Tomato Farmers and Modern Markets in Nicaragua: A Duration Analysis

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Abstract. We explore whether farm land and non-land assets determine the participation of tomato growers in modern markets in Nicaragua, and how farmers' duration as supermarket suppliers affects their farm capital accumulation and technology. We use a survival analysis approach constructed panel data set of tomato farmers over a 10-year period. Participation in supermarket supply chains is found to be not determined by farm size, and thus small farmers are included. However, non-land assets are important to being in the modern channel, time to adoption, and duration. Duration as a supplier is correlated with capital-led intensification and lower toxic pesticide use.

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1. INTRODUCTION

Farmer participation in modern market channels, such as export markets, supermarket channels, and contracts with large processors, presents the opportunity, relative to just selling to traditional markets, of increasing incomes (Swinnen, 2007), or decreasing risk (Saenz and Ruben 2004), or both. In the particular market segment on which we focus this paper, local supermarket supply chains, there are still only a few survey-based articles that test the hypothesis that participation in supermarket channels increases incomes; Rao and Qaim (2011) find for example that it does. Few studies examine impacts other than income or net returns. Exceptions are a recent examination of relative market channel risk using market (not farm) data in Nicaragua (Michelson et al. 2012), and of the technology choices impacts of adoption of supermarket channels using farm data in Guatemala (Hernandez et al. 2007).

Participation in modern channels can also challenge farmers with greater requirements of land or non-land assets compared to traditional markets, as the emerging, but still mixed and scant, survey evidence shows (Reardon et al. 2009). 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.

Moreover, even more rare are studies that examine modern market channel participation as a dynamic process. One can say that markets represent technologies, and the decision to participate in markets is akin 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 correlation of capital accumulation and farm technology adoption with modern market channel adoption. The latter has been hypothesized in a more general way as a posited link between commercialization (in general, without regard to market channel) and farm technology intensification (Pingali and Rosegrant, 1995).

In this paper we propose to address the above two relative gaps in the literature. Using a constructed-panel over 10 years of tomato 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 duration on farm capital accumulation and tomato farm technology choice, in particular of modern technologies for "capital-led intensification" (a term used by Lele and Stone, 1989)?

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 tomato growers (supermarket suppliers and non-suppliers) collected in 2004 and then in 2010 (with five year recalls in each). 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 use over time (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.

2. 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),

$$\prod_0(p_0, w_x, z_0) + \theta_0 \tag{2.1}$$

For modern market (crops),

$$\prod_1(p_1, w_x, z_1) + \theta_1 \tag{2.2}$$

With

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

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_I 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

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

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:

$$\Delta \mathrm{U_a} = \Delta \mathrm{U_a}(\mathrm{p_0}, \mathrm{p_1}, \mathrm{w_x}, \mathrm{FK}, \mathrm{HK}, \mathrm{SK}, \mathrm{CK}, \mathrm{T_o}, \mathrm{t_a}) \qquad (2.6)$$

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 adopt" (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,

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

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 and the use of modern technologies in tomato production, which can be modeled as follows:

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

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

where (ΔFK) is the change in farm assets, (Δq) is the change in the use 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, land^2, irrigated land, livestock, farm assets (other than land and livestock), nonfarm assets, durable consumption assets, distance to ag-store, distance to market, distance to village center, tomato price, farm elevation, urban share in the district; 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 entry (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

Village-level traditional-market prices for tomatoes (time-varying, 2005-2010). Households recalled the village price for first-grade tomato for each year from 2005 to 2010[1].

[1] We did not collect historic prices from 2000-2004, and thus use the 2005 recalled village price for that period of time.

Since the current period price can be 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): The a priori effect on time-to-adoption is ambiguous. More education could aid the farmer to adapt to the more demanding channel's technology and commercial requirements. But more education can also increase the HHH's options to work in nonfarm employment (Taylor and Yunez-Naude, 2000) and thus not depend on upgrading his/her 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 HHH want to withdraw from the modern channel. But more education could help the farmer to adapt to the evolving requirements of the modern channel and prolong his/her participation in it.

(d) Average years of education of the adults of the household (time-invariant): We have included this to control for other adults' education, as it may not be only the HHH who decides or executes the participation.

(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.

(g) Durable consumption assets from 2000 to 2010 (time varying): This index includes items such as bicycle, refrigerator, TV, solar panel, stove, computers, and so on. We use factor analysis of the principal component to calculate an asset index of durable consumption assets, and it proxies household wealth, which in turn reflects access to credit and risk aversion.

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) Total irrigated land (ha) each year from 2000 to 2010 (time-varying): This is posited to reduce time to adoption and increase duration as irrigation increases tomato 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.

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)Village elevation in 2010 (time-invariant). This is the average of the sample households' elevation (measured by our survey team by GPS). Villages 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.

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 32% 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

To control for duration in the second stage we include instrument variables in the first stage here. We use these time-invariant variables as instruments; they have very low mutual correlation. These are posited to affect time-to-adopt and time-to-withdraw from the market channel, but not technology choice:

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

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

(c) Distance from household to the village center.

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:

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

where

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

(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:

$$\log(t) = \beta' X + \sigma\varepsilon, \tag{4.4}$$

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' duration as supermarket channel suppliers (among other variables) on accumulation of farm physical capital and change in use of technology over time. The latter is selectively represented by indicators of technology modernization in tomato cultivation:

(a) area under drip irrigation, current, for all years 2000 to 2010: 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 for the year) for all years 2000 to 2010: These are superior to the traditional open-field tomato 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.

