cash-transfer to producers of maize and other basic staple crops on a per-hectare basis. Participation in this program has been widespread in the study site. A variation of this program called PROCAMPO *Capitaliza* allowed farmers to receive all of their remaining yearly PROCAMPO payments in one lump sum. Local government officials anticipated that this would help farmers' transition to capital-intensive activities such as cattle ranching. However, due to the limited number of registered hectares and correspondingly low payments, farmers were not able to purchase livestock. Instead, payments were mostly used to pay off debts, to invest in non-livestock agricultural goods, and to buy household supplies.

(b) *Seed subsidy*

In 2002, when the Federal Government Program known as "*Kilo por Kilo*" finished, the State government, recognizing the need to support maize production, began to subsidize seed under the *Programa Especial de Semilla*. In 2005, the *Secretaria de Desarrollo Rural* (SDR) subsidized 33,000 bags of seed benefiting 16,000 producers in La Frailesca. In 2006, the subsidy covered 29,000 bags destined for 15,500 individuals, although demand was estimated for as much as 36,000 bags. In 2006 the subsidy amounted to 300 pesos per bag of seed—sufficient to plant one hectare—with a limit of two bags per farmer, that is, 600 pesos per farmer (the exchange rate in September 2006 was US$1: 11 Mexican pesos), with farmers paying the difference between the cost of the seed and the subsidy.

In La Frailesca there are various private seed companies that supply hybrids, which include large transnational corporations, regional and national companies, as well as a cooperative and a national seed company offering OPVs and hybrids (Hellin, Keleman, Bellon, & van Heerwaarden, 2009). Interviews in 2006 with the eight largest seed distributors showed that over 60% of their sales were made up of subsidized seed. Furthermore, hybrid maize as opposed to OPV made up over 90% of the subsidized seed sales from these seed distributors in the main town of Villaflores. According to SDR, the demand for subsidized seed outstrips supply. Six companies selling hybrids indicated that they foresaw a substantial decrease in seed sales if the subsidy was stopped.

(c) *Fertilizer subsidy*

Although fertilizer subsidies have been phased out in other parts of the country, they have remained comparatively strong in La Frailesca. The main conduit of fertilizer subsidies has been via the *despachos* (see above), but their impact remains unclear. For example, in 2007 farmers reported that while higher grain prices were an incentive to grow more maize, the prices of inputs such as fertilizer had risen concomitantly, meaning that maize was no more profitable despite higher grain prices.

(d) *Marketing*

Farmer decision-making about what type of maize to grow cannot be seen in isolation from maize grain output chains. In 2002, the program of market support and development (*Programa de Apoyos a la Comercializacion y Desarollo de Mercados* (PACDMR)) was established. This program is managed by the government organization *Apoyos y Servicios a la Comercialización Agropecuaria* (ASERCA) and attempts to set a minimum reference price for maize and other products. Farmers sell grain to buyers who set up buying centers outside villages throughout La Frailesca. Farmers bring their grain to these centers and, assuming that the grain meets certain quality standards, the farmers receive from the buyer the price fixed by ASERCA. The farmer is issued with a document confirming the amount of grain that has been sold. The document subsequently enables the farmer to access a federal government subsidy per ton of grain sold. This subsidy is intended to compensate between the world-market price and the government's reference price for production costs, thereby ensuring a minimum level of income. Farmers receive the same price irrespective of whether the grain in question is a landrace, OPV, or hybrid.

(e) *Oportunidades*

Oportunidades is an anti-poverty program created by the federal government targeted at the rural poor (originally named *Progresa*). It provides cash transfers associated with

children's enrollment in and regular attendance at school and visits to a health clinic, as well as nutrition supplements and instructional meetings on health and nutrition issues. The transfers are given to the mother of the family (Hoddinott & Skoufias, 2004). This program is widely available in the study area. Women expressed positive opinions about the program, asserting that the assistance it offered for family nutrition was significant, and that they perceived major changes in their children's ability to stay in school, a higher level of educational attainment and more remunerative employment opportunities for those who finished high-school.

