SMALLHOLDERS, OUTPUT AND INPUT MARKETS, AND TECHNOLOGY ADOPTION IN CENTRAL AMERICA

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ABSTRACT

SMALLHOLDERS, OUTPUT AND INPUT MARKETS, AND TECHNOLOGY ADOPTION IN CENTRAL AMERICA

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Chapter 1 analyzes the determinants of Guatemalan farmer participation in off-farm employment (in different activities, the lion's share of which is in local rural nonfarm employment (RNFE), as skilled RNFE and unskilled RNFE, and in agricultural wage employment (AWE)). The paper then analyzes how that participation in off-farm employment is correlated with farming technology and crop choice, in particular in terms of diversification into horticulture (versus traditional grain and bean farming). The paper uses a switching regression model applied to rural data in the LSMS dataset collected in Guatemala in 2000. The overall results suggest a virtuous triangle of income inter-sectoral diversification, agricultural diversification into higher value crops, and modernization of agricultural technology. This process appears to be spurred by overall development of agricultural markets and rur-urbanization. The concern is that this combination is uneven distributed, with the asset-poor participating least. This suggests policy interventions to help the poor have greater access to RNFE would spur diversification which helps incomes and manages risk, and technology modernization which spurs farm productivity.

Chapter 2 explores 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 the farm technology they use. The methodology is based on a survival analysis approach. We use data from a stratified random sample of tomato farmers in Nicaragua over a 10-year period. Our results show that participation in supermarket supply chains as supermarket

supplier is not determined by farm size, contrary to a common hypothesis, and thus small farmers can be supermarket suppliers. However, non-land assets are important determinants of being in the modern channel. Duration as a supermarket supplier is positively correlated with farm asset accumulation and the use of modern technology (mainly in the form of capital-led intensification) of tomato farming – but negatively correlated with the share of highly toxic pesticides in overall pesticide use.

Chapter 3 is an extension of chapter 2. This paper studies how product choice, perishability and modern farm technologies can be both causes and consequences of participation of smallholders in horticultural modern markets. The methodology is based on a survival analysis approach, we use data from a stratified random sample of 794 growers of six horticultural crops in Nicaragua in 2010. Similarly to the second essay, our results show that participation as supermarket supplier is not determined by farm size. However, the use of drip irrigation (a modern technology) significantly determines participation and duration as supermarket supplier. Production of highly perishable products and/or niche varieties is a competitive advantage for smallholders, as they tend to last longer as supermarket suppliers. Duration is positively correlated with indicators of farm modernization and intensification, while late adopters (long time to adoption periods) tend to overuse pesticides and are negatively correlated with indicators farm technology modernization.

This dissertation is dedicated to Marcelo, Gretel, my mother Elisabeth, the rest of my family and friends.

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INTRODUCTION

Market participation and income diversification are often related topics in rural development. The economic literature has shown how the traditional view of rural livelihoods has changed in the last couple of decades. The perspective of rural households producing traditional agricultural goods for self consumption or to satisfy the local rural demand is obsolete. There are two important findings that have reversed the traditional view.

First, recent studies have confirmed that income diversification is the norm for rural households. Barrett and Reardon (2000) show that rural households collect their income from different sources, using their assets in many income generating activities, only few households collect their income from a single income source, or using all their assets in a single activity. Second, rural development has expanded market access for rural households. This has induced rural households to shift from the production of traditional goods (such as staples) to modern agricultural (such as horticultural crops for supermarkets and exports) and non-agricultural (such as clothing and metal manufacturing) goods for urban and foreign markets.

These findings have motivated this dissertation to analyze two of the most important household's strategies for economic development. First, rural households can diversify away from farming by using their labor endowment to pursue employment into the rural nonfarm sector. Second, rural households can shift from production of staples to production of horticultural crops that will enable participation in presumably more profitable modern market channels. The main objective of this dissertation is to contribute to the literature by analyzing the household strategies mentioned above through three empirical studies.

The first essay analyzes the determinants of Guatemalan farmer participation in off-farm employment (in different activities, the lion's share of which is in local rural nonfarm employment (RNFE), as skilled RNFE and unskilled RNFE, and in agricultural wage employment (AWE)). The paper then analyzes how that participation in off-farm employment is correlated with farming technology and crop choice, in particular in terms of diversification into horticulture (versus traditional grain and bean farming). The paper uses a switching regression model applied to rural data in the LSMS dataset collected in Guatemala in 2000. The overall results suggest a virtuous triangle of income inter-sectoral diversification, agricultural diversification into higher value crops, and modernization of agricultural technology. This process appears to be spurred by overall development of agricultural markets and rur-urbanization. The concern is that this combination is uneven distributed, with the asset-poor participating least. This suggests policy interventions to help the poor have greater access to RNFE would spur diversification which helps incomes and manages risk, and technology modernization which spurs farm productivity.

The second essay explores 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 the farm technology they use. The methodology is based on a survival analysis approach. We use data from a stratified random sample of tomato farmers in Nicaragua over a 10-year period. Our results show that participation in supermarket supply chains as supermarket supplier is not determined by farm size, contrary to a common hypothesis, and thus small farmers can be supermarket suppliers. However, non-land assets are important determinants of being in the modern channel. Duration as a supermarket supplier is positively correlated with farm asset accumulation and the use of modern technology (mainly in the form of capital-led intensification) of tomato farming – but negatively correlated with the share of highly toxic pesticides in overall pesticide use.

The third essay is an extension of the second essay. This paper studies how product choice, perishability and modern farm technologies can be both causes and consequences of participation of smallholders in horticultural modern markets. The methodology is based on a survival analysis approach, we use data from a stratified random sample of 794 growers of six horticultural crops in Nicaragua in 2010[1]. Similarly to the second essay, our results show that participation as supermarket supplier is not determined by farm size. However, the use of drip irrigation (a modern technology) significantly determines participation and duration as supermarket supplier. Production of highly perishable products and/or niche varieties is a competitive advantage for smallholders, as they tend to last longer as supermarket suppliers. Duration is positively correlated with indicators of farm modernization and intensification, while late adopters (long time to adoption periods) tend to overuse pesticides and are negatively correlated with indicators farm technology modernization.

[1] This is a larger dataset than the one used in the second essays, which consists of 108 tomato growers.

CHAPTER 1: Rural Nonfarm Employment and Farm Technology in Guatemala

3.1 Introduction

Pingali and Rosegrant (1995) posited the correlation of agricultural commercialization, agricultural diversification, and technological intensification via the increased use of external non-labor inputs and hired farm labor (agricultural wage employment), which Lele and Stone (1989) call "capital-led intensification". Reardon et al. (1994) further posited the correlation of the latter with rural nonfarm employment (RNFE). A 2009 issue of Agricultural Economics was devoted to exploring the links above links, in particular see Davis et al. (2009), Pfeiffer et al. (2009) for Mexico, Kilic et al. (2009) for Albania, Stampini and Davis (2009) for Vietnam, Oseni and Winters (2009) for Nigeria and Huang et al. (2009) for China. These papers tended to find off-farm employment is associated with capital-led intensification; Huang et al. (2009) was the only one to test the relation of RNFE and crop diversification (into fruit farming), and actually found a negative relation of substitution.

In this paper we extend the work from the above papers by focusing on the three way links among RNFE, capital-led intensification, and agricultural diversification into horticulture in Guatemala. We address the following three gaps in the above papers. (1) The above papers, and existing literature in general, does not systematically test the differential determinants of, and impacts on technology and crop composition of, different categories of off-farm employment – to wit, the three we note (skilled and unskilled RNFE and AWE). Skill levels, and sectors in which off-farm activity occurs, tend to be lumped together by the extant papers. We expect the different kinds of employment to differ in their determinants and impacts due to skill and other capital requirements to entry, and to complementarity or substitutability in terms of timing and thus labor use. (2) No paper tests the relation of all the three-way linkages we note; papers tend to focus on one or two of the links. (3) The papers do not address certain meso-level determinants we posit to be important, and to link to the debate on "rur-urbanization" and "territorial development" in Latin America on one hand (Schejtman and Berdegue (2003), and the production linkages perspective; we proxy these with urban share in the districts, the marketed surplus rate in the districts, and rural density of population.

This paper focuses on three research questions. (1) What are the differential determinants of farmers' participation in skilled rural nonfarm employment (RNFE), unskilled RNFE, and agricultural wage employment (AWE) in rural Guatemala? (2) What effects do those three off-farm employment activities have on farm technology? (3) What effects do the off-farm employment activities have on crop composition, in particular diversification into horticulture?

We expect farm size and non-land assets to determine entry into off-farm employment, with a strong positive correlation with skilled RNFE, a moderate one for unskilled RNFE, and a negative correlation with AWE. These hypotheses are based on the entry requirements in terms of skill and other forms of capital.

We expect that income diversification will have an impact on technology use through the opportunity cost of labor and the wealth effect in the presence of presumed constraints on access to credit – but the effect is a priori ambiguous and requires empirical testing. We will test the direct effect, but not test the reason for the effect, which would require testing for the presence of a credit constraint that own-liquidity would relax.

Moreover, we expect that especially skilled RNFE but also unskilled RNFE will be associated with farmers undertaking horticulture, the most important agricultural diversification activity away from or in addition to low-remunerated staples (maize and beans). This is because liquidity from RNFE helps to meet input expenditure needs for horticulture before grain sales cash is available; horticulture is more intensive in external inputs than grain farming.

We address these three questions with data from the Living Standards Measurement Survey (LSMS) for 2000 in Guatemala.

The paper proceeds as follows. Section 2 discusses the behavioral model, implementation model, estimation methods, and data. Section 3 presents descriptives. Section 4 presents the econometrics. Section 5 concludes.

3.2 Behavioral and Econometric Models

We first model participation in off-farm employment activities, and then model farm technology choice as an economic decision by modeling input use and output supplied.

In each section we describe three subsections, one presenting the conceptual model, then a general implementation model that derives from the conceptual model, and then the regression specification model that derives from the general implementation model with some empirical adaptations.

1.1.1 Participation in off-farm employment

Conceptual Model.

We use a farm household utility maximization framework to present our integrated model of labor allocation and farm production decisions. The subsequent model follows Sadoulet and de Janvry's (1995) model with adaptations from Lopez (1986) and Singh et al. (1986). It is a simple non-separable household model where households derive utility from consumption (c_i) and where households can have different preferences for working on and off the farm (E_t-q_f and E_t-q_{of}). The model is written as follows:

A household maximizes the following utility function:

$$\max_{c,q} u(E_t - q_f, E_t - q_{of}, c, z^h) \tag{1.1}$$

Subject to:

(i) $\sum_{i \in T} p_i(q_i - E_i - c_i) + S \geq 0,$ cash constraint,

(ii) $\sum_{i \in TC} p_i(q_i - E_i - c_i) + K \geq 0,$ credit constraint,

(iii) $g(q, z^q) = 0,$ production technology,

(iv) $p_i = \bar{p}_i, \;\; i \in T,$ exogenous market price for tradables,

(v) $q_i + E_i = c_i, \;\; i \in NT$ equilibrium conditions for nontradables,

(vi) $q_f + q_{of} + E_t = c_l,$ labor constraint

Where: $q>0$ represents goods produced; $q<0$ represents factors used; c represents goods consumed, including purchased and home-produced goods; E is the household initial endowment; S is net transfers received; K is access to credit for consumables or inputs (this is household specific and not good/commodity specific);); p_i is the vector of exogenous effective market prices of outputs and inputs (these prices are net of transaction costs); z^q is the vector of quasi-fixed production assets (both farm and non-farm), and z^h is the vector of assets that affect consumption decisions. z^q and z^h include nonfarm productive assets (because the maximization problem involves both farm and nonfarm activities) and consumption assets (as this is a non-separable household model, consumption and production decisions are decided jointly). For the labor allocation decision to work on and off the farm (E_t-q_f and E_t-q_{of}): q_f is household labor working on-farm; q_{of} is household labor working off-farm; E_t is time available by household members for all activities including leisure; and c_l is consumption of leisure.

Sadoulet and de Janvry show that after the manipulation of the first order conditions of the maximization problem, the production decisions are represented by a system of supply and factor demand functions in the decision prices (p*), and quasi-fixed production assets (z^q):

$$\mathrm{q} = \mathrm{q}(\mathrm{p}^*, \mathrm{z}^\mathrm{q}) \tag{1.2}$$

The decision of supplying off-farm labor can be modeled using the result obtained in equation 4.2, since as seen from the labor constraint in the model, the vector of factor demands and output supply (*q*), include the derivation of the decision of using their own labor to work on farm (q_f), off farm (q_{of}), and in leisure (c_l)

General implementation model.

Since the decision prices p^* are functions of the exogenous prices ($\bar{p}$), the household assets associated with production (z^q) and consumption decisions (z^h), transfers (*S*) and access to credit (*K*), then the equation 1.2 can be rewritten as follows:

$$\mathrm{q} = \mathrm{q}(\bar{\mathrm{p}}, \mathrm{z}^\mathrm{q}, \mathrm{z}^\mathrm{h}, \mathrm{S}, \mathrm{K}) \tag{1.3}$$

Sadoulet and de Janvry (1995) show that a reduced form of the model can be used, and it allows for the estimation of a subset of input demands and/or the supply functions without having to deal with the full system, and that the household assets that affect consumption decisions (z^h) are what makes this solution different from the one obtained from a pure producer model.

Our general implementation model for the decision of allocation of labor in off-farm employment then is an extension of equation 1.3:

q_{of}=f(input and output prices, farm assets, human assets, nonfarm assets, community assets, transfers, access to credit, risk)

Note that only "risk" does not map directly from the conceptual model (equation 1.3) to the implementation model. However, nonfarm employment is typically modeled as a function of risk as it is an instrument of risk management.

Regression specification model.

We estimated three models that have as left hand side variables the participation in different types of off-farm employment; household participation in skilled RNFE, participation in unskilled RNFE, and participation in AWE. The regressors are derived from the conceptual and implementation models noted above.

Vector of exogenous prices:

The variables included are the following

(1) Agricultural wage rate: this wage rate is defined as the average monthly wage rate in US dollars received by households participating in agricultural wage employment at the municipality level. This variable was calculated by: (1) dividing the household's net agricultural wage income received during the last 12 months by the amount of time (in months) that all members in the household have spent working as farm wage earners during the last 12 months; (2) once we had the average agricultural wage at the household level, we calculated the average at the municipality level by doing a simple average across all

households that have agricultural wage within the same municipality. The agricultural wage should have a positive effect on participation in AWE, since households will have the incentive to allocate their unskilled labor stock into AWE to increase their income. However, the effect of the agricultural wage in RNFE is ambiguous. On the one hand, as the agricultural wage increases it could have a negative effect in participation on unskilled RNFE, since both sectors are competing sectors for the household's unskilled labor stock. On the other hand, higher agricultural wage rates are common in areas where there is high production of agricultural products and in accord with the production linkages literature, those areas spur the availability of RNFE (both skilled and unskilled), for example in the high commercial watermelon zones in Guatemala, there is high demand of labor to work in transportation services.

(2) Skilled RNFE wage rate: this wage rate is defined as the average monthly wage rate received by households participating in skilled RNFE at the municipality level in US Dollars. This variable was calculated by: (1) calculating the skilled RNFE income, by aggregating the net incomes from RNF self and wage employment; (2) dividing the household's net skilled RNFE income received during the last 12 months by the amount of time (in months) that all members in the household have spent working in skilled RNF self and wage employment during the last 12 months; and (3) once we had the average skilled RNFE wage rate at the household level, we calculated the average at the municipality level by doing a simple average across all households that have skilled RNFE wage within the same municipality. The skilled RNFE wage should have a positive effect on participation in skilled RNFE. However, the effects of increasing skilled RNFE wages on AWE and unskilled RNFE are not obvious. On the one hand, skilled RNFE should not have an effect on unskilled RNFE and

AWE since those sectors use the household's unskilled labor stock, and therefore do not compete for the skilled labor stock. On the other hand, one can hypothesize opposite effect of the skilled RNFE wage on the unskilled sectors: (1) all else equal, households might have a higher preference to work on their farms than working off the farm, then they might under using their skilled labor stock in own farming until the skilled RNFE is high enough to offset the utility from own farming; and (2) higher skilled RNFE wages are common in more "urbanized" rural areas or in areas with higher agricultural production, these areas have lower transaction costs and greater availability of unskilled RNFE and AWE, therefore skilled RNFE can have a positive effect on both sectors.

(3) Unskilled RNFE wage rate: this wage rate is defined as the average monthly wage rate received by households participating in unskilled RNFE at the municipality level in US Dollars. This variable was calculated in an analogous way to the skilled RNFE wage rate. The effect of the unskilled RNFE wage rate on participation in unskilled RNFE should be positive. However, the effects of the unskilled RNFE on skilled RNFE and AWE are not obvious, and are similar to the ones discussed for the AWE wage rate.

Human capital assets:

(1) Years of education of the HHH (head of household). The effects of education as a determinant on participation in both farm and nonfarm employment has been studied extensively in the economic literature. We hypothesize that education is one of the most important barriers that household face in order to participate in skilled RNFE, hence education should have a positive effect on RNFE.

(2) Gender of the HHH. We hypothesize that female headed households have a positive effect on participation in unskilled RNFE and AWE. Empirical evidence in the literature (Lanjouw,

1996 in Ecuador) have shown that controlling for wealth level, women tend to undertake labor-intensive, low-skill, low entry barrier.

(3) Number of adults (members of the household between 14 and 60 years old) in the household. The number of adults in the household is also a proxy for the shadow price of own labor (Singh et al 1986). This variable should have a less ambiguous effect on participation in off-farm employment. All else equal, households with higher labor stock have the incentive to shift a portion of their labor stock to off-farm employment to increase the household's income.

(4) Age of the HHH, in itself a proxy for experience. This variable can have ambiguous expectations. On the one hand, as the HHH ages, he/she can be reluctant about letting the household to shift from on to off-farm employment. On the other hand, as age increases, experience increase, and therefore the HHH might have the necessary skills to participate in higher payment off-farm employment.

Farm assets:

In our empirical model we have included the following farm assets:

(1) Total land owned and total land squared: total land is the total area in hectares that the household owns (for all uses, for all types of crops plus pasture plus fallow plus wooded or barren), which includes the land owned and cultivated, land rented out, and lent out. Total land owned squared is included to allow for diminishing returns of the land assets. We would expect a positive effect of land on participation in RNFE, as one can expect that land owned can be used as a collateral for access to credit, that will allow for capital investments needed to engage in RNFE. However the empirical evidence in the literature, have shown that land has a U-curve relationship with the share of off-farm income in total household income

(Reardon et al. 2000), where the share is high for small farms, declines in the middle handholding range and then rises at the higher end of landholdings.