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

c) hired labor used per hectare (ha) for 2005 and 2010: 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 per ha in 2005 and 2010: 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 (2005 and 2010): We posit that this is correlated with duration as supermarket buyers seek less blemished tomatoes.

f) Share in 2005 and 2010 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 tomato pesticide safety; for example, Walmart provides manuals to its Nicaraguan suppliers wherein they note that highly-toxic pesticides should be avoided.

g) current year farm non-land assets (as defined in the first stage) for 2000 to 2010: this index includes items such as chainsaws, carpentry equipment, sewing machines, and so on. It was calculated using the method employed for the other indexes.

We posit that that duration should be positively related to farm asset accumulation 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 (predicted from the first stage);

b) the residuals from the first stage (duration equation); since duration as a supermarket supplier can be an endogenous determinant in the technology equations, we use a control function approach where the predicted residuals from the duration equation are included in the technology equations to control for the endogeneity of duration and generate consistent estimators of duration used in the technology equations;

c) farm productive non-land assets, current (this variable is in all technology equations but not in the farm asset formation equation);

d) the age of HHH (current) and gender of the household head (time invariant);

e) number of adults in the household (current);

f) land and livestock holdings (current);

g) and a measure of net profitability via including the tomato price (lagged one year) and input costs proxied by distance to input stores (time invariant).

The effects equations are estimated using panel data methods, specifically we use random effects[3], as we have both time varying and time invariant explanatory variables. Since we are using two variables not actually observed (duration and first stage residuals), 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 collected by revisiting in 2010 a sample of tomato producers selling to supermarkets and traditional sector that our institution surveyed in 2004.

[3] Since use of purchased tray seedlings is a binary variable, we use a random effects probit model for its estimation.

The 2004 data set was constructed 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 as a random sample of traditional producers (selling only to traditional wholesale markets, not to supermarkets) in the same or nearby communities. The sample consisted of 133 households: 63 selling to supermarkets (and possibly also traditional markets); and 70 selling to traditional wholesalers.

In 2010 we conducted a survey using 108 households from the original sample.[4] 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.

56% 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

[4] We were unable to locate 133-108=25 households of the 2004 sample. We compared the 2004 characteristics of the re-sampled set and the set of the 25 not found and found that they do not differ at 10% significance level in terms of share of observations selling to supermarkets, farm size, and total tomato cropped area.

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 three years after the household has adopted the supermarket channel. By the seventh year, 75% of the adopters remained as supermarket suppliers, and at the end of the observation period, around a quarter of the adopters supplied the supermarket channel 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, education, and gender of the HHH, do not differ much between adopters and non-adopters households. But when we divide adopters into short vs. long duration, we see that all the 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 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 early adopters and late adopters; the latter are actually are not statistically different from non-adopters in this respect. Moreover, households with a long duration as modern suppliers are twice as engaged in off-farm employment as non-adopters.

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 three to four times 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. But when we distinguish short duration (as supplier to supermarkets) from long duration, we find the latter to live closer to wholesale markets, hospitals, and schools, which are clustered in towns and proximity to these proxies lower transaction costs.

Fifth, total household income does not differ significantly between adopters and non-adopters, averaging \$1447 per capita in 2010, about 43% higher than the Nicaragua's GNI (\$1,008) for 2010.

But non-adopters are mainly dependent on farm income, while adopters have more diversified incomes, with off-farm income about a third of their incomes. Skilled nonfarm employment (the highest paying employment with the stiffest requirements) is thrice higher among adopters. The traits (perhaps of adeptness at business and entrepreneurial verve, but we do not test for these) that are linked to skilled employment may also then help farmers adapt to and brave participation in a modern crop channel, or the skilled employment may help them form commercial skills that spill over into an ability to participate in a modern market. To our knowledge the relation between these two has not before been shown in the literature. Moreover, early adopters earn 4-5 times more skilled RNFE compared with non-adopters and late adopters, so the above result is sharpened when focusing in on the early adopters.

(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 non-land farm asset holdings. While non-adopters have 28% more cropped land (than adopters), there is no statistical difference of early adopters and non-adopters in cropped land. This result is interesting because combined with the previous results, it begins to show how late adopters seem to be among the smallest and asset-poorest of small farmers.

Second, however, we do find an important farm size result, not for entry, but for how long the farmer stays in the modern channel: among adopters, those with long duration have nearly twice the farm sizes of the short duration farmers.

Third, non-adopters grow 50% more tomato area than adopters in 2005 and 2010; that would seem to suggest non-adopters are more specialized in tomato – yet this difference disappears when viewed from the perspective of tomato output – as the two groups have similar output given that the adopters have higher yields. Moreover, early adopters have 41% higher yields than non-adopters and 91% higher yields than late adopters. Finally, among adopters, those with longer duration have 46% higher yields than non-adopters 73% higher than short duration households. We will see below that these yield differences are linked to early adopters and longer-duration adopters having more capital-intensive production.

Fourth, contrary to our expectations, adopters and non-adopters do not differ much in share of farmers having drip-irrigation in 2010 (both groups show about half the farmers with it); but in 2005, the non-adopter group showed only a quarter of farmers using it, while nearly half the adopter group already did. Thus, while having this technology may have aided one group to enter the modern channel, in the next five years there was a convergence over farm types as there was a diffusion of drip irrigation among the non-adopters (of the modern channel) – in what appears to be a Cochrane Treadmill process. Interestingly, when focusing on the adopter group, we find that while late adopters had a somewhat lower share of users in 2005, the late adopter group (recall these are smaller farmers than the early adopters) actually pulled ahead and had a higher share, about 62% of farms having drip irrigation versus 40% for the early adopters. Comparing short and long duration farms we find, however, that long duration farms tended to have, in both 2005 and 2010, twice the probability of having drip irrigation (about 70%). Thus, the long duration adopters have a much higher share of farms with this technology than the average farm, despite some overall diffusion of the technology among all farms over the period.

