ΠΑΝΕΠΙΣΤΗΜΙΟ ΚΡΗΤΗΣ

ΤΜΗΜΑ ΟΙΚΟΝΟΜΙΚΩΝ ΕΠΙΣΤΗΜΩΝ

ΜΕΤΑΠΤΥΧΙΑΚΟ ΠΡΟΓΡΑΜΜΑ ΣΠΟΥΔΩΝ

Διπλωματική Εργασία:

Θέμα: ‘‘ The diffusion and adoption of irrigation technologies: The case of crop farms in Crete.’’

Όνομα: ΗΛΙΑΚΗΣ ΕΜΜΑΝΟΥΗΛ

Α.Μ: 36

1ος Επιβλέπων Καθηγητής: Βαγγέλης Τζουβελέκας

2ος Επιβλέπων Καθηγητής: Μαργαρίτα Τζίνιους

ΡΕΘΥΜΝΟ 2005

1. Introduction

The development of new technologies that increase the productivity or improve the allocation of the inputs that are used into the production procedure has always been an interesting issue to deal with. The benefits from the adoption of a high-yielding technology can be separated into two main categories. Those that refer to the benefits of the person that have made the adoption of the technology and those that refer to the benefit of the public through a positive externality that comes from the adoption of the innovation and provides better or more commodities or even by better environmental conditions, if we assume that the high-yielding technology is environmental friendlier comparing to the traditional. So the decision of the producer to adopt or not might not only has a positive effect on him but also on the public good. Especially when we are talking about innovations that concern the agricultural sector, the share of which in the total size of the economy is larger in the developing countries rather than the developed, the study of the diffusion process is even more important because of the effect that those technologies might have on the developing rate and to the well-being of the people of those countries. What is even more interesting apart from the study of the benefits that follow an innovation is the study of the factors that affect the adoption procedure of those technologies.

It has been widely seen that even when new improved technologies are available the diffusion of them is not instant, but on the contrary, it takes time until the diffusion reaches a compensatory level. That contradiction of the knowledge, from the part of the producers, of the existence of the new technology and the benefits that a possible adoption will bring to them, on one hand, and the slow diffusion process of the technology, on the other hand, is what directed the scientific interest into the study of the factors that affect the decision of adopting the new technology.

Many researches have been conducted and many papers have been written referring to the diffusion process of a new technology. Some of those studies focus more into the farm characteristics that affect the adoption process such as the farm size, the credit constrains that the household might face and the location of the farm, (Feder; Feder, Just and Zilberman; Sunding and Zilberman) and some others that emphasize on the importance of knowledge and on the ability of collecting and processing information (Foster and Rosenzweig; Cameron; Conley and Udry). Those studies can be separated into three basic empirical approaches according to the type of data that they use. (Beslay and Case).

The first approach is that of the time-series studies. Its main target is to model the pattern of adoption as a logistic-shaped function of time. The data that were used, in that kind of studies, were trying to capture the aggregate rate of adoption, usually by the use of the percentage of the total population, which had adopted the new technology. So what those studies were trying to do was to present the shape of the time-series diffusion process. The main disadvantage of the studies that use time-series data is that, although they try to present an example of the adoption procedure, they can not say much about what lies underneath this dynamic process. The early theories of technology diffusion used such data. Those theories were called epidemic theories of diffusion and supported the opinion that the diffusion is a disequilibria process due to information asymmetries between potential users.

The second approach is that of the cross-sectional studies which are based on two kinds of cross-sectional data, those data which take a snapshot of the producers' technology use and characteristics at the same date that the survey is conducted and those that contain information about the producers' characteristics the day that they adopted the technology. The first kind of data provide an insight into the producers' characteristics, at the time that the survey was conducted, which are associated with the decision of accepting the new technology. The hypothesis that is made about those characteristics is that they stay constant during time, which means that there is not any time-depended element in the adoption decision and this makes the analysis extremely limiting. The only existing difference between the first kind and the second kind of data is the fact that, the data of the second kind are based on recalled information from the time of the adoption of the new technology. This makes the study more flexible because now the decision of the adoption of the new technology is connected with the characteristics of the producer at the same time when the adoption took place. Although the second kind of data lead to more flexible structures, comparing to the first kind of data, those structures are still extremely limiting because the assumption of time-independent characteristics of the producers has to remain. The most common models that use those kinds of data are the logit or probit models that try to find the probability of a farm adopting the new technology at a given time. Another kind of models that also make use of those kind of data are the duration models that tries to find the probability of a farm adopting the new technology at the next short period. This duration model is the model that will be used in the present analysis.

The third approach is that of the panel-data studies which refer to producers' characteristics and decisions about the adoption or not of the new technology at each point of time available. For the use of panel data there have been developed many models but the main problem that those models face is the lack of panel-data, due to the hardness of collecting such data.

In this paper we will examine the diffusion progress of modern irrigation technologies into the agricultural sector, and particular the crop sector, in the island of Crete. It is a common knowledge that the water availability in the planet is restricted.

Two are the main facts that should be blamed for that observation, and those are the great rate of population increase, and the irrational, in many cases, use of the water by people. According to statistics, in 1996 the 69 per cent of the total water withdrawals in the whole planet were made by the agricultural sector and only 23 per cent from the industry (OECD 1999). Although that those figures vary from country to country, it can be easily said that the sector that should focus harder on the effort of reducing the use of water and increase the efficiency of the used water is the agricultural sector.

There have been proposed many ways of dealing with the problem of high consumption of water from the agricultural sector such as a better and more efficient pricing system, a better distribution and control of the network and the adoption of modern irrigation technologies that offer a higher efficiency comparing to traditional ones. Those technologies, due to the higher water efficiency that they provide, will lead to more effective allocations among the inputs used into the production procedure, leading to the reduction of the amount of water that it is used from the agriculture sector and that reduction will certainly have a positive effect to the problem of water scarcity problem.

The economic literature on the adoption of irrigation technologies suggests many key variables that address the decision of the farmers to proceed to the adoption of that technology. Some of these variables are the human capital (Caswell; Feder 1985; Dilan and Yaron), cost of irrigation water (Caswell and Zilberman), the size of the farms (Feder 1988), quality of the land and the environmental conditions (Dilan and Yaron) and others.