(2) Total value of animals owned: this variable is defined as the total value (in USD 100's) of the following animals owned by the household; cattle, goats, sheep, pigs, horses, beehive, small animals, and other animals.. We expect a positive effect of livestock holding in participation in RNFE, since livestock is a proxy for liquidity and wealth, then household with higher levels of livestock holdings are in a more favorable position to diversify into non-farm activities if diversification is costly (i.e. has high entry barriers) (Reardon et al. 2000).

(3) Irrigation (have or not): This is variable is defined as a binary variable that captures whether the household has (or doesn't have) irrigation system in the farm. we hypothesize that irrigation should favor participation in non-farm employment since investments in technological change in the farm can free labor to work in the non-farm sector (Estudillo and Otsuka, 1998).

(4) Total value of other agricultural assets: this variable is defined as the total value (in USD) of farm productive assets of the household. Agricultural assets should have a positive effect on participation in RNFE, since capital farm investments are often labor-saving investments, which allow households to allocate labor stock into non-farm employment.

Non-farm assets

Non-farm assets can be subdivided into assets that could affect non-farm production and assets that are needed for consumption. The former are important determinants of participation in off-farm employment, while the latter are included in accord with our theoretical model, where consumption and production decisions are non-separable. We have included the following nonfarm assets in our model:

(1) Household infrastructure: this is proxied by several dummy variables that show if the household have access to the following services; (a) electricity; (b) piped water; and (c) cemented floor. Electricity and piped water are productive assets, and they should have a positive effect on RNFE, since those can be entry barriers to engage in non-farm business investments.

(2) Non-agricultural household assets: this is proxied by two dummy variables that show if the household owns the following household assets: (a) land-line telephone or cellular phone; and (b) vehicles. Telephones are proxies for access to information, and vehicles are productive assets that could be entry barriers for RNFE activities, they both proxy lower transaction costs, and as transaction costs are reduced, there is greater incentive to shift from farm to non-farm activities.

Community assets

Reardon et al (2000) show that one of the main determinants of non-farm employment is the inter-location differences in infrastructure, market and population densities, since more developed infrastructure and denser population means lower transaction costs to market products, and greater availability of inputs at lower costs. We have included the following community characteristics to control for the zone effects:

(1) Urban population share: this variable is defined as the rate of urban population over total population at the municipality level.. The hypothesis normally found in the literature is that quality and quantity of infrastructure is tend to be correlated with urbanization and

population densities (Anderson and Leiserson, 1980; Lanjouw and Lanjouw, 1995; Reardon et al., 1994), therefore we expect that as urban population increases within the same municipality, there is more quality and quantity of infrastructure that will mean lower transaction costs for the households in the municipality, which will increase the availability of off-farm employment and business opportunities.

(2) Rural density: this variable is defined as the rate of rural population over rural area of the municipality. The hypothesis for this variable is similar to the one for urban population share, since quality and quantity of infrastructure is often correlated with population densities.

(3) The agricultural commercialization rate: this variable is defined as the average rate of sold crop production over total crop at the municipality level.. We expect that as the agricultural commercialization rate increases; there is higher availability of off farm employment. First, high commercial zones have higher demand for farm wage labor; therefore the effect of the agricultural commercialization rate should have a positive effect on participation in agricultural wage employment. Second, from the production linkages literature we can expect that higher commercial zones will bolster the demand for non-farm employment. We have also included agricultural commercialization rate squared since as the rate increases, farm wages increases, cost of land increases, and then farms are encourage to invest in labor-saving technologies, hence implying diminishing returns of the commercialization rate.

Transfers

Remittances as shown in our descriptive analysis are the most important transfers that rural households receive, but since remittances can be endogenous in our labor allocation equations, we have included the natural log of remittances received by the household using an instrumental variables approach, where we used the share of households receiving remittances at the municipality level as an instrument.

Access to credit

We do not measure access to credit directly, but we proxy access to credit by including farm assets (land and non-land) and livestock holdings, since these assets are often used as proxies of household's wealth.

Risk

Agricultural risk is normally included in empirical models with measures of weather conditions, we do not have weather information needed to construct these variables and therefore there is no explicit measure of agricultural risk.

Market risk is normally included as indexes of volatility of market. We proxy market risk in our implementation model by including the agricultural commercialization rate at the municipality level, then volatility of market is proxied by thickness of the market, we hypothesize that as the density of the market increases there is lower transaction costs and higher price stability. This approach goes far beyond controlling for location dummies since it controls for both; zone characteristics and transaction costs.

In addition, household's degree of risk aversion is proxied by farm assets and livestock holdings, as economic literature have shown that risk aversion varies inversely with wealth (Newbery and Stiglitz, 1981).

Estimation method for off-farm employment: We estimate the probability of participation in off farm employment activities using the IV probit model for the regressions, and we instrument remittances in each equation.

1.1.2 Modeling RNFE's Impact on Farm Technology

Conceptual Model and general implementation model

The conceptual model for the decisions in the farm is the same as the one used in the previous section since the solution of the maximization problem, the vector *q* (equation 1.2) includes the farm input demands and output supply functions. The general implementation model is similar to the one used in the previous section, the difference is that now we have included participation in off-farm employment as an explanatory variable of the farm decisions, therefore our general implementation models for input demands and output supply are as follows:

q^S*outputs=f(*$\underline{q_{of}}$*, input and output prices, farm assets, human assets, nonfarm assets, community assets, transfers, access to credit, risk)*

q^D*inputs=f(*$\underline{q_{of}}$*, input and output prices, farm assets, human assets, nonfarm assets, community assets, transfers, access to credit, risk)*

Regression model for technology and crop output we have estimated five input demand equations and two crop output equations. All input demands are expressed as input expenditures aggregated over all seasons in 2000. In these models, the regressands for the input equations are:

(1) Expenditure (as imputed use) of own labor.

(2) Expenditure on hired farm labor.

(3) Expenditures on Seeds.

(4) Expenditures on fertilizers.

(5) Expenditures on pesticides.

The output supply variables are expressed as the total production in metric tons aggregated over all seasons in 2000. The regressands for the crop output equations are:

(1) Production of beans and grains.

(2) Production of horticultural crops.

The regressors are as follows:

Participation in off farm employment

(1) The predicted probabilities of participation in skilled RNFE, unskilled RNFE, and AWE derived from the IV probit model estimation in section 4.A. We expect that participation in RNFE (skilled and unskilled) can have a positive effect on purchased inputs and outputs, but a negative effect on use of own labor. In accord with the RNFE literature, we expect that RNFE can relax the household's credit constraint and allow for self financing of crop inputs that will also increase production of outputs. AWE does not have a clear effect on the use of inputs and production of outputs. On the one hand, it may have the same effect as RNFE, since the earnings from AWE can be used for self financing of crop inputs. On the other hand, the economic literature shows that households that dedicate their household labor stock to AWE, are generally the poorest (asset based) households, who have very limited agricultural production.

Vector of prices:

(1) Agricultural wage rate.

(2) Nonfarm skilled wage rate.

(3) Nonfarm unskilled wage rate.

The hypothesis on the effects of all wages on input use and output produces are ambiguous. On the one hand higher wages might imply higher off-farm income, which can be used for financing in the farm, therefore increasing the use of purchased inputs and increasing the production of crop outputs. On the other hand, higher wages may induce households to shift from farm to off-farm, therefore reducing production and then reducing outputs.

Human capital assets:

(1) Years of education of the HHH. The effect of education on input use and output produced are ambiguous. On the one hand, we will expect that higher levels of education will allow farm households to switch between labor-using to capital-saving technologies. On the other hand, empirical evidence in rural Mexico (Taylor and Yuñez-Naude, 2000) have shown that as schooling levels increase, the returns from schooling shift away from crop production.

(2) Household labor stock. Empirical studies in the literature (Carletto et al. 2007) suggest that hired labor is an imperfect substitute of family labor, then as the number of available adults to work in the own farm increase, the supervision capability of the household increases, resulting in decreasing the overuse of variable inputs.

(3) Age of the HHH. this variable is a proxy for experiences, so we expect that as age of the HHH increases, there is greater production of crop outputs in the farm, and this might be accompanied by lower use of purchased inputs.

Farm capital assets:

(1) Total cropped land. This variable have ambiguous expectations. On the one hand, the use of inputs and labor can be affected by economies of scale, and then as land increases, the use of variable inputs can be more efficient. On the other hand as the area of production increases, there is higher pressure of pests and the managerial capacity of farmers decrease, resulting on overspending in variable inputs and reduction of crop yields.

(2) Irrigation. This variable should have a positive effect on use of purchased inputs and production of outputs, since having irrigation should allow farm households to crop more seasons during the year. However, all else equal, irrigation should have a negative effect on use of labor since irrigation systems can be labor saving technology.

(3) Total value of agricultural assets. This variable should have similar effects than irrigation.

Non-farm assets:

(1) Non-agricultural household assets (consumption assets). This variables do not have a clear effect on decision on the farm. However, those are included in accord to our theoretical model, since consumption and production decisions are made simultaneously and therefore we should have proxies of consumption decisions in the equations that model farm decisions.

(2) Distance to the main road: this is defined as the distance from the household to the main road (paved or unpaved) in the community where the household is located. As farm households are located in areas far from roads and urban areas, they have higher transaction costs that will affect negatively the use of inputs and production of crop outputs.

Community assets:

(1) The marketed surplus rate of the municipality. We will expect that as the agricultural commercialization rate increases, there is higher demand for variables inputs.

Estimation methods for technology correlates

Note that we call these regressions “technology correlates” because with a cross section data set, we cannot strongly posit causality, but just correlation. The seven equations of input use and output produced 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 three variables not actually observed (the probabilities of participation in off farm employment were derived from a first stage (probit estimation) we use a bootstrapping procedure to obtain the correct standard errors.

3.3 Data

The analysis uses farm household data from the Guatemala Living Standards Measurement Survey (LSMS) carried out in 2000. The sample for the Guatemala 2000 LSMS was drawn using a two-stage stratified sampling procedure using the census segments from the 1998 survey of family income and expenses (ENIGFAM) to draw the primary sampling units (PSUs). The sampling unit was the individual occupied or vacant household. 8,940 households were selected for the LSMS sample and after attrition, the total sample of completed survey interviews was 7,276 households (3,852 rural and 3,424 urban). We only use the rural portion of the data. After the exclusion of three groups of rural household observations (households without cropping, large scale ranchers, and households with large amounts of remittances) we ended up with a total sample of 2442 observations which represent 63% of the rural LSMS sample.

3.4 Descriptive Results

In this section, we present descriptive statistics. Table 1.1. shows the income sources of sample households, stratified by household total-income quartiles. The salient points are as follows.

First, the average overall household income per capita is 600 US dollars. This can be compared with Guatemalan GDP/capita of 1558 dollars (in 1995 dollars) in 2000 (www.earthtrends.wri.org), showing thus the urban-rural income divide. There is sharp inequality; the Gini is 52% and the ratio of the richest to poorest quartiles' incomes is 21 to 1 –

with the sharpest divide between the first two quartiles (4 to 1) and less difference over the others (with the other quartiles separated by 2 to 1 ratios).

Second, incomes are very diversified outside own-farming: the share of own-agriculture income (from crops and livestock) in total income is only 21%. This is similar to the 22% found by Ruben and van den Berg (2001) for Honduras, but below that in Nicaragua (42%) found by Corral and Reardon (2001). There is a sharp inverted-U in the share of own-cropping income as one goes from the poorest to the richest quartile, but a sharp descent in the share of livestock income. But crop income among the richest quartile is 23 times that of the poorest quartile, but only twice that of the 2nd quartile. Thus, as with overall income, there is a step function with the first step, the poorest, very low, and then the other steps well above the poorest but not far from each other. Livestock income also rises over the quartiles but only by a factor of 3.

Third, the corollary of the inverted-U shape of quartile income with own-agricultural income is a U shape of the share of off-farm income over quartiles. But the absolute level of off-farm income (total income less own-crop and livestock income) climbs quickly over quartiles, 30 times; off-farm income (with a gini of .63) is thus more concentrated than overall income (gini of .52), as is farm income (with a gini of .72), showing diversification in off-farm as partially compensating farm income inequality. Just the upper 25% of the rural population has 67% of the off-farm income earned in rural areas; the top half has 88%. These patterns (shares, levels, and concentration) are common in findings in surveys in Latin America and Asia, where poorer households enter low-paying off-farm jobs such as farm wage labor and low capital-entry-barrier nonfarm jobs, and the richer rural households dominate the higher-paying (and often more capital-intensive) nonfarm activities (Lanjouw and Lanjouw, 2001; Reardon et al. 2001).

Fourth, the share of farm wage-employment income (the lowest per day paid of the off-farm employment types) in total income is similar to that of own-farming, but less than half of the total share of RNFE. This finding echoes a number of similar findings elsewhere in Latin America (Reardon et al., 2001). Moreover, as in most other studies, this share drops as household income rises. This makes sense as farm wage labor is a low-entry requirement job. Despite the latter, however, the share of households doing this work rises from a quarter to half as one moves from the lowest to the second quartile and then stays steady as a share over other quartiles; moreover, while the upper two quartiles depend less on this activity, they earn 78% of the total earned in farm wage labor. Even this supposedly "refuge" off-farm employment is highly concentrated (gini of 75%).

Fifth, the overall share of RNFE in total income is 48%, similar to a Latin America-wide estimate from a review of studies provided by Haggblade et al. (2007). We decomposed it into skilled and non-skilled activity (self-employment and wage-employment), using specific activity categorizations as provided in the LSMS data set. We examine each.

On the one hand, skilled RNFE income is highly concentrated (with a gini of 97%). Its share is low (2% of income) for the first three quartiles and then inflects sharply upward (but only to 8% of income and 14% of households) in the highest quartile. The richest quartile is very dominant in the skilled RNFE labor market – earning 85% of the total.

On the other hand, unskilled RNFE is 42% of overall income, and is the most common income source of any income source. It is also however quite concentrated: its gini coefficient is 0.77, and its share in income rises from 20-23% for the first two quartiles to 35% for the third and 51% for the richest quartile. This pattern is common in Latin America and Africa (Haggblade et al. 2007; and Reardon et al. 2001). Despite the low skill requirement seeming to represent a low entry barrier to the poorest, the table shows that the richest quartile earns 77% of unskilled RNFE, and the top half of the income strata earn 93% of low-skilled RNFE. This may suggest barriers and requirements other than skill, such as capital investments, play a part in concentrating this income source. This leaves the poorest half of the rural population to depend on farming directly or in the labor market, and thus on the vicissitudes and risks of that sector.

Finally, while much public attention in sending areas focuses on migration as a source of income for rural households, only 10% of the households receive remittances, and it is only 7% of incomes, far less important than local RNFE. But this is a common research finding elsewhere in Latin America as well as Asia and Africa, explained by the capital entry requirements of migration (Haggblade et al. 2010; de Janvry and Sadoulet, 2001). Moreover, remittances are highly concentrated: the richest quartile earns 80% of the remittances. Pension distribution tells a roughly similar story.

Table 1.2. shows characteristics regarding demographics, education, and non-agricultural assets of the sample. Upper quartile households are slightly larger; but surprisingly, the average education barely differs over the quartiles – and is quite low, at several years. Consumer durables holdings, access to electricity and piped water increase with income, but far less steeply than does income; only about half the sample has access to the two latter. As this is 2000 (before the cell phone trend of the 2000s), access to phone service is slight. However, predictably, there is a very sharp correlation between distance to a bus stop (a proxy for distance to paved highway) and having a vehicle, on the one hand, and income quartile: the richer households face lower transaction costs. However, only a quarter of households in the first three quartiles and only a third in the highest quartile have a car/truck or motorcycle.

Table 1.3. shows farm characteristics. Several points stand out.

First, the richest two quartiles have more than twice the non-land assets (such as farm machinery) of the poorest two quartiles. Two technology characterizations emerge. As household labor stocks are similar across quartiles, this means capital/labor ratios rise with household income. Moreover, as cropped land is similar over quartiles, this also means the capital/land ratio rises with income.

Second, a surprisingly high share (29% on average, decreasingly slightly over quartiles) of households are “landless”; but as they are cropping-households (per our sample choice), they are renting-in or borrowing the land.

Third, land ownership is relatively even at 4 ha across all quartiles but the poorest (who have 2.2), and cropped land is on average 3.4 ha. Note that nearly all the cropped land is merely rainfed and thus particularly exposed to production risk: the irrigation rate is extremely low – only 1% over all quartiles. So these farms are very small by irrigated-equivalent hectares. Moreover, livestock holdings vary little over quartiles, and 80% of the farms have livestock; the average holdings are just a pig and a few chickens.

Fourth, land use varies over quartiles, with more crop diversification (as horticulture) as income rises. While a steady 92-93% of the households grow the staples (beans and grains), there is sharp variation in horticulture: 39% of the poorest and 58% of the richest undertake it, and the average area rises from 0.5 ha to 1.6 ha over the income quartiles. The share of households growing horticulture crops is surprisingly high – 51% of the sample – belying a conventional image of small farm agriculture in Guatemala being maize-bean apart from pockets of commercial horticulture and some garden plots.

Fifth, marketed surplus rates for grain/beans display the “step function” that we saw in other assets; while almost all the poorest quartile grow staples, only 37% sell, with the marketed surplus rate of only 19%; they are thus mainly subsistence farmers; the share of farms selling in the upper quartile is 48% and the rate, 53%. The average for the sample is a rate of 36%, with only 47% of households selling, so in the staples food economy, farms are still semi-subsistence. By contrast, for those doing horticulture (row 2.6), the market surplus rate is double that of grains - around 68%, and varying little over strata. Thus horticulture is mainly "cash cropping." The last rows show that grain/bean yields differ little over strata (and are quite low), but horticulture yields rise in the familiar step function from lowest quartile, to the two middle quartiles, to double among the highest quartile.

Table 1.4 shows farm input use and district characteristics by household income quartile.

First, 93% of farm labor is family labor, with only 7% hired; these shares are similar across quartiles. But differential labor use over quartiles leads to the hired labor market being concentrated (the gini is .82). The labor/land ratio rises 60% over the quartiles; this may be partly explained by the higher share of labor-using horticulture in total cropping as one ascends income quartiles. While 82% of farms use fertilizer, the expenditure averages only 50 USD per farm (with a gini of 55%), or only about 70 kg/ha. By contrast, only 45% of the farms use pesticides, at 15 USD per farm (with a gini of .80), with a sharp correlation with household income; this is probably correlated with horticulture.