Fifth, as expected, in both 2005 and 2010, adopters are twice as likely to use purchased-tray-seedlings compared to non-adopters (about 60 versus 30%). 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 12-15% of the adopters used tunnels, versus 4-7% among non-adopters. The most differentiation was between long-duration and short-duration farms, with 19% and 6% using tunnels, respectively.

Finally, adopters have much more variable-input intensive technology than non-adopters – spending 60% 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 third) between adopters and non-adopters. However, the comparison of adopters and non-adopters masks an important difference within the adopter group: while early adopters' variable input use 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 substantially more variable inputs than the early adopters. Interestingly (and unexpectedly), the labor share in total costs is about a third for each of them, so it is not that the small-farmer late adopters are using a higher labor intensity. Thus, the small late-adopters are using more of all variable inputs – but only getting half the yields. This could be an example – relatively common in the literature – where smaller farmers overuse variable inputs; this could be due to greater risk aversion (to getting their tomatoes rejected by the buyers), or using more expensive inputs (controlling for quality) because they may buy in smaller units, or having access to less or lower quality extension to inform them of what inputs to use in what efficient amounts.

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 <u>not</u> 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, alternatives, and wealth lead to shorter time to adoption, as we hypothesized. This is the case for: (1) average education of the households' adult members; (2) the greater the share of adults working in off-farm employment and the (lagged) stock of nonfarm productive assets.

Third, being a member (lagged) of a production cooperative lessens the time to adoption. This makes sense as a horticultural cooperative includes packing sheds and cold rooms and vehicles and other collective capital that reduce the household-specific capital requirements to enter the modern channel, and create a ready "bridge" reducing transaction costs to the supermarket procurement system. Our semi-structured key informant interviews with supermarket buyers corroborated this: we found that they prefer to work with cooperatives, as they can coordinate farm production, harvesting, deliveries, and payments, dealing with a cooperative coordinator rather than with many smallholders.

Fourth, irrigated land (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 village having greater elevation has the effect of lengthening the time to adoption. Villages in the mountains have worse agroclimatic and transaction cost situations compared to those on the plains.

Fifth, (lagged) durable consumption lengthens the time to adoption. This may mean that prior wealth already rendered into consumption goods reduces the incentives to "stretch" into the risky domain of supplying to a new type of market.

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

Seventh, the year of first exposure to supermarket participation significantly determines adoption of the supermarket channel. Farmers who were exposed early to the possibility of adoption tend to have shorter periods of time to entry. This may be because of a reason revealed in key informant interviews: in the "early days" of the supermarkets' presence in the production regions, few suppliers vied for the channels, and the requirements were somewhat looser in order to attract more suppliers. In a "Cochrane Treadmill" fashion, as time went on and more suppliers entered, the supermarkets could afford to be more selective, increase requirements, and suppliers vied for the supply channels.

(b) Determinants of duration or Withdrawal spell

We discuss the main findings below.

First, we did not find that farm size was a significant determinant of duration in the supermarket channel; again, this is an important finding added to the development literature which involves a controversy (as noted above) as to whether farmers who are poor in land can survive in modern market channels. While we did not find that, we find that various non-land assets indeed do determine their survival, as shown below.

Second, analogous to our findings that skills (education) and capital (specifically here, irrigation) shorten the time to adoption, these same factors lengthen the duration as a supermarket supplier for those households that adopted the modern channel.

Third, however, whereas a household's participating in off-farm employment had shortened the time-to-adoption, it has the opposite effect on duration as supplier. This could be because as the household endures as a supplier, it becomes increasingly clear how labor-intensive the supermarket channel is, and the competition with its off-farm activity becomes manifest. The negative effect of off-farm employment on duration could also be due to the households' progressively weighing the gains from off-farm employment against the apparently (from key informant interviews) gradual increase in competition among suppliers for spots in the supply channel and the costs from requirements to be in that channel. From our data the precise nature of this tradeoff is hard to quantify but the qualitative information points to this as a possible interpretation of the negative sign on off-farm employment in the duration equation.

Fourth, 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.

Fifth, transaction costs cut two ways. The closer the household is to input stores, the longer is their duration as modern channel suppliers. By contrast, the closer they are to traditional wholesale markets, the lower costs they face in just selling their tomatoes, poor and good quality, to the traditional market, and that proximity reduces their duration in the supermarket 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 accumulation of farm assets and use of capital-intensive "modern technologies" including drip irrigation, hired labor, fertilizer, and pesticide. Moreover, the significance of the residual term confirms that the duration variable is endogenous and by using the residuals we have controlled for that. Thus we cannot reject a main hypothesis of this paper.

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, we find that the age of the household head is correlated with greater accumulation of farm assets; this is explicable in terms of the life cycle. By contrast, households with more adults have lower holdings of farm assets, suggesting a labor-capital substitution. The latter also use less pesticide; this appears to be a substitution of labor (for weeding) for herbicides (a large component of pesticides).

Fourth, various household characteristics are correlated with specific technologies used. Households with female heads tend to use more purchased seedling trays, possibly due to the opportunity cost of presumably a sole head of household with less time to produce own seedlings on the farm or direct sow.

Moreover, the household head being more educated reduces use of fertilizer, again possibly for the reasons noted in the descriptive section showing that poorer households are using much more non-labor variable inputs, possibly over-using them, which could be for want of extension or education or both.

