TECHNOLOGICAL AND ECONOMIC DEVELOPMENT OF ECONOMY

2010
16(4): 703–716

EVALUATION OF INNOVATIVE AGRICULTURAL EXTENSION PROJECTS USING NOVEL INVESTMENT TOOLS

Anastasios Michailidis[1], Fotios Chatzitheodoridis[2], George Theodosiou[3]

[1]Department of Agricultural Economics,
Aristotle University of Thessaloniki, Thessaloniki, Greece
[2]Department of Agricultural Products Marketing and Quality Control,
Technological Education Institution of Western Macedonia, Florina, Greece
[3]Department of Business Administration,
Technological Education Institution of Larissa, Larissa, Greece
E-mails: [1]tassosm@auth.gr; [2]fchatzitheo@gmail.com; [3]geortheo@yahoo.gr

Received 8 March 2010; accepted 20 October 2010

Abstract. This article extends the employment of novel investment evaluation tools into agricultural extension issues. In particular the concept of real options methodology has modulated, into an innovative agricultural project called "wema", to model design flexibility in the realistically uncertain environment of information and communication technologies (ICT). Taking into account the great importance of ICTs, as the principal driver of change in agricultural areas, as well as the drastic increase in ICTs adoption over the last decade, a study evaluating the adoption parameters of ICTs can prove significantly valuable. Besides, any issue related to ICTs is extremely interesting and it belongs to the modern subject-matters of the agricultural economics science. Empirical results revealed that, according to the traditional criterion (Net Present Value), the implementation plan of the "wema" project is feasible. However, assuming the presence of uncertainty, application of a real options approach demonstrates that the Net Present Value may lead stakeholders to faulty decisions, as the innovative plan is rejected. The results indicate that the options have a significant value and highlight the fact that ignoring options value process can lead to a significant error. This obviously indicates the importance of combining the Net Present Value criterion in agricultural extension investments with the real options approach.

Keywords: agricultural extension, innovation, investment, Monte Carlo, real options, simulation.

Reference to this paper should be made as follows: Michailidis, A.; Chatzitheodoridis, F.; Theodosiou, G. 2010. Evaluation of innovative agricultural extension projects using novel investment tools, *Technological and Economic Development of Economy* 16(4): 703−716.

ISSN 1392-8619 print/ISSN 1822-3613 online doi: 10.3846/tede.2010.43
http://www.tede.vgtu.lt

1. Introduction

In today's knowledge-based societies the evolution of Information and Communication Technologies (ICTs) have long been argued as a catalyst for development and change as it reinforces new forms of social and business interactions and use of services. In fact, according to Verdegem and Verhoest (2009: 644), the overcoming digital inequality is considered to be one of the key drivers for social and economic welfare. Moreover, the diffusion of ICTs has been a double-edged sword (Sun and Wang 2005: 250) especially for rural areas which face radical changes, multifarious threats and significant opportunities (OECD 2006). In addition, the rapid evolution of ICTs has significant potential upon farming and offers agricultural extension services with a new array of channels and opportunities for information dissemination, thus tentatively replacing traditional modes of information delivery. However, the digital divide discourse as well as research findings addressing both extension agents' and farmers' adoption and use seem to defy such optimism. According to Koutsouris (2010), Greek rural areas are lagging behind in the adoption of ICTs. In particular, Greece is one of the most rural European countries and it is also one of the late adopters of a multi-sectoral approach to rural policy (Michailidis *et al.* 2010).

In the age of intensive development of new technologies farmers encounter increasing amounts of information. The ICTs provides the farmers with various data, including textual and graphic information. However, weather forecasts and answers to frequently asked questions are most often used to satisfy the needs with no analysis of economic activities, decision support, reasoned conclusions and suggestions (Kurlavicius 2009: 295). Recently, Koutsouris (2010) outlined the main research findings of two articles addressing the issue of the ICTs illustration by Greek farmers. The first one (Alexopoulos *et al.* 2010) aims at identifying the existence of a 'digital divide' within Greek rural areas while also explore which characteristics of rural inhabitants relate to the use of PCs and the use of Internet. On the other hand the second paper (Michailidis *et al.* 2010) aims at exploring farmers' use of ICTs and their views on preferred extension methods, utilising data from a large scale survey. Although both empirical findings are in line with previous studies, and support Rogers' (1995: 87) socioeconomic generalizations about early adopters, farther research is needed especially in the fields of a) exploring the potentials and pitfalls of ICTs development in rural areas and b) evaluating the adoption decision of ICTs projects that influence the outcome of rural development policies. Thus, the existing methodology aims to cover this major research gap providing an alternative view of rural development through ICTs as an investment decision under uncertainty.

