The impact of information and other factors on on-farm agrobiodiversity conservation: evidence from a duration analysis of Portuguese fruit growers

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Abstract

In spite of the increasing awareness of the importance of *in situ* and on-farm conservation of agro biodiversity, there is still limited knowledge about the factors that influence farmers' choices in variety adoption. The purpose of this paper is to contribute to a better understanding of the factors that influence farmers' adoption of traditional varieties of fruit trees so that better and more effective policy measures aiming at their preservation can be designed. While studies in this area have mainly employed standard probit/logit techniques, in this paper, an econometric technique which addresses simultaneously the issue of sample censoring and the joint determination of the occurrence and timing of adoptions —duration analysis— was applied. The use of this technique in the analysis of adoption data uncovers a sizably higher effect of information on farmers' decisions than that obtained by standard approaches. The results strongly support the idea that good extension services providing reliable and accessible information, as well as technical guidance adapted to local conditions, are fundamental components in determining the adoption of landraces.

Additional key words: adoption models; 'Bravo' apple; econometric models; *in-situ* conservation; landraces.

Resumen

El impacto de la información y otros factores sobre la conservación *in situ* de la biodiversidad agrícola: evidencia de un análisis de duración de los fruticultores portugueses

A pesar de la creciente conciencia de la importancia de la conservación *in situ* de la biodiversidad agrícola, hay todavía un conocimiento limitado por parte de los agricultores sobre los factores que influyen en las decisiones de adopción de variedades. El objetivo de este estudio fue contribuir a una mejor comprensión de los factores que determinan la adopción de variedades tradicionales de árboles frutales con el fin de contribuir al desarrollo de medidas de política más eficaces y eficientes en la conservación de la biodiversidad agrícola. Aunque la mayoría de los estudios en esta área han utilizado principalmente técnicas estándar probit/logit, en este trabajo se aplica una técnica econométrica, que aborda simultáneamente la cuestión de la censura de la muestra y la determinación conjunta de la ocurrencia y del momento de la adopción. El uso de esta técnica para el análisis de los datos revela un mayor efecto de la información en la adopción que el que surge en los enfoques estándar. Los resultados confirman que servicios de extensión eficientes, capaces de proporcionar información fiable y accesible, así como apoyo técnico adaptado a las condiciones locales, son un componente clave para mejorar la adopción de las variedades tradicionales.

Palabras clave adicionales: conservación *in-situ;* manzana 'Bravo'; modelos de adopción; modelos econométricos; variedad tradicional.

Abbreviations used: CAM (Cooperativa Agrícola de Mangualde); CBD (Convention on Biological Diversity); EU (European Union); PDO (Protected Designation of Origin).

Introduction

It is widely recognized that the conservation of agricultural biodiversity, or agrobiodiversity, is of paramount importance to secure a sustainable agriculture, food production, and environmental conservation. The dramatic loss in agrobiodiversity observed worldwide over the past decades led to FAO's International Technical Conference on Plant Genetic Resources held in Leipzig, Germany, in June 1996. At this conference, a Global Plan of Action for the Conservation and Sustainable Utilization of Plant Genetic Resources for Food and Agriculture was adopted by 150 countries, emphasizing the important role of *in situ* conservation and on-farm management in harmony with the Convention on Biological Diversity (CBD).

More recently, the International Treaty on Plant Genetic Resources for Food and Agriculture, which was adopted by the FAO Conference on November 2001 and enforced on June 2004, clearly highlights the fundamental role played by farmers in the preservation and promotion of traditional practices that conserve and maintain agrobiodiversity. Within the European Union (EU), the policy determination to promote agrobiodiversity has been mainly addressed through the implementation of specific agri-environmental policy measures. In Portugal, one of such measures consisted in the protection of regional varieties of fruit trees, but due to farmers' weak response, it was most recently abandoned. This is problematic for several reasons. First, according to the IUCN Red List of Threatened Species (IUCN, 2007) Portugal is the European country with the second highest number of endangered and vulnerable plant and animal species, following Spain. Considering plant species only, Portugal remains the European country with the second highest number of endangered, vulnerable and conservation dependent species. Secondly, given that agri-environmental measures are the most relevant policy tool for biodiversity conservation on farmland within the EU countries (European Environment Agency, 2007), the objective of halting biodiversity loss is critically compromised if EU farmers do not respond positively to such measures. Third, the weak response of farmers to these measures reveals that in spite of the political pressures, and the increasing general awareness of the importance of *in situ* and on-farm conservation of agrobiodiversity, there is still limited knowledge about the factors that influence farmers' management of diversity and adoption of particular varieties.

There is now a considerable body of literature on the economic theory of technology adoption. This literature can be organized according to two main lines of inquiry: the first relies on the development of diffusion models that emphasize aggregate adoption by a population of potential adopters over time, and the second is concerned with the factors that lead a particular producer to adopt or reject an innovation (Saha *et al.,* 1994; Ghadim & Pannell, 1999). Feder *et al.* (1985) present an extensive review of this literature, more recently enriched by authors such as Bhattacharya *et al.* (1986), Tsur *et al.* (1990), Leathers & Smale (1991), Feder & Umali (1993), Saha *et al.* (1994), Fischer *et al.* (1996), Ghadim & Pannell (1999), Rogers (2003), Martínez *et al.* (2005) and Dinis (2007). These studies address general issues related to the understanding of the reasons why the adoption of a new technology is postponed and why the diffusion rate varies among firms, sectors, and the technologies themselves.