The objective of this paper is to develop a farm-level model of the long-term adoption rate for modern irrigation technologies by farmers of Crete, using a duration model. In the paper there is the presentation of the data that there were used and also the results that came out from the analysis of those data, as well as a discussion of those results. The parameters that affect the diffusion of the new irrigation technology and are examined in this paper are some general farm and the household characteristics, the level of information that the farmer have for the existence of new technologies, some general characteristic, mainly of the household head, that represent the what it is known as human capital, the number of previous and expected adopters and also the current and expected price of the technology. All those parameters that affect the diffusion of the irrigation technology and the data that were used in order to get the effects of those parameters into the diffusion process will be presented and examined later in the paper and particularly when we will be discussing the empirical specification of the model.

The paper is organized as follows. At the first section we describe the situation concerning the water availability and the characteristics of the agricultural sector in Crete. Then we present the model of adoption that it is employed in the analysis. After that section follows the empirical specification of the model and then the data presentation as well as the definition of each variable. In the next section there are the results of the analysis and finally at the last section there is a summary of the key points of the paper.

2. Adoption of Irrigation Technologies in Crete

The water availability in the island of Crete is restricted and this condition is further affected by seasonal variation in water demand. More analytically during the period of the summer the demand for water is extremely higher than that of the rest of the year. This demand variation is caused by two main reasons. The first is increase of the need for irrigation water by the agricultural sector during the summer period due to the lack of rain and the existence of high temperatures and the second is the increase of the island's population, during that period, due to the arrival of many tourists.

An important element of the water scarcity problem in the island of Crete is that the main user of the available water is the agricultural sector. Particularly, according to data, which refer to the year of 1995, the agricultural sector used the 83% of the available water recourses. So it is clear that the scarcity of available water in Crete is affected by the huge demand for water by the agricultural sector. Another important issue is the fact that, although the percentage of water that it is used by the agriculture sector is huge, the needs of that sector are not fully covered according to the opinion of the local farmers.

A commonly presented solution for reducing the water that is spent from the agricultural sector is the use of modern irrigation technologies. Those technologies would increase the water efficiency and would lead to the reduction of the irrigation water that it is used. Just in technical terms it has been pointed out that modern irrigation systems, such as drip or sprinkler technologies, may increase the water efficiency from 0,6, which is the water efficiency with the use of traditional irrigation methods, to 0,95 with a proper management (Karagiannis, Tzouvelekas and Xepapadeas).

Those kinds of modern irrigation technologies are available in Crete for some years now. Although, the effects of those technologies for the water availability of the island are characterized by many people as positive the final decision for adopting or not that technology lies in the hands of the local farmers. The farmer's decision of adopting or not the modern irrigation technology is not mainly effected by his interest for the public good, such as the improvement of the water scarcity problem of the island. What they are mainly interested in, and that is what really affects their decision, is their own expected benefits from adoption. In other words the adoption of the new irrigation technology would be interesting to farmers, if their net profits from the adoption of the new irrigation method are higher comparing to those with the use of the traditional irrigation methods.

Another reason that theoretically should lead the farmers of Crete to adopt the new irrigation technology is the way the pricing of irrigation takes place. The farmers in Crete, in contrast to some other farmers of Greece, they are not charged with a fixed amount of money for each square kilometer of field that they want to water no matter how much water they spend, but they pay a price for each cubical meter (m^3) of water that they use. Analytically, the farmers pay a price which fluctuates from 0.06 € to 0.21 € depending to which area the field is located. Furthermore, in some areas the price of water per m^3 increases as the consumption of water increases (region of Crete www.crete-region.gr = περιφέρεια Κρήτης). So it is safe to say that a new irrigation technology that would increase the water efficient, and so would decrease the cost of production that the producers face should have a greater impact to the farmers of Crete than to those farmers that pay the water per square kilometer of irrigated field.

3. Modeling the Diffusion of a New Technology

As it has been mentioned earlier in this paper recent equilibrium models, dealing with the diffusion of a new technology, assume perfect information for the nature of the technology, as well as the benefits that will follow the adoption of the technology. The decision of a producers to adopt or not, and if he adopts when, is mainly affected by the comparison of the net benefits before the adoption and those after the adoption. Karshenas and Stoneman suggest that there are three mechanisms that affect the benefits from adoption for each producer during the time path and that in tern affect the decision for adoption. Those mechanisms, which each one refers to a different diffusion model, are the rank, stock and order effects.

In the rank effects models it is suggested that due to the heterogeneity among the potential users of the new technology, which is a result of the different characteristics of each producer, the benefits from the adoption varies among the potential users. So the different benefits from adoption for each potential user, from one hand, and the hypothesis that it is made for the tendency of acquisition cost to fall over time, from the other hand, leads to the conclusion that producers that achieve higher benefits from the adoption will adopt earlier, comparing to those which achieve lower benefits.

In the stock effects models it is assumed that as the number of the producers that have adopted the new technology increases the expected benefit from adoption for the potential adopter declines. This hypothesis is a result of the fact that as the number of adopters increases their production costs declines and that affects the prices of the good and makes the adoption of the technology harder for the remaining potential adopters. According to this hypothesis this condition will lead to a point at which the number of producers that have adopted the technology is large enough in order to make the decision of adoption for the rest of the producers and potential adopters no more profitable.

In the order effects models it is assumed that the benefits from the adoption are affected by the position in the order of adoption. Analytically, the benefits from the adoption for a producer, which is high in the adoption list, are greater than the benefits of those that are low in the adoption list. That effect will lead some producers to adopt earlier because they expect a possible increase to the number of adopters at the next session.

