Duration Analysis of Farmer Adoption of New Technologies and Markets in Nicaragua: Quality-Niche versus Commodity Vegetables

Ricardo Hernández and Thomas Reardon
Michigan State University

Submitted to AMA CRSP February 2012

Acknowledgements. This report was made possible by support provided in part by the US Agency for International Development (USAID) Agreement No. EDH-A-00-06-0003-00 awarded to the Assets and Market Access Collaborative Research Support Program (AMA CRSP). The data for the research were generated by the authors in collaboration with Nitlapan Institute at the Universidad Centro Americana in Managua, Nicaragua.

Product choice, Technology Adoption and Modern Markets in Nicaragua: A Duration Analysis

1. INTRODUCTION

Reduction of poverty and economic growth have been among the benefits of market participation by smallholders, making market participation an important topic for development policy debate. In developing countries, agricultural markets are evolving. There is evidence of market transformations, such as the rise of private standards and the shift of modern market procurement from spot markets to centralized procurement systems. These market transformations are presumably creating new opportunities and new challenges for smallholders.

Yet, the analysis of participation by smallholders into these "new market opportunities" is not a new topic in the literature. There is a growing strand of qualitative and quantitative studies, that focuses on analyzing the smallholder's choice between the traditional sector and a representative modern market such as food processors (Key and Runsten, 1999, on frozen vegetables to large processors in Mexico), exporters (Von Braun et al., 1989, on vegetable exports from Guatemala; Saenz and Ruben, 2004, on chayote exports from Costa Rica; Dolan and Humphrey, 2000, on fresh vegetable exports from Kenya and Zimbabwe to UK supermarkets), and more recently domestic supermarkets (Hernandez et al., 2007 on tomato growers in Guatemala selling to supermarkets in Guatemala, Blandon et al., 2009, on fresh fruit and vegetables in Honduras).

A common finding of the analysis of smallholder participation into modern markets is that these new opportunities require a set of incentives and capacities from the farmer's perspective. In order to participate in a modern market channel and its implied standards, the

farmer may have the challenge to have minimum land and non-land assets that were not necessary for supplying the traditional market. These required assets, can in turn become minimum investment thresholds at the private or public level (Reardon et al. 1999). For example, in order to have constant supply all year round, and minimum aesthetic characteristics farmers may have to invest in irrigation systems. After the harvest, they might need a packing shed (may be a collective investment), and transportation (in a truck, which could be private or collective investment) via paved roads (public good, to avoid mechanical damage) to the modern market procurement center.

Yet, the empirical evidence that analyzes the relation between household assets and modern market participation is very limited. In the supermarket market segment, only a few papers test hypotheses concerning farm size and non-land asset determinants of participation, and come to mixed conclusions. Rao and Qaim (2011) and Neven et al. (2009) show in Kenya that the larger the farm, the greater the probability of participation in the local supermarket channel; yet in Guatemala, Hernandez et al. (2007), and in Honduras, Blandon et al. (2009) show that farm size is not a significant determinant, and that small farmers sell to local supermarkets; this result is also shown in some export market studies, such as Minten et al. (2009) for Madagascar. Several studies show that non-land assets play a role, with different assets highlighted over studies. Most studies such as Rao and Qaim (2011) show that infrastructure cum transaction costs, for example in road access, are important to channel participation; some studies such as Blandon et al. (2009) show that membership in cooperatives is important; some like Rao and Qaim show that rural nonfarm employment (RNFE) plays a positive role, while Hernandez et al. (2007) show that irrigation plays a key role.

The upshot is that to date there are few cross-section survey-based studies of the determinants and impacts of farmer participation in supermarket channels in developing countries. There is a gap in the literature in that empirical evidence is only beginning to be brought to bear on this issue. The evidence of the rapid development of supermarkets suggests that this is an area that requires further empirical exploration (Berdegué et al. 2005). But the emerging evidence tends to point to positive impacts on incomes, mixed determination by farm size, and varied but usual determination by non-land assets.

Furthermore, modern market channel participation has usually been analyzed under static scenarios and therefore ignoring the dynamic structure of market participation. Markets represent post-harvest technologies, then the decision to participate in markets is analogous to adoption of a technology. While there have been a number of theoretical and empirical papers modeling the dynamics of adoption of technologies (Besley and Case, 1993, and a few using duration analysis, de Souza Filho, 1997; Dadi et al. 2004; Burton et al. 2003; and Fuglie and Kascak, 2001), there have been far fewer modeling the dynamics of market participation. As exceptions to the rule of rarity of these studies, one can cite two sets of studies of the dynamics of farmer participation in food markets.

On the one hand, some studies in Africa have examined the dynamics of farmers moving from autarchy to participation in the market (commercialization) and sometimes back out (such as Bellemare and Barrett, 2006 and Holloway et al. 2005).

On the other hand, a few studies on Guatemala (Carletto et al. 1999 and 2010) have modeled farmers' time to adoption and duration as an adopter of crops sold in non-traditional export markets. To our knowledge, this is the sole use of dynamic analysis in general, and

duration analysis in particular, to study farmers' participation (and income effects) of modern market channels per se.

This nascent duration-analysis literature has, however, not treated two important subjects: (1) the choice of traditional versus modern market channels in general, and local supermarket channels in particular; (2) the relation of farm capital and farm technology adoption with modern market channel adoption.

Particularly the relation between farm technology adoption and modern market participation is very intriguing as farm technology (such as product choice and the use of modern technologies) can be both cause and consequence of market participation.

In this paper we propose to address the above two relative gaps in the literature. Using a constructed-panel over 10 years of horticultural growers in Nicaragua, we address three questions: (1) What are the determinants of adoption per se, and (waiting) time to adoption, of farmers into the supermarket channel? (2) What are the determinants of "duration" as supermarket suppliers? (3) What is the effect of time to adoption and duration on farm capital and farm technology choice, in particular of modern technologies for "capital-led intensification" (a term used by Lele and Stone, 1989)? For questions 1 and 2 we want to particularly analyze the effect of product choice (production of niche crops) and use of drip irrigation (a modern technology) as determinants of adoption and duration as supermarket suppliers.

We address these questions with a single-spell duration model framework with time-varying and time-invariant covariates. The analysis uses a panel constructed from a stratified random sample of horticultural growers (supermarket suppliers and non-suppliers) collected in 2010 (with 10 year recalls). We follow Carletto et al. (2010) in the general empirical approach for the determinants of time to adoption and duration, but add a stage of analysis of impacts of

these on farm assets and technology choice (two categories of analysis absent in the Carletto analysis.)

The paper proceeds as follows. Section 2 describes the model. Section 3 describes the data and descriptive results. Section 4 describes the econometric results. Section 5 concludes.

THE MODEL: THE DETERMINANTS AND EFFECTS OF FARMERS' ENTRY AND DURATION IN THE MODERN CHANNEL

(a) Theoretical and General Implementation models

As our focus is an empirical contribution, we do not present a new theoretical model but draw heavily in this sub-section on the conceptual framework laid out in Carletto et al. (1999, 2010). While their work focused on entry in the non-traditional horticulture exports market by adoption of the crops for that market, it is directly relevant to our treatment of adoption of – entry in – and duration in the supermarket channel in the domestic food market. Thus we merely summarize their conceptual model in this subsection.

Carletto et al. specify a farm household model where a household decides the allocation of its land endowment (A) between traditional market (crops), $A_{o,}$ and non-traditional (modern) market crops, A_1. Participation in the traditional market is perceived as less production-risky but also has a lower expected return compared to the modern market. However, modern market entry costs are perceived higher than those of traditional markets, as modern markets demand higher quality and consistent supply all year long, which can imply capital led investments (such as irrigation). With the vector of variable inputs valued at the cost w_x, the income per hectare can be written as follows:

For traditional market (crops),

$$\prod_0(p_0, w, z_0) + \theta_0 \quad (2.1)$$

For modern market (crops),

$$\prod_1(p_1, w, z_1) + \theta_1 \quad (2.2)$$

With

$$E(\theta_0) = E(\theta_1) = 0, \sum(\theta_0, \theta_1) = (\sigma_0^2, \sigma_1^2, \rho_{01}\sigma_0\sigma_1) \quad (2.3)$$

where

(1) p_o and p_1, are the expected crop prices in the traditional and modern markets respectively;

(2) Π_0 and Π_1 are the expected incomes per hectare of the crops sold to the traditional and modern market;

(3) Σ is the variance-covariance matrix of the risk terms θ_0 and θ_1; and

(4) z_0 and z_l household assets that affect expected income from each market channel.

If the household decides to allocate land to the modern market channel ($A_1 > 0$), then the household's total income is

$$Y = (\Pi_0 + \theta_0)A_0 + (\Pi_1 + \theta_1)A_1 + T - c_1, \quad (2.4)$$

where

(1) c_1 is the modern markets' fixed entry costs; and

(2) T is other sources of income.

Assuming that the household is risk averse, it will decide to adopt the modern market channel when the change in utility due to adoption (ΔU_a) is positive, given an optimal level of allocation to modern market (A_1). That change in utility is determined by the following function:

$$\Delta U_a = \frac{1}{2\phi(\sigma_0^2+\sigma_1^2+2\rho_{01}\sigma_0\sigma_1)}[(\Pi_1 - \Pi_0) - \phi(\rho_{01}\sigma_0\sigma_1 - \sigma_0^2)]^2 - c_1 > 0 \qquad (2.5)$$

We now proceed to the specification of the regression model and estimation procedure we use to implement the conceptual model.

We "translate" the theoretical model into an implementation model that has the general form of the equations, and the general categories of variables used in Carletto et al. Following the theoretical model presented we can rewrite equation 2.5, the change in utility from adoption, as follows:

$$\Delta U_a = \Delta U_a(p_0, p_1, w_x, FK, HK, SK, T_o, t_a, V \qquad (2.6)$$

In an analogous way the decision to withdraw is determined by the change in utility that determines withdrawal ΔU_w; initially this change is negative, but may become positive ($\Delta U_w > 0$) and encourage the household to withdraw.

$$\Delta U_w = \Delta U_w(p_0, p_1, w_x, FK, HK, SK, T_a, t_w, V) \qquad (2.7)$$

2.7 is similar to 2.6, with the difference that the earliest time for withdrawal is the time when the household adopts the supermarket market channel (T_a) and the duration of the withdrawal spell is included as t_w.