Following Karshenas & Stoneman (1993), theoretical diffusion models can be classified in two major groups: disequilibrium and equilibrium models. The first group includes epidemic models that explain technology diffusion by non-adopters' imitation of the adopters' behaviour (Mansfield, 1961). It is assumed that there is a final efficient level of use of the new technology and that the diffusion pattern is the result of an unbalanced approach to that point. Equilibrium models, on the other hand, consider that economy has perfect information about the available technologies. It is assumed that the decision to replace an old technology by a new one depends on the relationship between benefits and costs of adoption. It is further assumed that the cost of a technology decreases over time, making it advantageous for an increasing number of potential users. Such models can be classified as rank models (Davies, 1979; Ireland & Stoneman, 1986), stock models (Reinganum, 1981) and order effect models (Fudenberg & Tirole, 1985; Ireland & Stoneman, 1985), according to the factors chosen to explain the rate of innovation diffusion. In addition to these models, Karshenas & Stonemam (1993) also report a class of newer models, the evolutionary models. This approach rejects the assumptions of perfect information and rationality of the classical model. Alternatively, it admits imperfect information and bounded rationality. Moreover, diffusion is not presented as a confrontation between a new technology and an old one but it is assumed that, at each moment,

there are a number of available technologies and that diffusion is the result of a competitive selection process between them. An application of this approach can be found in Colombo & Mosconi (1995). As referred by Faria *et al.* (2002), some recent studies on technology diffusion combine several of these approaches, contributing to a better understanding of the process (*e.g.* Karshenas & Stoneman, 1993).

Ryan & Gross (1943), and Griliches (1957), studying the diffusion of hybrid corn in the United States, constitute pioneering studies on diffusion models in the field of agriculture, showing that there is a strong relationship between these models and those concerning adoption behaviour at the individual level. More recently, Negatu & Parikh (1999) proposed a classification of the conceptual models explaining farmers' decision to adopt a new technology into three groups: innovation-diffusion models, economic constraints models, and technology characteristics-user's context models. In the first group, adoption depends essentially on the individual characteristics of the potential user. The central assumption of the models in the second group is that the resource endowment of potential users is the main constrain to adoption. The third group integrates models assuming that the characteristics of a technology underlying users' agro-ecological, socio-economic and institutional context play the central role in adoption.

In line with these conceptual models, explanatory factors typically considered in studies looking at technology adoption in agriculture include variables such as the size of the farm, the quality of the soil, the availability and cost of information, financial restrictions, and the characteristics of the farmers (including their human and social capital, and technical capabilities), which are hypothesized to condition the benefits that each individual farmer is able to extract from the adoption of a new technology and consequently also affect the rate of adoption (see, for example, Feder *et al.* (1985) and Khanna *et al.* (1999) for a synthesis of these factors).

The purpose of this paper is to contribute to a better understanding of the factors that influence farmers' adoption of traditional varieties of fruit trees so that better and more effective policy measures aiming at their preservation can be designed and implemented. The study focuses on a particular apple *(Malus × domestica)* variety, called 'Bravo', originated in the interior central region of Portugal which, due to its genetic and local value, was given the title of Protected Designation of Origin (PDO). The empirical approach was based on the assumption that the adoption of traditional plant genetic resources can be treated as a technological innovation, and, therefore, subject to the same rules and processes that characterize the adoption and diffusion of other innovations.

Material and methods

Duration models and estimation methods

The empirical research on the adoption of new agricultural technologies has frequently relied on probit (Klotz *et al.*, 1995; Negatu & Parikh, 1999, Faria *et al.*, 2002; Foltz & Chang, 2002) or logit models (Caffey & Kazmierczack, 1994; Dimara & Skuras, 1998; Bartoloni & Baussola, 2001; Somda *et al.*, 2002) that estimate the probability of adoption at a moment in time as a function of a set of explanatory variables expected to be relevant to the "adoption or non-adoption" decision. In their standard forms, these static models of adoption do not allow for different rates of adoption over time. However, as emphasized by Burton *et al.* (2003), the important question in a technology adoption study is to determine the probability that a firm adopts a technology immediately after moment *t*, given that it has not adopted the technology until that moment. Duration analysis is the most appropriate econometric tool to address this question empirically, as it focus on the length of time (or "duration") that a firm or an individual stays in a particular state (*e.g.* a non-adoption state) before leaving that state, allowing the study of both technological adoption and diffusion phenomena simultaneously. From a methodological point of view, the duration approach also constitutes a superior method of dealing with the dynamic nature of adoption data than the standard probit or logit models, allowing prompt corrections for censoring, heterogeneity and duration dependence. Censoring, or more specifically "right censoring", is a form of incomplete observation for those individuals who have not experienced the event of interest by the end of the observation period. Heterogeneity is a result of incomplete control occurring if some relevant explanatory variables are left out, the functional form is misspecified, or unobservable variables are important, all of which violate the assumption that the distribution of the dependent variable across individuals is homogeneous. Duration dependence occurs when the risk of an individual or firm

adopting a technology depends on how long it has been in a non-adopting state. In contrast to duration models, the standard probit/logit approaches fail to account for duration dependency, potentially resulting in misleading inferences.

Duration models are formalized by first specifying a probability density function $f(t)$ for the duration of the non-adoption state. Although this unconditional density function is the fundamental element in duration models, it is a conditional density function known as the hazard function that is more useful in our analysis. The hazard function is given by $h(t)=f(t)/[1-F(t)]$, where $F(t)$ is the corresponding cumulative density function of t. This function gives the probability of adoption at time t given that the non-adoption state has lasted until time t, and therefore it constitutes the basis to directly address the important question in this study: what is the probability that a farmer who has not adopted a regional variety of fruit trees will do so at a certain point in time.

When the objective of the analysis is to examine the effect of explanatory variables on the duration phenomenon, the so-called proportional hazards model is the most often used. This model specifies the hazard function as $h_i(t)=h_0(t)exp(\beta'x_i)$, where $\beta'x_i$ is the matrix of coefficients and explanatory variables for the ith individual. In this specification, the hazard function is a multiplicative function of two separate components. The first component, $h_0(t)$, is known as the baseline hazard and is a function of duration time only. It can be thought as the time path that durations follow if the effects of all covariates are zero, reflecting, therefore, time dependence (or independence). The second component takes the exponential form, and is a function of explanatory variables other than time. Since duration time is separated from the explanatory variables, the hazard function is obtained by simply moving the baseline hazard as the covariates change, so that it is proportional to the baseline hazard for all individuals. This means that each individual's hazard function follows exactly the same pattern over time, but there is no restriction on what this pattern can be. The above specification can be easily extended to allow for time-varying covariates. As the name suggests, a covariate is time-varying if its value changes over the course of durations. When such covariates are introduced in the model, however, the hazards cease to be proportional since $h(t)/h_0(t)$ varies over time along with the values of the time-varying covariates $x(t)$.