5. RESULTS

(a) *Recent trends in maize production in La Frailesca*

According to secondary data, area planted to maize and overall maize production decreased substantially between 2001 and 2009 (Table 2), but average yield increased at an annualized rate of growth of 5%. The average rural price of maize in the region, as well as the price of urea—the most widely used fertilizer—also increased in real terms. There is a strong and highly significant negative correlation between the area planted to maize by municipality and the price of urea ($-.55$, p-value $< .0006$), suggesting that urea price may be a strong driver of area planted, most likely through its effect on production costs.

(b) *Changes in maize germplasm at the farm level*

Results from the three surveys demonstrate significant changes in the area planted to each type of maize germplasm and the number of farmers growing them (Figure 2).[1] There was a negative trend in area planted to maize, which is consistent with the overall trend at a regional level. There were, however, increases in the area and number of farmers planting hybrids between 2001 and 2004, followed by a slight decrease between 2004 and 2006 (Figure 2). There was a decrease in area planted to landraces between 2001 and 2006. There was a reduction in number of farmers planting landraces between 2001 and 2004 but a slight increase between 2004 and 2006. For the other types of maize germplasm there were mixed results, with creolized varieties increasing and OPVs decreasing throughout the period, and recycled hybrids going up and down.

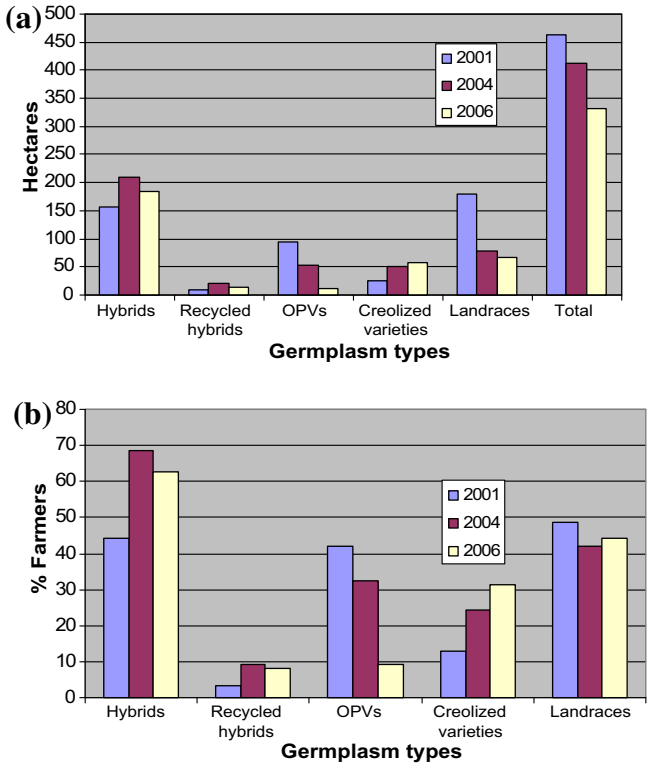

Figure 2. *Changes in area planted to (a) and percentage of farmers planting (b) different types of maize germplasm by common panel farmers 2001–2004–2007 (N = 89).*

Although farmers increasingly purchase commercial seed of hybrids and to a lesser extent OPVs, most still rely on traditional seed sources, such as saving seed or obtaining it from family and friends, that is, most farmers obtained seed both from the formal and informal seed system. Farmers who rely on both traditional seed sources and purchased commercial seed increased from 31.4% in 2001 to 45.3% and then decreased slightly to 43.0% in 2006, while farmers who rely exclusively on commercial seed decreased in the same period from 39.5% in 2001 and 38.4% in 2004 to 26.7% in 2006; the remaining are farmers who use traditional seed sources exclusively.