The equations show that the change in utility from adoption or withdrawal is a function of the following:

1) The exogenous output prices,
2) The exogenous input prices,
3) Household assets: human capital (*HK*); farm capital (*FK*); social capital (*SK*); and community capital (*CK*).

4) Time, which enters the duration equations in several ways:

   a. T_o, the potential earliest year for adoption which is either when the modern market becomes accessible to the household or when the household is formed;

   b. t_a, the household's "time to adoption" which is the time period between T_o and the year the household adopted (T_a);

   c. t_w, the time from adoption to the time of withdrawal, or the "duration," which is the time as a supplier if they adopted; note that withdrawal may not yet (or never occur).

In most duration models, observations on t_a are of two types:

(1) The household has adopted the supermarket market channel, then the value of t_a is directly observed; and

(2) The household has not yet adopted at the time of the survey, so that we have truncated information, since the length of the duration spell (t_a) is greater than the length of the observed pre-adoption spell.

We will analyze the "time to adoption" (waiting time of the household before adoption also called in the duration literature the adoption spell) and if the household adopts, the time to withdraw (or duration). Therefore, we manipulate equations 2.6 and 2.7 to express t(a) and t(w) as functions of the explanatory variables in those equations. This will be a prelude to specifying the regression equations in the next subsection. Thus,

$$t_a = t_a(p_0, p_1, w_x, FK, HK, SK, T_o, V) \qquad (2.8)$$

Since we analyze farm duration as supermarket supplier (waiting time before withdrawal, also known as the withdrawal spell), it is as follows:

$$t_w = t_w(p_0, p_1, w_x, FK, HK, SK, T_a, V) \quad (2.9)$$

We will also analyze **the effects** of duration itself on farm households, with a particular focus on effects on farm capital, product choice and the use of modern technologies in horticulture production, which can be modeled as follows:

$$FK = FK(p_0, p_1, w_x, A_0, A_1, \widetilde{t_w}, HK, V) \quad (2.10)$$

$$q = q(p_0, p_1, w_x, A_0, A_1, \widetilde{t_w}, HK, V) \quad (2.11)$$

where (*FK*) are farm assets, (q) is a vector of variable inputs and modern technologies, and $\widetilde{t_w}$ is the predicted duration from the first stage.

(b) Regression specification, First Stage

Following the general theoretical framework laid out above, in this sub-section we lay out and the details of the regression specification.

The two regressions we use to determine t(a) and t(w) are as follows, with a discussion of each variable thereafter. As t(a) and t(w) equations have most of the same arguments we represent them as follows.

t_a, t_w = f(age of HHH, education of HHH, gender of HHH, adults in HH, share of adults in OFE (off-farm employment), HH is member of cooperative, land, drip irrigation, livestock, farm assets (other than land and livestock), nonfarm productive assets, distance to ag-store, distance to market, horticultural price index, farm elevation, urban share in the district, rural density of the district, production of niche crops, product choice dummies; T_o (in the t_a equation only), and T_a (only in the equation for t_w)

The dependent variables for this model are:

(a) Time to adoption (Adoption spell, t_a): this variable is defined as the period of time (in years) the household takes from the initial exposure to the possibility of adoption of the supermarket market channel, to the actual time when the household adopts the supermarket channel. Duration analysis accounts for right censoring, as the value of t_a is not always observed. Some households that are exposed to the possibility of adoption do not adopt at the time of the survey, and therefore we have truncated information.

(b) Duration (withdrawal spell, t_w): Once households have adopted the supermarket market channel, this variable is defined as the period of time (in years) that the household takes from the initial time of adoption of the supermarket market channel, to the actual time when the household withdraws from the supermarket market channel. Similar to the definition of t_a, not all households that have adopted the supermarket channel withdraw from it before the time of the survey, therefore we do not observe withdrawal for some households and thus have truncated information. However, duration analysis accounts for right censored data.

The explanatory variables are as follows.

Output prices

Output price index (time-varying, 2005-2010). Using factor analysis of the principal component to calculate a price index. The index is based on the village-level traditional-market prices for tomato, lettuce and sweet peppers. Households recalled the village price for first-grade quality for each crop for each year from 2005 to 2010[1]. Since the current period price can be

[1] We did not collect historic prices from 2000-2004, and thus use the 2005 recalled village price for that period of time. For robustness, we re-estimated the econometric analysis, only using the 2005-2010 period. Results are presented in Annex A.

endogenous we use a one year lagged price as the expected price is formed assuming a naive price expectation.

Input prices

Input prices charged by the vendor are in general similar over households for a given input, as the geographic zone is not broad. To then get variation in input prices, we instead use the distance from the household to the nearest agro-inputs store, measured in kilometers (w_x, time invariant).

Household assets (z_0 and z_1)

Human capital (HK)

(a) Number of adults in the household from 2000 to 2010 (time-varying): the availability of household labor each year is posited to increase the probability of adoption and delay the decision of withdrawing from the supermarket channel, presumed to be more labor demanding to meet quality requirements.

(b) Age of the household head (HHH) at the time of adoption (time-invariant): The hypothesis is ambiguous. Younger HHHs may be less risk averse and willing to chance new market channels. But older HHHs have more experience that allows them to address the requirements of adapting to the modern channel.

(c) Years of education of the HHH at the time of adoption (time-invariant):

(d) Average years of education of the adults of the household (time-invariant): We have included this to control for all adults' education, as it may not be only the HHH who decides or executes the participation. The a priori effect on time-to-adoption is ambiguous. More education could aid the household to adapt to the more demanding channel's technology and

commercial requirements. But more education can also increase the household's options to work in nonfarm employment (Taylor and Yunez-Naude, 2000) and thus not depend on upgrading the farm market channel. The a priori effect on duration is also ambiguous. More education confers more flexibility in activity choice and so would facilitate options should the household want to withdraw from the modern channel. But more education could help the household to adapt to the evolving requirements of the modern channel and prolong their participation in it.

(e) Share of adults working in local off-farm employment in 2005 and 2010: The effect of this variable is a priori ambiguous. In the presence of credit constraints, in principal off-farm earnings can fund investments to participate in the modern channel, and off-set market risk. But off-farm employment can act as a substitute to new farm technology adoption (Huang et al. 2009) or the need to upgrade to a modern market channel.

(f) Nonfarm (productive) assets from 2000 to 2010 (time-varying): We used factor analysis of the principal component to calculate an asset index (using the Thomson scoring method); its effect is posited to be similar to the share of adults working in off-farm employment. However, non-farm productive assets are important for participation in off-farm self-employment, while the share of adults working off-farm is related to participation in off-farm wage employment and self-employment.

Farm physical capital (FK)

(a) Total land owned (ha) each year from 2000 to 2010 (time-varying): This is land for all uses (cropping, pasture, fallow, and rocky/bush land) each year in the past 10 years. Land owned is posited to decrease time to adoption and increase duration due to wealth effects (increasing access to credit and reducing aversion to risk (Newbery and Stiglitz, 1981)).

(b) Drip irrigation (dummy) each year from 2000 to 2010 (time-varying): This is posited to reduce time to adoption and increase duration as drip irrigation increases produce quality and allows multiple seasons and thus delivery to supermarket channels all year (a practice known to be desired by supermarkets).

(c) Non-land farm assets from 2000 to 2010 (time-varying): This vector includes irrigation equipment, greenhouses, tractors, plows, sprayers, fumigators, small tools, and other equipment. We posit that these assets decrease time to adoption and increase duration because they allow the farmer to meet quality and consistency requirements and may embody previous farming experience and performance (Carletto et al. 2010). We used factor analysis of the principal component to calculate asset indexes (using the Thomson scoring method)

(d) Total value of livestock owned in 2005 and 2010 (time-varying): The effects posited echo those of other assets.

(e) Farm elevation in 2010 (time-invariant). The elevation of the farm was measured by our survey team by GPS during data collection. Farm households that are located in the mountains tend to be in the "hinterlands" and thus present higher transaction costs to access modern market channels. Mountain areas tend also to have less favorable farming conditions.

(f) Cultivation of niche crops from 2000 to 2010 (time varying): this is a dummy variable that shows whether the household grew a niche variety crop. We posit that growing a niche variety crop reduces the time to adoption period, and extends the duration as supermarket supplier. These kind of crops are very important for supermarket buyers to attract customers, and therefore farmers who grow niche crops have a competitive advantage compared to farmers who don't.

(g) Cultivation of target crops (tomato, sweet peppers and lettuce) from 2000 to 2010 (time varying): we have included three dummy variables that show whether the household grew any of the three target crops in our sample (or combinations of them). Therefore we are able to control whether the household is specialized in one crop, or grows multiple crops. Furthermore, these crops represent three different degrees of perishability (high, medium and low perishability for lettuce, tomato and sweet peppers respectively), an therefore we can analyze the effect of perishability on time to adoption and duration as supermarket suppliers.

Community Capital (CK)

(a) Urban share of total population at the municipality level in 2005 (time-invariant). We use this as a proxy of density of road infrastructure. Procurement divisions of supermarket chains logically tend to want to work with areas with better road networks to reduce transaction costs. The data come from the Instituto Nacional de Informacion de Desarrollo (INIDE), http://www.inide.gob.ni/.

(b) Rural density at the municipality level in 2005 (time-invariant). This variable is another proxy for road infrastructure, and therefore we expect similar effects as posited for the urban share of population. The data come from the Instituto Nacional de Informacion de Desarrollo (INIDE), http://www.inide.gob.ni/.

Time variable

T_0 (for the t_a equation only) is either 2001, which is the earliest year that supermarket chains began procuring directly from farmers in Nicaragua, or the year of the household farm formation, if that occurred later than 2001. Note that about 10% of the households were formed after 2001, so there is significant variation in this variable. We posit ambiguous effects of this variable on

time to adoption: it can shorten it as those being exposed later enter a situation where many other households have adopted and they can more quickly assess the risk and learn the techniques from them; but a later exposure also means they enter a situation that may have (we cannot test for this) greater competition and requirements relative to the situation faced by those exposed earlier.