The classical approach to analyze investment decisions includes several traditional discounted cash flow (DCF) techniques such as the net present value (NPV), the cost/benefit ratio (C/B) and the internal rate of return (IRR). However, this approach is rather inefficient when the investment decision influenced by uncertainty parameters. In fact, there are many problems with the DCF approach: (a) the inability to account for managerial flexibility (Morck *et al.* 1989: 473), that (b) it is linear and static in nature and assumes that either the investment opportunity is reversible or it is a now-or-never opportunity (Dixit and Pindyck 1994: 36; Michailidis 2006: 381) and that (c) it is based on the assumption that future cash flows follow a constant pattern that can be accurately predicted from regeneration up to the rotation age (Tzouramani and Mattas 2004: 356). Consequently, the DCF approach fails to adequately address the assessment of growth opportunities or strategic alternatives arising from investments in large-scale agricultural extension projects.

The alternative methodology includes several uncertainty parameters through the evaluation of real options. Real options theory is explicitly based on the idea that most investment projects embed a series of alternative actions. It follows that 'the ability to delay an irreversible investment can profoundly alert the decision to invest' (Dixit and Pindyck 1994). The field of agricultural extension projects entails significant amounts of uncertainties, which make strategic managerial decision-making very crucial. Due to the irretrievable nature of most agricultural extension investments, greater focus must be placed upon investment evaluation. Thus, evaluating the adoption of any investment plan in ICTs must be accompanied by the investigation of uncertainty and risk effects.

Recently, both traditional and alternative methodologies were used to evaluate irrigation water storage projects (Michailidis and Mattas 2007: 1717), tourism investments (Michailidis 2006: 381) or modern greenhouses under uncertainty (Tzouramani and Mattas 2004: 355). In this paper, the concept of real options has extended into ICTs adoption project to model design flexibility under uncertainty. In particular, the modified model extends the evaluation techniques of an ICTs adoption project by combining the real options approach along with the traditional one (DCF). However, whereas financial options are well-defined traded contracts, real options in ICTs adoption projects are a priori undefined, complex and interdependent. Moreover, ICTs adoption projects involve many more options than designers could consider. Therefore designers need to identify the real options most likely to offer good flexibility and the most value. The presented case study example demonstrates the ease that ICTs adoption projects economic analysis with risk analysis and real options can be valued by simulation software that is readily available to owners of personal computers. Sequentially, DCF analysis accompanied with real options approach facilitates decision making and encourages more sophisticated and realistic economic analysis of ICTs adoption projects.

The main aim of this paper is to explore the extent to which novel investment evaluation tools can combined and used in collaboration with the innovation theory and the expected consequences for agricultural extension in Greece. In particular, this paper explores the application of real options in ICTs project evaluation. In addition, the paper presents a problem formulation for analysis of ICTs projects using real options. The selected approach uses DCF techniques in combination with Monte Carlo simulation. The work describes the methodology in detail and it illustrates a typical example of ICTs projects evaluation.

The contribution of the paper is a dual one. At a theoretical level, the paper yields the unambiguous result that evaluation under uncertainty causes significant changes in investment decision. At an empirical or practical level, the paper illustrates how novel investment tools can be applied into agricultural extension issues and how the theoretical findings can be translated into empirical actions, working as a catalyst of decision' change, through the employment of a real options model.

The rest of the paper is organized as follows: first a brief description of the theoretical model is portrayed. The next section contains the application of the example case study and presents the main results. Finally, the paper ends with concluding remarks and implications are drawn.

2. Empirical model

The typical cost-benefit model which is based on DCF methodology (Jones, 1996: 158) is used extensively in evaluating investment opportunities. Particularly, the traditional NPV can be considered as the double-edged sword of the cost-benefit model and can be represented as the net result of a choice between production "with" or "without" a specific investment (Ross *et al.* 2000: 245). However, traditional methodologies make no allowance for flexibility and assume a static environment (Kahraman and Kaya 2010: 46). On the other hand, real options valuation method makes more exact assessments since it considers future uncertainties as well as dependencies and dynamism (Ucal and Kahraman 2009: 666). According to the same source, by using the real options valuation method particularly to analyse the risky investments, wrong decisions could be easily avoided.

Optimal functioning of an agrarian ecosystem, as a complex biological-social-technical system, can be ensured only by systematic solution of the analyzed problems. Table 1 illustrates the equation sequence for both DCF technique and real options approach (Michailidis *et al.* 2008: 485). The first column lists the main functions of the empirical model and the second one presents the description of the key parameters of all the equations.