Second, the average marketed surplus rate is 33%, indicating a general situation of semi-subsistence. Surprisingly, this does not differ much when districts are stratified by household income quartile. The share of urban population in these mainly rural districts is about 30%, and population density in rural areas is about 128 persons/square km (similar to the country's average, but much more concentrated than most of the rest of Central America and Mexico, but much less than much of Asia). These district demographic measures do not differ much by household strata.

In sum, the descriptive tables yield two sets of images of the households of the sample.

On the one hand, regarding farm technology and crop composition, there is a somewhat flat distribution of cropped land at about 3.5 ha, and small holdings of livestock, but there is substantial variation (correlated with household income) in the share of horticulture, and the intensity of use of pesticides, farm capital, and labor. While the overall situation is one of semi-subsistence, there is substantial correlation of household income and crop marketed surplus rates. However, there is little correlation of household income and district market surplus rate, rural population density, and urban share in the district.

On the other hand, income from RNFE plays a major role in rural incomes – as much as own-cropping and farm wage-labor put together. But RNFE is very unequally distributed over households, mainly regressively, with the richer strata sharply dominant in higher paying skilled RNFE, and the top half of the population dominating the unskilled RNFE. The poorest tend to not only be relegated to mainly farming or farm wage-labor.

Table 1.5. foreshadows descriptively and heuristically some key results that will be econometrically demonstrated below. The table's columns shows four combinations of households (roughly quarters of the sample households) ranged over pairs of low and high technology (defined by intensity of variable input use, apart from labor, per hectare) and low and high RNFE (defined by share of RNFE in total household income). Several points stand out.

First, there is surprisingly little variation in the share of horticulture in total cropped area over the four groups. This suggests that horticulture is undertaken with substitution over households between capital and labor.

Second, the table shows that there is a correlation (at the municipality level) of cropped area with low technology and low RNFE, suggesting an “extensive” system (land using, labor using), versus the extreme opposite, with cropped area some half of the first group’s cropped area, for the group with high technology (capital intensive) and high RNFE (land saving, capital using technology). Interestingly, there is little difference over the four groups in terms of animal holdings; in Guatemalan rural areas outside of pockets of ranching, livestock husbandry does not appear as a major substitute for nonfarm activity and intensive cropping.

Third, the table shows that a dip in the crop marketed surplus rate among households with low farming technology and a high share of RNFE in total income; this suggests a group of households that have substituted off-farm activity for cropping income. The table shows that there is a clear correlation on the one hand between the urbanization rate of a municipality (as well as the rural density) and technology level of the farms, and controlling for technology level, a correlation with intensity of engagement in RNFE. Both these suggest that with great urban proximity and rural density, both associated with denser infrastructure, the labor market and the crop market are more developed.

Fourth, there is a striking correlation between incidence of the fourth group (high technology, high RNFE) with the richer regions, and the first group (low technology, low RNFE) with the poorer regions. This is as expected (although we did not expect the sharpness of the correlation) for the reasons of effective demand, perhaps access to capital, and transaction costs.

3.5 Econometric Results

1.1.3 Determinants of RNFE

Table 1.6 presents the IV probit estimation results for the determinants of participation in the three categories of off-farm employment.

First, the salient and significant determinants of participation in skilled RNFE are as follows. Participation in skilled RNFE is positively sensitive to own-wage, and negatively sensitive to the unskilled RNFE wage. This is rare empirical evidence of rural households' RNFE labor-supply responsiveness to relative RNFE wages.

Moreover, an interesting result is that the share of urban population in the municipality, and the rural population density in the municipality, significantly determine skilled RNFE participation. This result is unique in the literature. Prior research showed a relation of infrastructure density and share of RNFE in total employment, and the propensity of RNFE to develop near urban areas. However, no research has shown the effect of population density and urban share over a large sample of municipalities, on RNFE incidence in general, and skilled and thus higher paying RNFE incidence in particular. The interpretation is that economies of agglomeration and lower transaction costs associated with urban proximity and population density favor production and consumption linkages from agriculture, as well as the growth of manufactures and services for peri-urban areas. Our results show that in addition, access to electricity and telephone increase the incidence of skilled RNFE. However, contrary to expectation, neither farm size nor education has significant effect on skilled RNFE.

Second, the salient determinants of participation in unskilled RNFE are as follows. Participation in unskilled RNFE responds to the agricultural wage. This would point to farm wage labor and unskilled RNFE as being complements; this relation could be in reality indirect, as opportunities for unskilled nonfarm activity may abound in situations where agriculture is dynamic and inter-sectoral linkages occur, and at the same time increase the demand for hired farm labor.

In addition, a household's having access to electricity is correlated with unskilled RNFE, probably via facilitating cottage industry.

Moreover, an interesting result, and one not shown in any published article to date, is that unskilled RNFE participation is positively correlated with the marketed surplus rate of the municipality. This result is an extension, to the RNFE domain, of the findings by Pingali and Rosegrant (1995) of commercialized Green Revolution areas having higher hired agricultural-labor market participation. This could again suggest, like the result in the above paragraph, the presence of intersectoral production and consumption linkages leading to nonfarm employment. In addition, as with skilled RNFE, the results show that the urban share of the municipality and population density of the rural areas favors participation in unskilled RNFE, presumably by favoring via economies of agglomeration the multiplication of small-scale service and manufacture activities intensive in unskilled labor.

Third, the salient determinants of participation in agricultural wage employment are as follows. Consistent with the result in the unskilled RNFE regression, we find here that farm wage labor is positively influenced by the unskilled-RNFE wage, presumably with a similar interpretation.

Moreover, the head of household being female negatively affects the probability of agricultural wage employment, presumably because of the opportunity cost of this employment for z-good production in the household. Older and more educated household heads tend to have households participating less in this type of employment, presumably because this type of employment is low-paying and an "inferior good" that households in a more advanced point in the lifecycle of wealth accumulation would avoid. In addition, the results show that households with more abundant labor are more prone to participate in this employment, presumably because the opportunity cost to own-farming in the farming season of sending some of the households own members to other farms, is lower than in smaller households.

Furthermore, the results show that the smaller the farm, less access to electricity and communication (cell phone), the lower the value of the stock of livestock, and the household not receiving remittances, the more likely the household undertakes farm wage-labor. Both of these accord with the hypothesis that farm wage-labor is a “refuge” employment for those with the least productive or savings assets.

Finally, participation in farm wage-labor is positively correlated with the marketed surplus rate of municipalities. This corroborates for Central America a point made concerning Asian agriculture in Pingali and Rosegrant (1995). To explore this point further, we examined several correlations using the 165 municipality observations, and found that the higher the commercialization rate of the municipality, the (a) higher the share of horticulture in total cropping; (b) the higher the rate of labor hiring in total labor used; (c) and the higher the share of landless (depending partly on farm wage-labor); (d) but there is nearly no correlation between average farm size (cropped) area as well as variation in farm size over farms in the municipality, and the municipality’s commercialization rate, so there lacks the distinction we expected between subsistence areas with tiny farms and commercial areas with larger farms or greater inequality of farm size; in fact, small farms dominate on average (with an average of about 2 ha cropped area, but with only less than 5% of the farms with irrigation; as dry farm, this is the same as an average farm in India, and comparable to a 1 ha irrigated farm in Indonesia).

1.1.4 Nonfarm Employment effects on Technology and Crop Choice

Table 1.7 presents the SUR estimation results of regressions explaining input use (family labor, hired labor, seeds, fertilizer, pesticide) and output supply (of beans, grains, and horticultural crops). We organize our discussion of results by determinant.

First, more participation in skilled RNFE is associated with sharply less use of family labor, more hired farm labor, and more supply of horticultural crops. This suggests that skilled RNFE households save their scarce and relatively highly paid labor for off-farm activity, and intensify cropping with hired labor, and undertaking commercial horticulture. This result contributes to the literature by showing the empirical relation of skilled RNFE with commercialization, farm employment-creating intensification, and crop diversification. This result contradicts the hypothesis that there is a trade-off between RNFE and agricultural diversification; we surmise that this competitive relationship would exist mainly where there is a constraint in the farm wage-labor market.

Second, participation in unskilled RNFE is associated with lower use of hired farm labor, suggesting that the farm and unskilled RNFE labor are not competing for family labor use at the same time, or individuals are specialized in the two types of labor within a family. Interestingly, unskilled RNFE participation increases sharply non-labor variable input intensification (with use of seeds, fertilizers, and pesticides). This suggests that even the relatively meager wages of unskilled RNFE may be relaxing a credit constraint needed to buy these external inputs Moreover, unskilled RNFE has a positive effect on horticulture (as found for example in China by Huang et al. 2009); this could be related to facilitating buying inputs at the start of the horticultural season, combined with possible credit constraints.

Third, participation in farm wage-labor is significantly correlated with greater use of family labor and less use of hired labor; these results align with the descriptives above which show these households to be larger and poorer, and thus have relatively low opportunity cost of time. The lower use of external inputs correlated with the households' participation in farm wage-labor, plus the high own-labor use on-farm, paint a picture of labor-led intensification of farming, in contrast with the capital-led intensification one sees among the households with the extra liquidity arising from RNFE activity. Their participation in horticulture is also lower; they are more staple grains oriented.

Fourth, technology and product choice are somewhat sensitive to relative prices and wages. The results show that a higher skilled RNFE wage is associated with lower use of hired labor; these results are contrary to our expectations. Note that this is effect of RNFE wage already controlling for participation, so it could be that there is a tighter agricultural labor market in areas where the skilled RNFE wage is higher, such as near cities. However, a higher unskilled RNFE wage induces less use of own-farm own-labor and more use of hired labor. This latter result is presumably dependent on the households' ability to sell RNF labor and buy grain, which in turn suggests that in the areas where RNF demand is higher (and the wage is thus higher), farmers access grain output markets. Interestingly, a higher farm wage induces less use of own-labor on-farm, which may suggest a pool of surplus labor on-farm.

Fifth, there are several striking effects of human and farm assets on technology and crop output choices. Farms with larger cropped areas are shown to have great use of both labor and external inputs, and to have a greater tendency to horticulture. These results are at odds with a vision of medium farms being more grain oriented and using extensive technology. Rather, smaller farms tend to be more labor using and grain oriented, and medium farms using more intensive technology and crop diversification. This suggests that there are constraints to capital access for smaller farms.

Moreover, we find that lower shadow wage for labor (from more adult laborers in the household), the greater the tendency to labor on-farm. Moreover, there is an effect, similar to that of skilled RNFE, of education and farm assets on using less own-labor for farming and more hired labor (explicable by the opportunity cost of labor). Finally as expected, irrigation and horticulture are correlated.

Sixth, the impacts of transaction costs – proxied by distance from the road and having a vehicle – are important, and reinforce and coincide with the effects of skilled RNFE and education, with the additional effect of strongly reinforcing capital-led intensification.

Finally, and information rare in the literature, are the results concerning the effect of the market surplus rate of the municipality on farm technology and crop output mix. The effect is strongly positive and significant on all inputs and on both grains and horticulture. The relative effect on horticulture is greater, a point made above in our discussion of the descriptive correlates of the marketed surplus rate. This also supports empirically the hypothesis of the correlation of commercialization and agricultural diversification and intensification made by Pingali and Rosegrant (1995).

3.6 Conclusions

This paper first analyzes the determinants of Guatemalan farmer participation in off-farm employment (in different activities, the lion's share of which is in local rural nonfarm employment (RNFE), as skilled RNFE and unskilled RNFE, and in agricultural wage employment (AWE)). The paper then analyzes how that participation in off-farm employment is correlated with farming technology and crop choice, in particular in terms of diversification into horticulture (versus traditional grain and bean farming). The paper uses a two stage regression model applied to rural data in the LSMS dataset collected in Guatemala in 2000. The key results are as follows. First, RNFE has a major share in farm household incomes, but is very unequally distributed over households; in particular larger farmers and farmers with higher farm assets (controlling for land) have more RNFE. Secondly, meso variables including urbanization rate of the district, rural population density, and the agricultural commercialization rate in a rural area are correlated with households having more RNFE. This suggests the presence of production and consumption linkages intersectorally. Third, households undertaking more RNFE tend to diversify more into horticultural crops, and use more fertilizer, seeds and pesticides. By contrast, households who do more AWE (and tend to be poorer and less educated with smaller farms) tend to hire less labor, and use fewer external inputs. These results overall suggest a virtuous triangle of income inter-sectoral diversification, agricultural diversification into higher value crops, and modernization of agricultural technology. This process appears to be spurred by overall development of agricultural markets and rur-urbanization. The concern is that this combination is uneven distributed, with the asset-poor participating least. This suggests policy interventions to help the poor have greater access to RNFE would spur diversification which helps incomes and manages risk, and technology modernization which spurs farm productivity.

Table 1.1. Annual net income sources by household income quartiles for rural cropping-households in Guatemala in 2000

Quartile of total household income →	First			Second			Third			Fourth			Overall Sample	
Number of observations	611			611			611			610			2443	
1 On-farm income														
1.1 Crop income	16	(9%)	a	195	(27%)	b	326	(22%)	c	379	(10%)	c	229	(15%)
Share of households within the subsample (SHS)	100%			100%			100%			100%			100%	
1.2 Livestock income	37	(22%)	a	87	(12%)	b	99	(7%)	b	104	(3%)	b	82	(6%)
SHS	70%			74%			75%			76%			74%	
2 Off-farm income														
2.1 Agricultural wage employment	53	(31%)	a	222	(31%)	b	399	(27%)	c	556	(15%)	d	307	(21%)
SHS	27%			50%			56%			54%			47%	
2.2 Skilled RNFE (self + wage) income	4	(2%)	a	17	(2%)	a	33	(2%)	a	296	(8%)	b	88	(6%)
SHS	2%			4%			6%			14%			7%	
2.3 Unskilled RNFE (self + wage) income	39	(23%)	a	139	(20%)	a	508	(35%)	b	1840	(51%)	c	631	(42%)
SHS	24%			40%			58%			81%			51%	
3 Not earned income														
3.1 Remittances	9	(5%)	a	23	(3%)	a	50	(3%)	a	333	(9%)	b	104	(7%)
SHS	6%			7%			9%			19%			10%	
3.2 Other private transfers	6	(4%)	a	12	(2%)	a	10	(1%)	a	51	(1%)	b	20	(1%)
SHS	7%			9%			9%			10%			9%	
3.3 Social assistance	4	(2%)	a	6	(1%)	a,b	10	(1%)	b	9	(0%)	b	7	(0%)
SHS	4%			6%			7%			8%			6%	
3.4 Pensions	1	(1%)	a	11	(2%)	a	17	(1%)	a	47	(1%)	b	19	(1%)
SHS	0%			3%			3%			4%			3%	
4 Total household income	169	(100%)	a	712	(100%)	b	1452	(100%)	c	3613	(100%)	d	1486	(100%)
5 Total income per capita	79			326			608			1493			627	

a, b, c, d. show the differences among quartiles using Tukey-Kramer test at 10% significance level.

Table 1.2. Household Demographics, Education, and Non-agricultural assets of rural cropping- households in Guatemala: by household income quartiles in 2000.

	Quartile of total household income →	First		Second		Third		Fourth		Overall Sample
	Number of observations	611		611		611		610		2443
1	*Demographics and education*									
1.1	Age of head of household (HHH) (years)	42	a	43	a	43	a,b	45	b	44
1.2	Number of people in the household (HH) (unweighted)	4.0	a	4.3	a	4.5	b	4.8	b	4.4
1.3	Number of adults in HH (age between 14 and 60 years)	2.4	a	2.6	a	2.8	b	3.0	b	2.7
1.4	Female headed HH (% of HHs)	12%	b	9%	a	9%	a	12%	b	10%
1.5	Average years of education in HH (taken over all members of the HH)	1.9	a	1.9	a,b	2.1	b	2.1	b	2.0
1.6	Years of education of head of HH	1.9	a,b	1.8	a,b	2.1	b	1.7	a	1.9
2	*Non-land assets and services*									
2.1	Total value of durables (USD)	231	a,b	155	a	241	b	347	c	243
2.2	Distance from HH to public bus stop (Kms)	5.5	a	5.4	a	3.1	a	3.4	a	4.3
2.3	% of HHs with electricity	44%	a	40%	a	44%	a	51%	b	45%
2.4	% of HHs with piped water	55%	a	50%	a	53%	a	56%	a	53%
2.5	% of HHs with cemented floor	27%	a,b	23%	a	31%	b,c	33%	c	28%
2.6	% of HHs with phone service	2%	a	1%	a	2%	a	3%	a	2%
2.7	% of HHs with car or motorcycle	26%	a,b	22%	a	28%	b	35%	c	28%

a, b, c, d. show the differences among quartiles using Tukey-Kramer test at 10% significance level.

Table 1.3. Farm characteristics of rural cropping-households in Guatemala by household income quartile in 2000.

	Quartile of total household income →	First		Second		Third		Fourth		Overall Sample
	Number of observations	611		611		611		610		2443
1	*Farm characteristics*									
1.1	Total value of non-land agricultural assets (USD)	80	a	85	a	159	a,b	189	b	129
1.2	HH is owned-land-less (% of HHs)	29%	a,b	31%	b	31%	b	24%	a	29%
1.3	Household rents in land (% of HHs)	33%	b	35%	b	35%	b	29%	a	33%
1.4	Household borrows land (% of HHs)	9%	a	13%	a	12%	a	11%	a	11%
1.5	Total land owned (hectares)	2.2	a	3.8	b	3.9	b	4.3	b	3.6
1.6	% of HHs with irrigation	1%	a	0%	a	1%	a	1%	a	1%
1.7	Total cropped land (horticulture + beans & grains) area (Ha)	3.4	a	3.4	a	3.4	a	3.3	a	3.4
2	*Farm output produced*									
2.1	Total value of animals owned (USD)	99	a	127	b	134	b	128	b	122
	% of HHs	(77%)		(77%)		(82%)		(81%)		(79%)
2.2	Total production of beans and grains (MT)	1.2	a	1.6	a	1.7	a	1.6	a	1.5
	% of HHs	(93%)		(92%)		(92%)		(91%)		(92%)
2.3	Total output of horticultural crops (MT)	0.5	a	0.9	b	1.2	b,c	1.6	c	1.0
	% of HHs	(39%)		(52%)		(54%)		(58%)		(51%)
2.4	Marketed surplus rate of the HH	24%	a	32%	a	52%	a	63%	a	43%
	% of HHs	(51%)		(67%)		(70%)		(66%)		(64%)
2.5	Market surplus rate for beans and grains	19%	a	40%	a	31%	a	53%	a	36%
	% of HHs	(37%)		(50%)		(53%)		(48%)		(47%)
2.6	Market surplus rate for horticultural crops	51%	a	23%	a	41%	a	32%	a	37%
2.7	Market surplus rate for horticultural crops (non-zeroed out)	70%		65%		65%		68%		67%
	% of HHs	(24%)		(36%)		(39%)		(40%)		(35%)
2.8	Yields of beans and grains (MT/Ha)	1.3	a	1.4	a	1.4	a	1.6	a	1.4
2.9	Yields of horticultural crops (MT/Ha)	2.2	a	3.4	a,b	3.1	a,b	3.9	b	3.2

a, b, c, d. show the differences among quartiles using Tukey-Kramer test at 10% significance level.