Estimation of duration models may be carried out through non-parametric, semi-parametric, or parametric methods. A popular semi-parametric method is Cox's (1972) proportional hazard model which allows the estimation of the effects of covariates on the hazard function, but leaves unspecified the functional form of the baseline hazard. Cox's model is therefore very useful when the analysts have no prior expectations concerning the nature of the duration process.

Parametric methods, on the other hand, require the specification of the functional form of the baseline hazard. The most popular specifications in economic applications are the exponential and the Weibull densities, although any distribution for a nonnegative random variable may be chosen. The exponential density is given by $f(t) = \delta \exp(-\delta t)$ where $\delta > 0$. In this case, $F(t) = 1 - \exp(-\delta t)$, and the hazard function is a constant equal to δ, meaning that the hazard rate is invariant to time. The Weibull density is a generalization of the exponential given by $f(t) = \gamma a t^{a-1} \exp(-\gamma t^a)$, and the hazard function is equal to $\gamma a t^{a-1}$ where the parameters γ, α are positive. In this case, the Weibull becomes the exponential if $\alpha = 1$; if $\alpha > 1$ the hazard function is monotonically increasing over the duration, and it is monotonically decreasing if $\alpha < 1$. When the baseline hazard is correctly specified, these methods produce more efficient estimates of the covariates' coefficients than the semi-parametric methods. However, if the form of duration dependency is incorrectly specified, the inferences generated from parametric methods can be misleading (Bergström & Edin, 1992; Collet, 1994).

There are several theoretical models in the technology adoption literature focusing explicitly on the time taken to adopt, but they do not indicate any a priori specific functional form for the distribution of the durations. In general, the exponential specification is deemed appropriate when the probability of adoption by any individual, conditional on its survival up to the present, is expected to be the same regardless of how long the non-adopting state has lasted; the Weibull is considered a plausible specification when the probability of adoption is expected to increase or decrease monotonically with the duration of the non-adoption state. In our analysis, because we have no prior expectations about the nature of the baseline hazard function, we rely on the semi-parametric Cox model, but for completeness and comparison purposes the results of parametric estimations are also reported.

Data

Personal structured interviews were conducted in February 2006 with fruit growers located in the production area of the 'Bravo' apple to obtain the data used in the analysis. All the respondents were selected among the members of the Agricultural Cooperative of Mangualde (CAM) because virtually all of the apple producers in this region market their production through this Cooperative. To further ensure that the sample was composed of established apple producers, only those producers who delivered apple to CAM in the 2003-2004 crop, and who exploit a continuous area of apple trees higher than 0.1 ha were selected for the interviews.

The data collecting process started by a phone call to each farmer informing them about the objectives and scope of this research, and enquiring them about their willingness to participate in a survey. To ensure credibility, the involvement of CAM and its technician was mentioned in all contacts. Out of the total of 99 fruit producers selected according to the above criteria, 17 were eliminated from the sample because it was not possible to reach them in this initial contact and, from those contacted, seven declared to be unwilling to participate. A new phone contact was made with the remaining 75 fruit producers to schedule the date, time and place for the interview. The survey was composed of seven groups of questions. The first group of questions intended to characterize the producer and his/her family unit. The second group of questions intended to characterize the farm: location, type of management, labour force, total dimension, producing activities performed in the farm and the size of each activity. The third group of questions focused on fruit production in more detail. Information was collected concerning the installation dates of the fruit production activity as well as the date when the production of the 'Bravo' variety was initiated. The fourth group of questions intended to elicit farmers' attitude towards the environment. In particular, farmers were asked whether they were members of any environmental organization, whether they used agricultural practices usually classified as environmentally friendly, and what was their opinion about the relationship between agriculture and environmental preservation. The purpose of the fifth group of questions was to uncover farmers' relation to the EU Agricultural Policy. This group of questions focused on the use of EU's funds for investments on the farm, and on the type of direct assistance received. The sixth group of questions asked farmers about the sources of information they used to develop their activities. The aim of these questions was to understand which channels of information were more useful for farmers. A final group of questions was included in order to elicit farmers' perceptions towards the 'Bravo' variety.

Variables

The dependent variable in duration models is treated as a temporal variable. Its definition requires the determination of a moment of origin, a temporal scale, and the characterization of the event that determines the end. In this study, the adopted temporal scale was annual since the plantation of an orchard depends on weather conditions that occur only for a short number of months within a year. After this period it is necessary to wait for the subsequent year to have the opportunity to plant again. The moment of origin, or starting date, is the year of the first plantation of fruit trees since it corresponds to the date when the farmer first had to consider the possibility of introducing the 'Bravo' variety in his plantation. The event that determines the end of the duration process is the adoption of the 'Bravo' variety. Because we are dealing with the adoption of a traditional fruit tree, it is possible that this particular variety is present in some farms not as a result of a deliberate decision from the farmers to adopt it but because it was left by previous generations. Thus, to ensure that the end event was properly identified, the adoption year for any given farmer was taken as the year the farmer started exploring a continuous area of *Bravo* of at least 0.1 ha.

Selection of the independent variables in the estimated duration models is driven by theoretical considerations, and previous research findings. As indicated in the introductory section, the adoption of agricultural varieties is thought to depend on a number of factors that, in the discussion below, fall under the headings of "Characteristics of farmers", "Characteristics of farms", and "Perceptions and agricultural practices".