Table 1. Equations and description of the parameters

(1)	$PV = \int_0^{\infty} e^{-et} E[(P_t Q_{w,t} - C_{w,t}) - (P_t Q_{o,t} - C_{o,t})]dt$	I = incremental investment costs PV= present value of its incremental net revenue flow
(2)	$V(R) = \begin{cases} BR^{\beta} & \text{if } R \le H \\ R/\rho - K & \text{if } R \ge H \end{cases}$	e = Real discount rate t = Time period E = Expectations operator P = Output price
(3)	$B = (H - \rho K)/H^{\beta}$	Q = Output quantity C = Variable costs of production w = Indicate production "with" the investment
(4)	$\beta = 1/2\left[1 + \sqrt{1 + \frac{8\tilde{n}}{\acute{o}^2}}\right] > 1$	o = Indicate production "without" the investment BR^{β} = Value of waiting $R/\rho\text{-}K$ = Value of investing
(5)	$\rho' = \frac{\beta}{\beta - 1}\rho$	$V(R)$ = value of the opportunity to invest B = shifter which fixes the position of w_1w_2 β = shifter which determines the slope of w_1w_2
(6)	$\frac{dV}{V} = \mu dt + \sigma dz$	H = Optimal investment trigger ρ = decision maker's discount rate σ^2 = expected volatility in the value of investing over the life of the investment ρ'= modified rate which includes the effects of uncertainty and irreversibility V = value of the opportunity to invest μ = constant drift rate σ = constant variance rate dz = increment of Wiener process, $z(t)$

According to the acceptance rule *(NPV=PV-I ≥ 0)*, the choice between adopting a new project or not can be based on comparison (eq. 1) of the incremental investment costs *(I)* of the project and the present value of its incremental net revenue *(PV)* flow (Gittinger 1986: 27). The employment of real options methodology offers an extra value of the opportunity to invest (eq. 2) as a choice between the value of waiting and the value of investing while the optimal investment trigger (*H)* is the point where the value of investing and the value of waiting are tangent. The functional expression of the value of waiting includes the component β as an exhibitor which is a function of two known or estimable parameters: ρ and σ^2. As uncertainty about returns increases, β gets smaller and the difference between the Marshallian trigger (*M*) and the optimal trigger (*H*) increases. As a result, any raise of the discount rate increases β and together reduces the difference between *M* and *H* (eq. 3 and 4).

In addition, investments with uncertainty and irreversibility have to be evaluated using a modified rate of return ñ' (Dixit 1992: 111), which shows the effect of factoring in the value of waiting on the investment trigger (eq. 5). This modified rate has to be used to determine the *H* which represents the difference between the Marshallian and the revised triggers.

In order to estimate the variance and the expected volatility of the value of investing a specialized Monte Carlo simulation model is employed. The estimation of the variance will be used to solve the equation of β and derive the modified investment trigger. Assuming that simulated annual returns from investing follow a geometric Brownian motion process (GBM), a discrete approximation to a GBM process converges to the expected value of a geometric Brownian motion variate (Cox *et al.* 1979: 74). Therefore, the value of the opportunity to invest also follows a process of GBM, given by eq. 6 (Black and Scholes 1973: 645; Louberge *et al.* 2002: 161; Kassar and Lasserre 2004: 863).

On the other hand, the relationship between *dz* and *dt* is given by $dz = e_t\sqrt{dt}$ where, e_t has zero mean and unit standard deviation (e_t is *N(0,1)* and $E(e_t e_s)= 0$, for $t \neq s$). Therefore, changes in *V* over time are a function of a known proportion growth rate parameter μ, and σ, which is governed by the increment of Weiner process, *dz* (Dixit and Pindyck 1994: 89). Thus, *V* is modeled as the discounted sum of random draws from the distribution of expected returns from investing, annualized and projected into perpetuity. The trend (μ) of the GBM process is estimated by $\mu_V \approx \frac{1}{N}\sum_{j=1}^{N}[\Delta \ln V_j]$, where $E[\Delta \ln V_j] \Rightarrow 0$ and the variance of the opportunity value to invest is estimated by $\sigma_V \approx \frac{1}{N}\sum_{j=1}^{N}[\Delta \ln V_j - \mu_V]^2$, where $E[(\ln V_j - \mu_V)^2] > 0$. To calculate the statistics μ_v and σ_v from simulation data, the mean of *N* simulated log differences investing in *t* and *t+1* is calculated. The difference between natural logarithms of V_t and V_{t+1} gives a discrete estimate of the change in the value of investment opportunity occurring over an increment of a GBM process. An estimate of this discrete difference is simulated over 25,000 iterations. The evaluation of variance of the opportunity to invest is used to estimate the optimum investment trigger under uncertainty and irreversibility.

For better understanding of the above methodology an example application will be presented in order to *ex ante* evaluate an ICTs adoption project in the region of Western Macedonia in north-west Greece.