Table 1.4. Farm input use and municipality characteristics by household income quartile in 2000.

	Quartile of total household income →	First		Second		Third		Fourth		Overall Sample
	Number of observations	611		611		611		610		2443
1	*Farm (annual) input use*									
1.1	Imputed family labor expenditure (USD)	359	a	511	b	555	b,c	576	c	500
	Share of hh within the subsample (% of HHs)	(75%)		(90%)		(88%)		(86%)		(85%)
1.2	Hired labor expenditure (USD)	36	a,b	29	a	40	a,b	43	b	37
	% of HHs	(43%)		(36%)		(42%)		(45%)		(41%)
1.3	Fertilizers expenditures (USD)	48	a,b	42	a	47	a,b	51	b	47
	% of HHs	(82%)		(78%)		(82%)		(84%)		(82%)
1.4	Pesticides expenditures (USD)	11	a	11	a	17	b	19	b	15
	% of HHs	(41%)		(41%)		(50%)		(46%)		(45%)
1.5	Seed (purchased) expenditures (USD)	6	a	7	a	8	a,b	12	b	8
	% of HHs	(23%)		(23%)		(25%)		(25%)		(24%)
2	*District characteristics*									
2.1	Marketed surplus rate (sales/output)	29%	a	33%	b	35%	b	34%	b	33%
2.2	Share of urban population in rural district	29%	a	28%	a,b	31%	b,c	32%	c	30%
2.3	Rural population density (persons/sq. km)	129.7	b	115.0	a	129.2	b	137.2	b	127.8

a, b, c, d. show the differences among quartiles using Tukey-Kramer test at 10% significance level.

Table 1.5. Characteristics of households with different technology-RNFE combinations by cropping households in rural Guatemala in 2000

	Technology / RNFE Combinations →	Low Tech / Low RNFE	Low Tech / High RNFE	High Tech / Low RNFE	High Tech / High RNFE	Overall Sample
	Number of observations	641	571	571	640	2423
1	Share of skilled RNFE over total RNFE income	9%	8%	4%	10%	9%
2	Share of horticultural area over total crop area in the farm	25%	24%	22%	24%	24%
3	Average crop area (ha) at the municipality level	4.4 d	3.7 c	3.0 b	2.4a	3.4
4	Total value of animals (USD)	120	129	130	111	122
5	Market surplus rate (product sold / total production)	33% b	24% a	35% b	36% b	32%
6	Share of urban population over total population at the municipality level	22% a	28% b	31% b	38% c	30%
7	Rural density at the municipality level (persons/km2)	92.5 a	129.1 b	131.1 b	158.9 c	127.8
	Distribution of households by region:					
	Richer regions					
1	Metropolitan	13%	30%	5%	53%	100%
2	Central	6%	7%	32%	55%	100%
3	Southwest	18%	29%	22%	30%	100%
	Middle regions					
4	Northeast	24%	13%	41%	22%	100%
5	Northwest	23%	32%	22%	22%	100%
	Poorer regions					
6	Southeast	25%	19%	32%	24%	100%
7	North	50%	29%	13%	9%	100%
8	Peten	64%	15%	16%	4%	100%

a, b, c, d. show the differences among quartiles using Tukey-Kramer test at 10% significance level.

Table 1.6. IV probit results of determinants of participation in different types of off-farm employment by cropping households in rural Guatemala.

Type of off farm employment participation		Skilled RNFE	Unskilled RNFE	Agricultural wage employment
1. Prices				
1.1	Ln (agricultural wage rate (USD), by month at municipality level)	-0.032	0.234***	-0.048
		(0.103)	(0.066)	(0.068)
1.2	Ln (nonfarm skilled wage rate (USD), by month at municipality level)	0.357***	0.040	-0.023
		(0.082)	(0.058)	(0.059)
1.3	Ln (nonfarm unskilled wage rate (USD), by month at municipality level)	-0.278***	-0.042	0.119**
		(0.061)	(0.047)	(0.049)
2. Human capital assets				
2.1	Head of household (HHH) is female (yes=1, no=0)	-0.132	-0.014	-0.210*
		(0.156)	(0.105)	(0.109)
2.2	Age of the HHH (years)	-0.001	-0.000	-0.004**
		(0.003)	(0.002)	(0.002)
2.3	Years of education of HHH	-0.020	0.013	-0.113***
		(0.025)	(0.016)	(0.018)
2.4	Household labor (number of adults in HH)	0.008	0.008	0.177***
		(0.029)	(0.019)	(0.020)
3. Farm capital				
3.1	Total land owned (Ha)	0.010	-0.003	-0.035***
		(0.007)	(0.005)	(0.005)
3.2	Total land squared	-0.000	0.000	0.000***
		(0.000)	(0.000)	(0.000)
3.3	Total value of livestock (USD 100's)	-0.009	0.005	-0.035**
		(0.024)	(0.016)	(0.016)
3.4	HH has irrigation in the farm (yes =1, no = 0)	0.317	-0.093	0.024
		(0.413)	(0.288)	(0.321)
3.5	Total value of agricultural assets (USD)	-0.000	-0.000	-0.000
		(0.000)	(0.000)	(0.000)
4. Non agricultural assets and access to services				
4.1	HH has electricity (yes = 1, no = 0)	0.194**	0.178***	-0.235***
		(0.094)	(0.060)	(0.062)
4.2	HH has piped water (yes = 1, no = 0)	-0.022	-0.006	-0.067
		(0.089)	(0.057)	(0.058)
4.3	HH has cement floor (yes =1, no = 0)	0.014	-0.075	-0.160**
		(0.095)	(0.063)	(0.065)
4.4	HH has a telephone or cellphone (yes = 1, no = 0)	0.463*	-0.053	-0.981***
		(0.238)	(0.201)	(0.287)
4.5	HH has a vehicle or motorcycle (yes = 1, no = 0)	-0.149	-0.020	-0.086
		(0.102)	(0.064)	(0.066)

Coefficients with asterisks (*,**,***) imply statistical significance at (10,5,1)% level.

Table 1.6. (cont'd)

Type of off farm employment participation		Skilled RNFE	Unskilled RNFE	Agricultural wage employment
5. Meso characteristics				
5.1	Agricultural commercialization rate (unit) by municipality	-0.734	0.612*	1.119**
		(0.681)	(0.372)	(0.477)
5.2	Agricultural commercialization rate squared	0.555	0.357	-1.691***
		(0.938)	(0.606)	(0.647)
5.3	Share of urban population at the Municipality level (unit)	0.341*	0.886***	-0.081
		(0.206)	(0.140)	(0.143)
5.3	Rural population density at the Municipality level (people/kms2)	0.001*	0.002***	-0.000
		(0.000)	(0.000)	(0.000)
6. Instrumented variable				
6.1	Household recieves remittances (yes =1, no = 0)	0.024	0.009	-0.023
		(0.022)	(0.015)	(0.016)
	Constant	-1.675***	-1.263***	-0.249
		(0.590)	(0.386)	(0.393)
	Observations	2,443	2,443	2,443
	Wald chi^2 (22)	62.76	168.0	275.1
	Prob > chi^2	0.000	0.000	0.000

Coefficients with asterisks (*,**,***) imply statistical significance at (10,5,1)% level.

Table 1.7. SUR estimation results of input use by cropping households in rural Guatemala in 2000

	Input demands					Output Supply	
	Family Labor	Hired Labor	Seeds	Fertilizers	Pesticides	Beans & Grains	Horticultural Crops
1. Participation in off-farm employment							
1.1 Skilled non-farm	-1,863.759***	459.523***	-59.640	-114.862	-27.919	-4.730	15.004*
	(631.614)	(141.708)	(43.118)	(77.083)	(40.372)	(6.790)	(8.243)
1.2 Unskilled non-farm	-112.985	-57.124*	44.021***	112.400***	29.561***	0.381	4.287*
	(131.782)	(29.854)	(10.185)	(18.568)	(11.196)	(1.606)	(2.320)
1.3 Agricultural wage	245.935***	-60.258***	-3.798	-30.163***	-12.809**	-1.067	-1.296*
	(75.705)	(17.951)	(4.787)	(9.628)	(6.244)	(0.964)	(0.755)
2. Prices							
2.1 Ln (nonfarm skilled wage rate (USD), by month at municipality level)	66.992	-27.998***	2.059	5.828	1.865	-0.049	1.038
	(40.998)	(9.023)	(2.990)	(4.973)	(2.596)	(0.395)	(0.790)
2.2 Ln (nonfarm unskilled wage rate (USD), by month at municipality level)	-78.489**	22.576***	-0.949	-4.092	1.310	0.038	-0.975
	(31.768)	(7.433)	(2.278)	(3.925)	(2.161)	(0.331)	(0.625)
2.3 Ln (agricultural wage rate (USD), by month at municipality level)	-63.122**	-6.602	1.109	-13.103***	-2.620	-0.247	-0.417
	(27.641)	(5.835)	(2.214)	(3.384)	(2.028)	(0.195)	(0.394)
3. Human capital assets							
3.1 Household labor (number of adults in HH)	125.983***	0.930	0.521	4.948***	0.897	0.091*	-0.018
	(9.824)	(1.680)	(0.584)	(0.958)	(0.613)	(0.048)	(0.065)
3.2 Age of the HHH (years)	-0.529	0.025	-0.017	-0.038	-0.055	0.000	-0.002
	(0.509)	(0.131)	(0.035)	(0.065)	(0.044)	(0.006)	(0.004)
3.3 Years of education of HHH	-10.978***	2.019**	0.619*	-0.294	-0.030	-0.024	-0.019
	(3.858)	(0.901)	(0.373)	(0.498)	(0.337)	(0.033)	(0.047)

Coefficients with asterisks (*,**,***) imply statistical significance at (10,5,1)% level.

Table 1.7. (cont'd)

		Input demands					Output Supply	
		Family Labor	Hired Labor	Seeds	Fertilizers	Pesticides	Beans & Grains	Horticultural Crops
4. Farm assets								
4.1	Total land owned (Ha)	6.171**	4.213***	0.068	1.357***	1.218***	0.243***	0.229***
		(2.961)	(0.819)	(0.216)	(0.441)	(0.280)	(0.047)	(0.048)
4.2	HH has irrigation in the farm (yes =1, no = 0)	-161.078*	-9.321	-1.596	10.303	0.578	2.750	5.813*
		(89.513)	(35.948)	(5.239)	(11.884)	(7.842)	(2.057)	(3.366)
4.3	Total value of agricultural assets (USD)	-0.006	0.012***	0.001	0.001	0.000	0.000	0.000
		(0.023)	(0.004)	(0.003)	(0.005)	(0.002)	(0.001)	(0.001)
5. Non agricultural assets and access to services								
5.1	HH has a telephone or cellphone (yes = 1, no = 0)	64.172	-59.517***	4.026	-16.798	-3.757	-0.142	1.915
		(92.283)	(22.552)	(7.969)	(10.653)	(8.414)	(0.974)	(2.090)
5.2	HH has a vehicle or motorcycle (yes = 1, no = 0)	-71.977***	19.394***	5.709***	4.503	8.032***	0.216	0.372
		(24.716)	(5.652)	(1.806)	(2.857)	(2.094)	(0.189)	(0.262)
5.3	Distance from household to main road (km)	-0.027	0.165*	-0.022***	-0.032*	-0.004	0.001	-0.001
		(0.248)	(0.096)	(0.004)	(0.018)	(0.017)	(0.002)	(0.001)
6.	*Meso characteristics*							
6.1	Agricultural commercialization rate (unit) by municipality	163.97***	58.063***	37.917***	22.846***	38.247***	1.47***	2.758***
		(53.277)	(11.530)	(5.290)	(6.968)	(5.112)	(0.463)	(0.563)
	Constant	518.09***	76.286***	-34.35***	33.910**	-14.115	1.682**	0.041
		(123.230)	(28.826)	(9.857)	(15.965)	(11.426)	(0.834)	(1.134)
	Observations	2,423	2,423	2,423	2,423	2,423	2,423	2,423
	Share of observations with value=0	0.146	0.591	0.757	0.177	0.550	0.071	0.489
	R squared (16)	0.246	0.106	0.092	0.081	0.100	0.067	0.192
	Prob > F	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Coefficients with asterisks (*,**,***) imply statistical significance at (10,5,1)% level.

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CHAPTER 2: Tomato Farmers and Modern Markets in Nicaragua: A Duration Analysis

2.1 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.

2.2 The model: the determinants and effects of farmers' entry and duration in the modern channel

2.2.1 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),

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

For modern market (crops),

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

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_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

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

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:

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

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:

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

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.

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

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 ($\mathrm{T_a}$);

    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,

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

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

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

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:

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

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

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.

2.2.2 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[2]. 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

[2] 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.

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.

(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.

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

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;

(c) Distance from household to the village center.

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:

$$h(t) = \lambda(x)^{\rho} \rho t^{\rho-1} \qquad (2.12)$$

where

$$\lambda(x) = e^{-\beta' x} \tag{2.13}$$

(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:

$$\log(t) = \beta' X + \sigma\varepsilon, \tag{2.14}$$

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[3],

(5) σ is a scalar that is equivalent to the inverse of the shape parameter (σ=1/ρ).

2.2.3 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

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

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.

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 (fitted value from the first stage);

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

c) the age of HHH (current) and education of the household head (time invariant);

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

e) land and livestock holdings (current);

f) Elevation

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[4], 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).

2.3 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.

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.[5] 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.

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

[5] 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.

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 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 2.1 and 2.3) and hazard functions (Figures 2.2 and 2.4) 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 2.1) and then their farm characteristics and technology use (Table 2.2). 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).

2.3.1 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.

2.3.2 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.

2.4 Econometric findings

2.4.1 Determinants of Time-to-Adoption

Table 2.3 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, 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.

2.4.2 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.

2.4.3 Effect of Duration on Farm Capital Accumulation and Technology Use.

Table 2.4 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, 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, 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.

Fifth, 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").

Sixth, 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).

2.5 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.

Figure 2.1. Adoption survivor function.

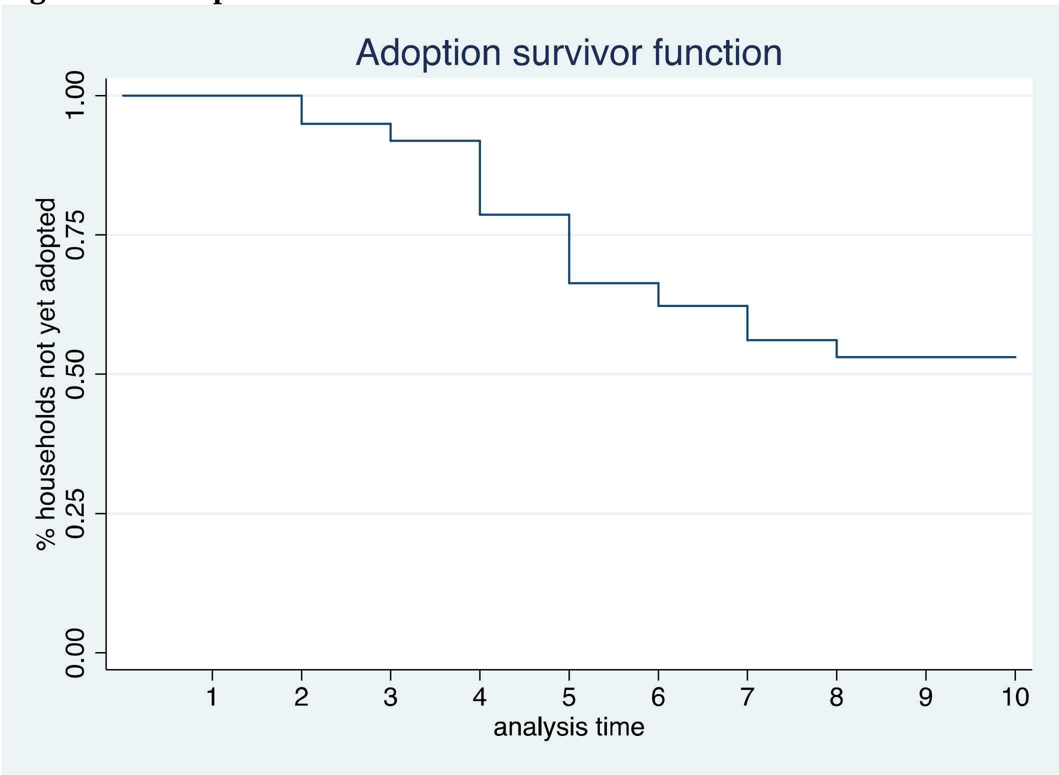

Figure 2.2. Hazard function, adoption.