The model of diffusion that we will use here incorporates those three effects that were mentioned earlier and it is based on the work of Karshenas and Stoneneman, and of Abdulai and Huffman. In this model it is assumed that the producers i in the agricultural sector can adopt the new technology at the time t by paying for it the price of P_t. It is also assumed that all the producers of the sector are aware of the existence and the characteristics of the new technology as well as the potential benefits that they will get from the adoption of the technology at any time. Assuming now that the profits before the adoption are π_{ot} and after the adoption are π_{1t} can then be written as:

$$\pi_{ot} = p_{ot} f_{ot}(k_{ot}, y_{ot}) - C_{ot}(k_{ot}, y_{ot}) \qquad (1)$$

$$\pi_{1t} = p_{1t} f_{1t}(k_{1t}, y_{1t}) - C_{1t}(k_{1t}, y_{1t}) \qquad (2)$$

,where p_{ot} and p_{1t} stand for the price of the crop before and after the adoption respectively, $f_{ot}(\cdot)$ and $f_{1t}(\cdot)$ are the production functions before and after the adoption respectively, k_{ot} and k_{1t} are the amounts of water used before and after the adoption respectively, y_{0t} and y_{1t} are the amounts of the other inputs used into the production procedure before and after the adoption respectively and finally $C_{0t}(\cdot)$ and $C_{1t}(\cdot)$ are the cost functions before and after the adoption respectively.

Those extra profits that the producer i gains from the use of the new technology, can be written as a function g_{it} that represents the benefits from adoption of the technology at each time t as the difference between the maximum profits after and before the adoption. So we can say that:

$$g_{it} = \max(\pi_{1t}) - \max(\pi_{ot}) \tag{3}$$

The next assumption that it is made is that those per period benefits $g_i(\tau)$ are determined by the three effects that were mentioned earlier (rank, order and stock effects). Analytically, $g_i(\tau)$ is assumed to be a function of:

i. A vector of variables which refer to the characteristics of the ith producer and potential user of the new technology representing the rank effects (C_i),
ii. The number of producers that have already adopted the new technology by time t, representing the stock effects (S_t),
iii. The number of producers that are expected to adopt the technology at the period right after t, which representing the order effects (W_t)

After those assumptions we can say that the per period benefits of the ith producer can be written as:

$$g_i(\tau) = f(C_i, S_t, W_t)$$

$$\tau \geq t \ , \ f_2 < 0, \ f_3 < 0 \tag{4}$$

, where C_i represents the rank effect, $S_t$the stock effect and W_t the order effect.

In order now to determine the optimal time for producer i to proceed to the adoption of the technology we use the term of the net present value. As it is widely known the optimal time to start an investment project, like the adoption of a new technology in our case, is when the net present value of the project is maximum and at the same time positive. The above statement is known as the present value rule. So the net present value of real benefits of the technology adoption that are represented by the equation (5) can be specified as:

$$R_{it} = -p_t + \int_t^{\infty} g_i(\tau) \exp[-r(\tau - t)] d\tau \qquad (5)$$

, where r is the discount rate and we assume no depreciation of the technology capital.

As it has been said earlier the rule on which the optimal time of adoption is found is the present value rule. That rule determines the optimal time of adoption by the use of two conditions. The first one, which is called the profit condition, suggests that the adoption of a new technology must take place at a time at which the net real benefits from adoption are positive, that is $R_{it} \geq 0$. The second one, which is called the arbitrage condition, tries to pick the optimum benefit out of those ones that fulfilled the profit condition. The idea in order to achieve that is that the optimal time to adopt is when the net real benefits from adoption are not increasing over time. In other words this takes place when the cost of waiting for more information, improvements or price reduction of the technology is higher, as the time passes, than the positive effects of more information, improvements or price reduction of the technology. So the arbitrage condition is given by:

$$y_{it} = \frac{d[R_{it}\exp(-rt)]}{dt} \leq 0 \tag{6}$$

Summarizing the profit condition determines the set of potential adopters, whilst the arbitrage, condition determines the optimal time of adoption for each producer that made it to the set of potential adopters.

Then, from the arbitrage condition, we can say that if the optimal time for a producer i is t_i^* it would be given from the expression of:

$$y_i(t_i^*) \leq 0 \tag{7}$$

, where the inequality sign allows the existence of corner solutions such as the adoption of the technology the same time that it became available. With the addition to the previous expression of the stochastic error term ε the model tries to capture those factors that the potential adopters might know and cannot be incorporated into the model. So the (4) expression is written as:

$$y_i(t) + \varepsilon \leq 0 \tag{8}$$

The assumption that it is made for the error term is that the distribution remains invariant across the producers over time and it is independent of y. The probability for a producer to adoption in a small time interval {t, t+y} given that he has not adopt until time t, the hazard rate $\lambda_i(t)$ is given from:

$$\lambda_i(t) = prob[y_i(t) + \varepsilon \leq 0] =$$

$$= V[-y_i(t)] \tag{9}$$

,where $V(\varepsilon)$ is the distribution function of the stochastic error term ε. We assume that the unconditional probability of adoption is a function $f(.)$ of time and other variables that we have already assume that affect the adoption decision and also a set of parameters. That function, which is defined as density function for adoption time, can be expressed as $f(t; X, \beta)$ and the distribution function will be expressed as $F(t; X, \beta)$.

After those assumptions for the density function and its distribution, the hazard function can then be written in term of the density and distribution function as:

$$\lambda_i(t) = \lim_{h \to 0} \frac{F(t+h) - F(t)}{h} \frac{1}{1 - F(t)}$$

$$= \frac{f(t)}{1 - F(t)} = \frac{f(t)}{S(t)} \tag{10}$$

,where $S(t)$ refers to the survival function, which express the state of non-adoption will last at least until (t) and it is equal to $S(t) = prob(h > t)$ (Wooldridge) . With the use of the joint density function for the adoption time we can be led to the likelihood function for a sample of producers. It is important to understand that if some producers have not adopted the technology by the time that the survey was conducted then these observations might be right censored. However, due to the fact that the survey was designed to specifically obtain retrospective information on the date of adoption, there are not any left-censored intervals, which is an important advantage of our data. The likelihood function $L(\beta)$ is then given by:

$$L(\beta) = \Pi_1^n \{ f(t; X_{it}\beta)^c [1 - F(t; X_{it}\beta)]^{(1-c)} \} \qquad (11)$$

In the above expression c is an indicator variable that takes the value 1 for those producers that have adopted the technology and 0 for those that have not, which are the right-censored.