Instrumental variables

Both time and adoption and duration as supermarket supplier can be endogenous determinants of the use of modern technologies, cultivation of niche/highly perishable crops, and capital led intensification in the farm. One can posit that for example natural ability (an unobserved household characteristic) can influence not just the decisions to adopt and remain as modern market suppliers, but can also influence the decision to adopt modern technologies, use of purchased variable inputs, and the choice of crops that the household grows.

Therefore, we need to find at least one instrumental variable which is (1) correlated with the decision of participation in a modern market (as supplier) , after controlling for other factors, but that is (2) not correlated with the error terms (unobserved household characteristics).

We have chosen the following two predetermined time-invariant variables as instruments:

(a) Distance from household to the nearest wholesale market;

(b) Distance from household to the nearest traditional retail market;

We have chosen these variables as instruments because of the following reasons:

First, both wholesale and retail markets are the main alternative traditional markets where horticultural households sell their produce. Shorter distances to any of the traditional alternatives

represent lower transaction costs, and will negatively impact the decision to adopt a modern market.

Second, controlling for zone and other meso level characteristics, there is no economic reasoning of why these distance variables are correlated with unobserved variables that will affect the decision to adopt modern technologies or the choice of inputs used in horticulture production.

Last, both traditional markets (and their respective distances) are exogenously predetermined to the individual household.

To estimate the first stage equations, we proceed as follows. Duration models are based on the implementation of hazard rates which are used to analyze decisions over time. The specification of the hazard rate can be done using both parametric and non-parametric methods. Our estimation is performed using Maximum Likelihood. We chose a parametric approach using a Weibull distribution. Drawing on Carletto et al. (2010) we specify the hazard function as follows:

$$h(t) = \lambda(x)^{\rho} \rho t^{\rho-1} \qquad (4.1)$$

where

$$\lambda(x) = e^{-\beta' x} \qquad (4.2)$$

(1) λ is the scale parameter, a function of the vector of covariates (x), and

(2) ρ is the shape parameter, which captures the monotonic time dependency of the event.

We use the Accelerated Failure Time (AFT) transformation of the proportional hazards model, as it yields easier results for interpretation. The AFT coefficients reflect the acceleration

and deceleration effect on time-to-adoption and time-to-withdrawal, which is an analogous interpretation of common regression models. The AFT model can be written form as follows:

$$\log(t) = \beta' X + \sigma\varepsilon, \qquad (4.4)$$

where

(1) t is a non-negative random variable denoting the time of the event (adoption or withdrawal),

(2) X is the vector of explanatory variables,

(3) β is the vector of coefficients,

(4) ε is the error term[2],

(5) σ is a scalar that is equivalent to the inverse of the shape parameter ($\sigma=1/\rho$).

(c) The Effects equations, second stage

The second stage models the effects of farm households' time to adoption and duration as supermarket channel suppliers (among other variables) on farm assets and technology use in 2010[3]. The latter is selectively represented by indicators of technology modernization in horticulture cultivation:

[2] The error term, in the case of a Weibull hazard function, follows an Extreme value distribution.

[3] There are two details about the second stage analysis that are important to address: First, since we are interested in analyzing duration as supermarket suppliers as a right hand side variable, then the second stage uses the subsample of farmers who at some point have adopted the supermarket market channel as you need to "adopt" the supermarket channel in order to have a record of duration as supplier. Second, the "time to adoption" period (adoption spell) stops when

(a) Area under drip irrigation: This is a substantial investment and important for plant growth and quality control as well as multiple season production to ensure steady supply to buyers, and thus we posit a positive effect of duration on this.

(b) Use of purchased tray-seedlings (dummy variable): These are superior to the traditional open-field nurseries on-farm as the latter are susceptible to pests and can produce weak seedlings (and thus affect output and uniformity of quality). Tray seedlings, produced in greenhouses, are more uniform in output and quality, though more expensive. Again we hypothesize a positive effect of duration as supermarkets seek consistency and quality.

(c) Hired labor used: We posit that duration is positively associated with hired labor as the latter relaxes labor constraints over the season thus avoiding quality-diminishing practices (like skipping weedings).

(d) Fertilizer used: We hypothesize that duration is associated with more fertilizer use; more fertilizer used, and more frequent fertilizer application allow both greater tomato quality consistency over the season and more harvestings from a given field.

(e) Pesticide used per ha: We posit that this is correlated with duration as supermarket buyers seek less blemished produce.

(f) Share of "highly-toxic" pesticide (red-labeled chemicals, as opposed to other chemical labels, which are yellow, blue, and green) in all pesticides used (red + yellow + blue + green). We posit that duration is negatively related to this share as supermarket buyers indicate their preference for pesticide safety; for example, Walmart provides manuals to its Nicaraguan suppliers wherein they note that highly-toxic pesticides should be avoided.

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the "duration" period (withdrawal spell) begins, therefore our panel is reduced to a cross section, hence the reason why we chose to analyze the effects on farm assets and technology use in 2010.

(g) Farm non-land assets (as defined in the first stage): This variable is the total value of non-land farm assets that includes irrigation equipment, greenhouses, tractors, plows, sprayers, fumigators, small tools, and other equipment. We posit that that duration should be positively related to farm asset as earnings from selling to supermarkets can be invested back into the farm.

The above variables are modeled as determined by the following.

a) Duration (fitted value from the first stage)[4]
b) Time to adoption (fitted value from the first stage)
c) Farm productive non-land assets. (this variable is in all technology equations but not in the farm asset equation);
d) The age of HHH and gender of the household head;
e) Number of adults in the household;
f) Land and livestock holdings;
g) and a measure of net profitability via including the price index (lagged one year) and input costs proxied by distance to input stores (time invariant).

The effects equations are estimated as a system using Zellner's seemingly unrelated regression (SUR) model to exploit potential correlation across the errors in all system equations. Since we are using two variables not actually observed (fitted values for time to adoption and

[4] We use the fitted values of duration and time to adoption derived from the first stage (duration and time to adoption equations); as time to adoption and duration as a supermarket supplier can be endogenous determinants in the technology equations.

duration periods), we use a bootstrapping procedure to obtain the correct standard errors (Wooldridge, 2002).

3. DATA AND DESCRIPTIVE STATISTICS

The analysis uses a longitudinal data set of farm household information for 10 years, 2000 to 2010; this was constructed through recalled information by surveying a sample of producers of three target crops (tomato, sweet peppers and lettuce) selling to supermarkets and traditional sector in 2010.

The sample was constructed by using a stratified random sampling procedure that relied on the identification of the quasi-population of supermarket producers as the treatment group; the control group was chosen from a nationally representative random sample of traditional producers (selling only to traditional wholesale markets, not to supermarkets) constructed from the 2005 agrarian census and revisited by the ministry of agriculture in 2009. The sample consisted of 794 households: 337 selling to supermarkets (and possibly also traditional markets); and 457 selling to traditional wholesalers.

We used a structured questionnaire to collect information about household and farm characteristics, production and farm income, market channel choices, participation in organizations, and access to services like credit and technical assistance.

42% of farmers included in the sample adopted the supermarket channel at some point over the observation period (10 years). However, the diffusion was gradual; Figure 1 shows the survivor function for the market channel adoption decision, which can be interpreted as the share of households that have not adopted the supermarket channel at a given time *t*. This graph shows

that farmers began adopting the supermarket channel soon after being exposed to the "risk" of adoption, but the shape of the survival function might suggests high entry costs of adoption, as the share of households not yet participating in the supermarket market channel decreased slowly. This is also confirmed by looking at the hazard function (Figure 2) of the adoption spell, which explains the likelihood of adoption in each time period, conditional on not having adopted by the previous time period. The adoption hazard function peaks around six years and then sharply declines after the peak, which implies that if farmers did not adopt the new market channel within six years of being exposed to the risk of adoption, then they are less likely to adopt in the following years.

Interestingly, once farmers adopted the supermarket market channel, they seem to remain as steady suppliers, and do not abandon the new market channel immediately. Figure 3 shows the survival function of the withdrawal decision; it shows that the first signs of desertion do not occur before four years after the household has adopted the supermarket channel. By the tenth year (which is the end of the observation period), 75% of the adopters remained as supermarket suppliers, and therefore supplied uninterruptedly. The withdrawal hazard function (Figure 4) shows similar results, as farmers supplying the supermarket channel (adopters) have an increasing pressure to withdraw that peaks between 7 to 8 years, implying that if farmers did not abandon the supermarket channel in this period, they are less likely to do it in the upcoming years. The results of the survivor functions (Figures 1 and 3) and hazard functions (Figures 2 and 4) should be interpreted with caution as a 10 year period is a relatively short period of observation.

Below we present selected descriptive statistics, analyzing first the households' characteristics and income distribution (Tables 1) and then their farm characteristics and

technology use (Table 2). We first discuss the strata of adopters vs. non-adopters (of the modern channel), and then, among adopters, early adopters (adopting within the first four years from being exposed to the risk of adoption) versus late adopters (adopting after five or more years), and then, also among adopters, those with short duration as suppliers (participating less than five years as supermarket suppliers) versus long duration (more than five years as supermarket suppliers).

(a) Household Characteristics

First, the household characteristics, including household size, age, and gender of the HHH, do not differ much between adopters and non-adopters households. However all education measures (education of the HHH, average education of the household, and the highest education level attained by any member of the household) are significantly higher for adopters vs. non-adopters and this difference is magnified when we divide adopters into short vs. long duration where education measures are significantly higher for households who have a long duration, compared with those with short duration. This suggests that education helps households adapt to evolving requirements of modern channels.

Second, households who have adopted the supermarket channel participate more in off-farm employment (compared with non-adopters). This could be because of the liquidity (retained earnings) effects of off-farm employment, or its risk management cum diversification role, or both. The off-farm participation is even more striking between long and short duration as modern suppliers; the latter are actually are not statistically different from non-adopters in this respect.

Third, the adopter group has a higher share of households participating in production cooperatives. This corroborates empirically what our key informant qualitative interviews with

supermarket procurement officers, who noted that they like to work with farm cooperatives to reduce their transaction costs, and with small farmers, who noted that when supplying supermarkets they like to work in cooperatives to overcome asset thresholds (such as by accessing a collective packing/sorting facility). Moreover, the share of late adopters participating in cooperatives is 10% higher than among non-adopters. This special importance of cooperatives for late adopters could imply that cooperatives are an important facilitator and inducement for small farmers to participate in modern channels, as suggested by von Braun et al. (1989) for non-traditional exports from Guatemala.