Characteristics of farmers

The theory of technology adoption in agriculture posits that farmers' human and social capital characteristics are important determinants of adoption decisions. Human capital is frequently measured by farm-

ers' age, schooling, and years of experience. These factors were considered in the model by including the variables *Age, Education* and *Experience*, respectively. Because older farmers are expected to be less receptive to change, *Age* is expected to lower the likelihood of adopting new agricultural practices or technologies (Gasson, 1988; Shucksmith and Smith, 1991; Dimara & Skuras, 1998). As pointed out by Khanna *et al*. (1999), years of experience are also expected to exert a negative effect on the likelihood of adoption as individuals' knowledge of previous practices or technologies is more established, and, consequently, they may be more reluctant to invest time and effort in acquiring the needed knowledge to successfully implement different practices or technologies. The effect of *Education* on the likelihood of adoption is expected to be positive since many empirical findings suggest that farmers with a higher education level adopt new technologies sooner, and are able to extract more benefits from the adoption (Rahm & Huffman, 1984; Feder *et al*., 1985; Brush *et al*., 1992; Klotz *et al*., 1995; Khanna *et al*., 1999).

The opportunity to earn income outside the farm is another variable often referred to as an important determinant of adoption decisions, although the direction of its effect is unclear. On the one hand, it may encourage adoption because it contributes to a higher income and a decrease in financial insecurity and also because it may promote better access to information. On the other hand, it may lower the probability of adoption by decreasing the incentives to invest time and energy in the adoption of new technologies and increasing the opportunity cost of the time required to adopt and manage the new technologies, which could alternatively, be used outside the farm (Brush *et al*., 1992; Bellon & Taylor, 1993). The *Income* variables were included in the estimated models to capture the influence of this factor. These variables group the farmers into three categories: farmers whose family income is totally raised within the farm; farmers whose family income is mainly raised within the farm, but not totally; and, farmers whose family income is mainly raised outside the farm.

The social capital, defined as the degree of social connections of the farmer, has been increasingly recognized as an important determinant in adoption decisions (Mathijs, 2003). In particular, it is expected that more frequent contacts with extension and consulting agents reduces farmers' uncertainty concerning the new variety thereby increasing the likelihood of adoption. The

role of information in adoption decisions has been emphasized by many authors, including Rogers (1962), Kislev & Shchori-Bachrach (1973), Stoneman (1981), Feder & O'Mara (1982), and Feder & Slade (1984). To capture farmers' exposure to information, some authors use the number of times that a farmer received visits of agricultural consultants, or the number of times that the farmer was present in sessions organized by these professionals. Other authors consider access to mass media, literacy rate, education level, or time spent outside the village as appropriate proxies (Feder *et al*., 1985). In the present analysis, the effect of farmers' social capital on the adoption decision is captured by two variables, one related to professional contacts, and the other related to contacts with other type of agents. The variable *Information* is defined as the number of sources on technical information that farmers actually used, and intends to capture their degree of information. The variable *Residence*, is a dummy variable taking the value of one if the farmer does not live in the same area of the farm, and zero otherwise. It aims to measure the effect of time spent outside the farm on his adoption behaviour.

Characteristics of farms

In many empirical and theoretical studies on innovation, farm size is usually pointed out as a significant variable with a positive relation with the probability and speed of adoption (Heffernan & Green, 1986; Klotz *et al*., 1995). The explanation for the finding is that the adoption decision is frequently associated with increasing returns to scale although, as pointed out by Khanna *et al*. (1999), if the technology is characterized by constant returns to scale the relative advantage of larger farms in technology adoption may disappear. In this analysis, the effect of farms' size was introduced in the estimated models through the variable *Agricultural Area*.

Other characteristics expected to influence adoption decisions are crop diversity, and tenure. Nowak (1987), for example, points out that investment in fixed assets is higher for farmers that exploit their own land than for farmers that rent the land. The variable *Percentage Area Owned* is the percentage of the total farm area owned by the farmer, and was intended to capture the effect of landownership on the adoption decision. Dimara & Skuras (1998) argue that crop diversity is used as a strategy to reduce risks, and may, therefore, be taken as a proxy for risk preferences. This factor was

included in this analysis through the variable *Percentage Area Dedicated to Apple* (the percentage of the total farm area that is dedicated to apple production), and farmers with higher levels of specialization in apple production were expected to have higher adoption rates.

The time span between the year of the farmer's first plantation of fruit trees and the year of the survey (*Time Span*) was also included as a control variable in the estimated models. It corresponds to the date when the farmer first had to consider the possibility of introducing the 'Bravo' variety in the plantation. The data reveals that this date varied to a great extent among farmers, with some planting as early as 1960, and others in 2004. During this period there were several important technical, social, economic, and political changes that may have affected farmers' decisions to adopt the variety. In particular, it was expected that farmers who started later had more incentives to adopt traditional varieties than farmers who started their activities 20 or 30 years ago, when these varieties were not valued in the market, and the conservation of agrobiodiversity was not on the political and technical agenda. In addition, given the lack of suitable time series data on input and output prices, we followed Burton *et al.* (2003) modelling strategy in including three time-varying dummy variables based on the calendar year to capture epoch effects on the time until adoption. The variable D1974 indicates the period after the Carnation Revolution which changed the Portuguese regime from a dictatorship to a democracy in 1974. The variable D1986 denotes the period after Portugal's accession to the EU in 1986, and the variable D1994 indicates the period over which the PDO designation has been awarded to the *Bravo* variety (since 1994). The inclusion of these variables was, therefore, a further attempt to control any systematic changes in the economic conditions faced by farmers which may affect their adoption behaviour.