The decision for the specific duration model that we will employ to the analysis was based to the need for the model to be able to incorporate a term for unobserved farm and household heterogeneity. The reason for such a need came out from the fact that if the heterogeneity exists and it is ignored it tends to bias the coefficients of any variable with which it is correlated. In our case with the irrigation technology in Crete such a thing would happen if some farm or household characteristics gave the ability to someone to be more profitable using the new rather than then traditional technology and that ability is not reported in the data nor represented by any variable in the model. That is why we need to employ a duration model that incorporates a term of unobserved farm heterogeneity. Due to the fact that there is no specific functional form for hazard rates, we employ a general class of models that are known as proportional-hazard models proposed by Cox.

The advantage of those models is that they ensure a positive hazard rate without imposing further restrictions on the parameters of the model. The general form of the proportional-hazard function is:

$$\lambda(t; X_{it}, \beta) = \lambda_0(t) \exp(X_{it}\beta) \qquad (12)$$

,where $\lambda_0(t)$ is the baseline hazard, X_{it} is the vector of variables which incorporate the three effects (rank, stock, order) and β is a vector of parameters which are to be estimated.

By looking at the diffusion path of the irrigation technology, which is presented in Figure 1 we can see that the diffusion rate is not uniform over time but it seems as it is increasing. This observation means that the probability that a producer to adopt at time t, given that he has not adopt until then, does not seem to be constant but it seems to be increasing. That does not allow us to use the exponential distribution as the baseline hazard function, because this would imply that the hazard rate is constant, and that does not seem to fit in our case. So the two common distributions remaining are those of Weibull and log-logistic distribution. The first of those distributions assumes a monotonic hazard rate that is either increasing or decreasing, depending on a parameter p, and the second one suggests that the hazard rate first increases and then decreases. As it is suggested by Greene which of those alternatives might be best in each application is uncertain.

In the present analysis we employ a Weibull distribution on producers' duration t to adopt the new irrigation technology, which is characterised as a popular choice by Greene. Assuming that V is distributed as gamma with unit mean and that variance θ represents the unobserved heterogeneity, the survival function is then given by:

$$S(t, X, \beta, \theta) = \int_0^\infty S(t|\upsilon) f(\upsilon) d\upsilon$$

$$= [1 + \theta(\lambda t)^p]^{-1/\theta} \qquad (13)$$

The hazard function then becomes:

$$\lambda_i(t; X, \beta, \theta) = \lambda p(\lambda t)^{p-1}[S(t, X, \beta, \theta)]^{\theta} \tag{14}$$

As far as the unobserved heterogeneity is concerned it is increasing when $\theta>0$ and when θ goes to zero the heterogeneity disappears. So if θ is not significantly different from zero the hazard of a producer to adopt will be monotone in duration (Greene).

4. The Empirical Specification

As it has been said above the duration models main target is the examination of the length of f time required for a farmer in Crete to adopt the available new irrigation technology. This length of time is assumed to be affected by some explanatory variables, which are going to be examined analytically later on. The estimation of the hazard function, which was presented earlier, could be done by either estimating the baseline nonparametrically or by assuming a priori a specific distribution. In our case, as it is mentioned earlier, we employ a priori a specific distribution and that is the Weibull distribution.

The estimated coefficients will point out the relationship between the explanatory variables, which are represented by vector X of the equation (14), and the conditional probability of adoption. Those variables that are used in this paper in order to examine the effect that they have to the length of time required for a crop farmer to proceed to the adoption of the new irrigation technology are presented in Table 1**.** In that table we present the name and also a short description of them.

An important thing to understand about those variables is that most of them are based on recall information from the date of the adoption. That means that the variables that refer to the number of previous adopters, number of visits to an extension agent, level of farm income, level of tenancy, age of the household head, level of specialization, water quantity that was used for the needs of the production procedure, the level of education, and the technology price are all from the period that each farmer proceed to the adoption of the irrigation technology. The variables of the expected number of adopters and expected price technology are data that refer to the period right after the adoption decision. Apart from the above statement it is important to get a better view on each variable and specifically what they stand for and what impact we expect to have to the length of adoption time.

The first variable that we examine is that of the number of adopters. That variable is expected to have two different and opposite effects to the likehood of adoption in the next short time. Firstly, as it is implied by the stock effect theory the accumulative number of previous adopters will have a negative effect to the likehood of adoption due to the fact that as the number of adopter increase, the expected benefit from adoption declines. The other effect, with the different impact to the likehood of adoption, is that of the epidemic effect. According to theory the epidemic effect has an positive impact to the likehood of adoption because it supports that as the number of previous adopters increase, they cause a positive externality to the potential adopters through the learning-by –contact process. So it is easy to understand that the total effect that the previous adopters will have to the likehood of adoption during the next short period will be negative if the stock effect is higher than that of the epidemic effect, and positive in the opposite case.

The next variable is that of the expected number of adopters during the next period. That variable is based, as and the previous one, to the self reported estimations of each farmer. This variable of the expected number of adopters represents the order effects, which were mentioned earlier, so according to theory it is expected to have a positive effect to the likehood of adoption. That is because it is assumed that the farmer that is higher into the adoption list is expected to get greater returns that those that are lower into the adoption list. That means that if a farmer expects a high number of adopters in the future he will decide to adopt earlier and that is the reason why we expect that this variable of expected number of adopters will have a positive impact to the likehood of adoption.

The variable of the number of visits that the farmer had by an extension agent during the year before the decision to proceed to the adoption of the modern irrigation technology tries to capture the possible level of information that the farmer possess, not only about the irrigation technology but general for new techniques and tendencies. Also the contact with the extension agents and the information that they provide could point out how much is the farmer interested into the development of his farm. So as it can be easy to see the expected impact to the likehood of adoption in the next short period of this variable is positive.

Age is another variable that its effects into the likehood of adoption would be interesting to examine. It can be supported that a younger would be higher motivated comparing to an older one to proceed to the adoption of a new technology that would improve the general farm condition because he is not stuck to traditional ideas and practices. Beside that it could be supported that older farmers, due to the many years that they have been into the crop production process, they are better experienced, than younger ones, and that gives them the ability to evaluate better the effects of each action and makes more sufficient their decisions. From the above it cannot be clear whether the effect of the variable of age to the likehood of adoption in the next short period is positive or negative.