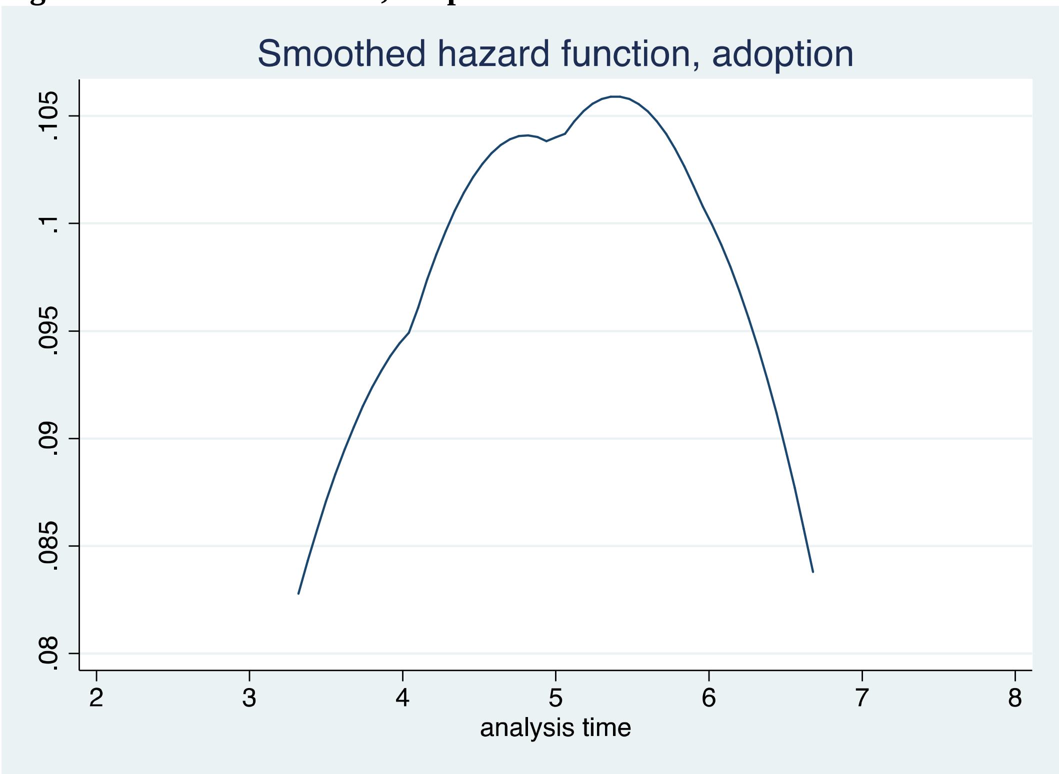

Figure 2.3. Withdrawal survivor function.

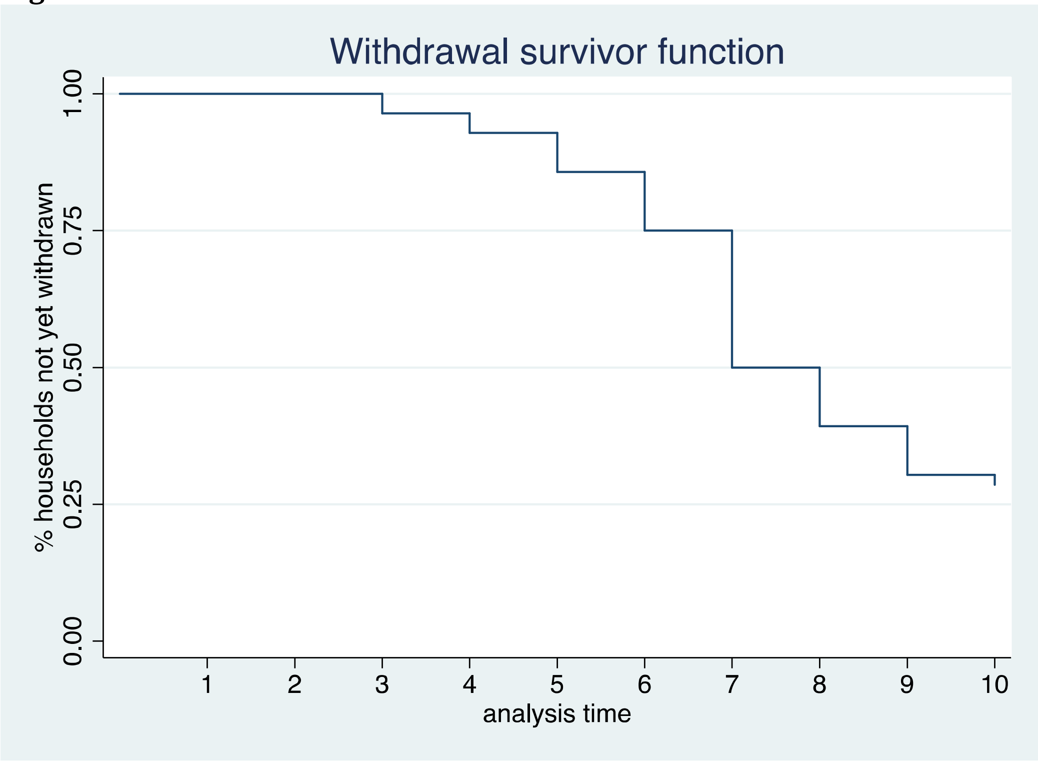

Figure 2.4. Hazard function, withdrawal.

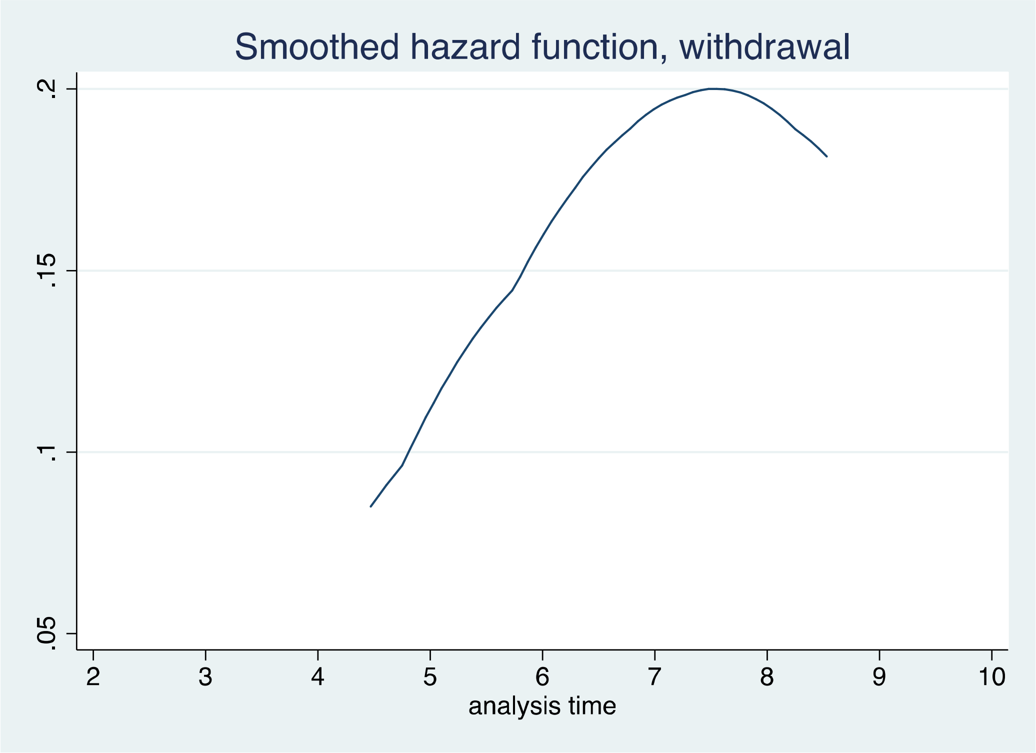

Table 2.1A. Household characteristics and income distribution of tomato farmers in Nicaragua in 2010, by early and late adoption.

		NON-ADOPTERS	ADOPTERS	ADOPTERS		TOTAL
			All	Early Adopters	Late Adopters	
	Observations	52	56	31	25	108
1	<u>Household Characteristics</u>					
1.1	Number of people in the household (HH) (unweighted)	4.9	5.1	5.1	5.3	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	3.6
1.3	Female headed HH (share over all HH SOH)	2%	7%	6%	8%	5%
1.4	Age of head of household (HHH) (years)	49.4x	53.0	53.6	52.5	51.3
1.5	share of HH members who work on the farm (SOH)	29%	30%	30%	30%	30%
1.6	share of HH members who work off the farm (SOH)	10%ax	17%**	18%b	14%a	13%
1.7	Education of HHH (years)	4.4x	4.7	5.3	4.0	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	7.3
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	10.7
1.10	Member of a production cooperative / farmer association/ farmer enterprise in 2010 (SOH)	19%ax	33%*	29%ab	40%b	27%
1.11	Member of a production cooperative / farmer association/ farmer enterprise in 2005 (SOH)	15%ax	36%**	29%ab	48%b	27%
2	<u>Household Local Non-farm and Migration</u>					
2.1	Total value of HH nonfarm consumption durables (USD 100s) in 2009	$833	$709	$629	$739	$753
2.2	Total value of HH nonfarm production assets (USD 100s) in 2009	$99	$114	$125	$111	$109
2.3	Total value of HH nonfarm consumption durables (USD 100s) in 2004	$202	$288	$303	$292	$252

*,**,*** = 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.

Table 2.1A. (cont'd)

		NON-ADOPTERS		ADOPTERS All		ADOPTERS Early Adopters		ADOPTERS Late Adopters		TOTAL	
2.4	Total value of HH nonfarm production assets (USD 100s) in 2004	$44		$104		$105		$111		$77	
2.5	Share of HH who had a temporary migrant in the past five years	17%		12%		13%		12%		15%	
2.6	Share of HH who had a permanent migrant in the past five years	38%by		21%**		16%a		24%ab		29%	
3	<u>Collective assets</u>										
3.1	Distance to the closest agrochemicals commercial distributor (km)	16.5y		15.2		14.0		16.8		15.9	
3.2	Distance to the closest wholesale market (km)	81.4y		58.7		60.2		60.4		70.5	
3.3	Distance to the closest retail market (km)	17.4xy		19.7		19.1		20.9		18.7	
3.4	Distance to the closest secondary school (km)	4.4by		2.6*		2.1a		3.1ab		3.4	
3.5	Distance to the closest hospital (km)	16.8x		20.5**		21.3		20.2		18.9	
3.6	Distance to the village center (km)	1.3x		2.4		1.4		3.7		1.9	
4	<u>Household Income</u>										
4.1	On-farm income	$4,337b	72%	$3,502	57%	$5,286b	69%	$1,288a	31%	$3,904	65%
	4.1.1Tomato income	$3,610b	60%	$2,363	38%	$3,981b	52%	$544a	13%	$3,007	50%
4.2	Off-farm income	$1,177	20%	$1,914	31%	$1,562	20%	$1,789	43%	$1,429	24%
	4.2.1 Skilled RNFE wage income	$126a	2%	$445**	7%	$603b	8%	$171a	4%	$274	5%
4.3	Not earned income	$417xy	7%	$730	12%	$568	7%	$990	24%	$593	10%
4.4	Total household income	$5,998	100%	$6,146	100%	$7,661	100%	$4,158	100%	$6,049	100%
4.5	Total income per capita (considering all HH members)	$1,340ab		$1,565		$2,126b		$830a		$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.

Table 2.1B. Household characteristics and income distribution of tomato farmers in Nicaragua in 2010, by short and long duration as supermarket supplier.

		NON-ADOPTERS	ADOPTERS	ADOPTERS		TOTAL
			All	Short duration	Long duration	
	Observations	52	56	37	19	108
1	Household Characteristics					
1.1	Number of people in the household (HH) (unweighted)	4.9	5.1	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	3.8	3.3	3.6
1.3	Female headed HH (share over all HH SOH)	2%	7%	5%	11%	5%
1.4	Age of head of household (HHH) (years)	49.4x	53.0	53.9y	51.4xy	51.3
1.5	share of HH members who work on the farm (SOH)	29%	30%	31%	29%	30%
1.6	share of HH members who work off the farm (SOH)	10%ax	17%**	14%x	21%y	13%
1.7	Education of HHH (years)	4.4x	4.7	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	7.1x	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	10.5x	12.4y	10.7
1.10	Member of a production cooperative / farmer association/ farmer enterprise in 2010 (SOH)	19%ax	33%*	27%x	47%y	27%
1.11	Member of a production cooperative / farmer association/ farmer enterprise in 2005 (SOH)	15%ax	36%**	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	$736	$565	$753
2.2	Total value of HH nonfarm production assets (USD 100s) in 2009	$99	$114	$117	$122	$109
2.3	Total value of HH nonfarm consumption durables (USD 100s) in 2004	$202	$288	$310	$274	$252

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

x, y, z, show differences between non-adopters, short and long duration as suppliers using Tukey-Kramer test at 10% significance level.

Table 2.1B. (cont'd)

		NON-ADOPTERS		ADOPTERS All		ADOPTERS Short Duration		ADOPTERS Long Duration		TOTAL	
2.4	Total value of HH nonfarm production assets (USD 100s) in 2004	$44		$104		$103		$116		$77	
2.5	Share of HH who had a temporary migrant in the past five years	17%		12%		14%		11%		15%	
2.6	Share of HH who had a permanent migrant in the past five years	38%by		21%**		24%y		11%x		29%	
3	<u>Collective assets</u>										
3.1	Distance to the closest agrochemicals commercial distributor (km)	16.5y		15.2		18.4y		10.2x		15.9	
3.2	Distance to the closest wholesale market (km)	81.4y		58.7		66.1xy		49.0x		70.5	
3.3	Distance to the closest retail market (km)	17.4xy		19.7		23.5y		11.8x		18.7	
3.4	Distance to the closest secondary school (km)	4.4by		2.6*		2.6x		2.5x		3.4	
3.5	Distance to the closest hospital (km)	16.8x		20.5**		23.3y		15.6x		18.9	
3.6	Distance to the village center (km)	1.3x		2.4		1.1x		5.2y		1.9	
4	<u>Household Income</u>										
4.1	On-farm income	$4,337b	72%	$3,502	57%	$3,029	51%	$4,422	69%	$3,904	65%
	4.1.1Tomato income	$3,610b	60%	$2,363	38%	$1,537	26%	$4,218	66%	$3,007	50%
4.2	Off-farm income	$1,177	20%	$1,914	31%	$1,799	30%	$1,398	22%	$1,429	24%
	4.2.1 Skilled RNFE wage income	$126a	2%	$445**	7%	$387	7%	$456	7%	$274	5%
4.3	Not earned income	$417xy	7%	$730	12%	$1,030y	17%	$223x	3%	$593	10%
4.4	Total household income	$5,998	100%	$6,146	100%	$5,930	100%	$6,424	100%	$6,049	100%
4.5	Total income per capita (considering all HH members)	$1,340ab		$1,565		$1,356		$1,921		$1,447	

*,**,*** = show statistically difference at 10%, 5%, 1% significant level.
x, y, z, show differences between non-adopters, short and long duration as suppliers using Tukey-Kramer test at 10% significance level.

Table 2.2A. Farm assets and technology choice of tomato growers in Nicaragua in 2010, by early and late adoption.

		NON-ADOPTERS	ADOPTERS			TOTAL
			All	Early Adopters	Late Adopters	
	Observations	52	56	31	25	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	8.0
1.2	Total land owned and rented out in Ha in 2010	0.3	0.3	0.3	0.2	0.3
1.3	Total land rented in in Ha in 2010	1.3	0.8	0.3	1.0	0.9
1.4	Total land owned and not rented out in Ha in 2005	8.3xy	7.6	8.5	7.0	8.1
1.5	Total land rented in in Ha in 2005	0.5	0.3	0.2	0.2	0.4
1.6	Total cropped land in Ha in 2010	3.2b	2.5*	2.5ab	2.1a	2.8
1.7	Total cropped land in Ha in 2005	3.1	2.6	2.4	2.1	2.7
2	Non land assets					
2.1	Total value of farm assets (USD) in 2010	$2,375	$3,264	$3,021	$3,481	$2,817
2.2	Total value of farm assets (USD) in 2005	$1,446	$1,884	$1,203	$2,540	$1,629
2.3	Total value of animals owned (USD) in 2010	$1,430	$1,152	$1,466	$695	$1,270
2.4	Total value of animals owned (USD) in 2005	$1,091	$1,145	$1,560	$723	$1,140
3	Tomato Production in 2010					
3.1	Total production (MT/year)	23.6	20.4	26.9	14.2	21.7
3.2	Total area grown (Ha)	0.9y	0.6*	0.6	0.6	0.7
3.3	Yield (MT/Ha)	30.6ax	32.3	43.2b	21.9a	31.6
4	Tomato Production in 2005					
4.1	Total production (MT/year)	29.6	21.8	25.5	17.8	25.2
4.2	Total area grown (Ha)	0.9by	0.6**	0.5a	0.6a	0.7
4.3	Yield (MT/Ha)	33.2	36.8	40.3	34.4	35.4
5	Irrigation Technology in 2010					
5.1	Share of HH without irrigation	7%	0%	0%	0%	3%
5.2	Share of HH with drip irrigation	47%x	51%	40%	62%	49%
5.3	Share of HH with canal irrigation	40%	49%	60%	38%	45%
5.4	Share of HH with other type of irrigation	7%	0%	0%	0%	3%

*,**,*** = 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.

Table 2.2A. (cont'd)

		NON-ADOPTERS	ADOPTERS			TOTAL
			All	Early Adopters	Late Adopters	
6	<u>Irrigation Technology in 2005</u>					
6.1	Share of HH without irrigation	9%	2%	0%	5%	5%
6.2	Share of HH with drip irrigation	26%x	46%*	48%	41%	35%
6.3	Share of HH with canal irrigation	49%	48%	48%	50%	49%
6.4	Share of HH with other type of irrigation	17%	4%	4%	5%	11%
7	<u>Seedling Technology 2010</u>					
7.1	Share of HH using direct seeding	0%	0%	0%	0%	0%
7.2	Share of HH using owned produced seedlings	70%	39%	25%	52%	52%
7.3	Share of HH using purchased tray seedlings	30%ax	61%**	75%b	48%a	48%
8	<u>Seedling Technology 2005</u>					
8.1	Share of HH using direct seeding	2%	4%	0%	9%	3%
8.2	Share of HH using owned produced seedlings	72%	40%	36%	45%	56%
8.3	Share of HH using purchased tray seedlings	26%ax	56%***	64%b	45%a	40%
10	<u>Inputs for Tomato Production in 2010 (USD/Ha)</u>					
10.1	Seedlings/seeds expenditures	72ax	126**	126b	137b	103
10.2	Labor expenditure	570ax	946**	817a	1180b	782
	10.2.1 Imputed family labor expenditure	222ax	389*	298a	532b	316
	10.2.2 Hired labor expenditure	347ax	557*	519ab	648b	466
10.3	Chemicals	835ax	1496***	1247b	1923c	1205
	10.3.1 Chemical fertilizers expenditures	316ax	651***	576b	796c	502
	10.3.2 Organic fertilizers expenditures	0ax	9*	5a	14b	5
	10.3.3 Foliar fertilizers expenditures	111ax	254**	186a	359b	190
	10.3.4 Insecticides expenditures	215a	359	302a	458b	296
	10.3.5 Herbicides expenditures	15ax	24	17a	34b	20
	10.3.6 Fungicides expenditures	179	199	161	263	193
10.4	Other inputs expenditure[#]	289ax	263	134a	443b	280
10.5	TOTAL	1767a	2830**	2325a	3683b	2371

a, b, c, 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 2.2B. Farm assets and technology choice of tomato growers in Nicaragua in 2010, by short and long duration category.