Fifth, greater distance from farm input stores was found to be associated with less use of purchased trays of seedlings (which are sold at input stores) and less use of pesticide (also at these stores).

Sixth, an increase in farm assets increases the area with drip irrigation and the expenditures on fertilizer, and reduces the expenditures of pesticides over time. These effects may be linked. More use of drip irrigation reduces water coverage on leaves of plants and thus the need for fungicides (part of the chemicals in our variable "pesticides").

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 off-farm participation and income, higher yields while using “modern” technologies, without overusing pesticides), late adopters lack these characteristics, and in some specific characteristics, have even less desirable levels than non-adopters. However, participation in modern markets seems to be linked to a high probability of participation in a production cooperative, which appears to have been helping late adopters overcome thresholds of modern market participation. Similar results have been observed by segregating adopters into short versus long duration suppliers; long duration households have more education, more land, 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 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.

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.

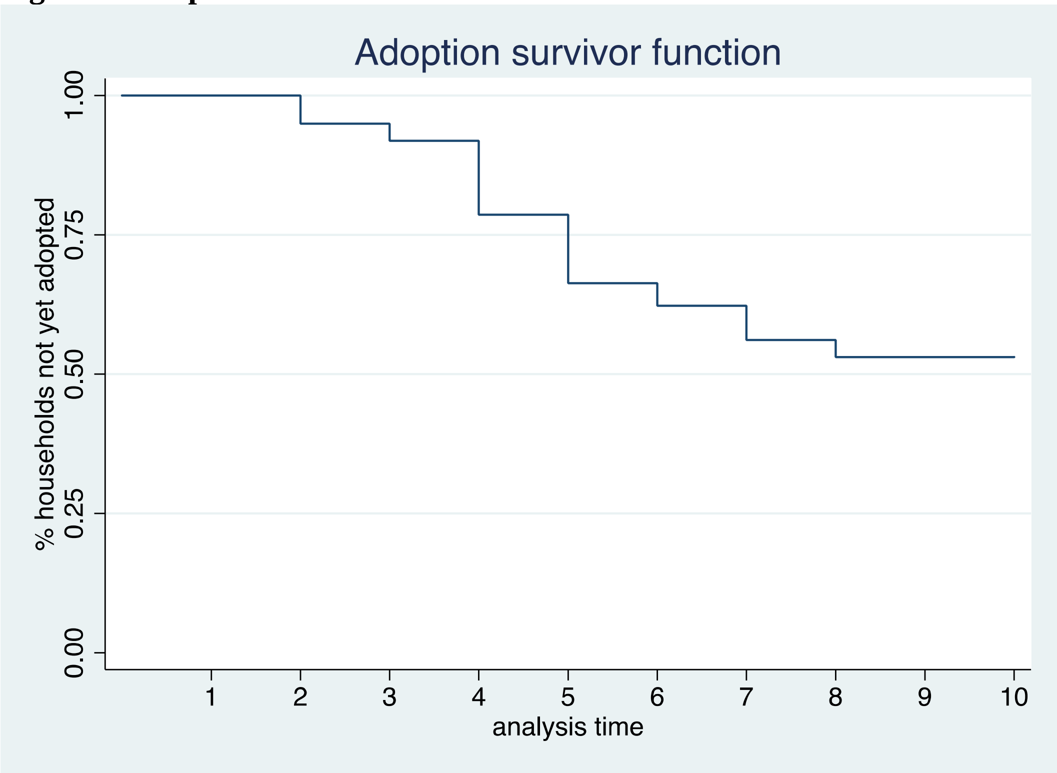

Figure 2. Hazard function, adoption.

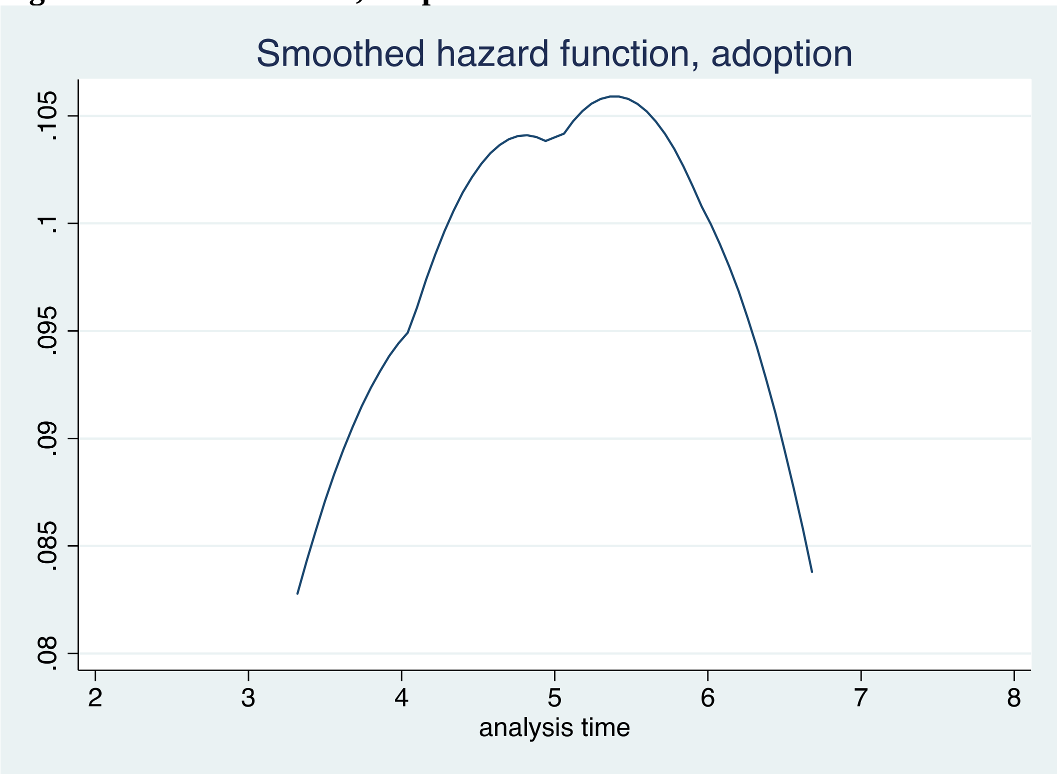

Figure 3. Withdrawal survivor function.