Another variable that it has been used in many papers in order to capture the effects of the human capital theory is the years of schooling that the household head received. Analytically the human capital theory supports that variables such the level of education affects the farmers' allocative skills and power to evaluate the cost and benefit that will come from the adoption of an available new technology and so affects the time of adoption. In other words farmer with higher education are assumed to be better informed about the existence and performance of new technologies and so to be able to take more accurate adoption decisions. It is important here to clarify that higher education level does not necessary means earlier adoption. That is because it might be more efficient to proceed to the adoption later in order to benefit from possible high price reductions or great epidemic effects. Summarizing, high education is assumed to lead to more efficient adoption decisions, which could result in either earlier or later adoption dates.

The farm income was also used as a variable in order to examine the possible effect that it has in the likehood of adoption. The expectation that we have for the effect that farm income will have on the likehood of adoption in the next short period is positive due to the fact that a high farm income will make it easier to proceed to the investment of a new technology because it will lead to lower budget constrains and also to greater need to maintain this high farm income. Another reason for supporting that positive effect is the possibility that the adoption of new technologies might require the payment of a high fixed cost that could be afforded only by farms that have high income.

The variable of tenancy, which shows the share of rented or leased land of total farms' land that it is used in the crop production, was examined because of the fact that many of the crop farmers used ranted land for their production. The expectation that we have for the effect that the variable of tenancy will have to the likehood of adoption in the next short period is that it should be have a negative effect and that is due to the fact that irrigation technologies require the installation of special equipment into the field that the crop production takes place and a possible relocation to another field will be costly.

The variable of specialisation shows how focused is each farmer to the production of crops. Analytically, the variable of specialisation was measured with the use of the Herfindahl index, which is the sum of the shares of each product j raised into cube. That is:

$$H = \sum_{j=1}^{n} (s_j)^2 \tag{15}$$

, where n stands for the number of different products that each farmer produces and s_j is the share of each product to the total amount of production Q, that is: $s_j = \frac{q_j}{Q}$. The values of this index varies between (0, 1] and when the value is near to 1 we should consider the farm production as monoculture or very specialised and when it is close to 0 as low specialized. The expected effect that this variable will have to the likehood of adoption in the next short period could be assumed to be positive. This is because it is reasonable to say that as the value of this variable increases, which means that the producer is more specialized, the harder is for him to protect himself from the risk of the investment cost of the new technology, due to the possible uncertainty of the production outcome of the only good that he produces. That means that as the number of goods that he produces increases it could be easier for him to protect himself from the production uncertainty, which means that as it makes it easier to cover the cost of adoption of the technology.

The water quantity, which each farmer had used at the crop production of the previous year, is used in this paper as a variable in order to see the effect that this input, which its use is expected to decline after the adoption of the new irrigation technology, will have to the likehood of adoption in the next short period. As it is already said the adoption of the new irrigation technology by a crop farmer will lead to the increase of the water efficiency and so to the reduction of the used water that in tern will lead to the reduction of the marginal cost of production. So the expected effect of the water quantity to the likehood of adoption is positive and that is because if a farmer was using a great amount of water in his production procedure before the adoption of the water saving irrigation technology this will give him the motivation to proceed earlier to the adoption of the new technology that will save him water and so consequently and money.

It would not be right not to refer the technology price as a variable that affects the diffusion of any technology. So the technology price, which represents the cost of purchase the new technology, must be used into the analysis. The expected effect that the price will have in the likehood of adoption in the next short period, as the demand law implies, is negative. That means that a high technology price today will lead to low demand for the technology or to small number of buyers during the next short period of time. The exact different effect that the technology price has to the likehood of adoption will have the expected technology price. This means that if the potential adopter expects a lower technology price in the future then he might think to delay the technology adoption in order to benefit from the lower technology price. So the effect of the expected technology price in the likehood of adoption in the next short time is expected to be positive.

5. Information Concerning the Survey and the Collected Data

The data used in this paper were obtained from a broader survey on the structural characteristics of the agricultural sector in the island of Crete in Greece, financed by the Regional Development Program 1995-1999 (Liodakis). The sample consists of 265 randomly selected crop producers that are located in the four major districts of Crete (Chania, Heraklio, Lasithi, Rethymno). The questionnaire apart from collecting information for the variables that were mentioned earlier, and the effects of them to the likehood of adoption we are interested in studying, collected information concerning whether each farmer had proceed to the adoption of the new irrigation technology, by the time that the survey took place, and if they had the year that they did so. This variable of the time of adoption is the key variable of our analysis because it is the depended variable into the model that we are going to estimate.

In Table 2. there are presented some general features of the collected by the survey data. Those general features of the data are the mean value of each variable, the minimum and maximum value of each variable and also the standard deviation of each variable. Apart from the presentation of those general features of the data, and in order to get a better picture of the diffusion process of the new irrigation technology in Crete, we mention that, according to data that came out from the sample of crop farmers that were examined, the first adoption of the new technology took place in 1985, that at the day of the survey 87 households had already proceed to the adoption representing approximately the 32,8% of the total sample. Furthermore the average time of adoption for those that did adopt was approximately 4,5 year since the first adoption.

Before proceeding to the estimation of the model we have to deal with the problem of the possible endogeneity among the variables that are used in the model as independed variables. An obvious case of possible endogeneity is the use of variables such as the number of adopters and the technology price and that is because the price of the technology falls with the increase in the number of adopters, and the diffusion path is a result of the interaction between supply and demand (Karshenas and Stoneman). Although that we recognize the significance of the supply-side, it is unlikely that small individual farmers would influence technology price. Another potential endogeneity problem is that between the previous and the expected number of adopters. This was tackled by employing a two stage estimation procedure outlined by Lee and by Murphy and Topel. First we estimate a time series autoregressive model for the variable of number of previous adopters and second the predicted values for this variable are substituted for the finally used variable of the number of previous adopters and the one period ahead expectation with the variable of the expected number of adopters.

6. Empirical Results

Before presenting the estimated coefficients of the duration model we test the null hypothesis that no unobserved heterogeneity exists, that is, $H_o : \theta = 0$ versus $H_1 : \theta \neq 0$. The p-value is 1 for a test of no heterogeneity using the likehood ratio test statistic. The reached conclusion is that unobserved heterogeneity in non adoption spell does not exist. Furthermore due to the fact that the Weibull distribution parameter P stands for the monotonicity parameter and the estimated value in our case is 0.953 and the standard error is 0.105, as it appears in Table 3., we strongly reject $H_o : a = 1$ against the $H_1 : a < 1$ and conclude that negative duration dependence exists. In the same table the parameter Lambda stands for the baseline hazard and the estimated value for this parameter is 0.00033 and the standard error is 0.00017.