3. Example application

The Western Macedonian Region (WMR) is located in the north-west of Greece. The Region comprises four prefectures: Florina, Grevena, Kastroria and Kozani (Fig. 1). From a geographical point of view, the WMR holds a central position in the Eastern Europe since it is the natural gate of Greece to the northwest borders. The landscape of the region mainly consists of highlands (69.2%), forest areas (26.0%), rangelands (43.0%) and cultivations or fallow lands (24.0%). The WMR occupies 9,451.6 km^2 or 7.2% of the country land (NSSG 2009).

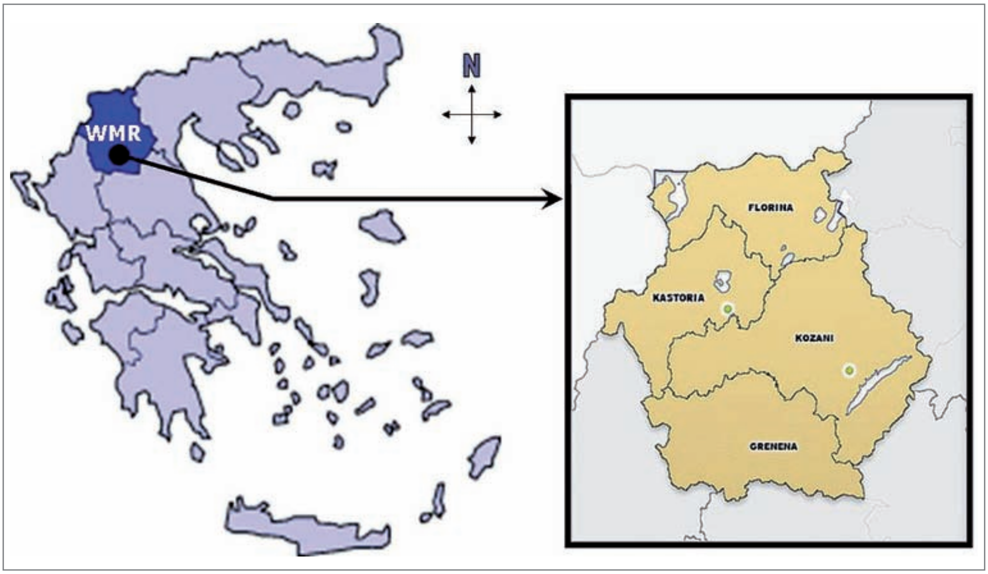

Fig. 1. Western Macedonian Region

An agricultural extension project, called "*wema*", is projected to implement (until the year 2020) in the WMR and destined mainly for rural development purposes. In particular, the "*wema*" project includes several ICTs and addressed in a representative farm framework of 600 farmers or residents of rural areas. Taking into account the great importance of communication in the development of rural areas any issue related to ICTs is extremely interesting and it belongs to the modern subject-matters of the agricultural economics science. However, the implementation expenses of the "*wema*" project constitute a significant part of the available funds and therefore play an important role in the investor's decision. Thus, the modelling of the economic profitability of the "*wema*" project is very important, notably in a region where funds available for agricultural investments are rather limited.

In this work, a typical investment option was evaluated by applying both DCF and real options. Cost projection estimates indicate that the "*wema*" project is expected to require an outlay of 750,000 € during the implementation phase. Moreover, the project is required to provide 10% of annual pre-tax revenue for payback during the operating stage. The annual operation cost (45,000 €) includes salaries, materials, any conservation expenses and payments for several other services. On the other side, the estimates of total direct annual revenues are equal to 30,000 € and include: a) quality improvement, b) new market's access, c) new distribution canal's access, d) marketing improvement and e) generally farm efficiency improvement.

Fig. 2 presents the analytical flow chart diagram of the employed methodology. First, a DCF approach is applied using primary data from a survey (600 questionnaires) and secondary data from (a) the statistical service of the Greek Ministry of Agriculture and (b) several earlier studies (feasibility, environmental, financial and study of the socioeconomic impacts). The NPV and the IRR were applied for a period of fifteen years. NPV equals to 138,214 € and IRR equals to 7.74% (Table 2), suggesting that this particular investment is feasible. The sensitivity analysis (±20% fluctuation of each factor *ceteris paribus*) of the IRR (Table 3) shows that the "*wema*" project is, in any case, an acceptable investment.