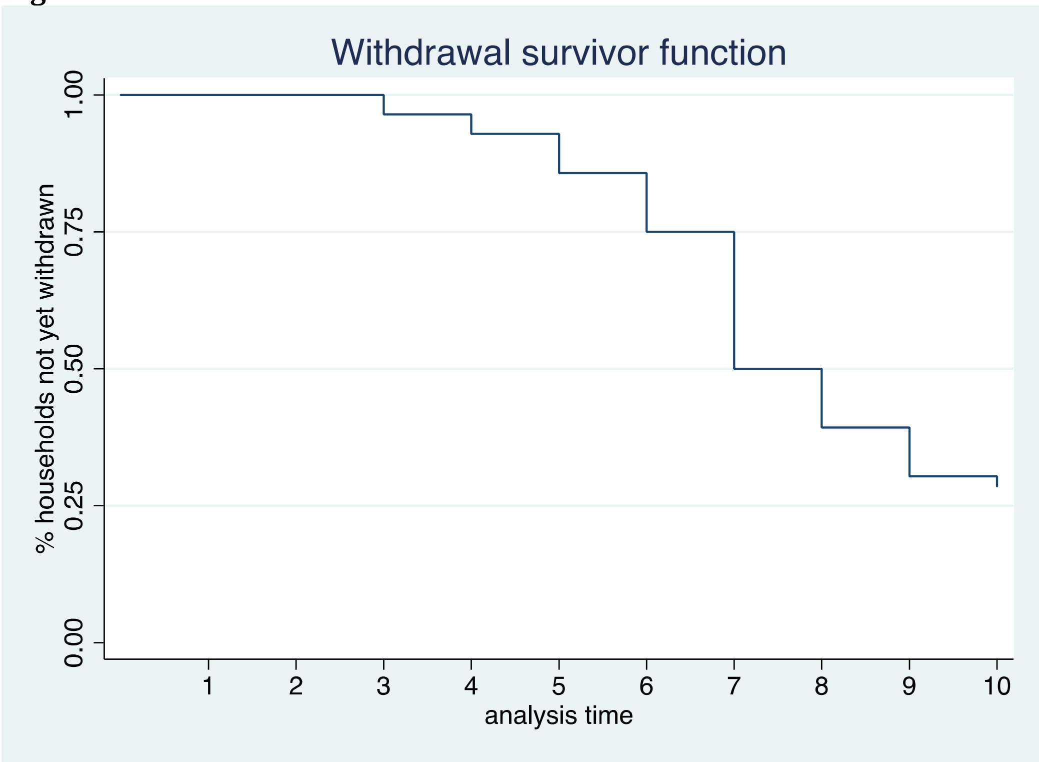

Figure 4. Hazard function, withdrawal.

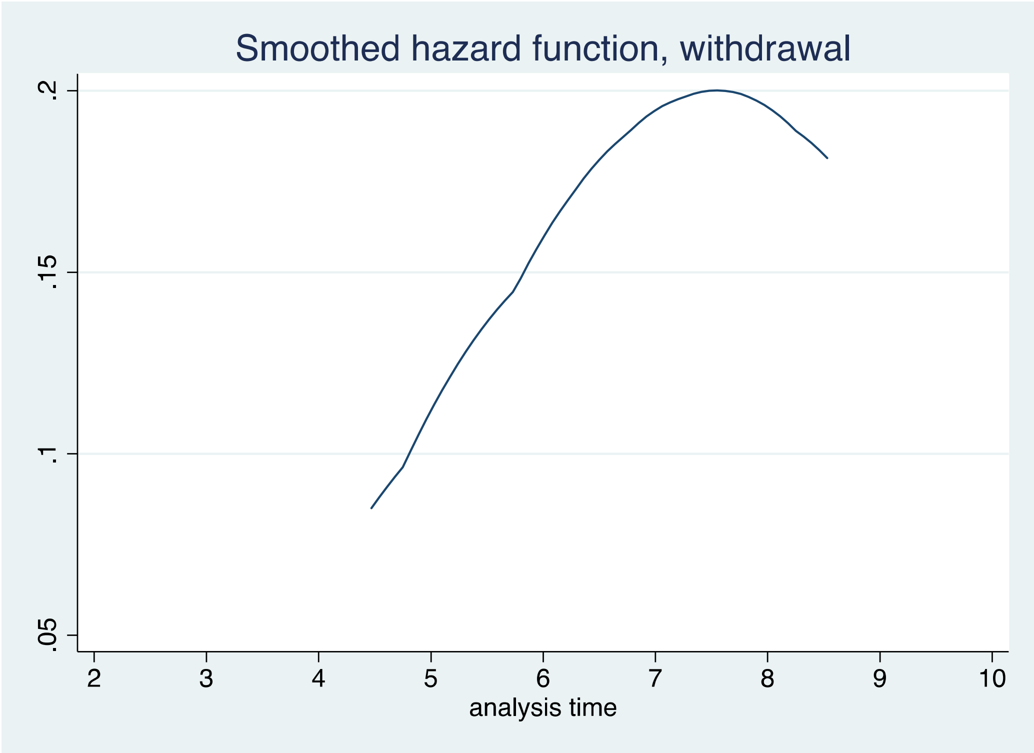

Table 1. Household characteristics and income distribution of tomato farmers in Nicaragua in 2010, by adoption category.