Fourth, adopters and non-adopters have similar profiles with respect to migration, distance to infrastructure and nonfarm assets. Nevertheless adopters seems to be less dependent on temporary migration and are closer to secondary schools and hospitals (proxies for transaction costs). However differences are magnified when we distinguish short duration (as supplier to supermarkets) from long duration, we find the latter to live closer to retail and wholesale markets, hospitals, and schools, which are clustered in towns and proximity to these proxies lower transaction costs.

Fifth, total household income is significantly different between adopters and non-adopters, as adopters earn 256% higher per capita income than non-adopters and this difference is considerably higher for early adopters (292%) and long duration households (433%). Only short duration households are statistically not different from non-adopters, which in turn are very similar to the Nicaragua's GNI ($1,008) for 2010.

Both adopters and non-adopters are mainly dependent on farm income. However adopters are more specialized horticulture growers, as they earn two thirds of their total income from production of tomatoes, sweet peppers and/or lettuce, while non-adopters only earn 38% from

production of those crops. Furthermore, when we analyze the difference in earnings from target crops, we can see that adopters make 370% higher earnings compared to non-adopters and this difference is even more striking when analyzing early adopters (495% higher) and long duration (as supermarket suppliers) households (566% higher).

(b) Farm characteristics: land and non-land assets and tomato production

First, contrary to expectations fueled by worries in the debate about whether small farmers will be excluded from modern supply chains, we find that modern market channel adopters and non-adopters have similar farm sizes and cropped land. Segregating adopters between early vs. late adopters, and short vs. long duration households show no statistical difference on farm size and cropped land with non-adopters, hence reinforcing the conclusion of no smallholder exclusion.

Second, farm assets show a different result as non-adopters have significantly lower non-land farm asset holdings compared to adopters. However, the results are even more striking when we segregate early vs. late adopters and short vs. long duration as early adopters and long duration households have significantly more farm assets than non-adopters, while late adopters and short duration households are not statistically different from non-adopters.

Third, adopters and non-adopters grow similar areas of target crops (with the exception of lettuce area, where adopters grow 57% more area than non-adopters). However, it seems that adopters are more specialized producers, as they harvest around twice the amount of produce, and have on average twice higher yields for all target crops both in 2005 and 2010. The results are even more striking when we analyze the differences between early and late adopters, where late adopters have more comparable yields with non-adopters, while early adopters are the group with the highest yields and production. This result is interesting because combined with the

previous results, it begins to show how late adopters seem to be as small, asset poor and non-specialized producers as non-adopters. Shorter and longer-duration adopters have similar yields and production for all crops in 2005 and 2010. However they are significantly higher than non-adopters. We will see below that these yield differences are linked to early adopters and longer-duration adopters having more capital-intensive production.

Fourth, the share of farmers having drip-irrigation is significantly higher for adopters than non-adopters in 2005 and 2010. There are around 33% more households with drip irrigation in both years, and the difference increases as we analyze short vs long duration adopters. Long duration adopters have around 50% more households with drip irrigation compared to non-adopters. This result reinforce the conclusion that adopters are more specialized, capital-intensive production systems.

Fifth, as expected, in both 2005 and 2010, adopters are three times as likely to use purchased-tray-seedlings compared to non-adopters (about 67 versus 22%). Within the adopter group, early adopters and long-duration farms are much more likely to use this technology – and to have increased substantially the use of it over five years – compared with the late adopters and short-duration farms. The bulk of the diffusion of this technology was thus among the "leading group" of modern market channel farmers.

Sixth, we expected a more widespread diffusion of tunnels overall, and a sharp difference between adopters and non-adopters, but found that only about 5-9% of the adopters used tunnels, versus 3-4% among non-adopters. The most differentiation was between early and late adopters, with 10% and 3% using tunnels, respectively. Once again this results is supporting previous results portraying late adopters as the asset poorest category of small farmers.

Finally, adopters have much more variable-input intensive technology than non-adopters – spending 20% more per hectare overall. But the main sources of difference are from expenditure on chemical fertilizers (giving better yields and greater consistency) and seedlings (from more use of purchased tray seedlings to get higher quality and yields); however, in terms of labor and pesticides, the two groups do not have statistically significant differences. Moreover, the share of labor (own and hired) in total variable input outlays is similar (a sixth) between adopters and non-adopters. However, non-adopters have higher family labor expenditures while adopters have higher hired labor expenditures.

Moreover, the comparison of adopters and non-adopters masks an important difference within the adopter group: while early adopters' variable input use (excluding seedlings) is not statistically different from non-adopters, the late-adopters (recall this is a smaller and more asset-constrained group than the early adopters) use slightly more variable inputs than the early adopters. Interestingly (and unexpectedly), the labor share in total costs is about a sixth for each of them, so it is not that the small-farmer late adopters are using a higher labor intensity.

4. ECONOMETRIC FINDINGS

(a) Determinants of Time-to-Adoption

Table 3 shows the results of regressions explaining time-to-adoption and duration (time to withdrawal), which we call adoption spell and withdrawal spell, after the literature. As noted above in the section on the regression specification, we use an Accelerated Failure Time (AFT) transformation of the proportional hazards model; the AFT coefficients reflect the acceleration and deceleration effect on time-to-adoption and time-to-withdrawal, which is an analogous

interpretation of common regression models. Negative coefficients imply higher probability of adoption (or withdrawal) as it suggests that the coefficient's variable reduces the pre-adoption (pre-withdrawal) spell. We discuss the statistically significant results below and in some cases highlight variables we expected to be significant but were not. The likelihood ratio test of significance of the regressions (chi squared statistics) and the p values associated with these statistics show the overall significance of both the adoption and withdrawal spells models to be significant at 1% level.

Several results are salient for the determinants of time-to-adoption.

First, we believe that an important result for the literature is that the (lagged) farm size (all owned land) does not affect time-to-adoption. We had expected larger farms to adopt earlier and to adopt at all, but this was not borne out by the analysis. This adds evidence of "small farmer inclusion in modern markets" to the recent development literature for which this is a controversy (see Swinnen 2007 and Reardon et al. 2009).

Second, several variables associated with skills and alternatives, lead to shorter time to adoption, as we hypothesized. This is the case for: (1) average education of the households' adult members; and (2) the greater the share of adults working in off-farm employment.

Third, drip irrigation (lagged) lessens the time to adoption. This is as expected, given the expectations of supermarket buyers of quality, consistency, and multi-seasonal supply from farmers. This result mirrors results for static adoption analysis of tomato growers' participation in supermarket channels in Guatemala (Hernandez et al., 2007) and horticulture farmers in Honduras (Blandon et al., 2009).

In the same line (regarding growing conditions), by contrast, a greater elevation of the farm has the effect of lengthening the time to adoption. farms located in the mountains have worse agroclimatic and transaction cost situations compared to those on the plains.

Fourth, the lagged first-grade (quality) traditional-market price index lengthens the time to adoption of the modern market, apparently as a simple situation of inter-channel competition via profitability.

Fifth, interestingly lagged decisions to grow tomatoes (medium degree of perishability) and lettuce (highly perishable) significantly reduces the time to adoption period. This may corroborate other findings from our semi-structure key informant interviews with supermarket buyers, where they point out the challenge to find adequate suppliers for these products as highly perishable products are more difficult to handle, and once supermarkets find suppliers they are interested in developing a long term relationship.

Sixth, the year of first exposure to supermarket participation significantly determines adoption of the supermarket channel. Farmers who were exposed late to the possibility of adoption tend to have shorter periods of time to entry. This may be attributed to "learning from others" where farmers take advantage from the experience from prior adopters.

(b) Determinants of duration or Withdrawal spell

We discuss the main findings below.

First, we found that (lagged) farm size was a significant determinant of duration in the supermarket channel. Farm households with larger land holdings tend to withdraw from supplying supermarkets than smallholders. This is a fascinating result as it corroborates recent findings in the literature (Michelson et al., 2011) where supermarkets have lower prices

compared to traditional market prices, but they also have lower price volatility, and therefore represent a lower risk alternative for smallholders. Therefore, larger farmers are more willing to take the risk associated with supplying the traditional market, rather than taking a more stable (but lower) supermarket price.

Second, analogous to our findings that drip irrigation shortens the time to adoption, the same factor lengthen the duration as a supermarket supplier for those households that adopted the modern channel.

Third, livestock has a negative effect on duration as supermarket supplier. This result might show the importance of specialization in horticulture, as farmers have an alternative farm income source as their livestock holdings increase.

Fourth, growing (lagged one year) niche crop varieties lengthen duration as supermarket suppliers. This result was expected as supermarkets are specially interested in recruiting farmers who have the capacity to grow niche varieties, as they are important supermarket products to attract customers.

Fifth, the earlier the (year of) adoption, the longer the duration of the adopter in the modern channel. This result may reflect a "first mover advantage" as they have time to accumulate the needed knowledge and skills to cope with the requirements and vicissitudes of being in the modern channel.

c) Effect of Duration on Farm Capital Accumulation and Technology Use

Table 4 shows the effects of duration and other variables. Several significant results emerged from the regressions.

First and most important for our purposes, duration is positively correlated with use of capital-intensive “modern technologies” including drip irrigation, purchased tray seedlings, hired labor, and production of niche crops.Thus supporting the main hypothesis that consistent participation in modern markets is correlated with capital led modernization and diversification.

Second, interestingly, duration is negatively correlated with the share of highly toxic pesticides in overall pesticide use. We had posited that this would be so because the supermarket chains tend to want this from their suppliers and our key informants from the chains noted that they communicate that to the farmers. Our finding that the modern channel reduces use of toxic pesticides stands in contrast to the impact of modern market channel development’s raising toxic pesticide use in horticulture in Latin America, posited (in the case of non-traditional export markets) by Lori Ann Thrupp in her 1995 book “Bittersweet harvests for global supermarkets: challenges in Latin America's agricultural export boom.”

Third, time to adoption is on the other hand positively correlated with use of pesticides. This result might show how farmers who wait longer to enter the market channel tend to overuse pesticides, which might be an effect of not being subjected to the stricter pesticide use policy instituted by supermarkets to their suppliers.