The real option approach is applied utilizing the same criteria as above while Monte Carlo simulation was used to determine the mean and the variance of net annual returns of the project. In particular, net annual returns of the "*wema*" project were determined by 25,000 Monte Carlo iterations through @RISK software (Palisade 2000). Two main uncertainty fac-

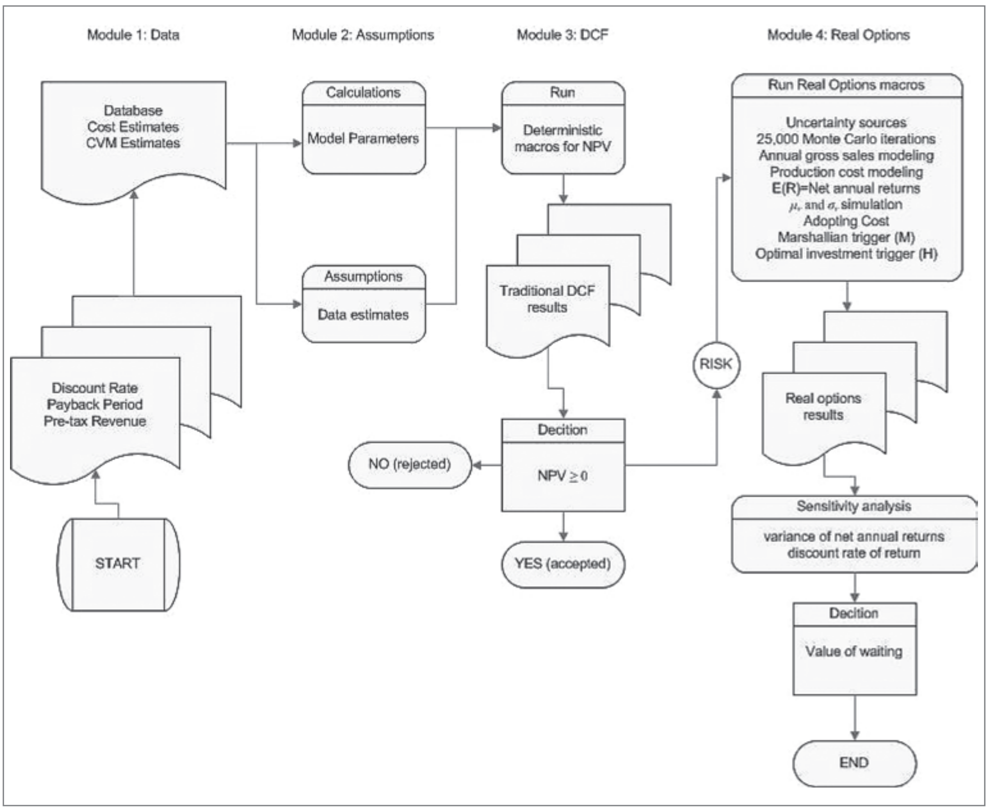

Fig. 2. Diagram of the flow chart of the method

tors were identified as critical for the evaluation of the "*wema*" project: (a) the annual gross sales and (b) the production cost. Then, @BEST FIT software (version 2) was employed in order to simulate the distribution of the uncertainty dataset (Palisade 1998). Specifically, annual gross sales of the "*wema*" project were modelled as a *gamma* distribution while the expected mean was 25,314 € per year with a standard deviation equal to 7,835 € per year. On the other hand, the production cost of the representative farm framework was modelled as *triangular* distribution while the most likely price was 0.28 € per kgr, with expected price ranging from 0.12 € per kgr to 0.69 € per kgr. In addition, simulated net annual returns [*E(R)*] from investing in the "*wema*" project have an expected mean equal to 1,823,451€ with a standard deviation of 512,000 €.

Table 2. Sensitivity analysis of the discount rate of return

NPV	Discount rate of return
1,316,789 €	1.00%
776,220 €	3.00%
312,678 €	5.00%
(NPV) 138,214 €	6.50%
0	7.74% (IRR)
−82,563 €	9.00%
−212,903 €	11.00%
−567,102 €	13.00%
−1,089,451 €	15.00%

Table 3. Sensitivity analysis of the model parameters

Model parameters (±20% fluctuation)	IRR				
	−20%	−10%	Basic scenario	+10%	+20%
Implementation cost	8.89%	8.27%	7.74%	7.24%	6.79%
Electromechanical outfit	7.76%	7.75%	7.74%	7.73%	7.72%
Mobile material	7.79%	7.77%	7.74%	7.72%	7.69%
Contract discounts	7.08%	7.41%	7.74%	8.04%	8.34%
Technical unpredictably	7.89%	7.81%	7.74%	7.66%	7.59%
Inflation	7.79%	7.76%	7.74%	7.71%	7.69%
Time horizon	7.53%	7.63%	7.74%	7.83%	7.94%
Operation cost	8.39%	8.11%	7.74%	7.45%	7.15%
Project benefits	7.33%	7.53%	7.74%	7.96%	8.15%

Following, one hundred iterations (simulations) were used to derive the parameters μ_v and σ_v on the value of the opportunity to invest in ICTs adoption project. The average investment cost of the "*wema*" project for the year 2009 is estimated to 750,000 €. The annuity is computed assuming a long-run loan of fifty years' duration and 6.5% rate of interest. The Marshallian trigger ($M = \rho K$) of the initial cost is equal to 75,312 € (Table 4). The net annual returns ($\beta/\beta-1$) of the investment have to be 1.493 times greater for the corresponding Marshallian trigger, which means that the net annual returns have to be larger than 112,440€ (Fig. 3).