Table 2. *Trends in area planted, production, yields, and prices in La Frailesca 2001–09*

Year	Area planted[a] (ha)	Production[a] (ton)	Yield[a] (ton/ha)	Average rural price[a,b] (MX$/ton)	Price of urea[b,c] (MX$/ton)
2001	141,004	366394.2	2.60	1461.02	2510.72
2002	154,706	416833.6	2.70	1482.83	2246.07
2003	133,615	379096.7	2.84	1418.27	2731.88
2004	112,013	278799.	3.03	1285.38	3007.70
2005	94,350	278959.6	3.27	1477.59	3366.19
2006	94,368	287035.7	3.04	1621.63	2951.02
2007	40,958	157328.3	3.84	1798.71	3470.08
2008	42,268	175570.6	4.15	1969.88	4483.18
2009	47,224	160929.5	3.41	1885.48	4803.51

[a] Data for maize grain for the spring-summer planting cycle (main growing season) and only for rainfed production, reported in http://www.siap.gob.mx/.
[b] Price in 2003 Mexican pesos converted to real prices using the National Producer Price Index, Banco de Mexico, reported in http://dgcnesyp.inegi.org.mx/cgi-win/bdieintsi.exe.
[c] Urea price is the average from a sample of wholesalers and retailers in different states across the country for the first two weeks of April of the respective years, reported in http://www.economia-sniim.gob.mx/nuevo/.

Table 3. *Diversity of maize germplasm types used by farmers*

Year	Mean number of germplasm types/farmer	% farmers planting only one type	% farmers planting hybrids exclusively	% farmers planting landraces exclusively	% farmers planting hybrids and landraces
2001	1.49	56.48	9.26	21.30	22.22
2004	1.78	40.00	20.83	4.17	30.00
2006	1.53	54.17	23.33	15.83	21.67

Table 4. *Changes in production environments used for maize production in La Frailesca, Chiapas (mean percentage of area planted to maize by farmer)*

Year	2001	2004	2006	
Soil quality				
High	40.8	63.7	88.5	****
Medium	55.4	30.6	10.3	****
Low	3.8	5.8	1.2	ns
Stoniness				
No	20.9	34.2	48.1	****
Low	46.3	29.4	28.0	***
Medium	17.3	17.8	18.2	
High	15.6	18.6	5.6	***
Slope				
Flat	nd	35.4	51.2	***
Low	nd	32.6	10.7	****
Medium	nd	28.3	37.1	*
High	nd	3.7	1.0	*

* Significant at the .10 level associated with a one-way Analysis of Variance.
*** Significant at the .01 level associated with a one-way Analysis of Variance.
**** significant at the .001 level associated with a one-way Analysis of Variance.

While slightly more than half of the farmers in the study planted only one type of maize germplasm, some planted up to four, on average individual farmers planted more than one type of maize germplasm (Table 3). Those who planted only one type did not necessarily specialize in hybrids. Those who did plant exclusively hybrids accounted for between less than 10% in 2001 to almost a quarter in 2006 of those planting one type. There were many farmers (over 21% in 2001 and almost 15% in 2006) who planted exclusively landraces in the same period. In spite of their increased market integration and use of inputs and their access to improved germplasm, these farmers continued to derive benefits from crop diversity.

(c) *Production environment*

In order to assess changes in the production environments in which maize is grown, farmers were asked to rate their maize plots in terms of soil quality, stone content, and slope. These data were converted into percentages of the area planted to maize by each farmer. Table 4 shows that the mean percentages of the area for soil quality, stone content, and slope have shifted over the study period in statistically significant ways: maize is increasingly grown in higher quality soils, with lower slopes and reduced stone content. For example, between 2001 and 2006 there was a net increase of 153 ha in plots considered to be of high quality, while there was a decrease of 324 ha in those considered of medium quality. These data, coupled with a reduction in maize area, indicate that more marginal areas (lower soil quality, steeper slopes, and higher stone content) have been shifted out of maize during the period. This trend is consistent with that of increasing yields over time noted above, since it indicates that although less maize is grown, it is being cultivated under better environmental conditions and, hence, a reduction in area planted is associated with increased productivity. The data presented here support a finding from other qualitative research in the area (Keleman *et al.*, 2009).