		NON-ADOPTERS	ADOPTERS			TOTAL
			All	Short Duration	Long Duration	
	Observations	52	56	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	5.1x	13.7y	8.0
1.2	Total land owned and rented out in Ha in 2010	0.3	0.3	0.3	0.3	0.3
1.3	Total land rented in in Ha in 2010	1.3	0.8	0.8	0.2	0.9
1.4	Total land owned and not rented out in Ha in 2005	8.3xy	7.6	5.0x	13.3y	8.1
1.5	Total land rented in in Ha in 2005	0.5	0.3	0.2	0.2	0.4
1.6	Total cropped land in Ha in 2010	3.2b	2.5*	2.3	2.4	2.8
1.7	Total cropped land in Ha in 2005	3.1	2.6	2.2	2.4	2.7
2	Non land assets					
2.1	Total value of farm assets (USD) in 2010	$2,375	$3,264	$3,040	$3,590	$2,817
2.2	Total value of farm assets (USD) in 2005	$1,446	$1,884	$1,917	$1,572	$1,629
2.3	Total value of animals owned (USD) in 2010	$1,430	$1,152	$757	$1,833	$1,270
2.4	Total value of animals owned (USD) in 2005	$1,091	$1,145	$751	$2,034	$1,140
3	Tomato Production in 2010					
3.1	Total production (MT/year)	23.6	20.4	18.8	23.3	21.7
3.2	Total area grown (Ha)	0.9y	0.6*	0.7xy	0.4x	0.7
3.3	Yield (MT/Ha)	30.6ax	32.3	25.9x	44.7y	31.6
4	Tomato Production in 2005					
4.1	Total production (MT/year)	29.6	21.8	17.7	29.5	25.2
4.2	Total area grown (Ha)	0.9by	0.6**	0.6x	0.5x	0.7
4.3	Yield (MT/Ha)	33.2	36.8	35.2	42.2	35.4
5	Irrigation Technology in 2010					
5.1	Share of HH without irrigation	7%	0%	0%	0%	3%
5.2	Share of HH with drip irrigation	47%x	51%	41%x	71%y	49%
5.3	Share of HH with canal irrigation	40%	49%	59%	29%	45%
5.4	Share of HH with other type of irrigation	7%	0%	0%	0%	3%

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

x, y, z, show differences between non-adopters, short and long duration as suppliers using Tukey-Kramer test at 10% significance level.

Table 2.2B. (cont'd)

		NON-ADOPTERS	ADOPTERS			TOTAL
			All	Short Duration	Long Duration	
6	Irrigation Technology in 2005					
6.1	Share of HH without irrigation	9%	2%	3%	0%	5%
6.2	Share of HH with drip irrigation	26%x	46%*	32%x	69%y	35%
6.3	Share of HH with canal irrigation	49%	48%	61%	25%	49%
6.4	Share of HH with other type of irrigation	17%	4%	3%	6%	11%
7	Seedling Technology 2010					
7.1	Share of HH using direct seeding	0%	0%	0%	0%	0%
7.2	Share of HH using owned produced seedlings	70%	39%	56%	7%	52%
7.3	Share of HH using purchased tray seedlings	30%ax	61%**	44%x	93%y	48%
8	Seedling Technology 2005					
8.1	Share of HH using direct seeding	2%	4%	6%	0%	3%
8.2	Share of HH using owned produced seedlings	72%	40%	48%	25%	56%
8.3	Share of HH using purchased tray seedlings	26%ax	56%***	45%x	75%y	40%
11	Inputs for Tomato Production in 2010 (USD/Ha)					
11.1	Seedlings/seeds expenditures	72ax	126**	114xy	165y	103
11.2	Labor expenditure	570ax	946**	914y	1106y	782
	11.2.1 Imputed family labor expenditure	222ax	389*	421y	367xy	316
	11.2.2 Hired labor expenditure	347ax	557*	493x	739y	466
11.3	Chemicals	835ax	1496***	1534y	1577y	1205
	11.3.1 Chemical fertilizers expenditures	316ax	651***	676y	671y	502
	11.3.2 Organic fertilizers expenditures	0ax	9*	2x	23y	5
	11.3.3 Foliar fertilizers expenditures	111ax	254**	234y	318y	190
	11.3.4 Insecticides expenditures	215a	359	376	364	296
	11.3.5 Herbicides expenditures	15ax	24	31y	11x	20
	11.3.6 Fungicides expenditures	179	199	215	191	193
11.4	Other inputs expenditure[#]	289ax	263	297	223	280
11.5	TOTAL	1767a	2830**	2860y	3071y	2371

x, y, z, show differences between non-adopters, short and long duration as suppliers using Tukey-Kramer test at 10% significance level.

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

Table 2.3. Duration analysis

	Adoption Spell	Withdrawal Spell
Household Characteristics		
Age of the head of the household (HHH)	-0.004	0.013**
	(0.010)	(0.005)
Years of education of the HHH	-0.004	-0.010
	(0.032)	(0.019)
Average years of education taken within the adult members of	-0.049*	0.032*
the household	(0.030)	(0.020)
HHH is female	-0.438	-0.033
	(0.480)	(0.283)
Number of adults (14 to 60 years old) in the household	0.038	0.007
	(0.061)	(0.041)
Share of adults working in local off farm employment	-1.363***	-1.706***
	(0.525)	(0.402)
Farm and Non Farm Characteristics		
Lagged (1 year) participation in a production cooperative by any	-0.390*	-0.106
adult member of the household	(0.238)	(0.198)
Lagged (1 year) total owned land in Ha	0.001	0.023
	(0.020)	(0.019)
Lagged (1 year) total owned land squared	0.000	-0.000
	(0.000)	(0.000)
Lagged (1 year) irrigated land in Ha	-0.229*	0.340***
	(0.135)	(0.099)
Total value of livestock holdings (USD thousands)	-0.045	-0.021
	(0.049)	(0.034)
Lagged (1 year) farm assets index	0.203	0.123
	(0.195)	(0.151)
Lagged (1 year) non farm productive assets index	-0.410**	0.093
	(0.180)	(0.132)
Lagged (1 year) durable assets index	0.427***	0.080
	(0.130)	(0.103)
Distance to the nearest agri-inputs distribution store	0.134	-0.093
	(0.134)	(0.074)
Distance to the nearest wholesale market (kms)	-0.001	0.017
	(0.018)	(0.014)
Distance to the nearest local market (kms)	-0.045	-0.071**
	(0.058)	(0.033)
Distance to the village center (kms)	0.039	0.018
	(0.086)	(0.050)

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

Table 2.3. (cont'd)

	Adoption Spell	Withdrawal Spell
Meso Level Characteristics		
Lagged (1 year) tomato price per lb at the village level	2.517*	-0.939
	(1.360)	(1.117)
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	0.022***	0.002
	(0.006)	(0.004)
Household time		
Origin of the adoption spell (To)	-0.150**	
	(0.075)	
Origin of the withdrawal spell (year of adoption of the supermarket channel, Ta)		-0.284***
		(0.029)
Constant	302.306**	568.734***
	(149.682)	(57.437)
ρ	1.591	2.859
$\sigma=1/\rho$	0.629	0.350
Observations	696	116
LR Chi^2 (21)	51.83	100.2
Prob > Chi^2	0.000	0.000

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

Table 2.4. The effects of duration as a supermarket supplier on technology choices

	Farm Assets	Purchased tray seedlings	Drip irrigation	Hired Labor	Fertilizers	Pesticides	Share of toxic pesticides
Age of the head of the	0.136***	-0.042	-0.000	8.638	19.652**	22.875***	0.001
household (HHH)	(0.034)	(0.072)	(0.004)	(6.649)	(7.985)	(8.497)	(0.001)
HHH is female	0.095	6.252**	-0.037	120.892	418.735	-652.345	0.060
	(1.924)	(2.989)	(0.179)	(339.183)	(412.377)	(505.602)	(0.045)
Average years of education	-0.178	-0.215	0.000	-31.774	-27.825	8.721	-0.000
of the household	(0.128)	(0.231)	(0.012)	(22.549)	(27.309)	(32.845)	(0.003)
Years of education of the	0.263*	-0.403	0.013	7.740	35.272	7.028	0.000
HHH	(0.151)	(0.329)	(0.014)	(26.248)	(31.993)	(39.684)	(0.003)
Number of adults (14 to 60	-0.437**	1.072***	0.034*	-22.834	40.664	17.325	-0.014**
years old) in the household	(0.171)	(0.346)	(0.020)	(35.221)	(40.185)	(32.912)	(0.006)
Total cropped land in Ha	0.040	-0.534	-0.026	-55.478*	-115.542***	-26.832	0.001
	(0.162)	(0.448)	(0.016)	(29.567)	(35.509)	(40.433)	(0.004)
Total value of livestock	0.188	3.218***	0.007	-19.235	0.920	54.098*	-0.002
holdings (USD thousands)	(0.141)	(0.697)	(0.015)	(27.723)	(32.601)	(30.454)	(0.004)
Farm assets index		0.601	0.131***	79.763*	245.246***	-72.939*	-0.006
		(0.542)	(0.027)	(47.254)	(52.895)	(39.531)	(0.009)
Lagged (1 year) tomato	-1.388	-3.808	-0.423	577.319	911.676	-1,283.984**	-0.126
price per lb .	(3.086)	(10.539)	(0.399)	(754.252)	(847.402)	(632.637)	(0.139)
Distance to the nearest	0.282	-6.576***	-0.024	256.042**	252.003**	176.453	0.001
agri-inputs store (km)	(0.586)	(1.118)	(0.056)	(104.764)	(126.631)	(150.801)	(0.014)
Elevation of the village	-0.095	-0.636	-0.020	303.911***	330.223***	-140.028	-0.025*
(meters above sea level)	(0.566)	(0.826)	(0.053)	(99.404)	(120.667)	(146.470)	(0.013)
Duration as supermarket	5.582***	0.273	0.341**	574.734*	705.118*	1,484.252***	-0.038*
supplier (fitted value)	(1.489)	(4.350)	(0.173)	(318.290)	(367.525)	(306.315)	(0.022)
Constant	-16.429***	16.843	-0.529	-3,150.2***	-4,356.9***	-3,107.0**	0.284
	(5.959)	(12.760)	(0.634)	(1,176.447)	(1,391.304)	(1,434.380)	(0.175)
Observations	246	246	246	239	240	240	240
Wald Chi^2 (10)	52.41	97.53	45.74	27.66	64.00	35.14	20.14
Prob > Chi^2	0.000	0.000	0.000	0.006	0.000	0.000	0.064

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

ANNEX A: Econometric analysis using 2005-2010 data only

Table 2.5. Duration analysis (using 2005-2010 data).

	Adoption Spell	Withdrawal Spell
Household Characteristics		
Age of the head of the household (HHH)	0.001	-0.003
	(0.007)	(0.003)
Years of education of the HHH	0.024	0.000
	(0.026)	(0.011)
Average years of education taken within the adult members of the household	-0.009	-0.003
	(0.022)	(0.012)
HHH is female	-0.163	-0.087
	(0.296)	(0.132)
Number of adults (14 to 60 years old) in the household	0.018	-0.013
	(0.034)	(0.020)
Share of adults working in local off farm employment	-0.606*	-0.011
	(0.360)	(0.243)
Farm and Non Farm Characteristics		
Lagged (1 year) participation in a production cooperative by any adult member of the household	-0.407***	0.102
	(0.141)	(0.075)
Lagged (1 year) total owned land in Ha	0.009	-0.016
	(0.015)	(0.011)
Lagged (1 year) total owned land squared	-0.000	0.000*
	(0.000)	(0.000)
Lagged (1 year) irrigated land in Ha	-0.121	0.047
	(0.084)	(0.054)
Total value of livestock holdings (USD thousands)	0.126*	-0.012
	(0.071)	(0.025)
Lagged (1 year) farm assets index	-0.033	0.044
	(0.081)	(0.033)
Lagged (1 year) non farm productive assets index	-0.173	0.003
	(0.114)	(0.046)
Lagged (1 year) durable assets index	0.290***	0.020
	(0.087)	(0.050)
Distance to the nearest agri-inputs distribution store	0.183**	0.035
	(0.084)	(0.041)
Distance to the nearest wholesale market (kms)	0.008	-0.002
	(0.013)	(0.005)
Distance to the nearest local market (kms)	-0.052*	0.023
	(0.031)	(0.021)
Distance to the village center (kms)	-0.036	-0.015
	(0.044)	(0.024)

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

Table 2.5 (cont'd)

	Adoption Spell	Withdrawal Spell
Meso Level Characteristics		
Lagged (1 year) tomato price per lb at the village level	3.400***	1.006*
	(1.086)	(0.590)
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	0.015***	0.003
	(0.004)	(0.002)
Household time		
Origin of the adoption spell (To)	-0.197***	
	(0.039)	
Origin of the withdrawal spell (year of adoption of the supermarket channel, Ta)		-0.076***
		(0.019)
Constant	394.412***	154.873***
	(78.265)	(37.478)
ρ	4.212	5.954
$\sigma=1/\rho$	0.237	0.168
Observations	374	152
LR Chi^2 (21)	56.87	51.71
Prob > Chi^2	0.000	0.000

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

Table 2.6. The effects of duration as a supermarket supplier on technology choices (using 2005-2010 data).

	Farm Assets	Purchased tray seedlings	Drip irrigation	Hired Labor	Fertilizers	Pesticides	Share of toxic pesticides
Age of the head of the	0.060	-0.002	-0.004	-3.320	-0.727	8.309***	0.001
household (HHH)	(0.037)	(0.005)	(0.003)	(6.997)	(5.521)	(2.505)	(0.001)
HHH is female	0.728	-0.143	-0.028	67.517	642.934**	-140.231	0.077*
	(1.843)	(0.267)	(0.162)	(332.286)	(265.935)	(126.338)	(0.046)
Average years of education	-0.130	0.003	-0.007	-33.032	-29.380	8.011	-0.000
of the household	(0.126)	(0.018)	(0.011)	(23.037)	(18.111)	(8.084)	(0.003)
Years of education of the	0.074	0.001	0.009	7.740	11.857	1.396	0.000
HHH	(0.150)	(0.021)	(0.014)	(27.291)	(21.650)	(10.001)	(0.004)
Number of adults (14 to 60	-0.343*	0.049**	0.033	-50.432	13.178	35.491*	-0.018***
years old) in the household	(0.190)	(0.021)	(0.023)	(43.520)	(37.538)	(18.572)	(0.007)
Total cropped land in Ha	0.096	-0.019	-0.005	-35.395	-76.241**	4.790	-0.001
	(0.160)	(0.022)	(0.018)	(34.305)	(29.925)	(15.376)	(0.005)
Total value of livestock	0.156	0.047***	0.019	-31.341	-4.111	-25.853*	-0.002
holdings (USD thousands)	(0.143)	(0.016)	(0.016)	(31.674)	(27.541)	(14.036)	(0.005)
Farm assets index		0.007	0.037	11.657	81.549	38.621	-0.002
		(0.035)	(0.038)	(82.041)	(75.538)	(40.401)	(0.014)
Lagged (1 year) tomato	-9.313***	-0.572	-0.531	-17.169	58.104	-511.754	-0.229
price per lb	(3.504)	(0.386)	(0.556)	(1,088.348)	(1,012.665)	(525.437)	(0.183)
Distance to the nearest agri-	-0.759	-0.167**	-0.072	159.619	217.831***	-10.432	0.004
inputs store (km)	(0.555)	(0.080)	(0.052)	(103.493)	(83.296)	(39.269)	(0.015)
Elevation of the village	-1.243**	-0.045	-0.113**	165.376	95.202	70.538	-0.060***
(meters above sea level)	(0.584)	(0.084)	(0.057)	(112.356)	(92.836)	(46.188)	(0.016)
Duration as supermarket	8.911***	0.250	0.507***	841.918**	1,344.521***	243.328	0.015
supplier fitted value)	(1.691)	(0.249)	(0.192)	(385.764)	(324.943)	(162.001)	(0.058)
Constant	-7.668	0.597	0.057	-1,821.107*	-2,835.507***	-920.629**	0.418***
	(5.421)	(0.755)	(0.549)	(1,086.949)	(903.975)	(443.773)	(0.160)
Observations	152	152	152	146	147	147	147
Wald Chi^2 (10)	51.26	19.96	25.30	20.58	62.37	43.21	43.52
Prob > Chi^2	0.000	0.068	0.014	0.057	0.000	0.000	0.000

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

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CHAPTER 3: Product choice, Technology Adoption and Modern Markets in Nicaragua: A Duration Analysis

3.7 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.

Particularly 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[6], 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)?

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

[6] 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.

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.

3.8 The model: the determinants and effects of farmers' entry and duration in the modern channel

3.8.1 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), $A_{0,}$ 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),

$$\prod_0(p_0, w, z_0) + \theta_0 \qquad (3.1)$$

For modern market (crops),

$$\prod_1(p_1, w, z_1) + \theta_1 \qquad (3.2)$$

With

$$E(\theta_0) = E(\theta_1) = 0, \sum(\theta_0, \theta_1) = (\sigma_0^2, \sigma_1^2, \rho_{01}\sigma_0\sigma_1) \quad (3.3)$$

where

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

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

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

(8) 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

$$Y = (\Pi_0 + \theta_0)A_0 + (\Pi_1 + \theta_1)A_1 + T - c_1, \quad (3.4)$$

where

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

(4) 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:

$$\Delta U_a = \frac{1}{2\phi(\sigma_0^2+\sigma_1^2+2\rho_{01}\sigma_0\sigma_1)}[(\Pi_1 - \Pi_0) - \phi(\rho_{01}\sigma_0\sigma_1 - \sigma_0^2)]^2 - c_1 > 0 \quad (3.5)$$

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 3.5, the change in utility from adoption, as follows:

$$\Delta \mathrm{U_a} = \Delta \mathrm{U_a}(\mathrm{p_0}, \mathrm{p_1}, \mathrm{w_x}, \mathrm{FK}, \mathrm{HK}, \mathrm{SK}, \mathrm{T_o}, \mathrm{t_a}, \mathrm{V} \quad (3.6)$$

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.

$$\Delta U_w = \Delta U_w(p_0, p_1, w_x, FK, HK, SK, T_a, t_w, V) \quad (3.7)$$

3.7 is similar to 3.6, 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:

5) The exogenous output prices,

6) The exogenous input prices,

7) Household assets: human capital (*HK*); farm capital (*FK*); social capital (*SK*); and community capital (*CK*).