Table 4. Parameters for value of adopting opportunity and value of waiting

Parameters	Values	Description
σ^2	0.018	Variance of the opportunity to adopt
β	3.028	Constant depended on the discount rate
β/β-1	1.493	Relation between Marshallian and Optimal triggers
B	2.3672E-19	Multiplicative constant
ρ	6.50%	Discount rate
ρ’	9.94%	Modified discount rate
M	75.312	Marshallian investment trigger
H	112.440	Optimal investment trigger
H-M	37.128	Difference between optimal and Marshallian triggers
ρ*V*(*R*)	37.128	Value of delay (waiting value)

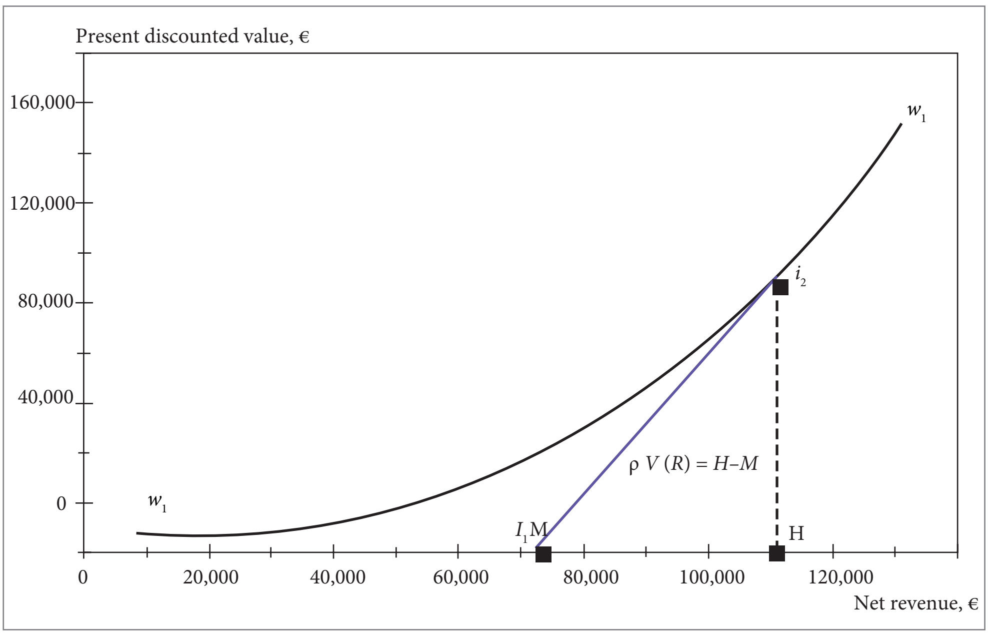

Fig. 3. Value of delay (waiting value)

Thus, while investing in the “*wema*” project proved feasible according to NPV criterion, it is not feasible according to a methodology incorporating real options approach. The simulated annual returns [*E(R)*] have to be larger than 112,440 € according to the optimal investment trigger (*H*); otherwise they are equal to 30,000 €. The real options procedure revealed that [*H>E(R)*], the project must be postponed and decision makers must keep the option of investing on hold. Thus, adopting a real options approach alters the results and enriches the assessment analysis.

The value of waiting can be illustrating using a diagram described by Dixit (1992: 118). This involves a single project with irreversible expenditure (*I*) that yields a stream of net revenue (*R*) which lasts forever. This revenue stream is uncertain with a given probability distribution and is discounted by a positive interest rate (*r*). The standard present discount approach implies that one should adopt whenever *R/r* exceeds *I*. This involves the implicit assumption that the choice is between adopting now or never. However, the additional possibility of waiting can be better than the possibility of not adopting at all or implementing the project immediately.