Fourth, both duration and time to adoption are positively correlated with higher use of hired labor, which might be a result of life cycle.

Fifth, various farm household characteristics are correlated with specific technologies used. Household head being more educated have a positive effect on farm assets. This might be the result of educated households investing in farm assets that allow for more capital-labor substitution..

Sixth, the share of adults working in local off-farm employment is positively correlated with the total value of farm assets in 2010. This is an interesting result, as it might be signaling how earnings from off-farm employment are invested back in the farm.

Moreover, total cropped land in 2010 is negatively correlated with the use of drip irrigation in the same period.

5. CONCLUSIONS

First, our analysis suggests that there are significant entry costs for participation by farmers in the supermarket channel. This is inferred because: (1) although farmers began adopting the supermarket market channel soon after being exposed to the possibility of adoption, the speed of adoption appeared somewhat slow; and (2) once farmers adopted the new market channel, they most remained as steady suppliers.

Second, our descriptive results have shown different types of farm households and their relation to modern market participation. The segregation of early and late adopters have shown two very different types of farm households: while early adopters seem to have the "ideal" characteristics that are desired by supermarket procurement agents (more education, more income, higher use "modern" technologies, without overusing pesticides), late adopters lack these characteristics, and in some specific characteristics, are no different from non-adopters. Greater differences have been observed by segregating adopters into short versus long duration suppliers; long duration households have more education, more income and assets, more off-farm employment participation, higher yields, and tend to have greater use of modern technologies, compared to short duration households.

Third, there is evidence of a link between off-farm employment and modern market participation. Our results suggests that income diversification into nonfarm activities might bolster participation in supermarkets.

Fourth, our results have shown that indeed small farmers are "included" in the modern market channel; although we find land is not an excluding factor, we do find that non-land assets are a barrier to entry. Our results show that consistent suppliers have more capital (in particular drip irrigation, but also education) and use modern technologies that allow them to supply all year and position themselves to achieve greater production, and uniform and consistent quality, which are desired characteristics by supermarket procurement officers.

Fifth, production of niche crops is a competitive advantage to enter modern markets. Farmers growing niche varieties are well positioned to supply supermarkets. Moreover, product perishability brings another competitive advantage for smallholders, as supermarkets are eagerly looking for suppliers of these type of products. Both production of niche varieties and high perishable products imply necessary farmer's conditions (such as drip irrigation) and capacities (such as education and experience) that can become thresholds for adoption.

These results imply for policymakers working to help small farmers access modern supply channels in domestic markets that there is a need to promote access to non-land assets, in particular education and farm capital assets most needed to participate in these channels, as well as formation of production cooperatives that will provide collective assets to help small asset-poor farmers participate in modern markets.

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Figure 1. Adoption survivor function.

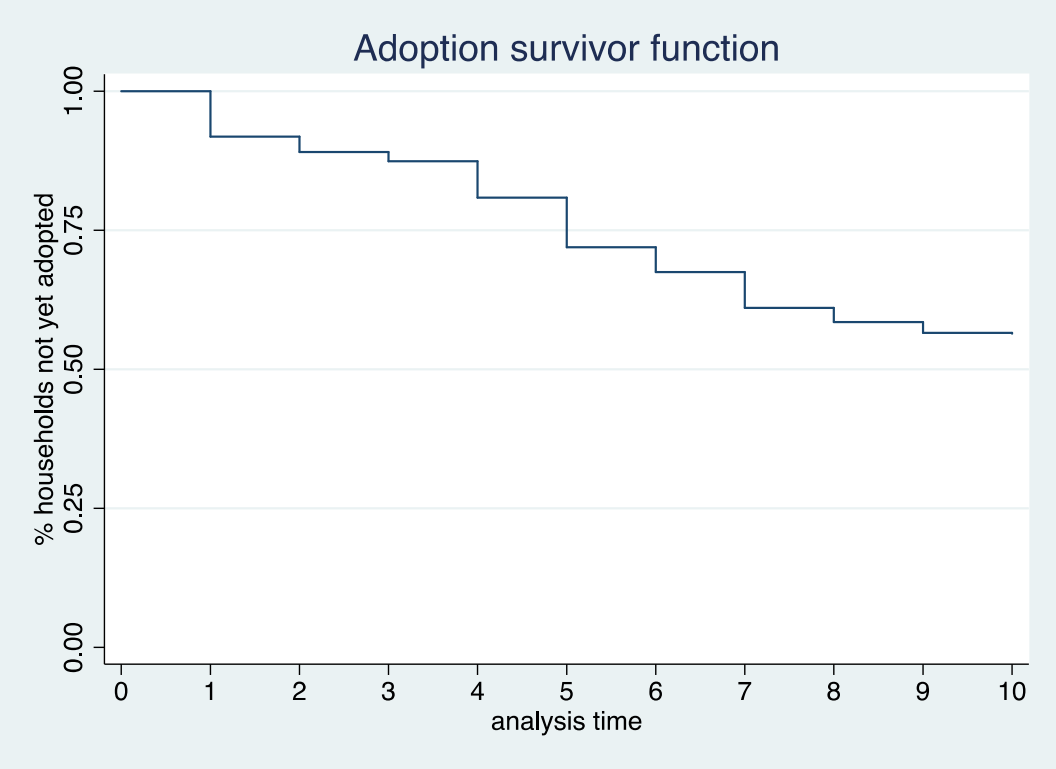

Figure 2. Hazard function, adoption.

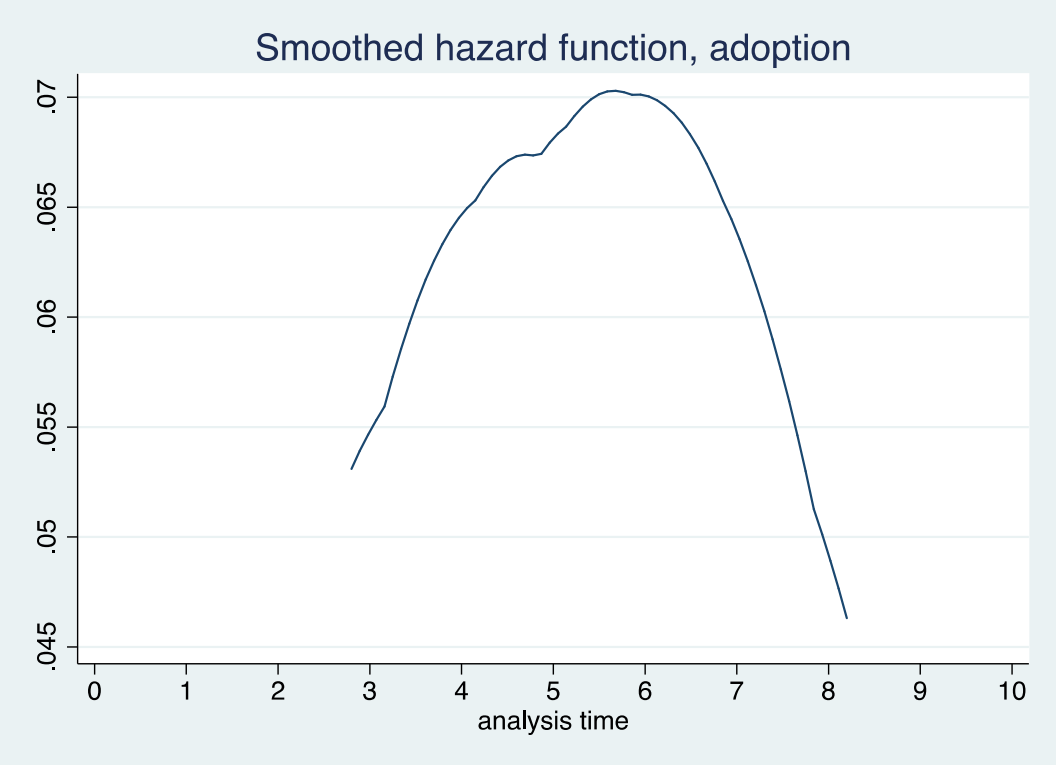

Figure 3. Withdrawal survivor function.

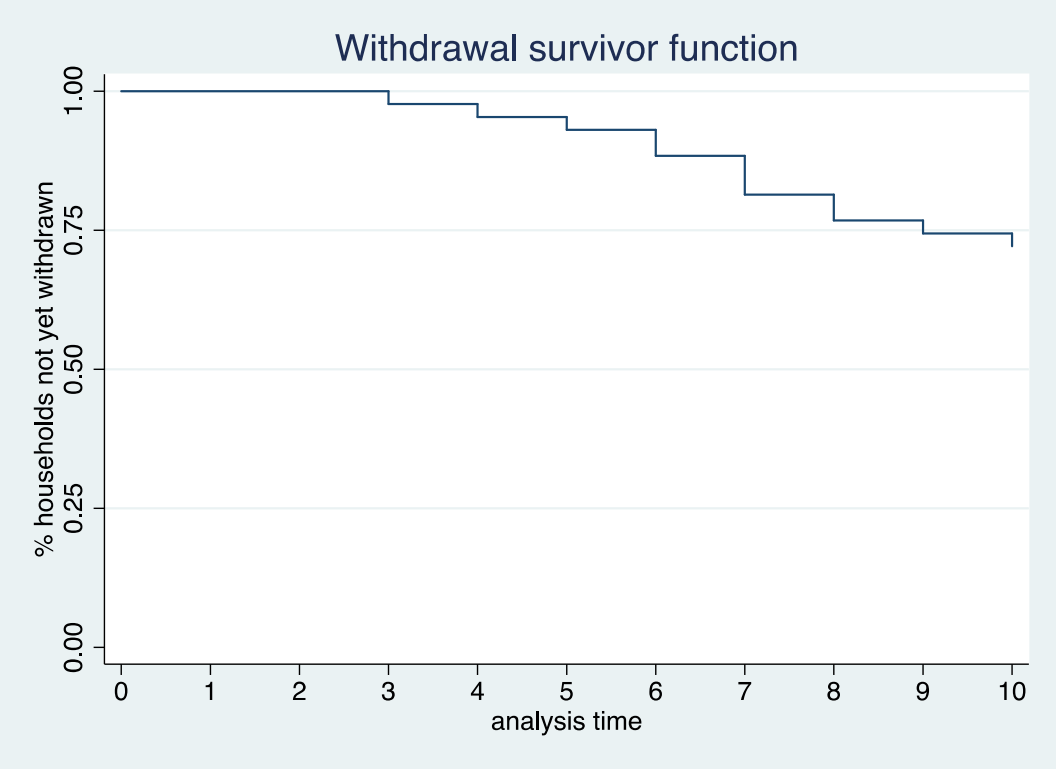

Figure 4. Hazard function, withdrawal.