8) 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:

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

(4) 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 3.6 and 3.7 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,

$$t_a = t_a(p_0, p_1, w_x, FK, HK, SK, T_o, V) \tag{3.8}$$

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

$$t_w = t_w(p_0, p_1, w_x, FK, HK, SK, T_a, V) \tag{3.9}$$

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:

$$\Delta FK = \Delta FK(p_0, p_1, w_x, A_0, A_1, \widetilde{t_w}, HK, V) \tag{3.10}$$

$$\Delta q = \Delta q(p_0, p_1, w_x, A_0, A_1, \widetilde{t_w}, HK, V) \tag{3.11}$$

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.

3.8.2 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 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[7]. 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

[7] 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.

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:

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

(e) 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:

$$h(t) = \lambda(x)^{\rho} \rho t^{\rho-1} \tag{3.12}$$

where

$$\lambda(x) = e^{-\beta' x} \tag{3.13}$$

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

(4) 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:

$$\log(t) = \beta' X + \sigma\varepsilon, \tag{3.14}$$

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[8],

(5) σ is a scalar that is equivalent to the inverse of the shape parameter (σ=1/ρ).

3.8.3 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

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

2010[9]. The latter is selectively represented by indicators of technology modernization in horticulture cultivation:

(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.

[9] 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 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.

(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.

(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)[10]

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).

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[10] 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.

The effects equations are estimated as a system using Zellner's seemingly unrelated regression (SUR) model to exploit potential correlation across the erros in all system equations. Since we are using two variables not actually observed (fitted values for time to adoption and duration periods), we use a bootstrapping procedure to obtain the correct standard errors (Wooldridge, 2002).

3.9 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 3.1) and then their farm characteristics and technology use (Table 3.2). 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).

3.9.1 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).

3.9.2 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.

3.10 Econometric findings

3.10.1 Determinants of Time-to-Adoption

Table 3.3 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.

3.10.2 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.

3.10.3 Effect of Duration on Farm Capital Accumulation and Technology Use

Table 3.4 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. Then, 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.

3.11 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.

Figure 3.1. Adoption survivor function.

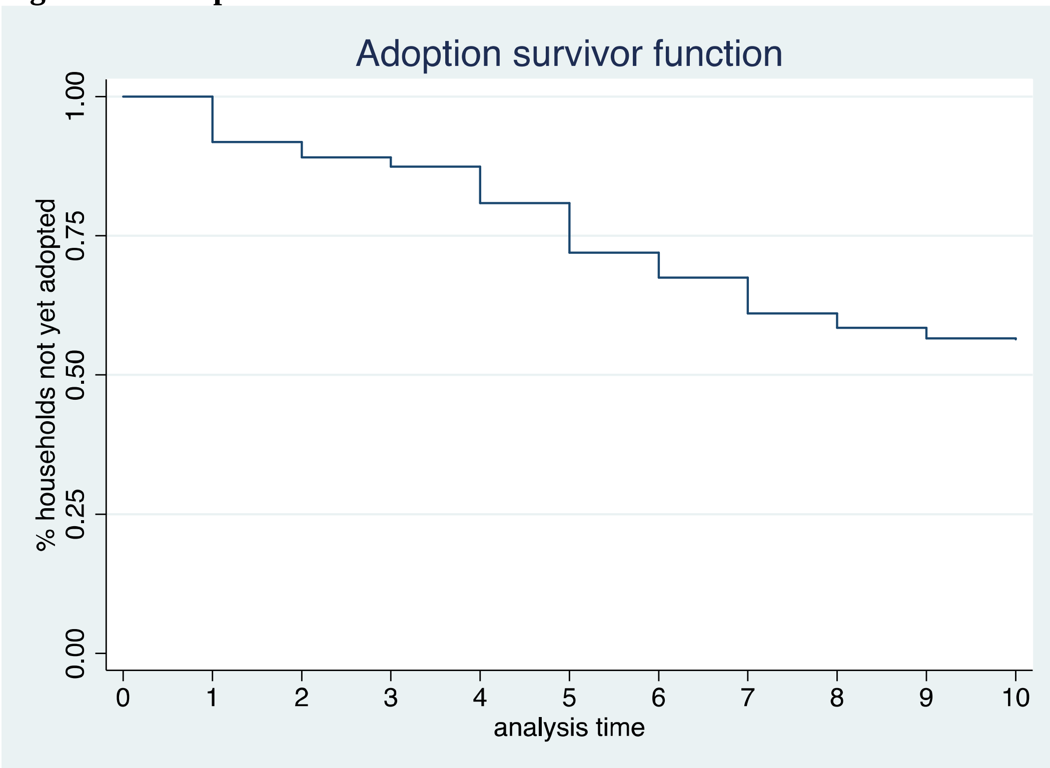

Figure 3.2. Hazard function, adoption.

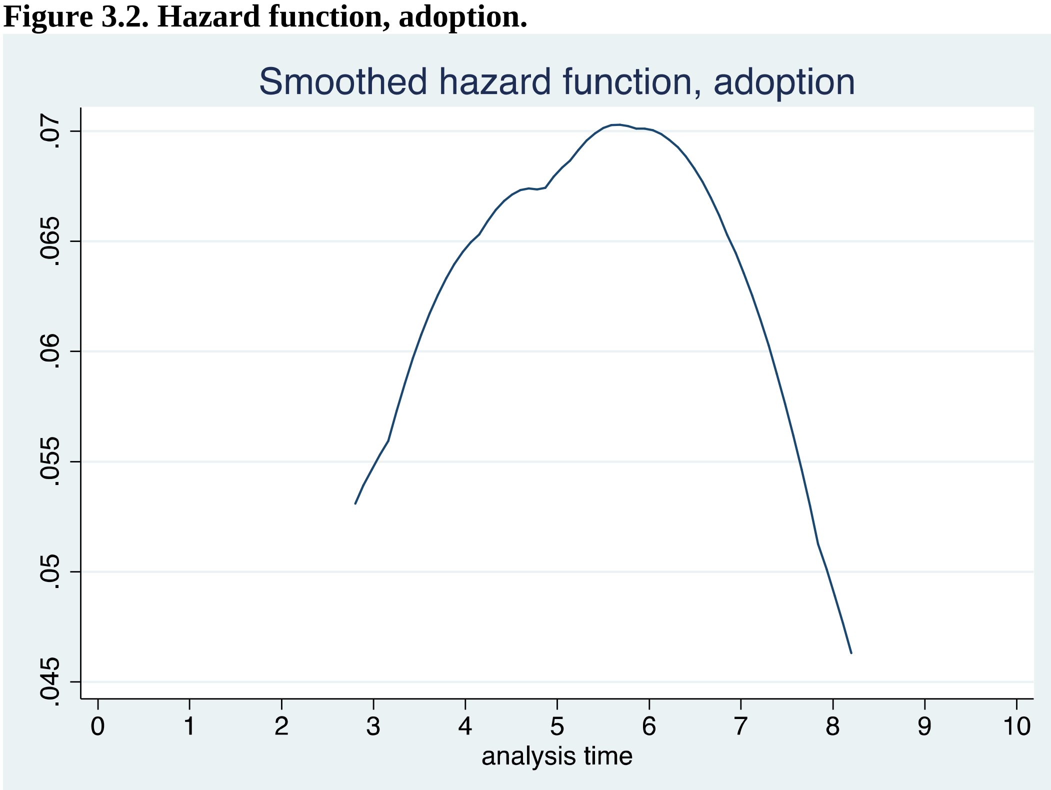

Figure 3.3. Withdrawal survivor function.

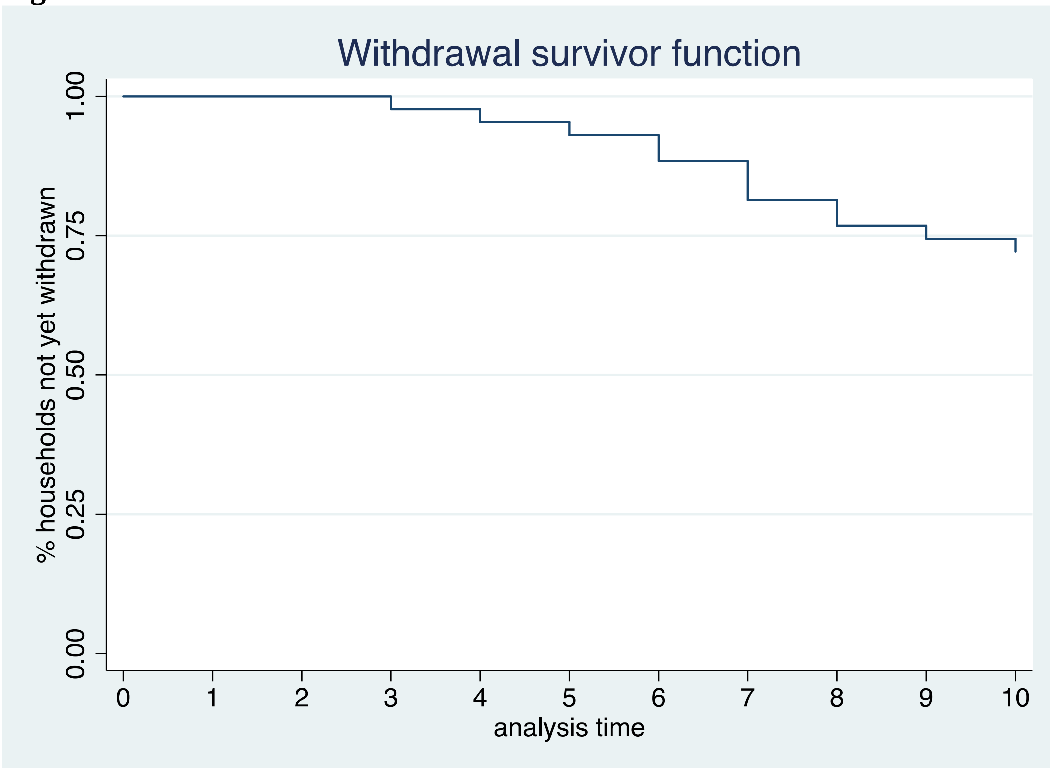

Figure 3.4. Hazard function, withdrawal.

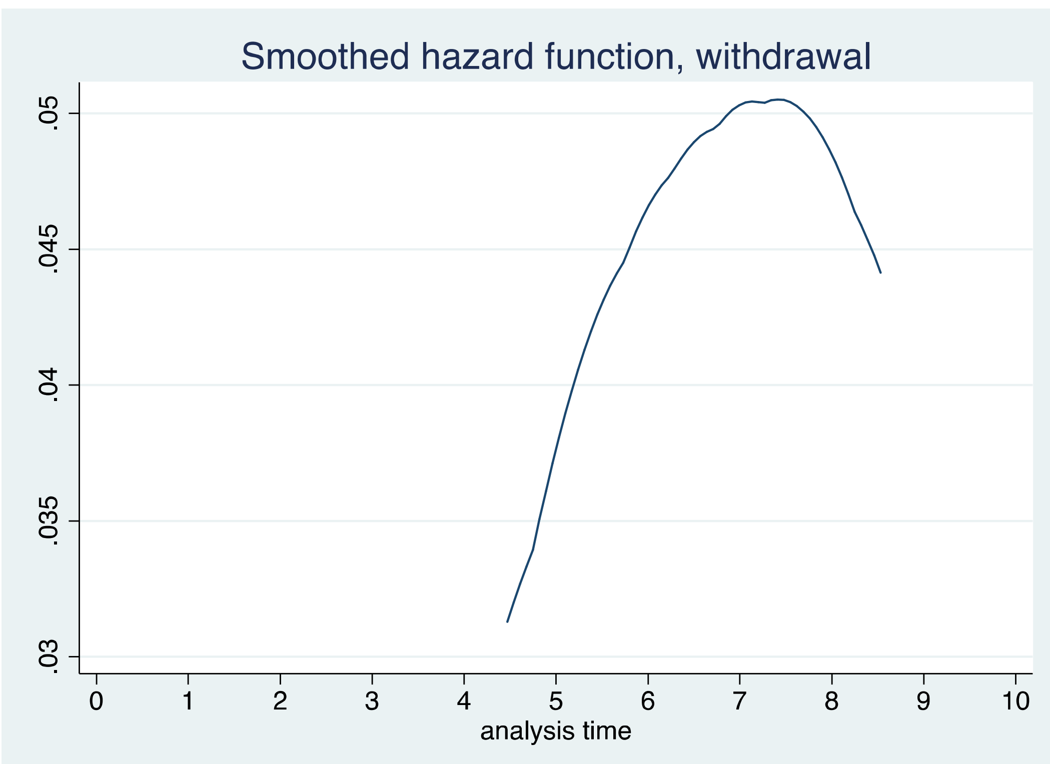

Table 3.1A. Household characteristics and income distribution of vegetable growers in Nicaragua in 2010, by early and late adoption category.

		NON ADOPTERS	ADOPTERS			TOTAL
			All	Early Adopters	Late Adopters	
	Observations	457	337	124	213	794
1	Household Characteristics					
1.1	Number of people in the household (HH) (unweighted)	5.1	5.3	5.4	5.3	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	3.6
1.3	Female headed HH (share over all HH SOH)	3%	4%	2%	5%	3%
1.4	Age of head of household (HHH) (years)	47.1	47.4	48.2	47.0	47.3
1.5	share of HH members who work on the farm (SOH)	33%y	30%**	29%	30%	31%
1.6	share of HH members who work off the farm (SOH)	9%x	12%**	11%	12%	10%
1.7	Education of HHH (years)	4.1ax	4.9***	4.5ab	5.1b	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	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	10.0
1.10	Member of a production cooperative / farmer association/ farmer enterprise in 2010 (SOH)	32%ax	42%***	41%ab	43%b	36%
1.11	Member of a production cooperative / farmer association/ farmer enterprise in 2005 (SOH)	17%ax	28%***	32%b	27%b	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	$739
2.2	Total value of HH nonfarm production assets (USD 100s) in 2010	$84	$91	$115	$80	$88
2.3	Total value of HH nonfarm consumption durables (USD 100s) in 2005	$208ax	$276**	$250ab	$295b	$238

*,**,*** = 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.

Table 3.1A. (cont'd)

		NON ADOPTERS		All		Early Adopters		Late Adopters		TOTAL	
2.4	Total value of HH nonfarm production assets (USD 100s) in 2005	$35a		$52		$77b		$39a		$43	
2.5	Share of HH who had a temporary migrant in the past five years	14%by		10%**		6%a		12%b		12%	
2.6	Share of HH who had a permanent migrant in the past five years	25%		22%		23%		22%		23%	
3	<u>Collective assets</u>										
3.1	Distance to the closest agrochemicals commercial distributor (kms)	18.6y		16.8		14.6		18.4		17.8	
3.2	Distance to the closest wholesale market (kms)	80.7y		78.3		74.6		81.0		79.8	
3.3	Distance to the closest retail market (kms)	19.0y		19.0		18.0		19.5		19.0	
3.4	Distance to the closest secondary school (kms)	4.6by		3.5***		3.6ab		3.4a		4.1	
3.5	Distance to the closest hospital (kms)	20.6by		16.9***		17.1a		17.0a		19.1	
3.6	Distance to the village center (kms)	3.4		3.0		3.0		3.1		3.2	
4	<u>Household Income</u>										
4.1	On-farm income	$3,303ax	71%	$7,957***	81%	$10,409c	87%	$6,454b	76%	$5,281	77%
	4.1.1Target crops income	$1,769ax	38%	$6,548***	67%	$8,758c	74%	$5,205b	61%	$3,805	56%
4.2	Off-farm income	$1,000a	21%	$1,467*	15%	$1,265b	11%	$1,563b	18%	$1,193	17%
4.3	Not earned income	$358	8%	$391	4%	$237	2%	$489	6%	$374	5%
4.4	Total household income	$4,441ax	100%	$8,953***	100%	$11,134c	100%	$7,748b	100%	$6,374	100%
4.5	Total income per capita (considering all HH members)	$1,053 ax		$2,699***		$3,079b		$2,505b		$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.

Table 3.1B. Household characteristics and income distribution of vegetable growers in Nicaragua in 2010, by early and late adoption category.

		NON ADOPTERS	ADOPTERS			TOTAL
			All	Short Duration	Long Duration	
	Observations	457	337	207	130	794
1	Household Characteristics					
1.1	Number of people in the household (HH) (unweighted)	5.1	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	3.7	3.6	3.6
1.3	Female headed HH (share over all HH SOH)	3%	4%	4%	3%	3%
1.4	Age of head of household (HHH) (years)	47.1	47.4	47.7	47.0	47.3
1.5	share of HH members who work on the farm (SOH)	33%y	30%**	29%x	31%xy	31%
1.6	share of HH members who work off the farm (SOH)	9%x	12%**	10%xy	13%y	10%
1.7	Education of HHH (years)	4.1ax	4.9***	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***	7.0y	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***	10.5y	10.9y	10.0
1.10	Member of a production cooperative / farmer association/ farmer enterprise in 2010 (SOH)	32%ax	42%***	34%x	55%y	36%
1.11	Member of a production cooperative / farmer association/ farmer enterprise in 2005 (SOH)	17%ax	28%***	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	$720	$739	$739
2.2	Total value of HH nonfarm production assets (USD 100s) in 2010	$84	$91	$96	$87	$88
2.3	Total value of HH nonfarm consumption durables (USD 100s) in 2005	$208ax	$276**	$270xy	$292y	$238

*,**,*** = show statistically difference at 10%, 5%, 1% significant level.
x, y, z, show differences between non-adopters, short duration and long duration households using Tukey-Kramer test at 10% significance level.

