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KNOWLEDGE, TOXICITY, AND EXTERNAL SHOCKS: THE DETERMINANTS OF ADOPTION AND ABANDONMENT OF NON-TRADITIONAL EXPORT CROPS BY SMALLHOLDERS IN GUATEMALA

by

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Knowledge, Toxicity, and External Shocks: The Determinants of Adoption and Abandonment of Non-Traditional Export Crops by Smallholders in Guatemala[1]

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I. Non-traditional agro-exports in the Central Highlands of Guatemala

Since the late 1970s, Guatemala, like several other less developed countries, has experienced an extraordinarily rapid growth in the production of non-traditional agro-exports (NTXs). The share of agricultural output coming from NTXs grew from less than 6% in 1980 to more than 22% in 1992. Rationales behind the promotion of NTXs by government and development agencies include foreign exchange earnings, depressed market conditions for traditional export crops, and rural poverty reduction. As part of the packages mandated by structural adjustment and trade liberalization programs, many national governments, including Guatemala, introduced policies in favor of NTX producers, such as export facilitation procedures, subsidy programs, and fiscal reforms. Trade agreements such as the Generalized System of Preferences (GSP) and the Caribbean Basin Initiative (CBI) created additional incentives for NTX exporters. In the Guatemalan context, private organizations and trade associations, such as the Association of Exporters of Non-Traditional Products (GEXPRONT), played a catalytic role in promoting NTXs in the 1980s. With a focus on rural poverty alleviation, international donors invested heavily in the promotion of NTXs as an instrument for a new approach to rural development.

One such effort, introduced as part of the recovery effort following the 1976 earthquake that devastated the Guatemalan highlands, was the agricultural cooperative *Cuatro Pinos* founded in 1979 with financial assistance from a Swiss aid agency with the primary objective of promoting the production of NTXs among smallholders. Cooperative membership grew tenfold in the following 10 years, reaching more than 1,900 members in the late 1980s and operating in ten different villages.

Pre-NTX agriculture in the region was dominated by the *milpa* system, a combination of maize and bean production. In one of the villages in the sample, for example, *milpa* used to cover 96% of the total cultivated area (von Braun et al., 1989). Since introduction of NTXs in the region, snowpeas have been the main crop promoted and marketed by the cooperative. Recently, new crops like berries and miniature vegetables were introduced as part of a diversification effort aimed at attenuating the increasing problems associated with snowpea cultivation. In spite of these problems, snowpeas remain by far the most diffused among the NTXs grown in the region and it is the NTX on which we focus in this paper.

Assessed from a long term historical perspective, previous agro-export booms have contributed to reinforcing the traditionally strong dualistic agrarian structure that characterizes Latin American agrarian societies as they have disproportionately been the domain of large farming operations (de Janvry, 1981; Barham et al., 1992). However, contrary to these antecedents, all but the tiniest farms appear to have initially adopted the new export crops in Guatemala (von Braun et al., 1989). Farm size may indeed be an important determinant of adoption since, in a context of transactions costs and imperfect information, the distribution of assets across farms affects not only equity but also efficiency in resource use (Eswaran and Kotwal, 1986; Carter et al., 1993). It has been suggested that the comparative advantage which small peasants have in growing NTXs is due to the labor intensity of these crops, allowing to use underemployed family labor, as well as to the high supervision requirements needed to meet high quality standards with hired labor, which, again, makes the use of family labor a natural mechanism to neutralize the moral hazard problems implicit with hired labor (von Braun et al., 1989). There are, however, innate difficulties in growing NTXs in the tropics, particularly for smallholders (Maxwell and Fernando, 1989). In the winter months, when climatological conditions are favorable, peasants' fields are affected by pest infestations. Proper application of pesticides during this season, and therefore availability of the required financial liquidity and access to technical assistance, become preconditions for successfully cultivating NTXs. Summer months are characterized by relatively low pest problems but low water availability. Irrigation, therefore, is a prerequisite for successfully growing NTXs during the summer. In addition, the risks involved in the production and marketing of the product have always been very high.

Characteristics of NTX cultivation that play against small producers in a context of transactions costs and imperfect information can be at least partially mitigated by institutional arrangements that emerge to reduce transactions costs and the inefficiencies associated with imperfect information (Carter et al., 1993). In this case, the major institutional response was the development of the *Cuatro Pinos* cooperative which provided members with access to credit, reduced risk through management of a price band system, and offered insurance through limited liability on loans. The balance between these positive and negative features of NTX cultivation for smallholders, including institutional mitigation, may have initially played in favor of or been neutral on smallholders, leading many to herald this latest agro-export boom as an effective market-driven mechanism to reduce the strong dualistic nature of Guatemalan agriculture (von Braun et al., 1989; Barham et al., 1995).

Initial success has, however, given way to increasing difficulties. In recent years, snowpea yields have registered a consistent drop across all the communities surveyed.[2] Among the emerging agronomic difficulties are the dramatic increase in pest problems and pesticide resistance build-up, and the rising pressure over scarce land resulting in accelerated soil degradation. These difficulties have contributed to escalate production costs and reduce NTX profitability over time, affecting most particularly the smaller farmers with weaker access to credit and higher risk aversion. Furthermore, increasing price uncertainty,[3] frequent temporary import bans into the United States for Guatemalan snowpeas due to pesticide residues,[4] and the prohibitive cost of pesticide residue spot checks have also had an impact on the profitability of NTX production in the 1990s.[5] Finally, the ability of the cooperative to assist producers with credit and technical assistance has been weakened after 1990 by a discontinuity in management, high default rates on pending debts as a consequence of extensive adverse selection during easy years, and low prices.[6] The consequence has been a gradual shift back to the production of traditional crops for the domestic market, which had been partially abandoned in the early stages of adoption (Immink et al., 1993b).

The determinants of adoption and abandonment can be conceptualized as the combination of two processes which are unfolding over time, but with different time origins. One pertains to what can be called "historical" time: following an easy phase where market and institutional conditions were highly favorable to adoption, roughly between 1979 and 1987, this environment gradually became more hostile to adoption, sharply reducing benefits for late compared to early adopters, reaching crisis proportions in 1990-94 which precipitated a wave of abandonments. The other pertains to what can be called "human" time and is composed of two opposite forces: a positive force for adoption and retention is the accumulation of knowledge associated with the passage of time before adoption (learning from

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[2] According to many of the interviewed farmers, snowpea yields have gone from 3,500-4,000 pounds per cuerda (1 cuerda = 0.11 hectare) in the mid-1980s to 800-1,200 pounds in the early 1990s.

[3] The prices of NTXs have always been quite variable. However, long harvest periods in the 1980s (up to 12 weeks) helped farmers cope with high price variation by spreading risk over a longer time interval. This is no longer the case. Due to both the use of different seed varieties and soil depletion, the average harvest period is now only 4-5 weeks, with clear effects on risk.

[4] In 1993, export of snowpeas to the US was interrupted for three months. In 1994, a 45-day "self-imposed" export ban took place starting October 1. Even though of shorter duration, this latest trade restriction affected farmers greatly since it came in a period of high production and was completely unexpected. The problem is aggravated by the fact that the United States is the only marketing channel open to most Guatemalan snowpeas because of low regional market opportunities and increasing competition of African snowpeas on European markets.

[5] In the decade 1984-94, 3,168 residue-related detentions of Guatemalan crops, mainly snowpeas, were reported. Of these, 3,081 occurred between 1990 and 1994. The vast majority of the detentions was due to chlorothalanil, a pesticide used in snowpeas unregistered in the United States. Residue analyses are now performed in Guatemala prior to shipment, causing substantial increases in costs for producers (Thrupp, 1995).

[6] The actual number of active members in the 1990s has been decreasing at an alarming rate. According to some cooperative officials, the number of active members in 1994, i.e., members still delivering products to the cooperative on a regular basis, barely exceeded 400.

others) and with years of NTX production after adoption (learning-by-doing) (Foster and Rosenzweig, 1995); and a negative force associated with the passage of time after adoption caused by pest resistance build-up and soil depletion, which we shall call the accumulation of "toxicity". Decisions to adopt and abandon are also influenced by a number of other covariates which empirical analysis will help identify, in particular the role of farm assets (land owned, quality of land), human capital assets (age, education, and number of adults), and social capital assets (cooperative membership). The various time and structural factors are unlikely to affect all rural households in an equal manner, creating, over time, biases capable of offsetting the apparent initial competitiveness of small farmers in growing NTXs.