(d) *Adoption of hybrids and maintenance of landraces*

The two most significant changes in area planted (see above) are associated with hybrids and landraces. The simplest hypothesis is that hybrids are planted for sale and, therefore, respond to commercial considerations, while landraces are kept for self-consumption and respond to consumption preferences and food security concerns. This would suggest that these two types of germplasm play distinct functions in farmers' livelihoods. The increase in area planted to hybrids (and concomitant reduction planted to landraces) can be interpreted as a shift in the relative importance of these functions, whereby the commercial function is replacing the self-consumption one. These shifts should be influenced by farmers' preferences and circumstances; hence by examining their effect on hybrid and landrace planting decisions, one can explore how agricultural modernization and tradition interact in maize production.

Based on this hypothesis one would expect that programs such as PROCAMPO, along with seed and fertilizer subsidies, will have a positive effect on area planted to hybrids, and either no or a negative effect on landraces. Thus, these interventions should contribute to make farmers more commercially-oriented and to rely less on self-production, fostering a decoupling of their production and consumption decisions and specialization into the most profitable options. Input

Table 5. *Definition of variables used in the regression*

Variables	Definition
Hybrids	Area planted to hybrids (ha)
Landraces	Area planted to landraces (ha)
PROCAMPO	1 if household participated in the PROCAMPO government program in the previous year; 0 if otherwise
Seed subsidy	1 if household participated in the seed subsidy government program in the previous year; 0 if otherwise
Fertilizer subsidy	1 if household participated in the fertilizer subsidy government program in the previous year; 0 if otherwise
Marketing support	1 if household participated in the marketing support government program in the previous year; 0 if otherwise
Oportunidades	1 if household participated in the *Oportunidades* anti-poverty government program in the previous year; 0 if otherwise
Urea-maize	Ratio of the price of one kg of urea[a] to the local price of one kg of maize
Labor-maize	Ratio of the daily minimum wage to the local price of one kg of maize in each of the studied communities
Poverty indicator	1 if house has an earth floor, 0 if it has a cement one
Remittances	1 if household received remittances from family members in the previous year; 0 if otherwise
Total farm area	Total farm area (ha)
Land fragmentation	Number of plots divided by total area
Distance	Distance between a community and a key nodal town measured in traveling time by truck
Family size	Number of household members adjusted by adult equivalents
Family labor	Number of male household members between 12 and 60 years old
Landraces quality differences	1 if farmer perceived a difference between tortillas made from landraces and industrially-made ones, 0 if otherwise
Age	Farmer's age (years)
Schooling	Number of years of education completed by the farmer
Dolores Jaltenango	1 if household lived in Dolores Jaltenango; 0 if otherwise
Queretaro	1 if household lived in Queretaro; 0 if otherwise

[a] Urea price is the average from a sample of wholesalers and retailers in different states across the country for the first two weeks of April of the respective years, reported in http://www.economia-sniim.gob.mx/nuevo/.

and output prices obviously should impact planting decisions. Data presented in Section 5a indicate that regional area planted to maize is strongly correlated with the price of urea. Fertilizers, particularly urea, have a long history of use by farmers in the region. Almost all farmers in our sample use fertilizers. Qualitative research indicated that while the price of maize has increased, the price of inputs such as fertilizer has increased as well, reducing the incentive to plant maize. Given that there are no price differentials between hybrid and landrace grain, hybrids should be preferred over landraces given the higher yield of the former compared to the latter. Furthermore, if fertilizer becomes expensive, and farmers start to ration its use, hybrids should be preferred because having been bred specifically to respond better to fertilizer, their marginal productivity to its application should be higher than that of landraces that have not. We also include *Oportunidades* in our analysis because previous qualitative research suggested a link between this government program and maize production decisions (Keleman *et al.*, 2009), even though this program is not aimed at agricultural production *per se*.