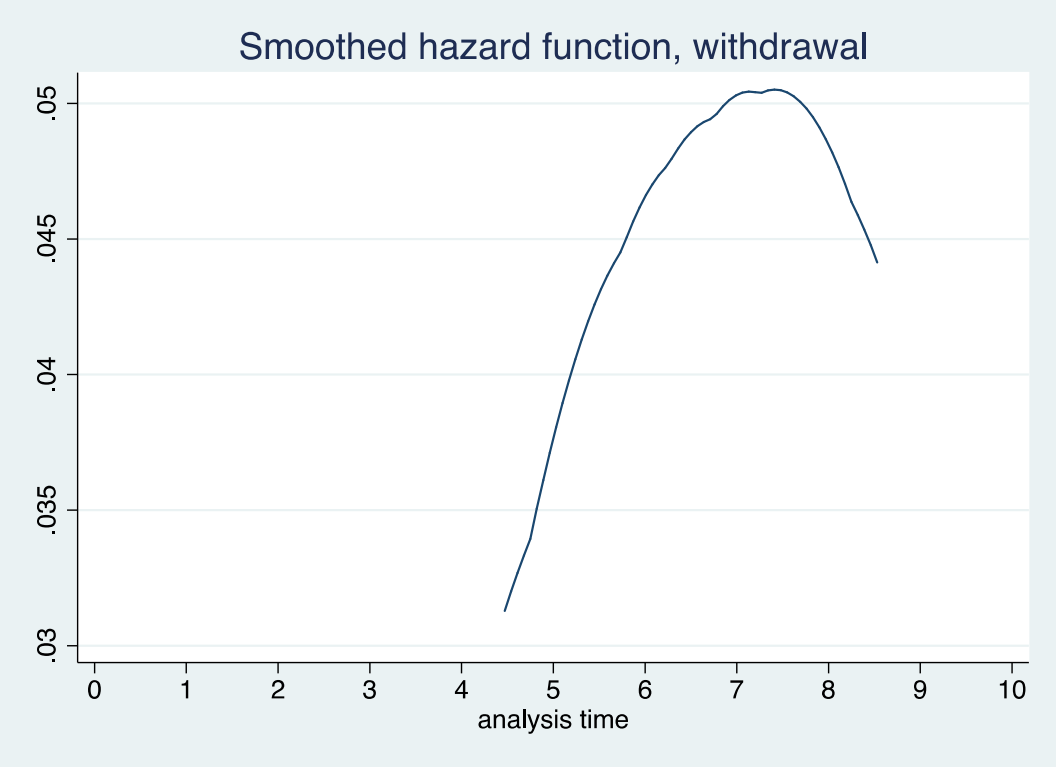

Table 1. Household characteristics and income distribution of vegetable growers in Nicaragua in 2010, by adoption category.

		NON ADOPTERS	ADOPTERS					TOTAL
			All	Early Adopters	Late Adopters	Short Duration	Long Duration	
	Observations	457	337	124	213	207	130	794
1	Household Characteristics							
1.1	Number of people in the household (HH) (unweighted)	5.1	5.3	5.4	5.3	5.4	5.2	5.2
1.2	Number of adults in HH (age older than 14 and younger than 60)	3.5	3.7	3.8	3.6	3.7	3.6	3.6
1.3	Female headed HH (share over all HH SOH)	3%	4%	2%	5%	4%	3%	3%
1.4	Age of head of household (HHH) (years)	47.1	47.4	48.2	47.0	47.7	47.0	47.3
1.5	share of HH members who work on the farm (SOH)	33%y	30%**	29%	30%	29%x	31%xy	31%
1.6	share of HH members who work off the farm (SOH)	9%x	12%**	11%	12%	10%xy	13%y	10%
1.7	Education of HHH (years)	4.1ax	4.9***	4.5ab	5.1b	4.5x	5.6y	4.4
1.8	Average years of education in HH (taken over all adults members of the HH)	6.4ax	7.2***	7.0ab	7.4b	7.0y	7.6y	6.7
1.9	Highest level of education attained by any member of HH (taken over all members of the HH)	9.6ax	10.6***	10.2ab	10.9b	10.5y	10.9y	10.0
1.10	Member of a production cooperative / farmer association/ farmer enterprise in 2010 (SOH)	32%ax	42%***	41%ab	43%b	34%x	55%y	36%
1.11	Member of a production cooperative / farmer association/ farmer enterprise in 2005 (SOH)	17%ax	28%***	32%b	27%b	23%x	38%y	22%
2	Household Local Non-farm and Migration							
2.1	Total value of HH nonfarm consumption durables (USD 100s) in 2010	$747	$731	$681	$755	$720	$739	$739
2.2	Total value of HH nonfarm production assets (USD 100s) in 2010	$84	$91	$115	$80	$96	$87	$88
2.3	Total value of HH nonfarm consumption durables (USD 100s) in 2005	$208ax	$276**	$250ab	$295b	$270xy	$292y	$238
2.4	Total value of HH nonfarm production assets (USD 100s) in 2005	$35a	$52	$77b	$39a	$52	$55	$43
2.5	Share of HH who had a temporary migrant in the past five years	14%by	10%**	6%a	12%b	13%y	5%x	12%
2.6	Share of HH who had a permanent migrant in the past five years	25%	22%	23%	22%	24%	19%	23%
3	Collective assets							
3.1	Distance to the closest agrochemicals	18.6y	16.8	14.6	18.4	19.1y	13.6x	17.8

		NON ADOPTERS		ADOPTERS										TOTAL	
				All		Early Adopters		Late Adopters		Short Duration		Long Duration			
	commercial distributor (kms)														
3.2	Distance to the closest wholesale market (kms)	80.7y		78.3		74.6		81.0		86.7y		65.8x		79.8	
3.3	Distance to the closest retail market (kms)	19.0y		19.0		18.0		19.5		22.2y		13.5x		19.0	
3.4	Distance to the closest secondary school (kms)	4.6by		3.5***		3.6ab		3.4a		3.3x		3.8xy		4.1	
3.5	Distance to the closest hospital (kms)	20.6by		16.9***		17.1a		17.0a		18.6y		14.5x		19.1	
3.6	Distance to the center of the village (kms)	3.4		3.0		3.0		3.1		2.8		3.4		3.2	
4	Household Income														
4.1	On-farm income	$3,303ax	71%	$7,957***	81%	$10,409c	87%	$6,454b	76%	$5,563x	75%	$11,194y	86%	$5,281	77%
	4.1.1Target crops income	$1,769ax	38%	$6,548***	67%	$8,758c	74%	$5,205b	61%	$4,029x	55%	$10,016y	77%	$3,805	56%
4.2	Off-farm income	$1,000a	21%	$1,467*	15%	$1,265b	11%	$1,563b	18%	$1,360	18%	$1,603	12%	$1,193	17%
4.3	Not earned income	$358	8%	$391	4%	$237	2%	$489	6%	$467	6%	$283	2%	$374	5%
4.4	Total household income	$4,441ax	100%	$8,953***	100%	$11,134c	100%	$7,748b	100%	$6,670x	100%	$12,695y	100%	$6,374	100%
4.5	Total income per capita (considering all HH members)	$1,053 ax		$2,699***		$3,079b		$2,505b		$1,559 x		$4,560y		$1,759	

*,**,*** = show statistically difference at 10%, 5%, 1% significant level.

a, b, c, show differences between non-adopters, early adopters and late adopters using Tukey-Kramer test at 10% significance level.

x, y, z, show differences between non-adopters, early adopters and late adopters using Tukey-Kramer test at 10% significance level.

Table 2. Farm assets and technology choice of horticultural growers in Nicaragua in 2010, by adoption category.

		NON ADOPTERS	ADOPTERS	ADOPTERS		ADOPTERS		TOTAL
			All	Early Adopters	Late Adopters	Short Duration	Long Duration	
	Observations	457	337	124	213	207	130	794
1	Land operated (for all crops in Ha)							
1.1	Total land owned and not rented out in Ha in 2010	7.7	9.8	7.4	11.4	10.0	9.9	8.7
1.2	Total land owned and rented out in Ha in 2010	0.3	0.4	0.3	0.4	0.4	0.3	0.3
1.3	Total land rented in in Ha in 2010	1.0	0.9	0.7	1.0	0.9	0.9	0.9
1.4	Total land owned and not rented out in Ha in 2005	7.4	8.9	7.0	10.1	8.7	9.4	8.1
1.5	Total land rented in in Ha in 2005	0.3	0.3	0.3	0.3	0.4	0.2	0.3
1.6	Total cropped land in Ha in 2010	2.7	2.9	2.8	3.0	2.9	2.9	2.8
1.7	Total cropped land in Ha in 2005	2.5	2.5	2.4	2.5	2.3	2.8	2.5
2	Non land assets							
2.1	Total value of farm assets (USD) in 2010	$1,946ax	$2,978***	$3,148b	$2,896ab	$2,770xy	$3,338y	$2,388
2.2	Total value of farm assets (USD) in 2005	$966	$1,382**	$1,422	$1,352	$1,269	$1,550	$1,141
2.3	Total value of animals owned (USD) in 2010	$1,483	$1,484	$1,316	$1,588	$1,526	$1,427	$1,485
2.4	Total value of animals owned (USD) in 2005	$1,241	$1,010	$940	$1,075	$1,003	$1,061	$1,150
3	Production in 2010							
3.1	Tomato production (MT/year)	25.1x	37.3***	38.4	36.6	38.7y	34.9xy	30.2
3.2	Total area grown (Ha)	0.8	0.8	0.7	0.8	0.9	0.6	0.8
3.3	Yield (MT/Ha)	28.4ax	48.0***	63.6c	38.9b	43.4y	54.3y	36.6
3.4	Sweet pepper production (MT/year)	5.7ax	12.4***	12.0b	12.6b	12.3y	12.4y	8.1
3.5	Total area grown (Ha)	0.5	0.4	0.5	0.4	0.5	0.4	0.5
3.6	Yield (MT/Ha)	11.1ax	33.5**	21.7ab	41.1b	40.3y	23.0xy	19.2
3.7	Lettuce production (MT/year)	15.2	32.5**	31.3	33.8	32.5	33.0	25.4
3.8	Total area grown (Ha)	0.7ax	1.1***	1.2b	1.0ab	1.0xy	1.3y	0.9
3.9	Yield (MT/Ha)	21.6	31.0	26.2	34.7	31.6	30.1	27.0
4	Irrigation Technology in 2010							
4.1	Share of HH without irrigation	20%	0%	0%	0%	0%	0%	12%