The optimal waiting time and therefore the optimal trigger point, is determined where the marginal value of waiting is equal to the marginal value of investing. The former is equal to the slope of the value of investing schedule shown as W_1W_2 in Fig. 3, where net revenue (*R*) is on the horizontal axis and the present discounted value of the entire investment project (*R/r-I)* is on the vertical axis. When the current value of *R* is very low, the present discounted value of future receipts is also very low, and the W_1W_2 schedules goes to zero from above as *R* goes to zero. Increasing current values of *R* raises the present discounted value of the project, resulting in the convex curve W_1W_2. The marginal value of investing is equal to *1/r* and is equal to the slope of the I_1I_2 schedule, which shows the value of net revenue (*R/r-I*) as a function of *R*. The optimal value for the net revenue is given by the trigger point which is where the two schedules are tangent to each other at point I_2. This is known as the smooth pasting condition which equates the marginal value of waiting with the marginal value of investing (Dixit 1992: 116).

As one can see in the Table 4 the discount rate of return (ρ) differs from the modified one (ρ') which includes uncertainty and irreversibility. The modified minimum rate of return (ρ') estimated 9.94% which have to be used hereafter, instead of the traditional discount rate of return (ρ), for the optimal investment decision. The multiplier β/β-*1* is a function of the discount rate of return (ρ) and the variance of the net annual return (σ) of the investment. Thus, in the analysis below, we will check the sensitivity of these two parameters to define their effects in the adoption behaviour of the stakeholders for the construction of the "*wema*" project.

There are a variety of ways to complete a sensitivity analysis on these results. We opted for the choice where we vary (±20%) the weights of net annual returns of the investment and the discount rate of return. Table 5 presents the sensitivity analysis of the variance of net annual returns of the investment. It is obvious that the modified rate of return (ρ') changes proportionately with the variance changes (σ), indicating positive influence. In particular the modified rate of return (9.94%) increases (12.23%), with standard deviation equal to 0.4 as the variance increases from 0.134 to 0.200. As well as perceived corresponding increase of the optimal investment trigger (*H*) from 112,440 € to 309,451 €. Finally, the annual value of net revenue [ρ*V(H)*] increases as the uncertainty increases (σ).

Consequently, the question to come is that the value of waiting increases as the uncertainty increases which means that the construction of the "*wema*" project must be postponed and the decision makers must keep the option of adopting on hold until obtain better information and know how. The second parameter which influences the optimal adoption decision is the discount rate of return. The sensitivity analysis indicates that the value of waiting increases as the discount rate decreases. In particular the value of waiting [ρ*V(H)*] and the Marshallian point increase as the discount rate of return decreases from 6.5% to 5.0%. As well as the modified optimal investment policy influenced from the changes of the discount rate of return. Table 6 appears that the annual value of investment increases with a bigger rate than the disease of the discount rate of return which means that it is better to delay the implementation of the "*wema*" project.

Table 5. Sensitivity analysis of the variance of net annual returns of the investment*

σ	0.134	0.100	0.150	0.200
σ^2	0.0018	0.0100	0.0225	0.4000
ρ'	9.81%	8.07%	10.38%	12.23%
H	112.440	98.886	156.390	309.451
$\rho V(H)$	37.128	27.543	56.212	78.332

* *the following parameters stand constant, M = 75,312 and ρ = 6.5%.*

Table 6. Sensitivity analysis of the discount rate of return**

ρ	6.50%	5.00%	8.00%
ρ'	9.94%	8.36%	10.68%
M	75.312	53.129	128.784
H	112.440	76.452	231.894
$\rho V(H)$	37.128	23.323	103.110

** *the following parameter stands constant* $\sigma^2 = 0.018$.

4. Discussion

This paper offers an example of contractual agreement within a large ICT project that can be assessed using real options techniques. In addition, an attempt has been made to employ both the NPV criterion and the real options approach and finally to compare results. Monte Carlo simulation was used to value the options as it offers the flexibility to directly simulate the underlying uncertainty factors and to capture a great deal of the complexity in the contractual terms.

Empirical results revealed that the options have a significant value and highlight the fact that ignoring options value process can lead to a significant error. This obviously indicates the importance of combining the NPV criterion in agricultural extension investments with the real options approach. In particular, two main results extract from the existing analysis: a) the value of waiting increases as the uncertainty increases, which means that the implementation of the "*wema*" project must be postponed and b) a negative relationship between the value of waiting and the discount rate is detected which means that the optimal investment decision significant influenced by the discount rate of return. Actually, the value of waiting and the Marshallian point increase as the discount rate of return decreases while the annual value of investment increases with a bigger rate than the disease of the discount rate of return which means that it is better to delay the implementation of the "*wema*" project and the decision makers must keep the option of investing on hold until obtain better information and know how.