Socioeconomic status (particularly poverty) may influence area planted to hybrids since these maize varieties are perceived as more input-intensive with strict timing requirements for input application. Furthermore, seed has to be purchased. One would expect the poor to plant a smaller area to hybrids and to focus on landraces which are less input-intensive, more forgiving in timing requirements and, where seed is saved. Resource constraints, however, may be mitigated by remittances, which may also reduce the risk of adopting new varieties and, therefore, have a positive effect on hybrid area. Another indicator of socioeconomic status is the total farm area, which indicates agricultural assets and scale of operation, leading one to expect a positive effect on hybrid area. However, landholding fragmentation, which is common among small-scale farmers, should also affect planting decisions since it is an indicator of environmental heterogeneity. In addition, if genotype-by-environment interactions are important, farmers would likely require more types of germplasm to manage the environmental heterogeneity. Landholding fragmentation also complicates the timing of agricultural operations because of the difficulty of coordinating activities across farmers' fields.

Small-scale maize farmers in Mexico face important market imperfections, such as high transaction costs and missing markets (de Janvry *et al.*, 1995; Key, Sadoulet, & de Janvry, 2000). The presence of transaction costs raises the price paid by buyers and lowers the price received by sellers creating a price band within which it is unprofitable for some households either to sell or to buy (Key *et al.*, 2000). This limits market participation and fosters self-consumption. A common indicator of transaction costs is distance to main market towns. Hence, an impact of this indicator on planting decisions would be evidence that transaction costs affect farmers' decisions. The presence of market transaction costs may lead to missing markets for products with valued characteristics by households, that is, particular maize types, forcing them to supply themselves (Van Dusen & Taylor, 2005; Arslan & Taylor, 2009). In the presence of high transaction costs and missing markets, production and consumption decisions tend to be interdependent (Taylor & Adelman, 2003), which will be indicated by the fact that family consumption demand (family size adjusted for age and gender consumption needs) should have an effect on area planted, as well as consumption preferences for certain types of maize. In addition family composition could also influence planting decisions if labor markets do not function well, since family labor may not be easily substituted by hired labor, and labor supply is restricted to family members who can work on farm. If consumption considerations influence planting decisions and given that generally landraces are considered superior to hybrids for consumption, then perceptions of consumption quality differences should be positively associated with area planted to landraces and negatively with hybrids if production and consumption decisions are interdependent.

Farmer personal characteristics, such as age and education provide important indicators for decision-making in planting maize. Age is an indicator of traditional preferences and local

Table 6. *Random effects Tobit panel regression (marginal effects reported)*

Variables	Hybrids	Landraces
PROCAMPO	1.55**	0.006
	(0.70)	(0.643)
Seed subsidy	1.79**	−1.76**
	(0.73)	(0.70)
Fertilizer subsidy	−0.03	0.75
	(0.83)	(0.76)
Marketing support	−0.67	−0.10
	(0.67)	(0.67)
Oportunidades	−0.13	1.65**
	(0.75)	(0.67)
Urea/maize	3.75**	−2.76**
	(1.62)	(1.41)
Wage/maize	−245.43	264.79
	(191.39)	(173.75)
Poverty indicator	−1.23*	0.20
	(0.70)	(0.63)
Remittances	1.12	−0.43
	(1.31)	(1.18)
Total farm area	0.24****	0.02
	(0.04)	(0.04)
Land fragmentation	−2.35***	0.47
	(0.87)	(0.56)
Distance	−0.02	0.06****
	(0.02)	(0.02)
Family size	0.43**	0.45***
	(0.18)	(0.17)
Family labor	−0.18	0.07
	(0.37)	(0.34)
Landraces quality differences	−1.53***	1.59***
	(0.59)	(0.60)
Age	−0.03	0.06***
	(0.02)	(0.02)
Schooling	−0.009	0.18*
	(0.105)	(0.11)
Dolores Jaltenango	−0.35	1.03
	(1.02)	(1.02)
Queretaro	−2.58***	−0.23
	(0.84)	(0.84)
Wald Chi-squared (df = 19)	150.91****	94.7****