Perceptions and agricultural practices

Another factor expected to affect farmers' adoption decisions is their attitudes towards the environment (Burton *et al.*, 2003). It is hypothesized that farmers who use environmentally friendly practices are more likely to adopt 'Bravo'. To reflect this influence the model included a variable (*Environmental Practices*) that intended to reflect whether or not farmers chose conservative farming practices. Three particular techniques were considered to assess that: application of organic material on the soil, non-tillage and lower than average level of pesticides use. This is a dummy variable taking the value of 1 if farmers use agricultural environmentally friendly practices, and the value of 0 if at least one of those is not used. Whether farmers follow more closely the traditional or the sustainable agriculture paradigms as defined by Beus & Dunlap (1990, 1991) was also expected to affect adoption decisions. The variable *Agricultural Paradigm* is an index variable based on the valuation of fifteen statements, adapted from Beus & Dunlap (1991) and Comer *et al.* (1999). Farmers were asked to evaluate their degree of agreement with each statement, on a scale from 1 to 5. This variable takes the value of one when the farmer totally follows the traditional agriculture paradigm and the value of zero when the farmer totally follows the sustainable agriculture paradigm. Similarly, farmers' perceptions towards different varieties may also affect their choices, as shown by Bellon (1996), Brush & Meng (1998) and Negatu & Parikh (1999). Farmers' perceptions of the 'Bravo' variety were also included through an index variable —*Perceptions Variety*— which varies between zero and one. As before, the index was built using the valuation by farmers of a set of statements (12), concerning 'Bravo'. The zero value indicates that the 'Bravo' variety was considered less valuable than the other apple varieties, and the value of one corresponds to the best possible evaluation of this variety compared to others.

A description of the variables appears in Table 1, and Table 2 contains the descriptive statistics of the sample. Variables denoted with the letter *t* were introduced in the estimated duration models as time-varying covariates; the *Education* variable was measured at the beginning of the activity since the highest level of formal education was obtained by these farmers prior to the beginning of the activity and did not change over the course of the duration; all other variables were measured at the time of data collection, a subject to which we will return later.

Results

The results of the estimated duration models are displayed in Table 3. The dependent variable in these models (Cox, Exponential and Weibull) is the length of time until adoption of the 'Bravo' variety, or, if adoption did not occur, it is the length of time that goes

Table 1. Description of variables

Variable	Description
Characteristics of farmers	
Age (t)	Age, in years
Experience (t)	Experience in agricultural activities, in years
Education	Number of years of schooling at beginning of activity
Income 100	Dummy variable equal to 1 if income from farm is 100% of total family income, 0 otherwise
Income < 100	Dummy variable equal to 1 if income from farm is higher than or equal to 50% and lower than 100% of total family income, 0 otherwise
Income < 50	Dummy variable equal to 1 if income from farm is less than 50% of total family income, 0 otherwise
Information	Number of information sources relevant for the farming activity actually used
Residence	Dummy variable equal to 1 if the farm is not in the same district as the farmer's residence, 0 otherwise
Characteristics of farms	
Agricultural area	Total agricultural area of the farm, in hectares
Percentage area owned	Percentage of the total farm area owned by the farmer
Percentage area dedicated to apple	Percentage of total agricultural area dedicated to apple trees
Time span	Time span between the year of the farmer's first plantation of fruit trees and the year of the survey, in years
D1974 (t)	Dummy variable equal to 1 if calendar year is 1974 and after, 0 otherwise
D1986 (t)	Dummy variable equal to 1 if calendar year is 1986 and after, 0 otherwise
D1994 (t)	Dummy variable equal to 1 if calendar year is 1994 and after, 0 otherwise
Perceptions and agricultural practices	
Environmental practices	Dummy variable equal to 1 if farmer uses agricultural practices technically classified as environmentally friendly, 0 otherwise
Agricultural paradigm	Index of farmer's attitudes towards the agricultural paradigm; varies between 0 (sustainable) and 1 (traditional)
Perceptions variety	Index of farmer's perceptions towards the variety 'Bravo'; varies between 0 (lowest evaluation) and 1 (best evaluation)

between the first plantation of fruit trees by the farmer and the date of the interview. The latter cases correspond to censored data on the right, since all that is known is the time origin of the duration but not its end. Thus, the dependent variable controls both the occurrence and the timing of adoptions.

Wald tests were conducted to test for parameter restrictions in each of the estimated models. The test statistic is χ^2 distributed with k degrees of freedom, where k is the number of restrictions. The results of this test for each of the estimated models are shown at the bottom of Table 3, and in each case indicate that the null hypothesis that all the slope coefficients are equal to zero be rejected at less than the 0.01 significance level. In addition, likelihood ratio tests were conducted to verify whether the coefficients of the statistically insignificant variables were jointly zero in each of the estimated duration models. The test statistic is defined as $-2(L_R - L_{UR})$, where L_R and L_{UR} are the

values of the log-likelihood functions for the restricted and unrestricted models. The computed test statistics were $\chi^2_{(13)} = 81.2$, $\chi^2_{(14)} = 64.9$, and $\chi^2_{(14)} = 62.7$ for the Cox, Exponential, and Weibull models respectively. We therefore did not find evidence justifying the omission of the statistically insignificant variables included in these models. Because we had no prior expectations concerning the nature of the baseline hazard, the results of the semi-parametric Cox's model were of utmost importance to us. We therefore conducted a further test to check for misspecification in this model. A remarkably powerful test in this context is the link test suggested by Pregibon (1980), and documented in StataCorp (2005). The result of this test revealed no problem with our specification of the Cox's model.

Remaining agnostic as to the functional form of the baseline hazard, Table 3 first presents the maximum likelihood estimates of Cox's proportional hazard model. For ease of interpretation, the results are dis-

played in terms of hazard ratios: these can take values inferior, equal or superior to 1, meaning that the associated explanatory variable has a negative, null, or positive effect on the hazard adoption rate, respectively. Inspection of the results for Cox's model revealed that farmers' age, experience and education level have no effect on the hazard adoption rate since the estimated hazard ratios associated with these variables took values close to 1, and were not statistically significant at conventional significance levels. Although lacking statistical significance, the included income variables showed a substantial impact on the hazard adoption in terms of magnitude, constituting *weak* evidence in favour of the argument that the opportunity to earn income outside the farm facilitates the adoption of new varieties by reducing financial insecurity.