		NON-ADOPTERS	ADOPTERS	ADOPTERS		ADOPTERS		TOTAL
			All	Early Adopters	Late Adopters	Short Duration	Long Duration	
	Observations	52	56	31	25	37	19	108
1	Household Characteristics							
1.1	Number of people in the household (HH) (unweighted)	4.9	5.1	5.1	5.3	5.4	4.7	5.1
1.2	Number of adults in HH (age older than 14 and younger than 60)	3.6	3.6	3.7	3.5	3.8	3.3	3.6
1.3	Female headed HH (share over all HH SOH)	2%	7%	6%	8%	5%	11%	5%
1.4	Age of head of household (HHH) (years)	49.4x	53.0	53.6	52.5	53.9y	51.4xy	51.3
1.5	share of HH members who work on the farm (SOH)	29%	30%	30%	30%	31%	29%	30%
1.6	share of HH members who work off the farm (SOH)	10%ax	17%**	18%b	14%a	14%x	21%y	13%
1.7	Education of HHH (years)	4.4x	4.7	5.3	4.0	3.9x	6.4y	4.6
1.8	Average years of education in HH (taken over all adults members of the HH)	7.0x	7.6	7.9	7.2	7.1x	8.7y	7.3
1.9	Highest level of education attained by any member of HH (taken over all members of the HH)	10.3x	11.1	11.4	10.9	10.5x	12.4y	10.7
1.10	Member of a production cooperative / farmer association/ farmer enterprise in 2010 (SOH)	19%ax	33%*	29%ab	40%b	27%x	47%y	27%
1.11	Member of a production cooperative / farmer association/ farmer enterprise in 2005 (SOH)	15%ax	36%**	29%ab	48%b	32%y	47%y	27%
2	Household Local Non-farm and Migration							
2.1	Total value of HH nonfarm consumption durables (USD 100s) in 2009	$833	$709	$629	$739	$736	$565	$753
2.2	Total value of HH nonfarm production assets (USD 100s) in 2009	$99	$114	$125	$111	$117	$122	$109
2.3	Total value of HH nonfarm consumption durables (USD 100s) in 2004	$202	$288	$303	$292	$310	$274	$252
2.4	Total value of HH nonfarm production assets (USD 100s) in 2004	$44	$104	$105	$111	$103	$116	$77
2.5	Share of HH who had a temporary migrant in the past five years	17%	12%	13%	12%	14%	11%	15%
2.6	Share of HH who had a permanent migrant in the past five years	38%by	21%**	16%a	24%ab	24%y	11%x	29%
3	Collective assets							
3.1	Distance to the closest agrochemicals commercial distributor (km)	16.5y	15.2	14.0	16.8	18.4y	10.2x	15.9
3.2	Distance to the closest wholesale market (km)	81.4y	58.7	60.2	60.4	66.1xy	49.0x	70.5
3.3	Distance to the closest retail market (km)	17.4xy	19.7	19.1	20.9	23.5y	11.8x	18.7
3.4	Distance to the closest secondary school (km)	4.4by	2.6*	2.1a	3.1ab	2.6x	2.5x	3.4
3.5	Distance to the closest hospital (km)	16.8x	20.5**	21.3	20.2	23.3y	15.6x	18.9
3.6	Distance to the center of the village (km)	1.3x	2.4	1.4	3.7	1.1x	5.2y	1.9

4	Household Income														
4.1	On-farm income	$4,337b	72%	$3,502	57%	$5,286b	69%	$1,288a	31%	$3,029	51%	$4,422	69%	$3,904	65%
	4.1.1Tomato income	$3,610b	60%	$2,363	38%	$3,981b	52%	$544a	13%	$1,537	26%	$4,218	66%	$3,007	50%
4.2	Off-farm income	$1,177	20%	$1,914	31%	$1,562	20%	$1,789	43%	$1,799	30%	$1,398	22%	$1,429	24%
	4.2.1 Skilled RNFE wage income	$126a	2%	$445**	7%	$603b	8%	$171a	4%	$387	7%	$456	7%	$274	5%
4.3	Not earned income	$417xy	7%	$730	12%	$568	7%	$990	24%	$1,030y	17%	$223x	3%	$593	10%
4.4	Total household income	$5,998	100%	$6,146	100%	$7,661	100%	$4,158	100%	$5,930	100%	$6,424	100%	$6,049	100%
4.5	Total income per capita (considering all HH members)	$1,340ab		$1,565		$2,126b		$830a		$1,356		$1,921		$1,447	

*,**,*** = 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 tomato growers in Nicaragua in 2010, by adoption category.