		NON ADOPTERS	ADOPTERS	ADOPTERS		ADOPTERS		TOTAL
			All	Early Adopters	Late Adopters	Short Duration	Long Duration	
4.2	Share of HH with drip irrigation	29%ax	62%**	56%b	65%b	50%y	78%z	43%
4.3	Share of HH with canal irrigation	48%by	35%**	40%b	32%a	49%y	16%x	42%
4.4	Share of HH with other type of irrigation	3%	4%	5%	3%	2%	6%	3%
5	Seedling Technology 2010							
5.1	Share of HH using direct seeding	2%	1%	2%	0%	0%	1%	1%
5.2	Share of HH using owned produced seedlings	76%cz	32%***	21%a	38%b	46%y	15%x	57%
5.3	Share of HH using purchased tray seedlings	22%ax	67%***	78%c	62%b	54%y	84%z	42%
6	Tunnel Technology 2010							
6.1	Share of HH using tunnels	3%a	5%	10%b	3%a	6%	5%	4%
6.2	Share of HH using open field	97%	95%	90%	97%	94%	95%	96%
7	Production in 2005							
7.1	Tomato production (MT/year)	35.0	36.7	49.0	28.1	39.1	32.5	35.6
7.2	Total area grown (Ha)	0.8	0.7*	0.7	0.7	0.7	0.6	0.8
7.3	Yield (MT/Ha)	35.8ax	57.4**	84.6c	39.9b	46.9xy	74.7y	44.6
7.4	Sweet pepper production (MT/year)	6.7	13.4*	13.7	13.4	13.1	14.5	9.5
7.5	Total area grown (Ha)	0.5	0.5	0.5	0.5	0.5	0.4	0.5
7.6	Yield (MT/Ha)	14.5	40.4*	22.9	52.2	48.1	27.1	25.1
7.7	Lettuce production (MT/year)	21.1a	31.3**	39.6b	26.2ab	30.6	32.4	26.8
7.8	Total area grown (Ha)	0.8	0.9	0.9	0.9	0.9	1.0	0.9
7.9	Yield (MT/Ha)	27.1ax	58.9	104.6b	31.1a	37.2xy	92.6y	44.8
8	Irrigation Technology in 2005							
8.1	Share of HH without irrigation	22%	3%	0%	5%	5%	0%	14%
8.2	Share of HH with drip irrigation	14%ax	48%***	47%b	48%b	34%y	65%z	29%
8.3	Share of HH with canal irrigation	59%by	46%	50%b	43%a	57%y	31%x	53%
8.4	Share of HH with other type of irrigation	5%	4%	3%	4%	3%	4%	4%
9	Seedling Technology 2005							
9.1	Share of HH using direct seeding	4%	3%	2%	4%	4%	1%	3%
9.2	Share of HH using owned produced seedlings	82%bz	41%***	33%a	46%ab	51%y	28%x	64%
9.3	Share of HH using purchased tray	14%ax	56%***	66%b	50%b	45%y	71%z	32%

		NON ADOPTERS	ADOPTERS	ADOPTERS		ADOPTERS		TOTAL
			All	Early Adopters	Late Adopters	Short Duration	Long Duration	
	seedlings							
10	Tunnel Technology 2005							
10.1	Share of HH using tunnels	4%ax	9%***	11%b	8%b	11%y	6%xy	5%
10.2	Share of HH using open field	96%	91%	89%	92%	89%	94%	95%
11	Inputs for Horticulture Production in 2010 (USD/Ha)							
11.1	Seedlings/seeds expenditures	172ax	330***	331b	332b	259y	448z	240
11.2	Labor expenditure	332	355	345	364	350	368	343
	11.2.1 Imputed family labor	144b	123**	110a	132ab	124	124	135
	11.2.2 Hired labor	188ax	232***	235b	232b	226xy	244y	207
11.3	Fertilizers expenditure	672ax	796***	796ab	808b	719x	939y	728
	11.3.1 Chemical fertilizers	520x	583**	590	588	545x	659y	549
	11.3.2 Organic fertilizers	4x	9	11	7	4x	16y	6
	11.3.3 Foliar fertilizers	149ax	204***	196ab	212b	170x	264y	173
11.4	Pesticides expenditure	472	495	460	522	456	568	484
	11.4.1 Insecticides	270	279	241	308	257	324	275
	11.4.2 Herbicides	16ax	20**	17ab	22b	23y	16x	18
	11.4.3 Fungicides	187	195	203	191	176	227	191
11.4	Other inputs expenditure[#]	237x	304**	280	314	261x	367y	264
11.5	TOTAL	1886ax	2281***	2213b	2340b	2045x	2689y	2059

*,**,*** = show statistically difference at 10%, 5%, 1% significant level.

a, b, c, show differences between non-adopters, early adopters and late adopters using Tukey-Kramer test at 10% significance level.

x, y, z, show differences between non-adopters, early adopters and late adopters using Tukey-Kramer test at 10% significance level.

[#] Other inputs include Rope, plastic, sticks, filters, fuel, connectors, and wire.

Table 3. Duration analysis

	Adoption Spell	Withdrawal Spell
Household Characteristics		
Age of the head of the household (HHH)	0.005	-0.003
	(0.004)	(0.007)
Average years of education taken within the adult members of the household	-0.043***	-0.009
	(0.015)	(0.029)
HHH is female	0.001	0.822
	(0.277)	(0.711)
Number of adults (14 to 60 years old) in the household	-0.021	0.010
	(0.033)	(0.053)
Share of adults working in local off farm employment	-0.528*	-0.032
	(0.309)	(0.553)
Farm and Non Farm Characteristics		
Lagged (1 year) participation in a production cooperative by any adult member of the household	-0.011	0.065
	(0.128)	(0.182)
Lagged (1 year) total owned land in Ha	-0.000	-0.004***
	(0.001)	(0.001)
Total value of livestock holdings (USD thousands)	0.006	-0.039**
	(0.017)	(0.016)
Lagged (1 year) farm assets index	0.054	0.121
	(0.070)	(0.127)
Lagged (1 year) non farm productive assets index	0.064	0.045
	(0.061)	(0.087)
Lagged (1 year) access to drip irrigation (yes=1, no=0)	-0.390**	0.717***
	(0.163)	(0.261)
Distance to the nearest agri-inputs distribution store	0.032	-0.048
	(0.045)	(0.056)
Distance to the nearest wholesale market (kms)	0.009	-0.013
	(0.008)	(0.011)
Distance to the nearest local market (kms)	0.024	-0.058
	(0.034)	(0.044)
LN[Elevation of the farm (meters above sea level)]	0.124*	-0.128
	(0.071)	(0.169)
Meso Level Characteristics		
Lagged (1 year) price index of tomato/sweet peppers/lettuce per lb prices at the village level	0.067	-0.063
	(0.056)	(0.101)
Rural density at the municipality level	0.001	0.006
	(0.002)	(0.005)
Share of urban population over total population at the municipality level	0.009***	-0.007
	(0.003)	(0.005)
crop production (lagged 1 year)		
HH produced a niche crop (yes=1, no=0)	0.217	0.854**
	(0.247)	(0.434)
HH grows sweet peppers (yes=1, no=0)	0.089	0.596**
	(0.140)	(0.250)
HH grows tomatoes (yes=1, no=0)	-0.631***	0.929***

	(0.130)	(0.221)
HH grows lettuce (yes=1, no=0)	-1.209***	0.963***
	(0.173)	(0.243)
Household time		
Origin of the adoption spell (To)	-0.102***	
	(0.039)	
Origin of the withdrawal spell (year of adoption of the supermarket channel, Ta)		-0.401***
		(0.048)
Constant	206.610***	806.402***
	(78.504)	(96.373)
ρ	1.117	1.453
$\sigma=1/\rho$	0.895	0.688
Observations	5,767	1,119
LR Chi^2 (24)	122.0	136.0
Prob > Chi^2	0.000	0.000

***,**,* = Statistically significant at 1,5,10% level.

Table 4. Effect of time to adopt and duration as supermarket suppliers on farm assets and technology in 2010.