Importantly, the variable *Information* exerted a positive and statistically significant effect on the conditional probability of adoption. Its effect was also quite substantial in terms of magnitude: *ceteris paribus,* the use of one more information source relevant to the farmers' activity is associated with a 22% higher hazard rate, *i.e.,* shorter adoption time. The variable *Residence* impacted negatively the hazard rate, but its effect was not statistically significant at conventional significance levels.

With respect to the impact of farms' characteristics, we observed that two out of the four included time-invariant variables had a significant effect on the hazard adoption rate. The variable measuring the total agricultural area of the farm was included in the model in its natural logarithm form because an anal-

Table 2. Means and standard deviations of the observed values of the explanatory variables

Variable	Full sample	Adopters	Non-Adopters
Characteristics of farmers			
Age	42.89	40.82	45.84
	(11.72)	(11.58)	(11.45)
Experience	12.73	12.50	13.06
	(12.31)	(12.04)	(12.87)
Education	7.71	8.68	6.32
	(4.85)	(4.84)	(4.58)
Income 100	0.15	0.20	0.06
Income < 100	0.24	0.23	0.26
Income < 50	0.61	0.57	0.68
Information	2.51	2.84	2.03
	(1.49)	(1.79)	(0.71)
Residence	0.08	0.14	0.00
Characteristics of farms			
Agricultural area	10.31	14.14	4.89
	(19.23)	(24.32)	(3.59)
Percentage area owned	88.90	83.86	96.05
	(27.67)	(32.03)	(18.10)
Percentage area dedicated to apple	50.18	56.11	41.77
	(34.06)	(36.52)	(28.71)
Time span	17.77	18.57	16.64
	(8.92)	(9.77)	(7.57)
D1974	0.87	0.82	0.93
D1986	0.69	0.64	0.77
D1994	0.17	0.20	0.13
Perceptions and agricultural practices			
Environmental practices	0.26	0.40	0.07
Agricultural paradigm	0.73	0.73	0.73
	(0.09)	(0.09)	(0.09)
Perceptions variety	0.55	0.56	0.54
	(0.10)	(0.10)	(0.11)
Sample size	75	44	31

ysis of the martingale residuals revealed specification problems with this covariate in its original form. As expected, *ceteris paribus,* the higher the agricultural area of the farm, the higher the conditional risk of adoption of the 'Bravo' variety. Similarly, controlling for the other variables, the estimated hazard of adoption was about 2% higher for each percentage point increase in the total agricultural area dedicated to growing apple trees. A reasonable deduction from this finding is that farmers with higher levels of specialization in growing specific fruit trees have higher adoption rates of their traditional varieties. While we expected the percentage area owned by the farmer and time span to be, respectively, positively and negatively related to the hazard adoption rate, this does not appear to be the case as the hazard ratios associated to these variables were near unity, and statistically insignificant. Of the included epoch dummies, only D1994 was statistically significant, indicating that time until adoption substantially decreased after the attribution of the PDO designation to the 'Bravo' variety.

Although lacking statistical significance, the variables intended to capture farmers' perceptions and agricultural practices revealed a substantial impact on the adoption hazard in terms of magnitude. According to our analysis, the estimated hazard of adoption among farmers who use environmentally friendly practices was about 1.5 times that of those who do not used such practices. Similarly, the estimated adoption hazards were clearly substantially increased the closer farmers follow the traditional agricultural paradigm, and the more valuable they judged this apple variety comparatively to other apple varieties.

To further check the robustness of these results, we also estimated the exponential and the Weibull proportional hazard models. As previously noted, estimation of these models produces more efficient estimates of the covariates' coefficients if the baseline hazard is correctly specified. The results displayed in Table 3 reveal that the estimates in these models differ little from the Cox estimates both in size and statistical significance. The closeness of the Cox and the exponential/Weibull estimates suggests that any bias arising

Table 3. Estimated duration models

Variable	Cox		Exponential		Weibull		Probit	
	HR[1]	SE[2]	HR	SE	HR	SE	ME[3]	SE
Characteristics of farmers								
Age (t)	0.997	(0.003)	0.960	(0.024)	0.958	(0.027)	−0.038**	(0.017)
Experience (t)	1.002	(0.002)	1.018	(0.025)	1.018	(0.026)	0.084**	(0.033)
Education	1.035	(0.048)	1.030	(0.052)	1.030	(0.053)	0.128**	(0.063)
Income < 100	1.212	(0.688)	1.533	(0.943)	1.542	(0.955)	−0.999***	(0.001)
Income < 50	1.032	(0.452)	1.504	(0.847)	1.502	(0.852)	−0.917***	(0.146)
Information	1.222**	(0.101)	1.307**	(0.166)	1.318**	(0.173)	−0.054	(0.108)
Residence	0.889	(0.591)	1.020	(1.006)	1.045	(1.087)	_	_
Characteristics of farms								
lnAgricultural Area	1.977***	(0.478)	2.016**	(0.574)	2.008**	(0.584)	1.190**	(0.485)
Percentage area owned	0.999	(0.005)	0.999	(0.007)	0.999	(0.007)	−0.002	(0.003)
Percentage area dedicated to apple	1.022***	(0.006)	1.027***	(0.007)	1.028***	(0.007)	0.040**	(0.017)
Time span	1.012	(0.035)	0.991	(0.032)	0.986	(0.035)	0.029	(0.029)
D1974 (t)	0.612	(0.329)	0.242	(0.308)	0.224	(0.291)	0.233	(0.873)
D1986 (t)	1.999	(1.085)	2.386	(2.816)	2.315	(2.788)	−0.423**	(0.198)
D1994 (t)	1.257*	(0.149)	1.952	(0.993)	1.833	(0.961)	−0.911***	(0.210)
Perceptions and agricultural practices								
Environmental practices	1.527	(0.564)	1.637	(0.801)	1.649	(0.820)	0.525***	(0.150)
Agricultural paradigm	1.181	(2.019)	1.833	(3.569)	1.861	(3.694)	4.330***	(1.573)
Perceptions variety	2.911	(5.606)	3.599	(7.418)	3.454	(7.344)	5.686**	(2.433)
	Wald $\chi^2_{(17)}$ = 99.57***		Wald $\chi^2_{(14)}$ = 148.57***		Wald $\chi^2_{(14)}$ = 77.54***		Wald $\chi^2_{(16)}$ = 43.23***	