		NON-ADOPTERS	ADOPTERS	ADOPTERS		ADOPTERS		TOTAL
			All	Early Adopters	Late Adopters	Short Duration	Long Duration	
	Observations	52	56	31	25	37	19	108
1	Land operated (for all crops in Ha)							
1.1	Total land owned and not rented out in Ha in 2010	8.0xy	7.7	8.7	7.1	5.1x	13.7y	8.0
1.2	Total land owned and rented out in Ha in 2010	0.3	0.3	0.3	0.2	0.3	0.3	0.3
1.3	Total land rented in in Ha in 2010	1.3	0.8	0.3	1.0	0.8	0.2	0.9
1.4	Total land owned and not rented out in Ha in 2005	8.3xy	7.6	8.5	7.0	5.0x	13.3y	8.1
1.5	Total land rented in in Ha in 2005	0.5	0.3	0.2	0.2	0.2	0.2	0.4
1.6	Total cropped land in Ha in 2010	3.2b	2.5*	2.5ab	2.1a	2.3	2.4	2.8
1.7	Total cropped land in Ha in 2005	3.1	2.6	2.4	2.1	2.2	2.4	2.7
1.8	Cropped land Gini coefficient 2010	0.46	0.50					0.50
1.9	Cropped land Gini coefficient 2005	0.78	0.81					0.53
2	Non land assets							
2.1	Total value of farm assets (USD) in 2010	$2,375	$3,264	$3,021	$3,481	$3,040	$3,590	$2,817
2.2	Total value of farm assets (USD) in 2005	$1,446	$1,884	$1,203	$2,540	$1,917	$1,572	$1,629
2.3	Total value of animals owned (USD) in 2010	$1,430	$1,152	$1,466	$695	$757	$1,833	$1,270
2.4	Total value of animals owned (USD) in 2005	$1,091	$1,145	$1,560	$723	$751	$2,034	$1,140
3	Tomato Production in 2010							
3.1	Total production (MT/year)	23.6	20.4	26.9	14.2	18.8	23.3	21.7
3.2	Total area grown (Ha)	0.9y	0.6*	0.6	0.6	0.7xy	0.4x	0.7
3.3	Yield (MT/Ha)	30.6ax	32.3	43.2b	21.9a	25.9x	44.7y	31.6
7	Tomato Production in 2005							
7.1	Total production (MT/year)	29.6	21.8	25.5	17.8	17.7	29.5	25.2
7.2	Total area grown (Ha)	0.9by	0.6**	0.5a	0.6a	0.6x	0.5x	0.7
7.3	Yield (MT/Ha)	33.2	36.8	40.3	34.4	35.2	42.2	35.4
4	Irrigation Technology in 2010							

4.1	Share of HH without irrigation	7%	0%	0%	0%	0%	0%	3%
4.2	Share of HH with drip irrigation	47%x	51%	40%	62%	41%x	71%y	49%
4.3	Share of HH with canal irrigation	40%	49%	60%	38%	59%	29%	45%
4.4	Share of HH with other type of irrigation	7%	0%	0%	0%	0%	0%	3%
8	Irrigation Technology in 2005							
8.1	Share of HH without irrigation	9%	2%	0%	5%	3%	0%	5%
8.2	Share of HH with drip irrigation	26%x	46%*	48%	41%	32%x	69%y	35%
8.3	Share of HH with canal irrigation	49%	48%	48%	50%	61%	25%	49%
8.4	Share of HH with other type of irrigation	17%	4%	4%	5%	3%	6%	11%
5	Seedling Technology 2010							
5.1	Share of HH using direct seeding	0%	0%	0%	0%	0%	0%	0%
5.2	Share of HH using owned produced seedlings	70%	39%	25%	52%	56%	7%	52%
5.3	Share of HH using purchased tray seedlings	30%ax	61%**	75%b	48%a	44%x	93%y	48%
9	Seedling Technology 2005							
9.1	Share of HH using direct seeding	2%	4%	0%	9%	6%	0%	3%
9.2	Share of HH using owned produced seedlings	72%	40%	36%	45%	48%	25%	56%
9.3	Share of HH using purchased tray seedlings	26%ax	56%***	64%b	45%a	45%x	75%y	40%
6	Tunnel Technology 2010							
6.1	Share of HH using tunnels	7%	12%	20%	5%	15%	7%	10%
6.2	Share of HH using open field	93%	88%	80%	95%	85%	93%	90%
10	Tunnel Technology 2005							
10.1	Share of HH using tunnels	4%	15%*	16%	14%	19%	6%	10%
10.2	Share of HH using open field	96%	85%	84%	86%	81%	94%	90%
11	Inputs for Tomato Production in 2010 (USD/Ha)							
11.1	Seedlings/seeds expenditures	72ax	126**	126b	137b	114xy	165y	103
11.2	Labor expenditure	570ax	946**	817a	1180b	914y	1106y	782
	11.2.1 Imputed family labor	222ax	389*	298a	532b	421y	367xy	316

	expenditure							
	11.2.2 Hired labor expenditure	347ax	557*	519ab	648b	493x	739y	466
11.3	Chemicals	835ax	1496***	1247b	1923c	1534y	1577y	1205
	11.3.1 Chemical fertilizers expenditures	316ax	651***	576b	796c	676y	671y	502
	11.3.2 Organic fertilizers expenditures	0ax	9*	5a	14b	2x	23y	5
	11.3.3 Foliar fertilizers expenditures	111ax	254**	186a	359b	234y	318y	190
	11.3.4 Insecticides expenditures	215a	359	302a	458b	376	364	296
	11.3.5 Herbicides expenditures	15ax	24	17a	34b	31y	11x	20
	11.3.6 Fungicides expenditures	179	199	161	263	215	191	193
11.4	Other inputs expenditure#	289ax	263	134a	443b	297	223	280
11.5	TOTAL	1767a	2830**	2325a	3683b	2860y	3071y	2371