Since introduction of NTXs in the region, households in the communities surveyed have been faced year after year with the decision of whether to adopt NTXs in view of their expected benefits (profitability and risk) for given household and village level characteristics as well as human and historical time conditions. Farmers who at a certain point in time did adopt were then faced with the decision of whether or not to withdraw from the NTX scheme, also in response to household and village level characteristics as well as human and historical time conditions which affect benefits. These passages from one state to another can be captured by conceptualizing the peasant's sequence of decisions as two different duration models, one reflecting the adoption decision and the other related to the decision to withdraw from cultivation of NTXs, given earlier adoption.

This study is based on a household survey conducted in 1994 in six rural communities serviced by the *Cuatro Pinos* cooperative in which adoption of NTXs has taken place to varying degrees and with different timing. The analysis builds on previous research undertaken in the same villages in 1985 (von Braun et al., 1989) and 1991 (Immink et al., 1993a) by the International Food and Policy Research Institute and the Institute of Nutrition of Central America and Panama.

The remainder of the paper is organized as follows. In sections II and III, a household choice model for the decisions to adopt and withdraw is developed and a number of hypotheses regarding the determinants of these two decisions are put forth. In section IV, some details on the survey methodology and the data are presented. In section V, summary statistics of the adoption process are given preceding the estimation of formal duration models of adoption and withdrawal. Section VI reports conclusions and recommendations based on the findings.

II. The determinants of NTX adoption over time

A household will adopt NTX production on its land $\bar{A}$ if this provides him with a higher utility than the production of traditional crops. A simple household choice model allows to identify the exogenous variables at play and the expected signs for econometric analysis. Let π be the expected profitability of NTX production per unit of land, when all labor use is valued at the cost of hired labor w. Family labor L and hired labor are perfect substitutes in production, although the cost of hired labor w, including supervision and recruitment, is higher than the opportunity cost of family labor w_L. We assume that NTX production is risky, while production of the traditional crop yields a non-risky return r per unit of land. The net revenue (NR) from growing NTX rather than the traditional crop is thus:

$$NR = \theta\pi\bar{A} + (w - w_L)L - r\bar{A},$$

where θ is a stochastic term with mean 1 and variance σ_θ^2. Using a mean-variance model, with absolute risk aversion Ψ, the utility U_a per unit of land derived from adopting NTX is:

$$U_a = \frac{1}{\bar{A}}\left[E(NR) - \tfrac{1}{2}\Psi\mathrm{Var}(NR)\right] = \left(1 - \tfrac{1}{2}\Psi\pi\bar{A}\sigma_\theta^2\right)\pi + (w - w_L)\frac{L}{\bar{A}} - r.$$

This utility is thus an increasing function of family size L and, if risk aversion is not too extreme (specifically if the risk premium $\tfrac{1}{2}\Psi\pi\bar{A}\sigma_\theta^2$ is less than $\tfrac{1}{2}$), it is also an increasing function of expected profitability π. Larger farms are at a disadvantage because of lower availability of family labor per hectare (term $L/\bar{A}$ above) and the higher riskiness of the project (term $\pi\bar{A}\sigma_\theta^2$). However, larger farms will also usually have lower risk aversion Ψ, implying an ambiguous sign for $\bar{A}$. Variables that affect π are land ownership $\bar{A}$ (scale economies), land quality F, the household's human capital HK and social capital SK, the village environment (δ_v), and different concepts of time representing particular epochs (D_a), the year of formation of the household (T_0), and the time process (t) of accumulation of knowledge. We now discuss each of these exogenous variables, how they are measured in the survey, and what are their expected signs in the utility for adoption.

Role of $\bar{A}$. In the adoption literature, factors such as access to credit and information and fixed costs, e.g. irrigation, combined with higher risks associated with NTX production, have been repeatedly emphasized as making the scale of the farming operation of paramount importance in adoption decisions. In view of the high diffusion of NTXs observed across peasants regardless of land endowment, we test the hypothesis that size of land owned $\bar{A}$ did not play a significant role in peasants' decision to adopt NTXs. To account for possible land accumulation processes during the adoption spell, the variable $\bar{A}$ is specified as a time-varying covariate that measures the amount of land owned by the household in each single year of the spell.

Role of F. Due to the unfavorable climatological conditions for growing NTXs in the summer months, irrigation is as an important prerequisite for successful adoption. Land quality is also an important determinant of NTX profitability. In the communities surveyed, a widely used indicator of land quality is the level of humidity retained by the soil. Due to very different microclimates, as a consequence of rapidly changing altitudes, and very diverse soil characteristics, adjacent lands are often characterized by sharply different levels of humidity. The advantage of high humidity land is that it allows farmers to continue growing NTXs well into the summer months without the need for irrigation. As such, high humidity land can be seen as an imperfect substitute for irrigation. The variables *F* measure the shares of cultivated land that are irrigated and high humidity, both of which affect positively a farmer's profitability of growing NTXs.

Roles of HK and L. The household's human capital assets (*HK*), such as age (or youth) and education of the head of household, affect positively NTX profitability, as these elements reflect unobservable characteristics of the decision maker such as farming skills, productivity, entrepreneurship, and risk aversion. Another household asset is the number of adults in the household (*L*). Previous studies on NTX adoption in Guatemala[7] have emphasized the importance of family labor availability in the decision to adopt labor intensive crops such as NTXs.[8] However, this hypothesis has more often been put forth than tested and, when tested, usually yielded inconclusive results.

Roles of SK. Cooperative membership (*SK*) must have been an important element of a household's social capital affecting the decision to adopt since the cooperative was virtually the only source of formal credit, insurance, and technical assistance in the communities. Until the mid-1980s, time of the von Braun et al.'s study, NTX adoption and cooperative membership were considered synonymous: the decision to adopt and the decision to become a cooperative member were taken jointly.[9] In the early stages of adoption, start-up costs for

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[7] von Braun et al. (1989), Katz (1992), Barham et al. (1995).
[8] Labor requirements for snowpeas are 663 man-days per hectare (md/ha), as compared to 58 md/ha for maize and 61 md/ha for beans (cited in Thrupp, 1995). The family labor variable reflects the number of household members between the ages of 12 and 65 in each year of the spell.
[9] Because of the strong relation between these two variables, the membership variable is not included in the modeling of the adoption decision.

input purchases and extension services were almost exclusively provided by the cooperative. Also, credit for land purchases was often given by the cooperative, conditional upon NTX adoption. Later on, as alternative marketing channels developed, and as the financial difficulties of the cooperative severely reduced its ability to provide credit and extension services to its members, the link between the two became weaker.

Role of D_a. The observed households' adoption behavior over time suggests that the conditions leading to adoption changed drastically, as reflected in the falling rate of adoption over time after 1987.[10] We introduce the role of historical time by specifying an adoption epoch dummy equal to one after 1987, identifying a period of greater hardship for adoption. It is used to test the hypothesis that adoption was relatively easier and more open to all households before 1987.

Role of δ_v. The geographical location of a household may also affect the adoption decision. Village dummies are introduced to account for the importance of local features influencing the profitability of adoption such as quality of infrastructure and remoteness from markets, as well as timing of availability of cooperative services.

Roles of t *and* T_0. The time determinant of adoption also depends on human time. It is measured by two effects. One is a pure human time effect that enters through a time drift (t) in the profitability of NTX cultivation, whatever the year of origin of the duration spell. This trend captures the learning effect associated with duration, i.e., the effect of learning from others on adoption irrespective of idiosyncratic household characteristics and of historical time. The other is the origin of the duration spell for adoption (T_0) measured by the year of household formation which marks the beginning of accumulation of knowledge obtained by learning from others. The variable equals 1979 if the household was already formed by that year, and the year of household formation otherwise. It combines human and historical time since the information gained by waiting to adopt has differential value according to the context for adoption. Older households are more likely to adopt early for they accumulate knowledge under more favorable conditions for adoption. T_0 is thus an idiosyncratic measure of historical time.