	Farm Assets	Drip irrigation area	Niche cropped area	Purchased tray seedlings	Hired Labor	Fertilizers	Pesticides	Share of toxic pesticides
Age of the head of the household (HHH)	0.010	-0.008**	0.004	0.001	0.277	-1.466	0.291	0.001
	(0.025)	(0.004)	(0.003)	(0.002)	(2.648)	(2.997)	(2.119)	(0.001)
HHH is female	-0.006	-0.063	-0.075	-0.017	-32.492	-96.256	-217.874*	0.054
	(1.680)	(0.129)	(0.064)	(0.123)	(163.127)	(176.515)	(115.149)	(0.049)
Years of education of the HHH	0.280***	0.012	0.029	0.005	0.736	-5.948	7.964	0.004
	(0.087)	(0.010)	(0.020)	(0.007)	(6.831)	(8.717)	(7.210)	(0.003)
Number of adults (14 to 60 years old) in the household	-0.015	0.001	0.023	0.004	-16.224	-19.072	-11.980	-0.002
	(0.219)	(0.017)	(0.024)	(0.013)	(20.771)	(21.489)	(13.682)	(0.003)
Share of adults working in local off farm employment	5.273**	0.406	-0.324	0.017	-183.320	-209.403	-243.697	0.076
	(2.533)	(0.295)	(0.276)	(0.173)	(215.414)	(283.094)	(188.898)	(0.060)
Total cropped land in Ha	-0.001	-0.029**	0.014	-0.000	14.465	-10.513	-4.565	0.004
	(0.136)	(0.013)	(0.012)	(0.012)	(13.158)	(14.325)	(11.711)	(0.003)
Farm assets index		0.065	0.019	0.016	5.108	3.764	-12.859	-0.009
		(0.070)	(0.038)	(0.023)	(24.857)	(22.070)	(20.334)	(0.006)
Total value of livestock holdings (USD thousands)	0.487*	-0.004	0.000	-0.004	-5.973	-5.846	-6.264	0.001
	(0.257)	(0.014)	(0.009)	(0.008)	(7.845)	(8.294)	(6.401)	(0.002)
Distance to the nearest agri-inputs distribution store (km)	-0.260	-0.032	-0.000	-0.052	-5.669	1.460	5.375	-0.006
	(0.294)	(0.031)	(0.015)	(0.033)	(26.728)	(27.689)	(26.461)	(0.006)
LN[Elevation of the farm (meters above sea level)]	0.829	-0.042	0.045	-0.019	84.383	-50.637	-165.339	-0.047
	(0.715)	(0.100)	(0.067)	(0.063)	(85.699)	(88.684)	(110.943)	(0.029)
Duration as supermarket supplier (fitted value)	0.470	0.084***	0.085**	0.095***	84.425***	37.533	38.902	-0.008*
	(0.348)	(0.031)	(0.033)	(0.021)	(28.223)	(30.711)	(24.103)	(0.005)
Time to adopt the supermarket channel (fitted value)	0.514	0.032	-0.012	0.012	176.051***	103.368	120.029**	0.022
	(0.501)	(0.065)	(0.057)	(0.055)	(53.641)	(67.289)	(57.169)	(0.016)
HH is located in semi-dry zone	2.855	-0.060	-0.002	-0.233	-298.157	-393.031	179.618	0.068
	(2.652)	(0.340)	(0.156)	(0.241)	(366.737)	(293.376)	(505.871)	(0.114)
HH is located in humid zone	-0.377	-0.127	0.089	-0.419***	-359.689***	-74.671	18.375	0.055**
	(0.656)	(0.079)	(0.055)	(0.060)	(77.193)	(79.406)	(72.775)	(0.024)
Constant	-7.243	0.852	-0.823	0.578	-309.843	1,158.523*	1,281.498*	0.254
	(6.084)	(0.769)	(0.655)	(0.463)	(580.328)	(629.860)	(743.437)	(0.196)
Observations	305	305	305	305	305	305	305	305
R squared	0.209	0.188	0.117	0.294	0.141	0.112	0.090	0.135
Wald Chi^2 (14)	80.7	66.89	42.1	126.98	49.69	38.4	31.15	48.14

Prob > Chi^2	0.000	0.000	0.000	0.000	0.000	0.000	0.008	0.000

***,**,* = Statistically significant at 1,5,10% level.

ANNEX A: Econometric analysis using 2005-2010 data only

Table 5. Duration analysis

	Adoption Spell	Withdrawal Spell
Household Characteristics		
Age of the head of the household (HHH)	0.003	-0.005
	(0.003)	(0.006)
Average years of education taken within the adult members of the household	-0.028***	-0.017
	(0.011)	(0.027)
HHH is female	-0.191	0.762
	(0.181)	(0.642)
Number of adults (14 to 60 years old) in the household	-0.026	0.021
	(0.023)	(0.051)
Share of adults working in local off farm employment	-0.353*	-0.099
	(0.215)	(0.533)
Farm and Non Farm Characteristics		
Lagged (1 year) participation in a production cooperative by any adult member of the household	-0.060	0.006
	(0.088)	(0.172)
Lagged (1 year) total owned land in Ha	0.000	-0.003***
	(0.001)	(0.001)
Total value of livestock holdings (USD thousands)	-0.004	-0.044***
	(0.010)	(0.014)
Lagged (1 year) farm assets index	0.001	0.213
	(0.050)	(0.139)
Lagged (1 year) non farm productive assets index	0.080*	0.016
	(0.044)	(0.081)
Lagged (1 year) drip irrigated land in Ha	-0.335***	0.686***
	(0.119)	(0.247)
Distance to the nearest agri-inputs distribution store	0.012	-0.045
	(0.028)	(0.051)
Distance to the nearest wholesale market (kms)	0.003	-0.012
	(0.005)	(0.011)
Distance to the nearest local market (kms)	-0.004	-0.055
	(0.020)	(0.041)
LN[Elevation of the farm (meters above sea level)]	-0.006	-0.054
	(0.055)	(0.165)
Meso Level Characteristics		
Lagged (1 year) price index of tomato/sweet peppers/lettuce per lb prices at the village level	0.071*	-0.065
	(0.041)	(0.103)
Rural density at the municipality level	0.001	0.006
	(0.002)	(0.005)
Share of urban population over total population at the municipality level	0.005**	-0.005
	(0.002)	(0.005)
crop production (lagged 1 year)		
Lagged (1 year) HH produced a niche crop (yes=1, no=0)	0.513**	0.622*
	(0.202)	(0.379)
HH grows sweet peppers (yes=1, no=0)	0.196**	0.708***

	(0.095)	(0.252)
HH grows tomatoes (yes=1, no=0)	-0.189**	0.955***
	(0.083)	(0.215)
HH grows lettuce (yes=1, no=0)	-0.486***	0.873***
	(0.119)	(0.231)
Household time		
Origin of the adoption spell (To)	-0.219***	
	(0.023)	
Origin of the withdrawal spell (year of adoption of the supermarket channel, Ta)		-0.467***
		(0.053)
Constant	440.439***	937.665***
	(46.499)	(105.510)
ρ	2.076	1.618
$\sigma=1/\rho$	0.482	0.618
Observations	3,262	958
LR Chi^2 (24)	148.0	157.9
Prob > Chi^2	0.000	0.000

***,**,* = Statistically significant at 1,5,10% level.

Table 6. Effect of time to adopt and duration as supermarket suppliers on farm assets and technology in 2010.

	Farm Assets	Drip irrigation area	Niche cropped area	Purchased tray seedlings	Hired Labor	Fertilizers	Pesticides	Share of toxic pesticides
Age of the head of the household (HHH)	0.006	-0.007**	0.004***	0.001	1.313	-1.733	0.229	0.001
	(0.031)	(0.003)	(0.001)	(0.002)	(1.314)	(1.341)	(1.990)	(0.001)
HHH is female	0.230	-0.046	-0.055	0.008	31.123	-56.103	-172.066***	0.059
	(1.297)	(0.107)	(0.037)	(0.100)	(40.675)	(81.289)	(61.379)	(0.041)
Years of education of the HHH	0.281***	0.010	0.031	0.006	-2.146	-5.433	7.826	0.004
	(0.101)	(0.008)	(0.019)	(0.007)	(8.289)	(6.630)	(7.612)	(0.003)
Number of adults (14 to 60 years old) in the household	-0.016	-0.001	0.024	0.004	-18.858	-19.429	-12.704	-0.002
	(0.208)	(0.011)	(0.019)	(0.013)	(18.178)	(21.142)	(17.839)	(0.004)
Share of adults working in local off farm employment	5.153**	0.347	-0.310	0.019	-284.845***	-226.474**	-276.985**	0.074*
	(2.131)	(0.220)	(0.273)	(0.243)	(82.577)	(104.766)	(126.843)	(0.040)
Total cropped land in Ha	0.004	-0.029*	0.013	-0.001	13.981**	-10.909	-5.053*	0.004
	(0.136)	(0.015)	(0.014)	(0.010)	(6.627)	(16.780)	(2.773)	(0.003)
Farm assets index		0.067	0.017	0.012	6.643	-1.170	-15.411*	-0.010
		(0.048)	(0.024)	(0.019)	(26.691)	(9.719)	(9.365)	(0.006)
Total value of livestock holdings (USD thousands)	0.495***	-0.005	0.000	-0.004	-6.035	-4.410	-5.299	0.001
	(0.172)	(0.008)	(0.005)	(0.004)	(4.975)	(5.308)	(4.299)	(0.001)
Distance to the nearest agri-inputs distribution store (km)	-0.231*	-0.030	-0.003	-0.053***	-1.369	3.590	7.598	-0.005***
	(0.119)	(0.020)	(0.010)	(0.009)	(25.867)	(15.953)	(5.416)	(0.002)
LN[Elevation of the farm (meters above sea level)]	0.851	-0.048	0.042	-0.021	89.359***	-42.618	-157.622	-0.045**
	(0.662)	(0.076)	(0.063)	(0.064)	(32.707)	(62.000)	(123.766)	(0.022)
Duration as supermarket supplier (fitted value)	0.567*	0.069**	0.067**	0.081***	53.285**	28.098	22.964*	-0.007**
	(0.290)	(0.033)	(0.030)	(0.015)	(22.587)	(25.723)	(13.905)	(0.004)
Time to adopt the supermarket channel (fitted value)	0.993	-0.123***	0.025	0.035	28.821	150.040**	133.576	0.034*
	(0.655)	(0.030)	(0.019)	(0.061)	(98.346)	(70.408)	(92.503)	(0.020)
HH is located in semi-dry zone	2.669**	-0.043	-0.012	-0.240	-275.659	-396.365***	180.787	0.067
	(1.235)	(0.373)	(0.136)	(0.264)	(329.156)	(142.645)	(143.717)	(0.154)
HH is located in humid zone	-0.426**	-0.105	0.076***	-0.426***	-337.028***	-80.298	16.793	0.054**
	(0.177)	(0.086)	(0.028)	(0.062)	(72.588)	(102.011)	(53.542)	(0.022)
Constant	-8.691*	1.293**	-0.848	0.570	115.317	1,033.879***	1,258.784*	0.214
	(4.609)	(0.626)	(0.616)	(0.485)	(340.718)	(382.235)	(690.616)	(0.145)
Observations	305	305	305	305	305	305	305	305
R squared	0.222	0.188	0.109	0.291	0.118	0.115	0.087	0.134
Wald Chi^2 (14)	87.14	67.22	38.96	125.25	40.26	39.72	30.4	48.18

Prob > Chi^2	0.000	0.000	0.001	0.000	0.000	0.001	0.011	0.000

***,**,* = Statistically significant at 1,5,10% level.