Before moving on to the discussion of the estimated coefficients we present in Figures 2 and 3 the estimated survival function for time of adoption and the estimated hazard function for time of adoption as they came out from LIMDEP. Figure 2. refers to the estimated survival function and represents the estimated relationship between the rate of producers that do not proceed to the adoption of the new technology and the duration. It is important to mention here that the duration in both figures is measured in days. Figure 3. refers to the estimated hazard function and represents the level of hazard at each point of duration.

The maximum likehood estimations of the parameters of the duration model for the adoption of the new irrigation technology and the associated standard errors, which were conducted with the use of the econometric software of LIMDEP, are presented in Table 4. It should be also mentioned that in this framework a negative coefficient for a regressor in the hazard function implies a negative effect on duration or in other words a faster adoption of the irrigation technology by the crop farmers.

The estimated coefficient for the variable of previous adopters of the new irrigation technology is positive and also significant at the 1% level. This implies that this variable has a positive effect on duration and so it has a negative effect on the likehood of adoption in the next short period. But as it has been discussed earlier, a negative effect of the variable of previous adopters on the likehood of adoption implies that the stock effect is higher comparing to the epidemic effect. Analytically, this means that the total effect that the previous number of adopters have to the potential adopters is negative, because that the negative action that the stock effects have, is higher than the positive action of the epidemic effects, which are expressed through the learning-by-contact process. So from the above analysis comes out that the stock effect plays an important role into the diffusion process.

The estimated coefficient for the expected number of adopters of the new irrigation technology came out to be negative and significant important at 5% level, which means that the effect of this variable on the duration is negative or that the effect to the length of the adoption time is positive. This is compatible with the fact that this variable of expect number of adopters is used in order to play the roll of the order effects, which as the theory suggests the effect that they have to the likehood of adoption is positive.

After the examination of the coefficients that represent the stock and order effects we proceed to the examination of those coefficient that the represent the rank effects. In the category of the variables that represent the rank effects are all those variables that refer to farm and household characteristics that might affect the diffusion process. So those variables are extension agents, age, education, farm income, tenancy, specialization and that of water quantity. Out of these variables those that their coefficient came out to be statistically significant at the range of 1% to 10% level are those of the number of visits from an extension agent with a negative coefficient and significant at the 5% level, of the level of education with also a negative effect to the duration and significant at 1%level the farm income with again a negative coefficient and significant at 5% level and finally the level of specialization with a positive coefficient and significant at 10% level.

From the above it can be said that the effect of the variables of the extension agents, education and farm income is negative on the length of adoption time which means that they have a positive effect on the likehood of adoption in the next short period, as it was expected to be according the analysis that was made during the presentation of each variable. The coefficient, from the other hand, of the specialization came out to be positive which means that the effect that this variable has on the length of adoption time is positive or that the effect that it has on the likehood of adoption in the next short period is negative also as we expected to be. So that mean that as higher is the values of variables of number of visits, level of education and farm income so higher would the likehood of adoption in the next short period be and that as higher is the value of the variable of specialization so lower would the likehood of adoption in the next short period be. The other variables that were used in order to capture the rank effects, which are the age, tenancy and water quantity, came out to be not statistically significant.

A really interesting result that came out from the analysis is that the effects both of current and expected technology price to the duration are not statistically significant. That is something that we did not expect to come out from the analysis. Apart from the parameters of current and expected technology price that their effects came out not to be statistically significant, the exact same thing was observed with parameters of age, tenancy and quantity of water. From the above we conclude that the effects of those parameters do not play an important role into the diffusion process.

7. Conclusions

In this paper we examined the diffusion of a new irrigation technology in the island of Crete, Greece by employing a hazard function. We assumed that the decision of a producers to adopt or not is mainly affected by the three effects that Karshenas and Stoneman suggested which are the rank, stock and order effects. From the analysis of the data, which were obtained by a survey that examined 265 crop farms and were referring to self-reported information mostly from the day of adoption, came out that all three effects, which were mentioned earlier, had in important role into the diffusion process. Analytically the stock effects, which were captured from the variable of number of previous adopters, had a negative effect to the diffusion process. The order effects, which were captured from that variable of the expected number of adopters, had o positive effect to the diffusion process. The rank effects, which were captured by the variables of extension agents, education, farm income and tenancy, had also an important role to the diffusion and analytically the first three of them had a positive effect on the diffusion process, while the last one had a negative effect. What could be characterized as an important finding is that both the variables of current and expected technology price came out to be not statistically significant.

APPEDIX

Figure 1. Diffusion of Irrigation Technology in Crete (1985-1995)