In summary, the signs of the exogenous variables affecting NTX profitability and the household's utility for NTX adoption are:

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10 This break point was established by tatonnement in estimating the adoption duration model.

$$\pi = \pi\left(\pm\overline{A}, +F, +HK, +SK, -D_a, -T_0, +t, \delta_v\right) \text{ and}$$

(1) $$U_a = U_a\left(\pm\overline{A}, +F, +L, +HK, +SK, -D_a, -T_0, +t, \delta_v\right).$$

The household will decide to adopt when $U_a \geq 0$. The time t_a at which adoption will take place, which is the minimum t for which U_a is positive, is thus ambiguously related to land ownership, a decreasing function of soil quality, family labor, and human and social capital assets, and an increasing function of the time origin of the household and the epoch dummy:

(2) $$t_a = t_a\left(\mp\overline{A}, -F, -L, -HK, -SK, +D_a, +T_0, \delta_v\right).$$

The various concepts of time in the adoption model are summarized in Figure 1. Adoption occurs when utility from adoption is positive. For household 1, initial utility is positive and it adopts in year 0. Household 2 is formed in year A. While lower than for household 1, initial utility is still positive for household 2 and it also adopts immediately upon formation. Household 3 is formed in year B when initial utility is negative. There is a delay in adoption until year C when learning from others has increased productivity, allowing non-negative utility. There is a duration in adoption of length BC. Household 4 adopts in year D after a longer duration than the previous household because its initial utility upon formation was even more adverse, requiring more time to learn. Finally, initial conditions are so adverse for household 5, due to a combination of deteriorating initial conditions and epoch effects, that it never adopts.

III. The determinants of NTX withdrawal over time

Once the farmer has adopted NTX production, profitability and risk are assessed each year to decide whether to maintain NTX production or return to traditional crops. The decision model is the same as above, with utility from use U_u of NTX equal to:

$$U_u = U_u\left(\overline{A}, F, L, HK, SK, D_w, T_a, t, \delta_v\right),$$

where D_w is an epoch dummy for withdrawal and T_a is the year of adoption of NTX cultivation.

Withdrawal from NTXs can be a reflection of either loss of profitability or the result of a switch by farmers to more profitable ventures. As mentioned earlier, a process of crop diversification has been underway since the early 1990s to cope with the increasing problems faced by snowpea growers. The new strains of NTXs promoted in the region include miniature vegetables and berries. So far, this diversification process has been quite slow and has affected only a few farmers, mainly cooperative members. To disentangle these two phenomena and separate the few farmers who have benefited from such programs, we treat all peasants who have abandoned snowpeas to grow these new NTXs as if they never stopped cultivating NTXs. As such, withdrawal will more genuinely reflect a situation where farmers were unable to maintain profitability in face of rising costs, falling yields, and an increasingly hostile market and institutional context.

Role of $\bar{A}$. As discussed in the adoption duration model, the vast majority of peasants in the region may have adopted NTXs, regardless of land endowments. However, as conditions deteriorate, the poorest farmers may be the ones least likely to be able to cope with the increasing problems and to successfully weather the current NTX crisis. As a result, this group of households may withdraw earlier. The proposition is directly linked to the sustainability of adoption and the potential impact NTXs may have in reducing Guatemala's strongly dualistic agrarian structure.

Role of F. Lack of irrigation and poor land quality may contribute to earlier abandonment of NTXs. Like in the adoption duration model, these variables are measured by the shares of cultivated land which are irrigated and high humidity in 1993-94.

Role of D_w. After 1990, profitability of NTX production deteriorated markedly.[11] A withdrawal epoch dummy D_w is thus introduced to capture the change in historical context for permanence in NTX production after 1990.

Roles of t *and* T_a. Duration before eventual abandonment is also affected by human time which enters through two effects. One is a pure human time effect represented by a time drift t in the hazard function, whatever the time of origin of the withdrawal spell. This trend captures the net between two opposite forces: on the negative side, "toxicity" accumulates as soon as adoption has occurred, creating a drift toward lower profitability and earlier abandonment; on the positive side, learning-by-doing occurs as soon as adoption has occurred, creating a drift over time toward higher profitability and longer spells before abandonment. The other is a combined human and historical time effect as the year of

[11] This break point was established by tatonnement in estimating the withdrawal duration model.

adoption T_a matters: having benefited from more years of high profitability in NTX production, early adopters are in better financial condition to weather the subsequent profitability crisis.

Role of SK. Simple inclusion of the binary variable *SK* may not correctly measure the true impact of cooperative membership on the conditional probability of withdrawal. The reason is that an autoselectivity process is likely to have been at play, with only adopters with certain unobservable characteristics joining the cooperative. These unobservable characteristics may be affecting the decision to withdraw from NTX cultivation and, if not treated separately, their effect will be captured by the membership variable. Consequently, to estimate the true impact of membership on duration, we must account for the possibility of selectivity bias created by these unobservable features.

In summary, the signs of the exogenous variables affecting the household's utility for continued use of NTX are:

(3) $$U_u = U_u\left(\pm\bar{A}, +F, +L, +HK, +SK, -D_w, -T_a, \pm t, \delta_v\right)$$

The household will decide to withdraw when $U_u < 0$ and the time t_w at which withdrawal will take place is the maximum t for which U_u is positive. If U_u depends negatively on t (which is what the empirical analysis will later reveal), then t_w is an ambiguous function of land ownership, an increasing function of soil quality, family labor, and human and social capital assets, and a decreasing function of the year of adoption and the epoch dummy:

(4) $$t_w = t_w\left(\pm\bar{A}, +F, +L, +HK, +SK, -D_w, -T_a, \delta_v\right).$$

The different concepts of time in the withdrawal model are summarized in Figure 2. For adopters, cultivation of NTX will be discontinued when utility from use becomes negative due to deteriorating conditions of adoption, the build up of toxicity in excess of learning-by-doing, and a negative epoch effect. Household 1 adopted in year 0 under the most favorable conditions and abandons in year A. Duration in use is 0A years. Household B adopted later when conditions were already more adverse. It will abandon in year C when utility is reduced to zero as a consequence of the toxicity and epoch effects. Duration in use is BC years. Finally, household 3 adopted in year D and abandons in year E. Duration is only DE years.

IV. The survey

A household survey was undertaken in the Fall of 1994 in six of the ten villages serviced by the cooperative.[12] A total of 157 families (79 cooperative members and 78 non-members), extracted from a 1991 INCAP-IFPRI sample[13], were interviewed using two different questionnaires. A first questionnaire was addressed to the male household head addressing issues of agricultural production for three separate seasons[14] and characteristics of the production unit. Historical recalls covered three themes: the year of household formation, land ownership (land owned at the time of household formation, and all the land transactions since), and cultivation of NTX (first year of cultivation, last year of cultivation, and eventual years of interruption in between). A second questionnaire was directed at the wife of the household head and covered family characteristics such as family composition and educational levels.

V. A duration model specification of NTX adoption and withdrawal

5.1. Descriptive statistics

Table 1 reports descriptive statistics by adoption status for some of the explanatory variables considered. Casual adopters are included as non-adopters by defining as adopters only those households who remained in NTX production for more than two years. We see that there is no significant difference in the amount of land owned at the beginning of the adoption duration spell, supporting the proposition that adoption was unbiased by farm size. There are, however, significant differences in area cultivated in 1993-94 between adopters and non-adopters, as adopters were able to use their success to enlarge their operational areas. However, here it is adoption that created large farms, not large farms that induced adoption. The land quality variables, which expectedly did not change during the period, also show advantages for adopters: higher shares of irrigated land and of high humidity land are important for adoption. The number of adults in the household at the beginning of the adoption spell does not differ among adopters and non-adopters, putting in question the ability of the data to evidence the importance of family labor for adoption. However, by 1994, there

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[12] The six villages, all located in the department of Sacatepéquez, are: Santiago Sacatepéquez, Pachalí, San José Pacul, Santa Maria Cauqué, San Mateo Milpas Altas, and El Rejón. The cooperative headquarters are located in Santiago.

[13] Because of considerations beyond the scope of this paper, we included in the sample all households which at the time of the INCAP-IFPRI survey had a child younger than 60 months.

[14] The three seasons are: Winter (May-October) 1993, Summer (November-April) 1993-94, and Winter (May-October) 1994.

were more adults in the households who have adopted, showing that NTXs allow greater retention of labor in agriculture. Finally, cooperative membership is very closely associated with adoption.

The data on adoption evidence the extremely dynamic nature of adoption behavior and appear to support the assertion that major changes in the conditions leading to adoption have occurred over time. By 1987, 86% of the total number of adopters had already adopted. Among all adopters who subsequently dropped out at some point in time, 68% did so between 1991 and 1993, while only 1% of the adopters joined during the same period. Of the 157 observations in the sample, only 36% never adopted. Of the remaining 101, 57% stopped growing snowpeas at some point in time, implying that 73% of the households were not growing snowpeas in 1994.