Standard errors in parentheses. Total sample size 301.
* Significant .10 level.
** Significant at the .05 level.
*** Significant at the .01 level.
**** Significant at the .001 level.

knowledge and one which can be expected to be related positively to cultivation of landraces and negatively to hybrids. Education, as an indicator of farmers' ability to adopt technical innovations and interacting with markets, should foster hybrid planting. Community-level characteristics that provide the broad local institutional and infrastructural context in which planting decisions are taken should also influence these decisions.

These predictions were tested through the estimation of two random effect Tobit regressions on panel data[2,3] (Greene, 2008; McPherson, Redfearn, & Tieslau, 2000): one for area planted to hybrids and the other for area planted to landraces. A panel data model is able to capture both cross-section and cross-series variation in the dependent variable, as well as measure not only the effect of the observable variables over the dependent variable, but also the effect of relevant unobservable ones. It is assumed that the unobservable variables that differentiate cross sectional units can be characterized as randomly distributed variables. The Tobit model takes into account that we are dealing with a censored process, that is, many farmers do not plant hybrids or landraces (area planted is zero). It estimates the effect of a series of independent variables over a latent variable which represents an unobservable index of ability or desire on the part of a farmer to plant some non zero quantity of his farm to either hybrids or landraces. We assume that these areas take a positive value if this measure of ability or desire is positive, while it takes a value of zero if this measure of ability or desire is zero or negative (e.g., McPherson *et al.*, 2000).

A description of the variables used is presented in Table 5 and the results in Table 6. The results show that the income provided by PROCAMPO contributes to hybrid area and the resulting increased productivity (see Sadoulet, de Janvry, & Davis, 2001), but has no effect on landrace area. However, the seed subsidy positively influences area planted to hybrids, and negatively the area planted to landraces. The results are consistent with statements made by seed distributors and farmers, that adoption of hybrids was linked to the seed subsidy and that many farmers would stop planting hybrids if it were discontinued (see seed subsidy section above). The results suggest that without government intervention farmers would plant a larger area to landraces. The poverty indicator (house with an earth floor) was not significant for landraces, but negative and significantly related to hybrid area, which is consistent with our expectation that hybrids are input and management intensive and less attractive to the poor. Results also indicate that the ratio of price of labor to the price of maize is not significant for area planted to either hybrids or landraces. The ratio of the price of urea to the price of maize is significant, with a positive influence for the area planted to hybrids and a negative one for landraces. This is consistent with our expectation that the marginal productivity of fertilizer application is higher among hybrids than landraces. Thus if fertilizer becomes more expensive relative to maize it is better to apply it to hybrids than to landraces. This is consistent with the observed patterns of concentrating maize production on better quality land and increase use of hybrids, which may be leading to higher productivity. Total farm size had a very significant and positive effect on area planted to hybrids which suggests that the decision to plant hybrids is not scale neutral; however, landholding fragmentation had a negative effect on hybrid area, indicating that hybrid varieties require more homogenous environment and continuous plots. These three factors were not significant for landrace area.

Family size is significant and positive for both hybrids and landraces, indicating that that production and consumption decisions are interdependent in maize production and, therefore, farmers face transaction costs in spite of a commercial orientation, good marketing infrastructure, and government support, and that both landraces and hybrids have self-consumption value. Furthermore, family labor is not significant for either germplasm, reinforcing the idea that the effect of family size is on consumption and not linked to labor availability, and also indicating that labor markets may not be a constraint.