Table 3.1B. (cont'd)

		NON ADOPTERS		ADOPTERS All		ADOPTERS Short Duration		ADOPTERS Long Duration		TOTAL	
2.4	Total value of HH nonfarm production assets (USD 100s) in 2005	$35a		$52		$52		$55		$43	
2.5	Share of HH who had a temporary migrant in the past five years	14%by		10%**		13%y		5%x		12%	
2.6	Share of HH who had a permanent migrant in the past five years	25%		22%		24%		19%		23%	
3	<u>Collective assets</u>										
3.1	Distance to the closest agrochemicals distributor (kms)	18.6y		16.8		19.1y		13.6x		17.8	
3.2	Distance to the closest wholesale market (kms)	80.7y		78.3		86.7y		65.8x		79.8	
3.3	Distance to the closest retail market (kms)	19.0y		19.0		22.2y		13.5x		19.0	
3.4	Distance to the closest secondary school (kms)	4.6by		3.5***		3.3x		3.8xy		4.1	
3.5	Distance to the closest hospital (kms)	20.6by		16.9***		18.6y		14.5x		19.1	
3.6	Distance to the village center (kms)	3.4		3.0		2.8		3.4		3.2	
4	<u>Household Income</u>										
4.1	On-farm income	$3,303ax	71%	$7,957***	81%	$5,563x	75%	$11,194y	86%	$5,281	77%
	4.1.1Target crops income	$1,769ax	38%	$6,548***	67%	$4,029x	55%	$10,016y	77%	$3,805	56%
4.2	Off-farm income	$1,000a	21%	$1,467*	15%	$1,360	18%	$1,603	12%	$1,193	17%
4.3	Not earned income	$358	8%	$391	4%	$467	6%	$283	2%	$374	5%
4.4	Total household income	$4,441ax	100%	$8,953***	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***		$1,559 x		$4,560y		$1,759	

*,**,*** = show statistically difference at 10%, 5%, 1% significant level.
x, y, z, show differences between non-adopters, short duration and long duration households using Tukey-Kramer test at 10% significance level.

Table 3.2A. Farm assets and technology choice of horticultural growers in Nicaragua in 2010, by early and late adoption.

		NON ADOPTERS	ADOPTERS			TOTAL
			All	Early Adopters	Late Adopters	
	Observations	457	337	124	213	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	8.7
1.2	Total land owned and rented out in Ha in 2010	0.3	0.4	0.3	0.4	0.3
1.3	Total land rented in in Ha in 2010	1.0	0.9	0.7	1.0	0.9
1.4	Total land owned and not rented out in Ha in 2005	7.4	8.9	7.0	10.1	8.1
1.5	Total land rented in in Ha in 2005	0.3	0.3	0.3	0.3	0.3
1.6	Total cropped land in Ha in 2010	2.7	2.9	2.8	3.0	2.8
1.7	Total cropped land in Ha in 2005	2.5	2.5	2.4	2.5	2.5
2	Non land assets					
2.1	Total value of farm assets (USD) in 2010	$1,946ax	$2,978***	$3,148b	$2,896ab	$2,388
2.2	Total value of farm assets (USD) in 2005	$966	$1,382**	$1,422	$1,352	$1,141
2.3	Total value of animals owned (USD) in 2010	$1,483	$1,484	$1,316	$1,588	$1,485
2.4	Total value of animals owned (USD) in 2005	$1,241	$1,010	$940	$1,075	$1,150
3	Production in 2010					
3.1	Tomato production (MT/year)	25.1x	37.3***	38.4	36.6	30.2
3.2	Total area grown (Ha)	0.8	0.8	0.7	0.8	0.8
3.3	Yield (MT/Ha)	28.4ax	48.0***	63.6c	38.9b	36.6
3.4	Sweet pepper production (MT/year)	5.7ax	12.4***	12.0b	12.6b	8.1
3.5	Total area grown (Ha)	0.5	0.4	0.5	0.4	0.5
3.6	Yield (MT/Ha)	11.1ax	33.5**	21.7ab	41.1b	19.2
3.7	Lettuce production (MT/year)	15.2	32.5**	31.3	33.8	25.4
3.8	Total area grown (Ha)	0.7ax	1.1***	1.2b	1.0ab	0.9
3.9	Yield (MT/Ha)	21.6	31.0	26.2	34.7	27.0

*,**,*** = 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.

Table 3.2A. (cont'd)

		NON ADOPTERS	ADOPTERS			TOTAL
			All	Early Adopters	Late Adopters	
4	Irrigation Technology in 2010					
4.1	Share of HH without irrigation	20%	0%	0%	0%	12%
4.2	Share of HH with drip irrigation	29%ax	62%**	56%b	65%b	43%
4.3	Share of HH with canal irrigation	48%by	35%**	40%b	32%a	42%
4.4	Share of HH with other type of irrigation	3%	4%	5%	3%	3%
5	Seedling Technology 2010					
5.1	Share of HH using direct seeding	2%	1%	2%	0%	1%
5.2	Share of HH using owned produced seedlings	76%cz	32%***	21%a	38%b	57%
5.3	Share of HH using purchased tray seedlings	22%ax	67%***	78%c	62%b	42%
6	Tunnel Technology 2010					
6.1	Share of HH using tunnels	3%a	5%	10%b	3%a	4%
6.2	Share of HH using open field	97%	95%	90%	97%	96%
7	Production in 2005					
7.1	Tomato production (MT/year)	35.0	36.7	49.0	28.1	35.6
7.2	Total area grown (Ha)	0.8	0.7*	0.7	0.7	0.8
7.3	Yield (MT/Ha)	35.8ax	57.4**	84.6c	39.9b	44.6
7.4	Sweet pepper production (MT/year)	6.7	13.4*	13.7	13.4	9.5
7.5	Total area grown (Ha)	0.5	0.5	0.5	0.5	0.5
7.6	Yield (MT/Ha)	14.5	40.4*	22.9	52.2	25.1
7.7	Lettuce production (MT/year)	21.1a	31.3**	39.6b	26.2ab	26.8
7.8	Total area grown (Ha)	0.8	0.9	0.9	0.9	0.9
7.9	Yield (MT/Ha)	27.1ax	58.9	104.6b	31.1a	44.8
8	Irrigation Technology in 2005					
8.1	Share of HH without irrigation	22%	3%	0%	5%	14%
8.2	Share of HH with drip irrigation	14%ax	48%***	47%b	48%b	29%
8.3	Share of HH with canal irrigation	59%by	46%	50%b	43%a	53%
8.4	Share of HH with other type of irrigation	5%	4%	3%	4%	4%

*,**,*** = 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.

Table 3.2A. (cont'd)

		NON ADOPTERS	ADOPTERS			TOTAL
			All	Early Adopters	Late Adopters	
9	<u>Seedling Technology 2005</u>					
9.1	Share of HH using direct seeding	4%	3%	2%	4%	3%
9.2	Share of HH using owned produced seedlings	82%bz	41%***	33%a	46%ab	64%
9.3	Share of HH using purchased tray seedlings	14%ax	56%***	66%b	50%b	32%
10	<u>Tunnel Technology 2005</u>					
10.1	Share of HH using tunnels	4%ax	9%***	11%b	8%b	5%
10.2	Share of HH using open field	96%	91%	89%	92%	95%
11	<u>Inputs for Horticulture Production in 2010 (USD/Ha)</u>					
11.1	Seedlings/seeds expenditures	172ax	330***	331b	332b	240
11.2	Labor expenditure	332	355	345	364	343
	11.2.1 Imputed family labor	144b	123**	110a	132ab	135
	11.2.2 Hired labor	188ax	232***	235b	232b	207
11.3	Fertilizers expenditure	672ax	796***	796ab	808b	728
	11.3.1 Chemical fertilizers	520x	583**	590	588	549
	11.3.2 Organic fertilizers	4x	9	11	7	6
	11.3.3 Foliar fertilizers	149ax	204***	196ab	212b	173
11.4	Pesticides expenditure	472	495	460	522	484
	11.4.1 Insecticides	270	279	241	308	275
	11.4.2 Herbicides	16ax	20**	17ab	22b	18
	11.4.3 Fungicides	187	195	203	191	191
11.4	Other inputs expenditure[#]	237x	304**	280	314	264
11.5	TOTAL	1886ax	2281***	2213b	2340b	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.
[#] Other inputs include Rope, plastic, sticks, filters, fuel, connectors, and wire.

Table 3.2B. Farm assets and technology choice of horticultural growers in Nicaragua in 2010, by short and long duration as supermarket supplier.

		NON ADOPTERS	ADOPTERS			TOTAL
			All	Short Duration	Long Duration	
	Observations	457	337	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	10.0	9.9	8.7
1.2	Total land owned and rented out in Ha in 2010	0.3	0.4	0.4	0.3	0.3
1.3	Total land rented in in Ha in 2010	1.0	0.9	0.9	0.9	0.9
1.4	Total land owned and not rented out in Ha in 2005	7.4	8.9	8.7	9.4	8.1
1.5	Total land rented in in Ha in 2005	0.3	0.3	0.4	0.2	0.3
1.6	Total cropped land in Ha in 2010	2.7	2.9	2.9	2.9	2.8
1.7	Total cropped land in Ha in 2005	2.5	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***	$2,770xy	$3,338y	$2,388
2.2	Total value of farm assets (USD) in 2005	$966	$1,382**	$1,269	$1,550	$1,141
2.3	Total value of animals owned (USD) in 2010	$1,483	$1,484	$1,526	$1,427	$1,485
2.4	Total value of animals owned (USD) in 2005	$1,241	$1,010	$1,003	$1,061	$1,150
3	Production in 2010					
3.1	Tomato production (MT/year)	25.1x	37.3***	38.7y	34.9xy	30.2
3.2	Total area grown (Ha)	0.8	0.8	0.9	0.6	0.8
3.3	Yield (MT/Ha)	28.4ax	48.0***	43.4y	54.3y	36.6
3.4	Sweet pepper production (MT/year)	5.7ax	12.4***	12.3y	12.4y	8.1
3.5	Total area grown (Ha)	0.5	0.4	0.5	0.4	0.5
3.6	Yield (MT/Ha)	11.1ax	33.5**	40.3y	23.0xy	19.2
3.7	Lettuce production (MT/year)	15.2	32.5**	32.5	33.0	25.4
3.8	Total area grown (Ha)	0.7ax	1.1***	1.0xy	1.3y	0.9
3.9	Yield (MT/Ha)	21.6	31.0	31.6	30.1	27.0

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

x, y, z, show differences between non-adopters, short duration and long duration households Tukey-Kramer test at 10% significance level.

Table 3.2B. (cont'd)

		NON ADOPTERS	ADOPTERS			TOTAL
			All	Short Duration	Long Duration	
4	Irrigation Technology in 2010					
4.1	Share of HH without irrigation	20%	0%	0%	0%	12%
4.2	Share of HH with drip irrigation	29%ax	62%**	50%y	78%z	43%
4.3	Share of HH with canal irrigation	48%by	35%**	49%y	16%x	42%
4.4	Share of HH with other type of irrigation	3%	4%	2%	6%	3%
5	Seedling Technology 2010					
5.1	Share of HH using direct seeding	2%	1%	0%	1%	1%
5.2	Share of HH using owned produced seedlings	76%cz	32%***	46%y	15%x	57%
5.3	Share of HH using purchased tray seedlings	22%ax	67%***	54%y	84%z	42%
6	Tunnel Technology 2010					
6.1	Share of HH using tunnels	3%a	5%	6%	5%	4%
6.2	Share of HH using open field	97%	95%	94%	95%	96%
7	Production in 2005					
7.1	Tomato production (MT/year)	35.0	36.7	39.1	32.5	35.6
7.2	Total area grown (Ha)	0.8	0.7*	0.7	0.6	0.8
7.3	Yield (MT/Ha)	35.8ax	57.4**	46.9xy	74.7y	44.6
7.4	Sweet pepper production (MT/year)	6.7	13.4*	13.1	14.5	9.5
7.5	Total area grown (Ha)	0.5	0.5	0.5	0.4	0.5
7.6	Yield (MT/Ha)	14.5	40.4*	48.1	27.1	25.1
7.7	Lettuce production (MT/year)	21.1a	31.3**	30.6	32.4	26.8
7.8	Total area grown (Ha)	0.8	0.9	0.9	1.0	0.9
7.9	Yield (MT/Ha)	27.1ax	58.9	37.2xy	92.6y	44.8
8	Irrigation Technology in 2005					
8.1	Share of HH without irrigation	22%	3%	5%	0%	14%
8.2	Share of HH with drip irrigation	14%ax	48%***	34%y	65%z	29%
8.3	Share of HH with canal irrigation	59%by	46%	57%y	31%x	53%
8.4	Share of HH with other type of irrigation	5%	4%	3%	4%	4%

*,**,*** = 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.

Table 3.2B. (cont'd)

		NON ADOPTERS	ADOPTERS			TOTAL
			All	Short Duration	Long Duration	
9	Seedling Technology 2005					
9.1	Share of HH using direct seeding	4%	3%	4%	1%	3%
9.2	Share of HH using owned produced seedlings	82%bz	41%***	51%y	28%x	64%
9.3	Share of HH using purchased tray seedlings	14%ax	56%***	45%y	71%z	32%
10	Tunnel Technology 2005					
10.1	Share of HH using tunnels	4%ax	9%***	11%y	6%xy	5%
10.2	Share of HH using open field	96%	91%	89%	94%	95%
11	Inputs for Horticulture Production in 2010 (USD/Ha)					
11.1	Seedlings/seeds expenditures	172ax	330***	259y	448z	240
11.2	Labor expenditure	332	355	350	368	343
	11.2.1 Imputed family labor	144b	123**	124	124	135
	11.2.2 Hired labor	188ax	232***	226xy	244y	207
11.3	Fertilizers expenditure	672ax	796***	719x	939y	728
	11.3.1 Chemical fertilizers	520x	583**	545x	659y	549
	11.3.2 Organic fertilizers	4x	9	4x	16y	6
	11.3.3 Foliar fertilizers	149ax	204***	170x	264y	173
11.4	Pesticides expenditure	472	495	456	568	484
	11.4.1 Insecticides	270	279	257	324	275
	11.4.2 Herbicides	16ax	20**	23y	16x	18
	11.4.3 Fungicides	187	195	176	227	191
11.4	Other inputs expenditure#	237x	304**	261x	367y	264
11.5	TOTAL	1886ax	2281***	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.
Other inputs include Rope, plastic, sticks, filters, fuel, connectors, and wire.

Table 3.3. 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)

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

Table 3.3 (cont'd)

	Adoption Spell	Withdrawal Spell
<u>*crop production (lagged 1 year)*</u>		
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)
<u>*Household time*</u>		
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 3.4. 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	0.010	-0.008**	0.004	0.001	0.277	-1.466	0.291	0.001
(HHH)	(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	-0.015	0.001	0.023	0.004	-16.224	-19.072	-11.980	-0.002
old) in the household	(0.219)	(0.017)	(0.024)	(0.013)	(20.771)	(21.489)	(13.682)	(0.003)
Share of adults working in local	5.273**	0.406	-0.324	0.017	-183.320	-209.403	-243.697	0.076
off farm employment	(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	0.487*	-0.004	0.000	-0.004	-5.973	-5.846	-6.264	0.001
(USD thousands)	(0.257)	(0.014)	(0.009)	(0.008)	(7.845)	(8.294)	(6.401)	(0.002)
Distance to the nearest agri-inputs	-0.260	-0.032	-0.000	-0.052	-5.669	1.460	5.375	-0.006
distribution store (km)	(0.294)	(0.031)	(0.015)	(0.033)	(26.728)	(27.689)	(26.461)	(0.006)
LN[Elevation of the farm (meters	0.829	-0.042	0.045	-0.019	84.383	-50.637	-165.339	-0.047
above sea level)]	(0.715)	(0.100)	(0.067)	(0.063)	(85.699)	(88.684)	(110.943)	(0.029)
Duration as supermarket supplier	0.470	0.084***	0.085**	0.095***	84.425***	37.533	38.902	-0.008*
(fitted value)	(0.348)	(0.031)	(0.033)	(0.021)	(28.223)	(30.711)	(24.103)	(0.005)
Time to adopt the supermarket	0.514	0.032	-0.012	0.012	176.051***	103.368	120.029**	0.022
channel (fitted value)	(0.501)	(0.065)	(0.057)	(0.055)	(53.641)	(67.289)	(57.169)	(0.016)

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

Table 3.4. (cont'd)

	Farm Assets	Drip irrigation area	Niche cropped area	Purchased tray seedlings	Hired Labor	Fertilizers	Pesticides	Share of toxic pesticides
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 B: Econometric analysis using 2005-2010 data only

Table 3.5. Duration analysis (using 2005-2010 data)

	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)

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

Table 3.5. (cont'd)

	Adoption Spell	Withdrawal Spell
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 3.6. Effect of time to adopt and duration as supermarket suppliers on farm assets and technology in 2010 (using 2005-2010 data).

	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	0.006	-0.007**	0.004***	0.001	1.313	-1.733	0.229	0.001
household (HHH)	(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	0.281***	0.010	0.031	0.006	-2.146	-5.433	7.826	0.004
HHH	(0.101)	(0.008)	(0.019)	(0.007)	(8.289)	(6.630)	(7.612)	(0.003)
Number of adults (14 to 60	-0.016	-0.001	0.024	0.004	-18.858	-19.429	-12.704	-0.002
years old) in the household	(0.208)	(0.011)	(0.019)	(0.013)	(18.178)	(21.142)	(17.839)	(0.004)
Share of adults working in	5.153**	0.347	-0.310	0.019	-284.845***	-226.474**	-276.985**	0.074*
local off farm employment	(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	0.495***	-0.005	0.000	-0.004	-6.035	-4.410	-5.299	0.001
holdings (USD thousands)	(0.172)	(0.008)	(0.005)	(0.004)	(4.975)	(5.308)	(4.299)	(0.001)
Distance to the nearest agri-	-0.231*	-0.030	-0.003	-0.053***	-1.369	3.590	7.598	-0.005***
inputs store (km)	(0.119)	(0.020)	(0.010)	(0.009)	(25.867)	(15.953)	(5.416)	(0.002)
LN[Elevation of the farm	0.851	-0.048	0.042	-0.021	89.359***	-42.618	-157.622	-0.045**
(meters above sea level)]	(0.662)	(0.076)	(0.063)	(0.064)	(32.707)	(62.000)	(123.766)	(0.022)
Duration as supermarket	0.567*	0.069**	0.067**	0.081***	53.285**	28.098	22.964*	-0.007**
supplier (fitted value)	(0.290)	(0.033)	(0.030)	(0.015)	(22.587)	(25.723)	(13.905)	(0.004)
Time to adopt the modern	0.993	-0.123***	0.025	0.035	28.821	150.040**	133.576	0.034*
channel (fitted value)	(0.655)	(0.030)	(0.019)	(0.061)	(98.346)	(70.408)	(92.503)	(0.020)

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

Table 3.5. (cont'd)

	Farm Assets	Drip irrigation area	Niche cropped area	Purchased tray seedlings	Hired Labor	Fertilizers	Pesticides	Share of toxic pesticides
HH is located in semi-dry	2.669**	-0.043	-0.012	-0.240	-275.659	-396.365***	180.787	0.067
zone	(1.235)	(0.373)	(0.136)	(0.264)	(329.156)	(142.645)	(143.717)	(0.154)
HH is located in humid	-0.426**	-0.105	0.076***	-0.426***	-337.028***	-80.298	16.793	0.054**
zone	(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.

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