Figures 3 and 4 show the observed survival functions for the adoption and withdrawal spells measured in human time. The survival functions for these two spells give the probability that the spell of years since household formation for adoption, and since NTX adoption for withdrawal, is at least of length *t* (years on the horizontal axis). The adoption spell in Figure 3 shows that the probability of non-adoption declined over time but at a decreasing rate: while 27% of the households adopted in the first year, subsequent years show a linear trend with approximately 5% of the remaining households adopting every year until year 9, and 36% never adopted (this includes the 24% shown on the Figure 3 at year 16 and the censored observations). Hence, adoption becomes increasingly less likely as years pass after formation of the household, with a sharp drop after nine years. As Table 2 shows, on average it took farmers 6.9 years to enter the NTX scheme and adopters cultivated NTXs for 9.2 years. The withdrawal spell in Figure 4 also shows non-linearities in the probability of withdrawal over time for adopters. Specifically, there is a high likelihood of abandonment after just one year of adoption. After this, the probability of withdrawing falls rather linearly with length of the spell until the last five years when there is again a sharp increase in withdrawals. Since the spells are measured in human time (i.e., as though all households started their adoption spell in year 0 in Figure 3 and their withdrawal spell in year 0 in Figure 4), the correspondence between discontinuities in the survival functions and historical time (9 years for adoption = 1987, first of last five years for withdrawal = 1990) is only due to the fact that a high share of households adopted in 1979 (23%), creating some correspondence in survival between historical and human time.

These global trends hide considerable heterogeneity across households. Table 2 shows the average lengths of the two spells by cooperative membership status and farm size classes. On average, cooperative members took a much shorter time to adopt (3.4 years vs. 10.9 years for non-members) and, once they had adopted, continued planting for longer periods of time than non-members (11.2 years vs. 5 years). Larger farmers appear to adopt earlier (on average, after 6.0 years compared to 8.2 years for smaller farmers), but to abandon equally rapidly as small farmers (9.3 years for both). However, there are many spurious correlations hidden behind the apparent correspondence between descriptive statistics and length of spells for adoption or withdrawal as well as problems of truncation since not all potential adopters had adopted, and all potential withdrawers had withdrawn, by the time of the survey. To control for these spurious correlations and truncation problems, duration models are used to identify and test for the structural determinants and the changing conditions of NTX adoption and withdrawal in an intertemporal framework.

5.2. Duration models

Econometric analysis of adoption behavior has favored specifications such as linear regressions and discrete choice models (Feder, Just, and Zilberman, 1985; von Braun et al., 1989; Katz, 1992). More recently, models based on Tobit specifications have been introduced to account for the extent of adoption (Barham et al., 1995). In this paper, both NTX adoption and abandonment are modeled not as one time behavioral choices within specified time intervals, but as processes of choice of when to adopt and when to abandon.

Econometric specification of the waiting time t_a before adoption, the spell, starts from equations (2) and (4). In the empirical analysis we estimate a Weibull duration model based on the semi-log functional form:

(5) $$\ln t_a = \beta' x + \frac{1}{p}\varepsilon,$$

where x represents all the explanatory variables included in (1) and (3) other than time t, and ε is an error term accounting for unobservables that follows an Extreme-Value distribution, (i.e., $\varepsilon = \ln u$, where u has a Weibull distribution). The same holds for the year of withdrawal. Like in most duration models, observations on t_a (t_w) are of two types: either the household has indeed adopted (or withdrawn) and the value t_a (t_w) is directly observed; or the household has not yet adopted (or withdrawn) at the time of the survey, and hence we have a truncated information, $t_a > T$ ($t_w > T$), where T is the length of the observed pre-adoption (or use) spell.

From this expression, we can derive what are known in duration models as survival and hazard functions. The survival function, defined as $S(t)$ = Prob($t \leq t_a$), gives the probability that the spell t_a is at least of length t. The hazard function $h(t)$ gives the probability that the spell ends at time t, conditional upon the spell not having ended before. With the specification chosen here, these functions are:

$$(6) \qquad \begin{aligned} S(t) &= e^{-(\lambda(x)t)^p} \\ h(t) &= \lambda(x)^p p t^{p-1}, \text{ with } \lambda(x) = e^{-\beta' x}. \end{aligned}$$

In a more general formulation, the covariates x themselves can change over time, becoming time-varying covariates $x(t)$. In this specification, the hazard function is decomposed into two effects: the term in λ is a function of the covariates x, while p indicates the effect of pure human time on the hazard rate. The land ownership variable and the number of adults in the household change over time during the adoption spell. For these two variables, we consequently construct complete series of time-varying covariates $x(t)$.

The choice of functional form (5) is equivalent to assuming that the utility function can be approximated by:

$$U(x,t) = g(e^{-p\beta' x} t^p), \text{ with } g' > 0, \ g(1) = 0.$$

The parameter p gives the role of t in the evolution of utility. If $p > 1$, utility increases over time, which means that, if benefits are not initially positive, the household will wait some time before eventually adopting (Figure 1). In the post-adoption process, if $p < 1$, utility decreases over time (as drawn in Figure 2), which means that the household will eventually withdraw; while if $p > 1$, time itself plays in favor of maintaining the production of NTXs.

In our adoption duration model, human time captures the accumulation of information toward adoption. Hence, p is expected to be greater than one after controlling for historical time. In this case, the hazard function slopes upward in time: the likelihood of ending the spell, conditional upon duration up to time t, is increasing in t. In the withdrawal duration model, the effect of human time is the net between the continued positive accumulation of information and the negative accumulation of toxicity . Hence, p will be greater than one if the accumulation of toxicity dominates and less than one if the learning effect dominates. If $p < 1$, the likelihood of ending the spell decreases with human time.

One of the important covariates in the duration models is cooperative membership. Since this variable is endogenous, we first estimate separately a probit model of the binary choice of whether or not to become a cooperative member. The IMR obtained from the estimation is later included in the duration model of the withdrawal decisions to account for autoselectivity by adopters into the membership treatment. The probability of joining the cooperative is assumed to be determined by a household's initial land endowment, life cycle position measured by the time origin of household, age and education of the household's head, and geographical location of the household.[15] The result of this probit model is reported in Table 3. The two-by-two matrix of the predicted and actual values of the dependent variable reported at the bottom of the table shows an overall satisfactory predictive power of the model, with 79% of the observations correctly predicted.

5.3. Adoption

The estimations of several specifications of the adoption model are given in Table 4. In duration models, the sign of the coefficient indicates the direction of the effect of the covariate on the conditional probability of completing a spell and on the average length of the spell. For instance, with the Weibull duration model, a positive sign for a β coefficient indicates that a higher value of the explanatory variable x corresponds to a lower conditional probability of NTX adoption (6) and to a longer spell (5).

The land ownership variable is not significant in any model. The vast majority of peasants in the communities surveyed adopted at some point in time regardless of the size of their landholdings. The hypothesis that participation to the NTX boom was not biased against small farmers, thus cannot be rejected. Among household characteristics, age of the household head is irrelevant but education systematically reduces the duration spells for adoption, identifying an important policy variable to accelerate diffusion of NTX.

Another important policy result is the role of land quality in accelerating adoption. Both the high humidity land (model 2) and irrigation (model 4) variables increase adoption. When considered together (model 3), the role of irrigation dominates. Thus, while the amount

[15] For members, both the land ownership and the age variables refer to the year in which the household joined the cooperative. The variables are computed as the averages values in the interval of time between 1979 and 1994 for non-members whose household was already formed by 1979, and between the year of household formation and 1994, for all other non-members.

of land *per se* may not be a factor in a household's decision to adopt NTX in any given year, land quality is important, particularly the share of irrigated land out of total cultivated land.

If we take model 3 as the complete adoption model without specification of time variables, we see that $p = 0.98$ (not significantly different from 1) , indicating that there is no human time drift in the hazard function. Hence, there is no apparent learning from others. In model 5, introduction of the role of idiosyncratic historical time is not significant and p remains close to one. Hence, there is no continuous degradation in the likelihood of adopting in spite of rising hardship. In model 6, by contrast, the epoch dummy found by tatonnement is significant, indicating a marked structural change in the conditions of adoption around 1987, with easy times before followed by difficult times after. This reveals that there was a modest process of learning from others at play hidden under structural change ($p = 1.13$, significantly different from 1 at the 81% confidence level). That learning from others be only a modest source of knowledge is not surprising since capturing this effect would require finer specification of who is whose neighbor, whether specific neighbors have adopted or not, and since when (Foster and Rosenzweig, 1995). When both time effects are included together in model 7, only the epoch dummy matters. Model 6 is hence the best fit model.