Distance to a key nodal city is also significant and positive for landraces, but not hybrids, suggesting the presence of missing markets for valued traits in landraces, but not for hybrids. Farmers' perception of quality differences between tortillas made of landraces and industrially-made ones had a significant negative effect on area planted to hybrids and positive on landraces, which underline the importance of consumption preferences on planting decisions and supports the hypothesis of missing markets for special consumption maize characteristics in the case of landraces. Furthermore, while a majority of

farmers perceived differences in consumption quality between tortillas made of landraces and industrial ones (63.3%) regardless of what they consumed, almost two thirds of those who actually consumed landraces perceived quality differences.

While there is strong evidence of the consumption value of landraces, it is clear that landraces have been planted for sale as well, particularly in 2001, since an average family in the region needs only to plant 0.81 ha to this type of germplasm to fulfill its consumption requirements[4]; or between 15% and 21% of the average total area planted to maize over the three periods. Even allowing for some post-harvest loss, the rest would have been sold or fed to animals. At the same time, not all farmers prefer landraces for domestic use and many also consume hybrids.

The positive and significant effect of participation in the anti-poverty program *Oportunidades* on the area planted to landraces suggests that the program may be having a positive effect on the maintenance of landraces. Traditional agricultural research and development systems typically do not consult female farmers and end-users and, hence, many improved varieties do not take into account women's needs, preferences, and resources (Quisumbing & Pandolfelli, 2010). Women have positive perceptions of landraces compared to hybrids (Bellon *et al.*, 2006) and there is evidence that recipients of *Oportunidades* modify their food consumption behavior and food purchasing patterns (Hoddinott & Skoufias, 2004). Cash payments from *Oportunidades* are made directly to women, rather than men, specifically to empower them to look after the health and welfare of the family. Maize is a crucial household consumption product with strong culinary and cultural importance and, given the success of *Oportunidades*, it would be logical to assume that some empowerment has taken place, and, therefore, that women receiving money from the program have more say on agricultural choices. To the extent that agricultural production is responding to consumption concerns and preferences, it would be logical then that women's preferences for landraces contribute to their maintenance on-farm.

Of course, *Oportunidades* is given to the poor, and it is possible that its impact on landrace area simply reflects the constraints faced by the poor rather than any specific consumption concerns or preferences. Recognizing that poverty is complex and we only have a proxy for poverty status (house with an earth floor), we cannot reject the possibility that the correlation between participation in *Oportunidades* on the area planted to landraces is a spurious one. The results, however, indicate the need to study the unintended effects of this program on agricultural decision-making and particularly on planting landraces.

In addition, older farmers plant a statistically significant larger area to landraces, but not to hybrids, and education has a positive though marginally significant positive effect on the former, but not in the latter, which is surprising since one could have expected differently, given that higher education is associated with cultural change and better ability to be commercially-oriented. Also, the fact that farmers located in one of the communities (Queretaro) tended to plant a lower amount of area to hybrids compared to the others indicates that some institutional factors that vary across communities and municipalities may also influence area planted to hybrids.

6. DISCUSSION

The results show that hybrids and landraces have different but overlapping functions in the livelihood strategies of smallholder farmers. This is not, however, a simple dichotomy of hybrids being planted for the market and driven by commercial considerations and landraces being planted for self-consumption and driven by consumer preferences and food security concerns. Hybrids are also planted for self-consumption, and decisions to keep landraces in the farm are influenced by the price of fertilizers and seeds and their commercial competitiveness. The average area planted to landraces in 2001 exceeded substantially what farmers needed to feed their families, indicating the commercial nature of their planting. On the one hand, the observed considerable drop in aggregate maize area after 2001 seems to be related to the reduction in area planted to landraces where they were partly being grown for commercial production in marginal environments. As they became more expensive to produce due to increases in fertilizer prices, lower responsiveness to fertilizer application, and lower yields, and in the absence of any price premium, farmers reduced the commercial production of landraces, abandoning the environments where they were produced, and retreating to their consumption function, that is, landraces as valued consumption products that mostly have to be self produced.