*,**,*** = 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)	-0.010	0.010*
	(0.010)	(0.005)
Years of education of the HHH	0.004	-0.010
	(0.029)	(0.018)
Average years of education taken within the adult members of the household	-0.051*	0.033*
	(0.031)	(0.019)
HHH is female	-0.459	0.001
	(0.438)	(0.270)
Number of adults (14 to 60 years old) in the household	0.016	0.007
	(0.055)	(0.039)
Share of adults working in local off farm employment	-1.037**	-1.551***
	(0.493)	(0.381)
Farm and Non Farm Characteristics		
Lagged (1 year) participation in a production cooperative by any adult member of the household	-0.404*	-0.120
	(0.241)	(0.186)
Lagged (1 year) total owned land in Ha	-0.002	0.021
	(0.020)	(0.017)
Lagged (1 year) total owned land squared	0.000	-0.000
	(0.000)	(0.000)
Lagged (1 year) irrigated land in Ha	-0.148*	0.299***
	(0.090)	(0.092)
Total value of livestock holdings (USD thousands)	-0.036	-0.019
	(0.047)	(0.032)
Lagged (1 year) farm assets index	0.086	0.120
	(0.187)	(0.142)
Lagged (1 year) non farm productive assets index	-0.307*	0.088
	(0.173)	(0.124)
Lagged (1 year) durable consumption assets index	0.433***	0.083
	(0.127)	(0.096)
Distance to the nearest agri-inputs distribution store	0.118	-0.116*
	(0.124)	(0.069)
Distance to the nearest wholesale market (km)	-0.002	0.016
	(0.017)	(0.013)
Distance to the nearest local market (km)	-0.038	-0.063**
	(0.055)	(0.031)
Distance to the village center (km)	-0.007	0.011
	(0.085)	(0.047)
Meso Level Characteristics		
Lagged (1 year) tomato price per lb at the village level	2.365*	-1.005
	(1.289)	(1.028)
Elevation of the village (meters above sea level)	0.001**	-0.000
	(0.000)	(0.000)
Share of urban population over total population at the municipality level	0.021***	0.001
	(0.006)	(0.004)
Household time		

Origin of the adoption spell (*T_o*)	0.081**	
	(0.036)	
Origin of the withdrawal spell (year of adoption of the supermarket channel, *T_a*)		-0.261***
		(0.025)
Constant	1.451*	1.683***
	(0.871)	(0.485)
ρ	1.674	3.053
$\sigma=1/\rho$	0.597	0.327
Observations	740	116
LR Chi^2 (21)	55.13	108.1
Prob > Chi^2	0.000	0.000

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

Table 4. The effects of duration as a supermarket supplier on technology choices

	Farm Assets	Purchased tray seedlings	Drip irrigation area	Hired Labor	Fertilizers	Pesticides	Share of toxic pesticides
Age of the head of the household (HHH)	0.118***	-0.056	-0.003	-4.559	-2.529	16.725**	0.001*
	(0.032)	(0.056)	(0.003)	(6.039)	(5.871)	(7.980)	(0.001)
HHH is female	-1.575	6.304*	-0.071	174.238	482.338	-420.239	0.054
	(1.730)	(3.504)	(0.168)	(313.703)	(303.053)	(443.259)	(0.043)
Years of education of the HHH	-0.072	-0.148	0.007	-55.077***	-45.068**	7.694	0.002
	(0.102)	(0.170)	(0.010)	(18.375)	(17.934)	(25.175)	(0.003)
Number of adults (14 to 60 years old) in the household	-0.342**	1.054***	0.020	-40.273	17.633	10.975	-0.015***
	(0.169)	(0.395)	(0.020)	(34.386)	(35.308)	(33.963)	(0.006)
Total owned land in Ha	0.007	0.120	0.003	-11.242	-8.053	-10.055	0.002
	(0.038)	(0.165)	(0.004)	(7.567)	(7.741)	(8.554)	(0.001)
Total value of livestock holdings (USD thousands)	0.129	2.435***	-0.015	11.221	3.914	34.127	-0.009
	(0.170)	(0.723)	(0.020)	(35.995)	(37.638)	(34.179)	(0.006)
Farm assets index		-0.482	0.089***	-5.748	125.047**	-100.450**	-0.004
		(0.644)	(0.026)	(45.822)	(49.653)	(41.943)	(0.009)
Lagged (1 year) tomato price per lb at the village level	-1.271	4.793	-0.121	343.234	840.605	-1,143.828*	-0.036
	(3.132)	(9.722)	(0.399)	(739.675)	(794.113)	(669.351)	(0.138)
Distance to the nearest agri-inputs distribution store (km)	0.186	-3.227***	-0.050	52.050	-37.584	151.298	0.011
	(0.462)	(0.904)	(0.046)	(83.533)	(81.255)	(115.530)	(0.012)
Duration as supermarket supplier (years)	0.887***	0.414	0.046**	146.211***	158.007***	165.056***	-0.011*
	(0.183)	(0.581)	(0.023)	(40.137)	(42.440)	(37.888)	(0.006)
First stage residuals	1.712*	7.460***	0.577***	1,372.631***	1,816.701***	485.095***	0.010
	(0.938)	(2.881)	(0.123)	(211.750)	(231.757)	(186.238)	(0.042)
Constant	-10.163***	-3.214	-0.196	-360.280	-665.261	-1,743.86***	0.088
	(2.698)	(7.023)	(0.316)	(564.805)	(577.083)	(632.239)	(0.091)
Observations	246	246	246	239	240	240	240
Wald Chi^2 (10)	73.98	32.65	67.44	61.67	112.1	33.62	19.33
Prob > Chi^2	0.000	0.001	0.000	0.000	0.000	0.000	0.036

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