To test the hypothesis about the importance of family labor in NTX production, we introduce in model 8 the potential level of family labor contribution in NTX production, measured by the number of adults in each year of the duration spell. Consistent with previous findings (von Braun et al., 1989; Katz, 1992; Barham et al., 1995), results do not support the hypothesis that family contribution in NTX labor requirements was important in affecting the farmer's adoption decision.

Finally, village level characteristics matter in adoption, capturing the influence of many differential geographical features of space and time, including among the latter a different timing in the influence of the cooperative across villages.

We show in Figure 5a the hazard function over historical time calculated at the mean value of the x variables. We make the roles of historical and human time coincide by drawing the function for a household whose date of formation is 1979. With no time specification (model 4), there is no trend in the role of pure historical time ($p = 0.98$). Introducing pure historical time under the form of an adoption epoch dummy (model 6) shows the sharp fall due to deterioration of external conditions and existence of a modest process of learning from others ($p = 1.13$) which is more important in the easy years than in the difficult ones.

To explore the mechanisms through which learning from others occurs during the adoption spell, we estimate in Table 5 the parameter p for different configurations of villages. The four villages that were initially targeted by the cooperative are Santiago, Pachalí, San José Pacúl, and Santa Maria Cauqué. We see that, in these villages, p = 1.04 or 1.05 and hence that learning from others is modest. The cooperative headquarters are located in Santiago. Calculating p for this village alone gives us a test of the role of proximity to both the coop and to other members since the area is more restricted than over four villages. We see that learning is enhanced by proximity, with p rising to 1.06. Finally, when the newer villages are introduced (San Mateo where the cooperative started working around 1983 and El Rejón around 1985), learning further accelerates. Late comers thus have a faster learning curve. This suggests both that the cooperative may have become more effective over time (at least before the 1990s) and that there had been learning from other villages that could be capitalized upon once the opportunity to adopt was offered. Learning with delayed adoption allows catching up by late comers, a result consistent with convergence in endogenous growth models.

5.4. Withdrawal

Results of the estimation of a withdrawal duration model, in which the length of spell reflects the number of continuous years a farmer planted NTXs before abandoning them, if ever, is presented in Table 5. A positive coefficient implies that higher values of the explanatory variable are associated with lower conditional probabilities of abandoning NTX cultivation and hence with longer use spells.

A first important finding relates to the role of land ownership, which, in model 1, is positive and significant. Smaller landholders abandon NTX production earlier. This result raises concerns about the long-run participation of less well endowed farmers in potentially profitable ventures such as NTXs. While favorable conditions in the 1980s lured the vast majority of households into NTX production regardless of land holdings, the increasing problems associated with cultivation of NTXs drove the less well endowed households away, with obvious regressive consequences on the long-run distributional effects of NTX cultivation.

Among demographic characteristics, age and education play opposite roles in adoption and withdrawal. While age was insignificant on adoption, older farmers appear to abandon

NTX production faster. And while education helped increase the likelihood of adoption, it does not influence a farmer's decision to withdraw. Both make sense: education is most important for the decision to adopt a complex production system, while younger entrepreneurs have longer time horizons and greater incentives to remain in production.

Quality of land is an important determinant in a household's decision to continue producing NTXs. Households with larger shares of irrigated land remain longer in NTX production (model 2). Furthermore, farmers with additionally higher percentages of high humidity land also continue to grow NTXs over a longer time period (model 3). As we introduce in the model this latter variable, the coefficient of the land ownership variable loses significance, indicating correlation between these two covariates: a higher level of land ownership is favorable to growing NTXs over a longer spell inasmuch as it also reflects higher shares of better quality land in which to grow the new crops.

With model 3, before introduction of time variables, the Weibull p parameter is equal to 1.22 (significantly different from 1 at the 90% confidence level), indicating a strong drift toward a higher likelihood of withdrawal as human time passes due to a process of toxicity build-up. When the time origin of the withdrawal spell is introduced (model 4), the coefficient on the variable is negative and significant, which implies that households which adopted earlier remain longer in NTX production as a result of having enjoyed the higher levels of profitability of NTXs in the 1980s and benefited from a longer period of learning-by-doing. However, introduction of this variable decreases the role of irrigation, indicating that early adopters were also households with more access to irrigation, as evidenced in the adoption analysis (Table 4).

The withdrawal epoch dummy (model 5), established by tatonnement, shows the importance of historical time with a serious profitability crisis after 1990, inducing accelerated abandonments. Both epoch dummy and origin of spell are significant when introduced together (model 6), indicating that the two time processes are simultaneously at play. However, since year of adoption is related to irrigation, model 7 gives the best specification of the role of the three dimensions of time on withdrawal, omitting the irrigation variable: (1) there is a pure historical time effect captured by a Weibull p = 1.17 (significantly different from 1 at the 74% confidence level), indicating rapid build up of toxicity that reduces profitability and precipitates withdrawals; (2) there is a pure historical time effect captured by the withdrawal epoch dummy, indicating the negative role of crisis conditions after 1990; and (3) there is a combined human-historical time effect captured through the origin of the withdrawal spell showing that earlier adoption delays withdrawal due to both greater accumulation of knowledge through learning-by-doing and greater financial strength built-up by adoption under more profitable times.

In model 8, the role of cooperative membership is analyzed. The estimated coefficient is positive and strongly significant, indicating that member households continue growing NTXs over a longer spell of years. However, this coefficient may grossly overestimate the true effect of membership if a selectivity process based on unobservable characteristics determined adopters' inclusion into the membership treatment. To account for this potential autoselectivity bias, we introduce in model 9 the IMR estimated from the first stage probit on membership (Table 3). While, as expected, the coefficient on the IMR is positive and significant, to our surprise the coefficient on cooperative membership changes sign. This indicates that superior survival of cooperative members is due to their innate characteristics, which were either properly recognized by the cooperative in screening members or achieved through self-selection in their choosing to become members, not to the direct role of the cooperative. Due to these inborn characteristics, cooperative members continue to grow NTXs for a longer period. Finally, the best predictor models is model 11 which shows the combined effects of the various roles of irrigation, historical time, and human time on continued cultivation of NTXs.

In Figure 5b, we represent the hazard functions for models 2 and 5 when the two concepts of time are pure human time (p = 1.23 in model 2, which is significantly different from 1 at the 91% confidence level, and 0.9 in model 5 which is not significantly different from 1) and pure historical time (withdrawal epoch dummy in model 5). The apparent detrimental trend effect of length of spell in model 2 is overwhelmed in model 5 by the macro-institutional contextual change captured by the withdrawal epoch dummy. External shocks are thus devastating on sustainability of NTX production. In addition, there is a combined effect of human and historical time contained in the origin of spell (year of adoption) variable. In Figure 5c, the hazard function for model 4 shows how early adopters (1979) have a low withdrawal hazard rate compared to intermediate period adopters (1983 and 1987) and to late adopters (1991). Even though these lines are at four year intervals, the effect of late adoption is highly non-linear and the rate of build-up of toxicity accelerates rapidly. Finally, in Figure 5d, we combine all three effects: the later the year of adoption, the more devastating the withdrawal epoch dummy and the more nefarious the passage of time for toxicity.

VI. Conclusions and recommendations

This paper has examined peasants' adoption behavior in the highlands of Guatemala following introduction in 1979 of non-traditional agro-exports. Use of a duration model framework has enabled us to capture the important dynamics of the adoption and abandonment processes, thus extending the empirical literature on adoption behavior toward a characterization of dynamics and sustainability.

One of the objectives of the paper was to analyze the degree of participation of the small peasantry in NTX agriculture. Contrary to previous agro-export booms in the region, NTXs appear to have been accessible, at least initially, to all farmers, regardless of the size of their land holdings. The findings embrace the optimistic outlook heralded in previous studies, at least as far as adoption is concerned. However, while initially accessible to all farmers, only the better endowed households with more land owned and better quality land were able to persist in growing NTXs. This finding raises serious doubts about sustainability of the positive distributional effects that NTX adoption initially had, as equity in adoption gave way to a distressing scenario of selective abandonment by the rural poor.[16] There are, however, policy instruments available to counteract this negative result. Availability of irrigation emerged as a crucial factor in both the decisions to adopt NTXs and to persist in growing them. This indicates that targeted complementary programs of improved access to irrigation can help smallholders increase adoption and sustain cultivation of NTXs.