On the other hand, the substantial increase in maize productivity after 2001 is associated with the adoption of hybrids, which have higher yields and responsiveness to fertilizer application, and a shift to planting maize in the best environments. Government policies and support have played a major role in these shifts. Hybrid adoption has been enabled by PROCAMPO and the government-financed seed subsidy that has made seed cheaper and also created an enabling environment that has fostered increased activity by private seed companies. Furthermore, government support has created an infrastructure to market the maize output, provide purchased inputs, and compensate for lower maize prices. *Oportunidades* may have contributed to the retention of landraces by providing women additional income and empowers them to "purchase" landraces as a valuable consumption product through self-production. Although this requires further research, it is an intriguing possibility, and could explain why transfers from PROCAMPO have no impact on landrace area while *Oportunidades* do: Unlike *Oportunidades*, PROCAMPO transfers are controlled by male farmers. The value of landraces is further supported by the fact that a majority of farmers considered landraces to be different from a consumption perspective, which suggests that landraces are neither an inferior good nor exclusively associated with poverty. The results also indicate that without government interventions, farmers of their own accord would plant more area to landraces, and hybrids would be less competitive than they are.

We found evidence that in spite of widespread government intervention in input and output markets, missing markets and transaction costs are still common and important when it comes to farmers' variety choice. Production and consumption decisions continue to be interdependent in their decision making process. This also has been documented for more subsistence-oriented farmers in Mexico (e.g., Dyer *et al.*, 2006; Van Dusen & Taylor, 2005). The maintenance of landraces in farmers' fields, with their associated management practices and knowledge, is related not just to self-consumption, but more importantly to cultural preferences; hence the maintenance of landraces requires that interdependent production and consumption decisions coincide with the presence of strong cultural preferences for traits in landraces not supplied by improved varieties (e.g., Arslan & Taylor, 2009). Furthermore, to the extent that commercial and self-consumption functions co-exist in farmers' livelihoods, crop diversity continues to be important as well as the "informal" and "formal" seed systems that support it.[5] In the case of multi-functional

crops like maize in Mexico, the challenge is to develop agricultural modernization pathways that build on the complementary functions of hybrids and landraces to improve farmers' livelihoods, rather than focusing on substituting one by the other. This would not only be good for farmers, but also for the conservation of agricultural biodiversity on farm.

In summary our study has shown that small-scale commercially-oriented maize farmers are adapting to the economic changes brought about by market liberalization in the maize sector, but also shows the enduring value to farmers of maize diversity and landraces even under these changing conditions.

NOTES

1. The data used were restricted to exactly the same farmers who participated in the three surveys.

2. Consideration of participation in government programs was restricted to the year immediately preceding the year when areas were planted to hybrids or landraces in order to avoid endogenity. Barham, Foltz, Jackson-Smith, and Moon (2004) used a similar approach to resolve endogeneity for explanatory variables that are also choice variables where a similar calculation of the expected profitability/utility of those choices may be part of farmers' decision-making process.

3. The model was run in Stata/SE 10.0 for Windows (Stata Corp, 2007) with the procedure "xttobit." The panel used is unbalanced since all data available were used, not just the ones common to the three surveys.

4. The expected subjective yield for landraces in 2001 was 2,031 kg/ha and the amount of maize needed to fulfill a household's own consumption requirements is1,650 kg/ha assuming a *per capita* consumption of 274 kg/year (Rose, 1992 cited by de Janvry *et al*. (1995, p. 1351)), a family size in adult equivalents of 5 and losses to storage and other uses of 20%. Hence a farmer only needs to plant about 0.81 ha to fulfill his/her household needs ([1,650 kg/household]/[2,031 ton/ha]).

5. Discussing the implications of these results for genetic diversity and erosion in the region are beyond the scope of this study. See van Heerwaarden, Hellin, Visser, and van Eeuwijk (2009) for a discussion.

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