[1] HR: hazard ratio. [2] SE: robust standard errors are in parentheses. [3] ME: marginal effects. ***Statistically significant at *p*-value < 0.01; **Statistically significant at *p*-value < 0.05; *Statistically significant at *p*-value < 0.1.

from unobserved heterogeneity (or misspecified baseline hazard) was not large in this sample.

As in any regression analysis, failure to account for unobserved heterogeneity (*i.e.,* variability between individuals due to unmeasured characteristics) leads to biased parameter estimates if unmeasured variables are correlated with the covariates included in the model. While comparison of estimates obtained through different models is useful in assessing the potential presence of unobserved heterogeneity, it is worth proceeding with formal testing for unobserved heterogeneity in the models. The usual approach to test for unobserved heterogeneity is to estimate the models including a random effect, also known as frailty, which represents unobserved risk factors that are specific to an individual. The usual distribution functions chosen for the random effects were the gamma and the inverse-Gaussian distributions, although any continuous distribution with mean unity and finite variance could have been chosen. The testing procedure for unobserved heterogeneity consisted in applying a likelihood-ratio test to the null hypothesis that the frailty variance component is zero (Hougaard, 1986). In our analysis, the estimates for the frailty variance were near zero using both the gamma and the inverse-Gaussian distributions, and in each case the likelihood-ratio test failed to reject the null hypothesis with *p*-values equal to one. Thus, this formal statistical testing corroborates the conclusion that no significant heterogeneity was present in our sample.

An important observation worth adding here, however, is that, as noted earlier, many of the covariates were measured at the time of data collection and treated as time-invariant when in fact they are time-varying in nature. While this treatment is probably valid for some covariates, such as geographical location, it is possible that other farm and farmer characteristics, including perceptions and agricultural practices, evolved over time. Thus, without relying on recall data, it was not possible to determine whether responses expressed at the time of data collection were held at the time of adoption, potentially influencing the adoption decision, or whether they have changed after adoption itself and were, consequently, immaterial to the adoption decision. Although a complete examination of this empirical question would require a long-term longitudinal survey of farmers, we investigated the potential extent of this problem in the present sample comparing the responses of recent adopters with those who adopted a long time ago concerning all the time-

invariant variables measured at the time of data collection. More precisely, we divided the sample of adopters in four groups: those who adopted prior to 1989, and between the years of 1990 and 1995; 1996 and 1999, and 2000 and 2004. We would expect to find significant differences in the responses given by the adopters in these different groups, particularly between those belonging to the first and last groups, if the event of adoption is altering the values of the variables *Income* and *Information*, and of those under the headings *Farm Characteristics*, and *Perceptions* and *Agricultural Practices*. The results, however, revealed no statistically significant differences in the values of the variables amongst the groups using appropriate (concerning the variables' scale) nonparametric χ^2 and Kruskal-Wallis tests (results available from the authors). This suggests that, while caution is certainly required in interpreting the results in studies of this type using ex post data, any risk of endogeneity is not large in this sample as adoption itself does not seem to be altering the values of the covariates which were likely formed prior to adoption.

Also reported in Table 3 for purpose of comparison are binomial probit estimates. The time-variant covariates *Age* and *Experience* were introduced in this model as time-invariant taking their values at the time of data collection, and the time-variant epoch dummies take the unit value if farmers' first plantation of fruit trees occurred in the indicated calendar years. To aid in interpretation, the results are displayed in terms of marginal effects showing the impact of each variable on the probability of adoption. Because the variable *Residence* predicts the dependent variable perfectly, it was left out of this estimation procedure. Comparison of the Cox and probit results revealed that, in general, the direction of the effects of the covariates on the probability of adoption was the same as on the hazard adoption, in accordance to theoretical expectations. The exceptions to this observation were the effects of the included *Income* variables, *Information* and epoch dummies. Contrary to their effects on the hazard adoption, the income variables impacted negatively the probability of adoption of the 'Bravo' variety, a finding that supports the argument that the opportunity to earn income outside the farm hinders adoption decisions because it entails higher opportunity costs associated with the adoption of new products or processes. Likewise, contrary to Cox's results, and contrary to *a priori* expectations, the most recent epoch dummies exerted a negative effect on the probability of adoption, indicat-

ing that farmers who installed their first plantation of fruit trees more recently were less likely to adopt traditional varieties.

An important difference between the Cox and the probit results concerns the statistical significance of the explanatory variables included in this analysis. While only four of the included variables show a statistically significant effect on the hazard of adoption, we observe from the probit results that only four of the covariates (*Information, Percentage Area Owned, TimeSpan* and D1974) do not impact the probability of adoption at conventional significance levels.