The findings also indicate that knowledge, toxicity, and mitigating institutions interact in complex ways which are important in adoption and sustainability. Knowledge is accumulated by learning from others during the phase leading to eventual adoption. We have seen that proximity to the cooperative headquarters and proximity to others increase learning, and that late comers have a faster learning curve, allowing them to catch up with early adopters. Knowledge also accumulates through learning-by-doing after adoption, but this effect is overwhelmed by rising toxicity. Finally, specific external shocks were important determinants of adoption (favorable conditions before 1987) and of abandonment (crisis conditions after 1990), particularly in affecting the strength of institutional arrangements that helped mitigate small farmers' disadvantages in access to capital and insurance. The importance of these shocks on adoption and sustainability shows the fragility of NTX production in unreliable macro and institutional contexts. Clearly, success in NTX-based rural development programs needs very careful management of this broader context. Finally,

[16] Reservations about the sustainability of NTX production among smallholders in Central America had been suggested by Carter et al. (1993) and Rossett (1991).

human and historical time combine in the ability of households to face up to hard times. Households with an earlier time origin were able to adopt more rapidly because the information they accumulated by learning from others had greater economic value in a favorable context. And early adopters were slower to drop out of NTX production because they had consolidated their economic position through the high profitability of the 1980s and a longer spell of learning-by-doing.

Non-traditional agro-exports are much more capital intensive than both traditional and subsistence crops. Inevitably, this created an increased demand for liquidity which, in the area under study, was almost exclusively provided by the cooperative. The cooperative was thus the fundamental institutional mitigating factor to smallholder bias in adopting NTX in a context of transactions costs and imperfect information. However, cooperative membership, once corrected for selectivity bias, does not have a positive impact on the household's decision to continue growing NTXs. This disappointing role of the cooperative is due to its increasing managerial and financial difficulties. In recent years, this phenomenon has had a substantial impact on the cooperative's ability to back-up its members' increasing demands for credit, insurance, and information in order to continue growing NTXs. The shift in priorities by international donors which had so vehemently promoted NTXs in the 1980s, and the consequent withdrawal of financial support to NTX activities, contributed to weakening the cooperative. At a time when the importance of access to credit, insurance, and information grew as a consequence of increasing capital requirements, higher risk, and lower productivity of NTXs, the role of the cooperative as a source of liquidity, insurance, and technical assistance was much reduced, weakening its mitigating role precisely when it was most needed to overcome anti-smallholder biases in the cultivation of NTXs. The result was a vicious cycle which small peasants found difficult to overcome. Thus, restoring institutional sources of credit, insurance, and technical assistance to break this cycle is an important policy instrument in support of future NTX production.

Analysis of the different concepts of time in adoption and sustainability allows to identify the relative roles of historical and structural factors in affecting NTX production. Continuous expansion in the number of cooperative members may be a solution to the cooperative's short-term difficulties in satisfying the level of NTX demand caused by the dramatic drops in supply by its older members, but it is no solution to the difficulties faced by individual NTX adopters.[17] Unless these issues are addressed, the newer adopters are likely

[17] Recently, the cooperative has been active in recruiting new members in other departments such as Chimaltenango and Quiché in an effort to cope with the large decrease in the volume of supply due to both the

to follow the path of their predecessors as the toxicity effect, a structural problem intrinsic to NTX production, undermines profitability. Implementation of complementary programs such as irrigation, rural credit, extension services, promotion of crop diversification, and improvement of market outlets for both NTXs and traditional products can help in reaching an equilibrium in the communities, with more adopters enjoying sustained benefits in NTX production and an increasing number of non-adopters finding productive niches in other activities. The overall conclusion is thus that rural development initiatives need go beyond simplistic reliance on NTXs as the magical labor intensive instrument for success and address the broader questions of stable macro policy environment, institutional support, activity diversification, and market development to achieve sustainable rural development.

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Table 1. Characteristics of adopters and non-adopters: summary statistics

	Adopters (1)	Non-adopters (2)	% difference*	All households
Number of observations	101	56		157
Land assets				
Average land owned at beginning of adoption duration spell (cuerdas) (3)	3.4	1.9	79	2.9
Average cultivated land, 1993-94 season (cuerdas)	6.3	2.7	133*	5.1
Average irrigated land, 1994 (% of total cultivated land)	18	2	800*	13
Average high humidity land, 1994 (% of total cultivated land)	53	37	43*	47
Human capital assets				
Average year of household formation	1980	1983		1981
Average number of adults in the household at beginning of adoption duration spell (3)	2.0	2.1	-5	2.1
Average number of adults in the household, 1994	4.3	3.4	26*	3.9
Average age of household head at beginning of adoption duration spell (3)	26.4	25.8	2	26.2
Average educational level of head of household, 1994 (% with more than first grade)	85	82	4	85
Organizational assets				
Percent ever member of the cooperative (%)	79	9	778*	57

(1) Includes only households who adopted NTXs for more than two years.
(2) Includes households who adopted for less than two years.
(3) In 1979 or at time of household formation.
* Difference between adopters and non-adopters is statistically significant at the 95% level.
t-tests are used for differences in means, chi-square for differences in frequencies.

Table 2. Average duration of spells by membership and farm size status

	Adoption spell (years)	Withdrawal spell (years)
Number of observations	157	121
All households	6.9	9.2
By cooperative membership status†		
Member	3.4	11.2
Non-member	10.9	5.0
Test of difference, member vs non-member	– –	+ +
By farm size (hectares)	(1)	(2)
Small: 0 - 0.5	8.2	9.3
Medium: 0.5 - 1	9.3	7.3
Large: ≥ 1	6.0	9.3
Test of difference, small vs large	+ +	

(1) Farm size measured at beginning of adoption duration spell: 1979 or year of household formation.
(2) Farm size measured at begining of withdrawal duration spell: year of adoption.
++ or – –: test of difference of means significant at the 95% level.

Table 3. Probit analysis of cooperative membership status

	Coefficient	z-statistic†
Household characteristics		
Land owned (cuerdas) (1)	0.04	1.0
Time origin of household	-0.09	-3.4
Age of household head (1)	-0.16	-4.8
Education of household head	-0.36	-0.9
Village dummies		
Pachalí	0.15	0.3
San José Pacúl	0.10	1.5
Santa Maria Cauqué	-0.09	-0.2
San Mateo Milpas Altas	0.44	0.9
El Rejón	0.52	1.0
Constant term	12.7	4.4

Goodness-of-fit

Zavoina and McKelvey's pseudo-R2 = 0.54

Predictive power

	Predicted		
Observed	Non-member	Member	Total
Non-member	17	19	36
Member	7	78	85
Total	24	97	121
% correct	70.8	80.4	78.5

(1) Measured at the year when they joined the coop for members and at the average over 1979-94 for non-members.

† Ratio of coefficient to standard error.

Table 4. Maximum likelihood NTX-adoption duration models, Weibull hazard functions

Length of adoption spell†	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
Number of households	152	143	143	143	143	143	143
Number of household-years (sum of spells by households)	1066	971	971	971	971	971	971
Household characteristics							
Land assets							
Land owned (cuerdas) (1) $(\bar{A})$	-0.02	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01
	(-0.8)	(-0.6)	(-0.2)	(-0.3)	(-0.3)	(-0.3)	(-0.3)
High humidity land in % of total cultivated land (2) (F)		-0.01	-0.004				
		-(2.1)	-(1.2)				
Irrigated land in % of total cultivated land (2) (F)			-0.02	-0.02	-0.02	-0.02	-0.01
			-(3.6)	-(4.1)	-(4.0)	-(3.8)	-(3.7)
Human capital assets (HK)							
Age of household head at origin of adoption spell (3)	0.004	0.013	0.016	0.01	0.02	0.02	0.01
	(0.1)	(0.6)	(0.7)	(0.5)	(0.7)	(0.8)	(0.7)
Education of household head (2) (4)	-0.56	-0.54	-0.51	-0.56	-0.63	-0.55	-0.52
	-(1.5)	-(1.4)	-(1.5)	-(1.6)	-(1.8)	-(1.8)	-(1.7)
Number of adults in the household (1) (5) (L)							
Role of time in adoption							
Idiosyncratic human time: Origin of adoption spell (6) (T_0)					0.06		-0.04
					(1.2)		-(0.9)
Pure historical time: Adoption epoch dummy (1) (7) (D_a)						1.0	1.2
						(3.7)	(4.2)
Village dummies (8) (δ_v)							
Pachalí	0.80	0.70	0.63	0.74	0.71	0.55	0.55
	(1.5)	(1.3)	(1.3)	(1.5)	(1.4)	(1.3)	(1.3)
San José Pacúl	-0.1	-0.09	-0.17	-0.18	-0.26	-0.35	-0.33
	-(0.2)	-(0.1)	-(0.3)	-(0.3)	-(0.5)	-(0.7)	-(0.7)
Santa Maria Cauqué	-0.45	-0.35	0.04	0.11	0.08	0.03	0.02
	-(1.3)	-(1.0)	(0.1)	(0.3)	(0.2)	(0.1)	(0.1)
San Mateo Milpas Altas	-0.05	-0.08	-0.05	0.03	0.05	0.08	0.07
	-(0.1)	-(0.2)	-(0.1)	(0.1)	(0.1)	(0.0)	(0.0)
El Rejón	0.76	0.64	0.47	0.49	0.52	0.46	0.44
	(1.5)	(1.6)	(1.2)	(1.3)	(1.3)	(1.4)	(1.4)
Constant term	2.8	2.8	2.6	2.5	-2.7	2.1	5.3
	(3.4)	(3.4)	(3.4)	(3.4)	-(1.6)	(3.2)	(1.5)
Statistics of the Weibull hazard function							
Generic human time: p (9)	0.87	0.92	0.98	0.98	0.96	1.13	1.16
Median duration (years)	7.3	6.9	6.7	6.7	7.0	8.5	8.5
Log likelihood	-321	-299	-291	-292	-291	-283	-283