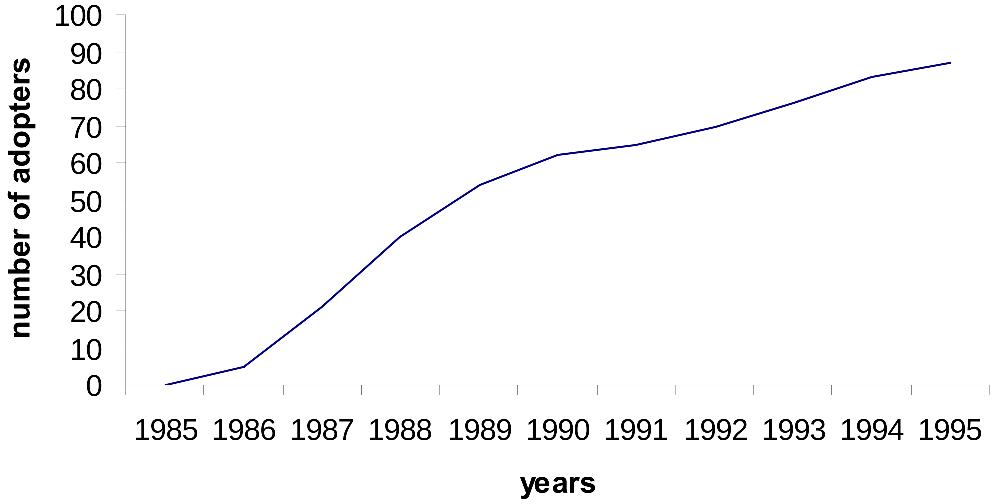

Table 1. Variable Names and Short Variable Definition

Variable	Variable description
Number of adopters	Number of farmers that had adopted the technology
Expected number of adopters	Expected number of farmers that will have adopted the technology in the next period
Age	Age in years of the household head
Education	Years of schooling of the household head
Extension agent	Number of visits to the farmer by an extension agent
Farm income	Amount of money that came from the farm
Tenancy	Share of rented or leased land of total farms' land
Specialization	Level of farm specialization, if close to 1 monoculture (Herfidall index)
Water quantity	Amount of used water into the farm measured in m^3
Technology price	Purchasing price of irrigation technology
Expected technology price	Expected purchasing price of irrigation technology in the next period

Table 2. Descriptive Statistics of the Variables

Variable	Mean	Min	Max	StDev
Number of adopters	312.16	83.54	380	75.5
Expected number of adopters	353.62	160.29	420	69.8
Age	49.26	23	85	13.61
Education	7.77	3	20	3.53
Extension agent	4.2	0	29	5.51
Farm income	23648.41	696.41	180769	29260.43
Tenancy	0.25	0	0.85	0.19
Specialization	0.63	0.5	0.95	0.11
Water quantity	163.88	4.75	879.95	154.86
Technology price	4388.43	661.1	21494.45	3477.05
Expected technology price	4035.62	615.49	20003.67	3184.91

Table 3. Maximum likehood Estimates of Parameters of underlying density at data means for Cretan Crop Farmer's Adoption of New irrigation technology (n=256)

Variable	Estimate	Standard Error
Sigma	1.0496	0.1159*
Lambda	0.00033	0.00017**
P	0.9527	0.1052*