Discussion

The objective of this paper has been to examine the impact of farmers' characteristics, their perceptions and agricultural practices, and farm characteristics on farmers' adoption of traditional varieties of fruit trees. The study focused on a particular apple variety originated in the interior central region of Portugal, known as 'Bravo', which is considered an important resource-conserving measure. In line with previous empirical studies looking at the adoption of agricultural technologies using standard logit/probit econometric techniques, we found that a number of individual factors influence adoption behaviour. According to our probit results, traditional varieties of fruit trees are more frequently adopted by younger and more educated farmers and by those whose perceptions and agricultural practices are in general more environmentally friendly. Moreover, farmers with larger agricultural areas and more specialized in apple production are more likely to adopt traditional varieties of apple trees. Conversely, these results suggest that farmers engaged in off-farm employment are less likely to adopt these varieties. However, as previously noted, standard logit/probit techniques do not take into account the time-dependent nature of adoption data and may give rise to misleading results. In fact, while generally conforming to theoretical expectations and previous empirical findings both in sign and magnitude, the statistical significance of many of these factors drops once more appropriate econometric techniques are applied to the analysis of the same data. We analysed the data using duration methods that not only directly address the censoring and temporal-dependency problems, but also allows us to control both the occurrence and the timing of adoptions. The results show that the size of the farms' agri-

cultural area and farmers' specialization in apple production are significant predictors of the hazard adoption rate. Importantly, and contrary to the probit results, the variable *Information* exerts a statistically significant impact on the hazard adoption rate. The statistical significance of this variable is borne out in each of the duration methods we applied to the data –semiparametric and parametric. It is, therefore, a robust result with an important policy implication. In particular, our findings based on semi-parametric and parametric duration analyses suggest that, all else the same, the use of one more information source relevant to the farmers' activity is associated with a 22 to 32% higher hazard rate of adoption. This constitutes strong evidence that good extension services providing farmers with abundant information covering both technical and broader issues are fundamental components to effect the adoption of resource-conserving measures. The importance of information, particularly good extension services, on the adoption of sustainable agricultural technologies, is also enhanced by Burton *et al.* (2003), Genius *et al.* (2006) and Kallas *et al.* (2009) regarding the adoption of organic farming. The same conclusions cannot, however, be withdrawn from Läpple (2010) study.

The differences in the findings obtained from probit / logit and duration models are in line with Burton *et al.* (2003) who also found many significant predictors of adoption in static models to be insignificant in their duration analysis. To the extent that the dependent variable in the Cox model controls both the occurrence and the timing of adoptions, but the probit model only controls for the occurrence of adoptions, these results might be interpreted as an indication that the factors that explain adoption decisions are not necessarily those that explain such decisions once the time of adoption occurrence is taken into account. Accordingly, the results suggest that the included variables capturing the characteristics of the farms, the individual characteristics of the farmers, as well as their attitudes and perceptions, are, in general, powerful determinants of the decision to adopt regional varieties of fruit trees, but their significance is diminished when explaining the time that farmers take to actually adopt such varieties. In light of this interpretation, the results also indicate that the size of the agricultural area of the farm, and the percentage of that area dedicated to trees are powerful determinants of both the decision to adopt and of the time taken for adoption, while the variable *Information* is a significant predictor of the adoption rate per unit time but

has no significant impact on the unconditional probability of adoption. An important observation here, however, is that considerable caution needs to be exercised when formulating these inferences because the probit estimates may be misleading due to the probit's failure to account for temporal dependence in the data. In fact, the results from the comparison herein along with the findings reported by Burton *et al.* (2003) suggest that considerable caution is required in interpreting the results from the static bivariate analyses of adoption data reported in the literature. As noted, while not claiming that these studies draw incorrect conclusions, the validity of their substantive findings might be questioned, a subject that would benefit from further research comparing the findings from static and dynamic models.

Like in every empirical study, several limitations associated with this one require prudence.

First, the results rest on the analysis of a relatively small sample of fruit growers located in a specific geographical area, and focus only on a particular variety of fruit trees. Although it may be argued that intensive sampling of site and resource-specific agricultural practices and adoption processes are more informative for the design of effective policy measures than broad surveys designed to capture international or national averages that are subject to potential aggregation biases, it should still be borne in mind that the findings from these focused studies may not transfer easily to other settings. Second, the collected data does not track changes on the values of many of the covariates over time, precluding us from exploring how the timing of the adoptions relates to changes in the values of those covariates. Similarly, the lack of data on costs and prices, and their evolution over time, constitutes an important limitation of the analysis. Finally, the data was collected retrospectively, with farmers asked to recall the dates of the beginning of their activity, and the date they adopted the particular variety under analysis, which, given the length of the recall period, may entail a significant recall error.

Currently, the worldwide concern over climate change and biodiversity loss highlights the importance of agrobiodiversity conservation. Whether one believes that the market will create suitable incentives for agrobiodiversity conservation or one advocates active international and national policy to address the problem of agrobiodiversity loss, the effectiveness of either may depend on whether farmers' decisions to adopt *in situ* and on-farm conservation measures are influenced by

their perceptions and attitudes towards the environment, their human and social capital, farm characteristics, and other economic or noneconomic factors affected by strategies. Since neither farms nor farmers are all alike, we may expect that there will be differences in whether a particular agrobiodiversity measure is adopted and when. If agrobiodiversity loss is to be slowed down, or even reversed, policy-makers need an understanding of the factors that influence farmers' adoption of agrobiodiversity measures. Given that many agrobiodiversity problems are inherently site-specific, such an understanding is enhanced by collecting data at a geographically relevant scale. This study exemplifies such an approach, clearly indicating that that farmers' weak response to previous agri-environmental measures aiming at the protection of regional varieties of fruit trees in Portugal may have been due to the lack of information dissemination concerning the advantages of growing such varieties. In the face of our results, it is predictable that once farmers are aware of such advantages, they implement the necessary changes and respond positively to agrobiodiversity conservation measures. It is therefore important that governments and other relevant institutions provide reliable and accessible information, as well as technical guidance adapted to local conditions in order to foster a successful adoption process of agrobiodiversity conservation measures. Thus, despite the above identified caveats, this study has succeeded in developing and implementing a field survey that has contributed to an understanding of how farmers choose their production practices. In particular, our extensive econometric analysis allowed us to identify an important policy variable affecting the adoption of resource-conserving measures, providing a valuable insight into the mechanisms that policy-makers need to implement in order to help the process of adoption of agrobiodiversity conservation measures.

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