† In adoption hazard functions, the positive sign of a coefficient indicates that the corresponding variable lowers the conditional probability of adoption, and hence extends the adoption dura

t-statistics in parentheses.

(1) Specified as a time-varying covariate.

(2) Measured in 1993-94.

(3) Age in 1979 if household formed before or in 1979, or in year of household formation if formed after 1979.

(4) Dummy variable equal to one if educational level is higher than first grade.

(5) Number of household members between the ages of 12 and 65.

(6) Origin of adoption spell = Year of household formation.

(7) Epoch dummy = 0 in 1979-87 (easy phase), 1 in 1988-94 (difficult

(8) Santiago Sacatepequez is the base village.

(9) p is a parameter of the Weibull hazard function. See text.

Table 5. Village-level mechanisms of learning from others in adoption duration spell
Estimates of Weibull p, role of pure human time in adoption duration spell, in model 6 of Table 4

Role of coop	Early presence of coop	Seat of coop	Extension to late comers
Villages	Santiago Pachali Pacul Santa Maria	Santiago	Santiago Pachali Pacul Santa Maria San Mateo (1983) El Rejon (1985)
Number of households	110	57	143
p without village effects	1.04 (6.29)	1.06 (4.80)	1.11 (7.74)
p with village effects	1.05 (6.30)	1.06 (4.80)	1.13 (7.39)

Ratio of coefficient to standard error in parenthesis.

Table 6. Maximum likelihood NTX-withdrawal duration models, Weibull hazard functions

Length of withdrawal spell†	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9
Number of households	121	116	116	116	116	116	121	116	116
Number of household-years (sum of spells by households)	1121	1087	1087	1087	1087	1087	1121	1087	1087
Household characteristics									
Land assets									
Land owned (cuerdas) (1) $(\bar{A})$	0.06	0.05	0.04	0.04	0.09	0.07	0.07	0.03	0.04
	(2.3)	(1.8)	(1.2)	(1.6)	(2.1)	(1.8)	(2.2)	(0.9)	(1.2)
High humidity land in % of total cultivated land (2) (F)			0.007						
			(2.2)						
Irrigated land in % of total cultivated land (2) (F)		0.01	0.01	0.01	0.01	0.01		0.01	0.01
		(2.2)	(2.2)	(1.2)	(1.6)	(1.2)		(1.5)	(1.4)
Human capital assets (HK)									
Age of household head at origin of adoption spell (3)	-0.04	-0.04	-0.03	-0.01	-0.04	-0.02	-0.02	-0.01	-0.06
	-(2.0)	-(1.7)	-(1.4)	-(0.8)	-(1.1)	-(0.8)	-(0.8)	-(0.5)	-(2.1)
Education of household head (2) (4)	0.09	0.014	0.032	-0.03	0.03	-0.03	-0.001	0.2	0.05
	(0.2)	(0.3)	(0.8)	-(0.1)	(0.1)	-(0.1)	-(0.1)	(0.5)	(0.1)
Social capital assets (SK)									
Cooperative membership (5)								1.2	-0.9
								(4.7)	-(1.4)
Inverse Mills Ratio for cooperative membership (Table 3)									1.5
									(3.3)
Role of time in withdrawal									
Idiosyncratic human time: Origin of withdrawal spell (6) (T_a)				-0.13		-0.08	-0.1		
				-(4.7)		-(1.6)	-(2.5)		
Pure historical time: Withdrawal epoch dummy (1) (7) (D_w)					-1.8	-1.2	-1		
					-(2.6)	-(1.7)	-(1.8)		
Constant term (8)	3.8	3.6	2.9	14	4.4	10.2	11.6	2.0	4.9
	(4.4)	(3.7)	(3.1)	(5.6)	(3.0)	(2.6)	(3.7)	(2.2)	(3.8)
Parameters of the Weibull hazard function									
Generic human time: p (9)	1.24	1.23	1.22	1.50	0.90	1.07	1.17	1.30	1.34
Median duration (years)	15.2	15.8	15.5	13.0	9.4	10.2	10.2	15.1	16.4
Log likelihood	-213	-194	-192	-185	-181	-180	-197	-183	-177

† In withdrawal hazard functions, the positive sign of a coefficient indicates that the corresponding variable lowers the conditional probability of abandonment, and hence extends the withdrawal dura

t-statistics in parentheses.

(1) Specified as a time-varying covariate.

(2) Measured in 1993-94.

(3) Age in 1979 if household formed before or in 1979, or in year of household formation if formed after 1979.

(4) Dummy variable equal to one if educational level is higher than first grade.

(5) Dummy equal to one if the household ever was a member.

(6) Origin of withdrawal spell = Year of adoption.

(7) Epoch dummy = 0 in 1979-89 (easy phase), 1 in 1990-94 (difficult phas

(8) All village dummies were non-significant.

(9) p is a parameter of the Weibull hazard function.