* refers to significant at the 1% level

** refers to significant at the 5% level

Figure 2. The Estimated Survival Function for Time of Adoption

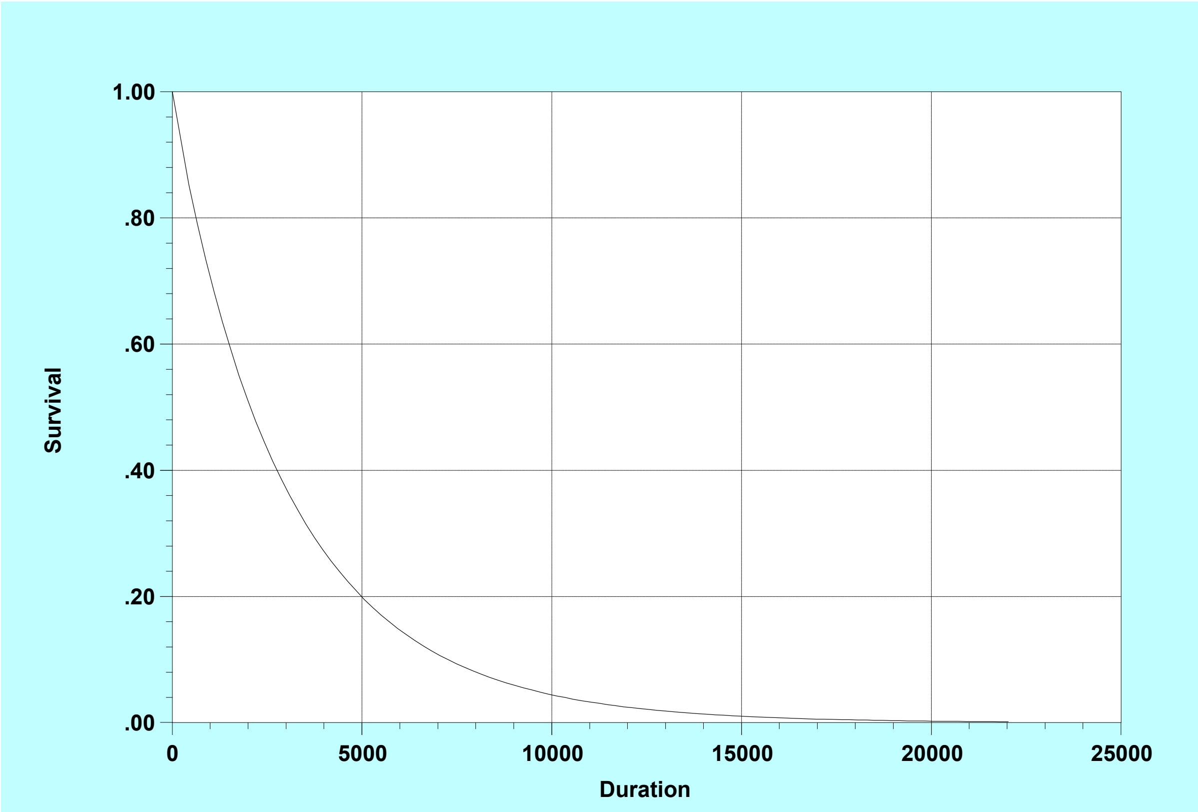

Figure 3. The Estimated Hazard Function for Time of Adoption

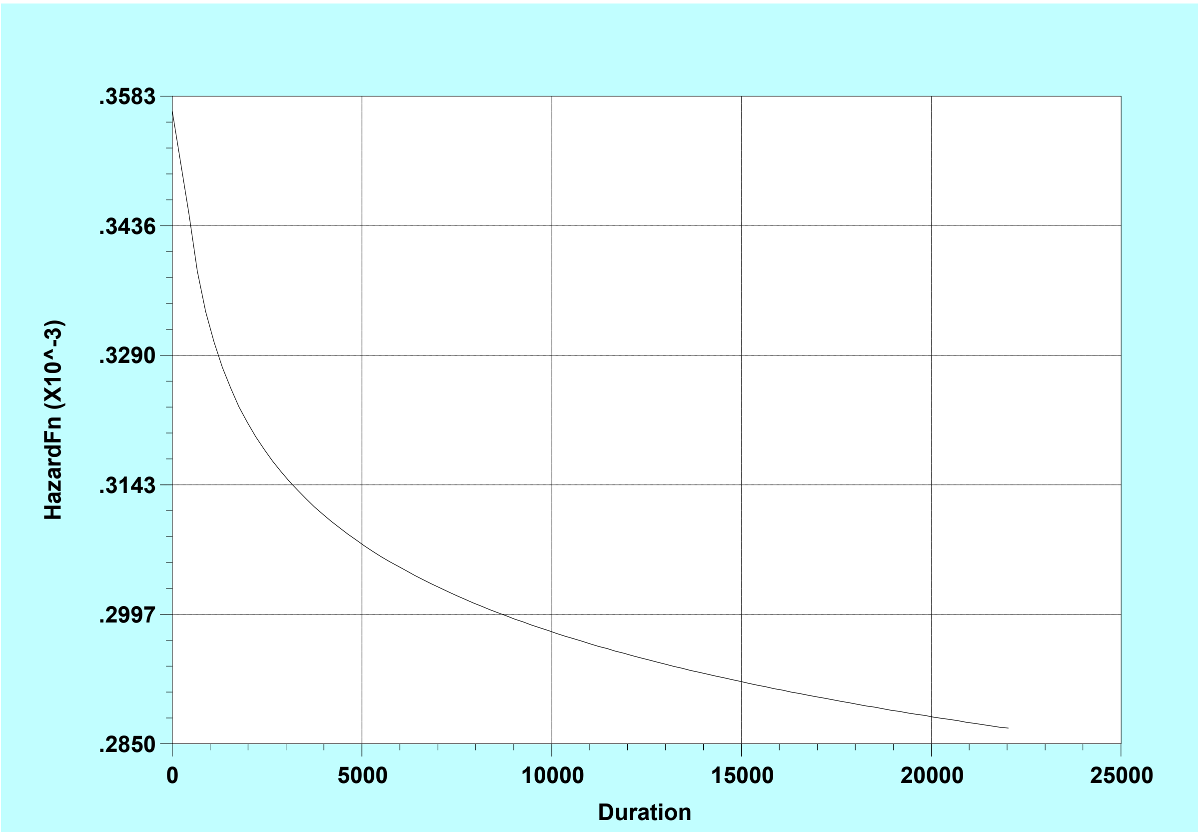

Table 4. Maximum likehood Estimates of Parameters for Hazard Function for Cretan Crop Farmer's Adoption of New irrigation technology (n=256)

Variable	Coefficient	Standard Error
Number of adopters	5.6776	0.9956*
Expected number of adopters	-3.4365	1.3794**
Age	-0.1916	0.8577
Education	-2.7377	0.6197*
Extension agent	-0.4031	0.1997**
Farm income	-0.4126	0.1847**
Tenancy	-0.1412	2.0648
Specialization	2.7952	1.4439***
Water quantity	-0.0367	0.1295
Technology price	-4.5810	6.5730
Expected technology price	4.5638	6.5315

* refers to significant at the 1% level

** refers to significant at the 5% level

*** refers to significant at the 10% level

References

- Abdulai, H. and Huffman, W. “The Diffusion of New Agricultural Technologies: The Case of Crossbred-Cow Technology in Tanzania” *American Agricultural Economics Association* 87(3) (2005) 645-659.
- Besley, T., and A. Case. “Modelling Technology Adoption in Developing Countries.” *American Economic Review* 83(1993):396–402.
- Cameron, L.A. “The Importance of Learning in the Adoption of High-Yielding Variety Seeds.” *American Journal of Agricultural Economics* 81(1999):83–94.
- Caswell, M. and D. Zilberman, “The Choice of Irrigation Technologies in California” *American Journal of Agricultural Economics* 67(2) (1985): 224-234.
- Caswell, M. F. “Irrigation Technology Adoption Decisions: Empirical Evidence’’, *The Economics and Management of Water and Drainage in Agriculture.* Kluwer Academic Publishers, Boston, MA,(1991): 295-312.
- Conley, T., and C. Udry. “Learning about a New Technology: Pineapple in Ghana.” Economic Growth Center Working Paper, Yale University, New Haven, CT, 2003.
- Dinar, A. and D. Yaron, “Influence of Quality and Scarcity of Inputs on the Adoption of Modern Irrigation Technologies” *Western Journal of Agricultural Economics* 15(2) (1990) 224-233.
- Dinar, A. and D. Yaron, “Adoption and Abandonment of Irrigation Technologies’’ *Agricultural Economics* 6(1992): 315-332.
- Feder, G., T. Onchan, Y. Chalamwong, and C. Hongladarom, “Land Policies and Farm Productivity in Thailand”. John Hopkins University Press for World Bank (1988).
- Feder, G. “Farm Size, Risk Aversion and the Adoption of New Technology under Uncertainty.” *Oxford Economic Papers* 32(1980):263–83.
- Feder, G., R. Just, and D. Zilberman. “Adoption of Agricultural Innovations in Developing Countries: A Survey.” *Economic Development and Cultural Change* 33(1985):255–98.
- Foster, A., and M. Rosenzweig. “Learning by Doing and Learning from Others: Human Capital and Technical Change in Agriculture.” *Journal of Political Economy* 103(1995):1176–209.

- Greene,W.H. *Econometric Analysis*, 5th ed., Upper Saddle River, NJ: Prentice Hall, 2003.
- Karagiannis, G., Tzouvelekas, V. and Xepapadeas, A. "Measuring Irrigation Water Efficiency with a Stochastic Production Frontier" *Environmental and Resource Economics* 26 (2003) 57-72.
- Karshenas, M., and P. Stoneman. "Rank, Stock, Order, and Epidemic Effects in the Diffusion of New Technologies: An Empirical Model." *RAND Journal of Economics* 24(1993):503–28.
- Sunding, D., and D. Zilberman. "The Agricultural Innovation Process: Research and Technology Adoption in a Changing Agricultural Sector." *Handbook of Agricultural Economics*, vol. 1B. NewYork: Elsevier Science-North Holland, 2001, pp. 208–61.
- Wooldridge, J.M. *Econometric Analysis of Cross Section and Panel Data*. Cambridge, MA: MIT Press, 2002.