Figure 1. Adoption duration model

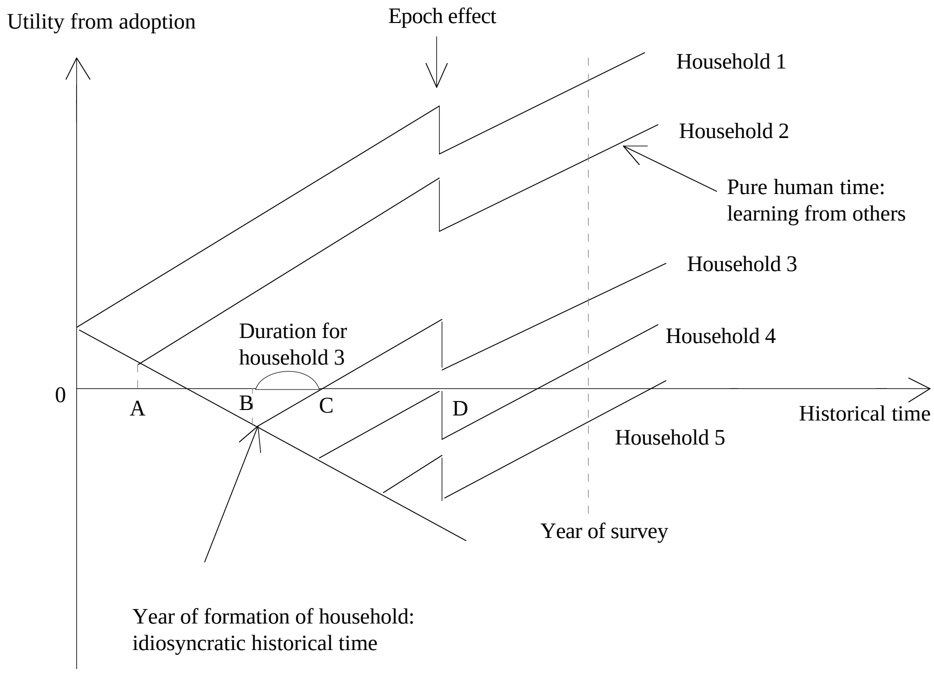


Figure 2. Withdrawal duration model

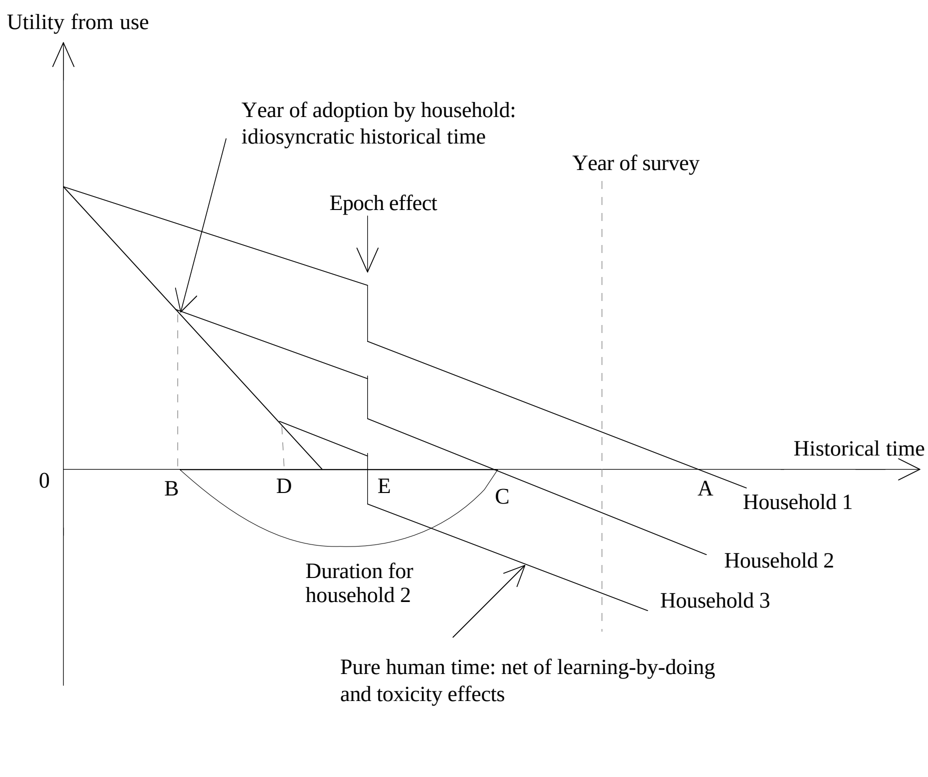


Figure 3. Kaplan-Meir Survival Curve: Adoption Spell

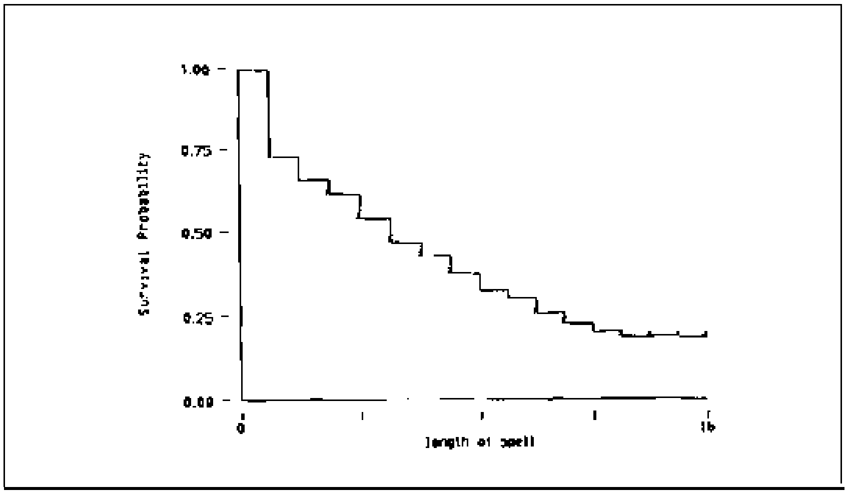
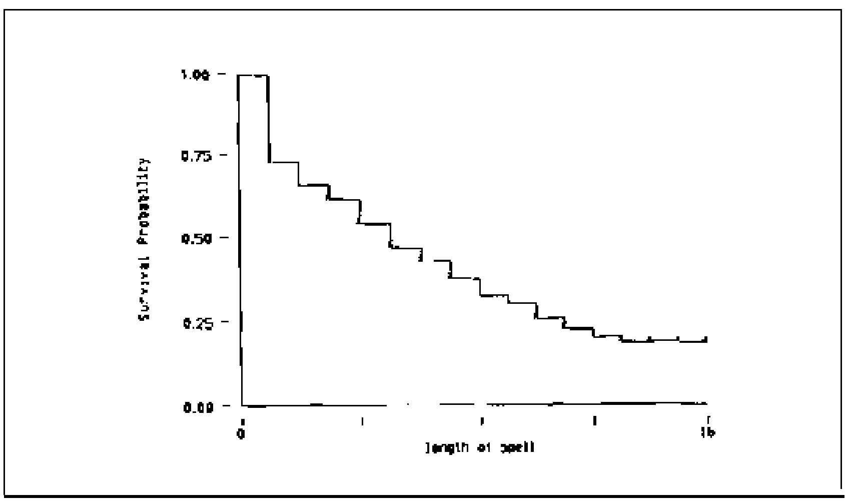
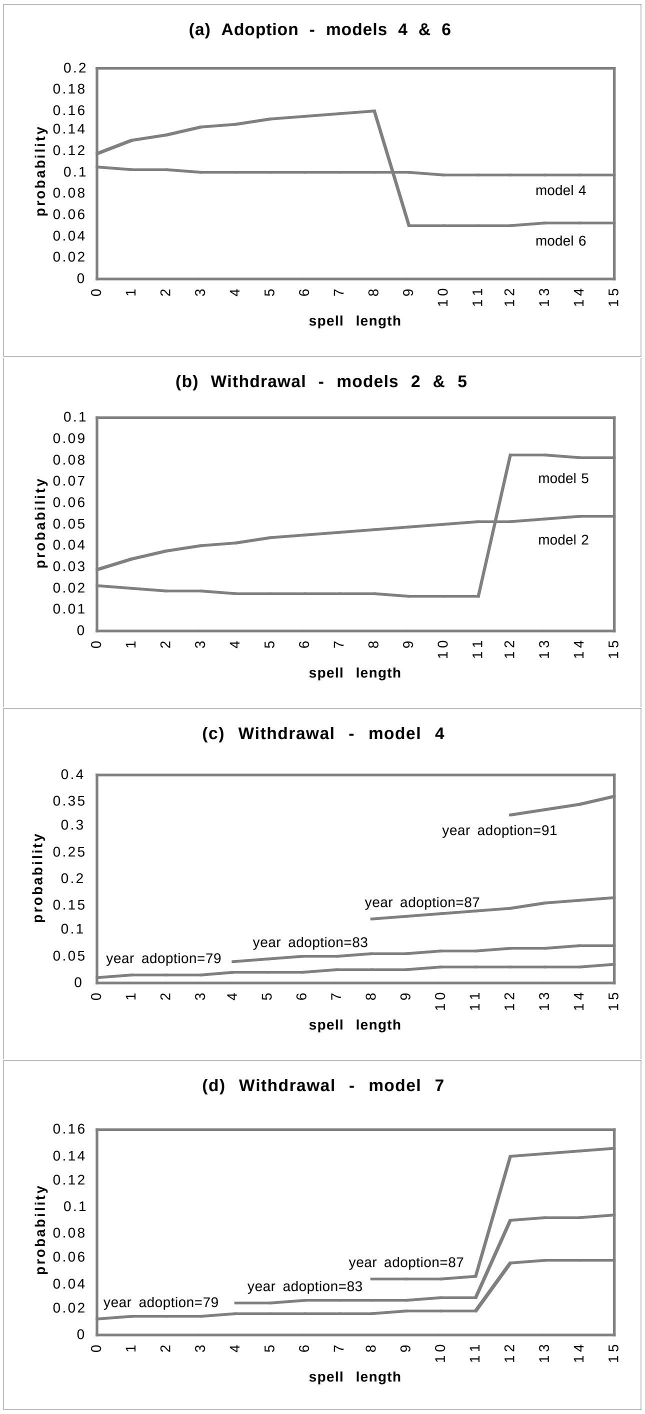


Figure 4. Kaplan-Meir Survival Curve: Withdrawal Spell




(a) Adoption - models 4 & 6
probability
spell length
model 4
model 6
(b) Withdrawal - models 2 & 5
probability
spell length
model 5
model 2
(c) Withdrawal - model 4
probability
spell length
year adoption=91
year adoption=87
year adoption=83
year adoption=79
(d) Withdrawal - model 7
probability
spell length
year adoption=87
year adoption=83
year adoption=79