From a methodological point of view, traditional DCF techniques in agricultural extension investments are often associated with uncertainty problems and they are not adequately addressed. Thus, a real options approach can be very useful in investment evaluations as the uncertain and irreversible investment environment can be better accommodated. At a theoretical level, the paper yields the unambiguous result that evaluation under uncertainty causes significant changes in investment decision. At an empirical or practical level, the paper illustrates how novel investment tools can be applied into agricultural extension issues and how the theoretical findings can be translated into empirical actions, working as a catalyst of decision' change, through the employment of a real options model.

5. Conclusions

The application presented here has not only local interest but it also has influential implications for international economics and agricultural policies. Actually, it is not a unique agricultural extension project. There are many other similar ones in several other local communities, in both developed and developing countries, that rely on agriculture to some degree. In particular, an extra purpose of this application is to assist policy makers, programme planners and agricultural extension workers, internationally, to understand, implement and promote farm management strategies in their respective countries. Besides, most farmers often express the need for information to support their investing decisions and the desire to make best use of available and limited resources. So, the innovated application presented here could well have resonance in many other countries well beyond the Greece.

In addition, taking into account the great importance of ICTs as a principal change driver in rural areas, as well as the great contribution of the agricultural sector in the general domestic product of the country, a study describing a structural tool of ICTs investment evaluation for rural community based groups, in order to enhance farm efficiency, can prove extremely valuable. Besides, the implementation of the "*wema*" project has been proven useful to both local policy makers and individual farmers. Actually, vita the "*wema*" project local policy makers will improve their communication process with farmers and therefore they will be able to assess the farm business' efficiency in rural areas and the feasibility of farm management practices in order to achieve the rural development of the area. On the other hand, farmers will be able to have access to a large, detailed socioeconomic and geospatial datasets in order to have a clearer understanding of the consequences of any decision that would affect the status of their current agricultural economic activity.

Consequently, the study attempts both to provide interesting results as well as to demonstrate verifiability since the generalized application of the real options approach lead to compatible outcomes. However, as a first systematic attempt to adapt an engineering economics model in the agricultural extension issues, the employed model was limited to an *ex-ante* examination and to a rather small number of estimated uncertainty elements. Therefore, results should be seen with caution when are used for generalizations. Further, it is advisable to concurrently investigate differing rural areas, including, for example, areas close to urban centres or related to more 'elitist' activities such as agro-tourism which may be more familiar to technologies and thus have different ICTs diffusion patterns.

References

Alexopoulos, G.; Koutsouris, A.; Tzouramani, I. 2010. Adoption and use of ICTs among rural youth: Evidence from Greece, *International Journal of ICT and Human Development* 2(3), 1–18. doi:10.4018/jicthd.2010070101

Black, F.; Scholes, M. 1973. The pricing of options and corporate liabilities, *Journal of Political Economy* 3: 637–654. doi:10.1086/260062

Cox, J.; Ross, R; Rubinstein, M. 1979. Option pricing: a simplified approach, *Journal of Financial Economics* 7(4): 71–90.

Dixit, A. 1992. Investment and hysteresis, *Journal of Economic Perspectives* 6(1): 107–132.

Dixit, A.; Pindyck, R. S. 1994. *Investment under uncertainty*. Princeton University Press, Princeton, NJ.

Gittinger, J. P. 1986. *Economic analysis of agricultural projects, International bank for reconstruction and development*. The John Hopkins University Press, Baltimore.

Jones, C. 1996. *Investments: analysis and management*. John Wiley & Sons, Inc. (Fifth edition), New York.

Kahraman, C.; Kaya, I. 2010. Investment analyses using fuzzy probability concept, *Technological and Economic Development of Economy* 16(1): 43–57. doi:10.3846/tede.2010.03

Kassarr, I.; Lasserre, P. 2004. Species preservation and biodiversity value: a real options approach, *Journal of Environmental Economics and Management* 48(2): 857–879. doi:10.1016/j.jeem.2003.11.005

Koutsouris, A. 2010. *The emergence of the intra-rural digital divide: a critical review of the adoption of ICTs in rural areas and the farming community.* Prepared for presentation at the 9th European IFSA Symposium. Vienna (Austria), 4–7 July (forthcoming).

Kurlavicius, A. 2009. Sustainable agricultural development: knowledge-based decision support, *Technological and Economic Development of Economy* 15(2): 294–309. doi:10.3846/1392-8619.2009.15.294-309

Louberge, H.; Villeneuve, S.; Chesney, M. 2002. Long-term risk management of nuclear waste: a real options approach, *Journal of Economic Dynamics and Control* 27(1): 157–180. doi:10.1016/S0165-1889(01)00058-6

Michailidis, A. 2006. Managing tourism investment opportunities under uncertainty: a real options approach, *International Journal of Tourism Research* 8(5): 381–390. doi:10.1002/jtr.585

Michailidis, A.; Mattas, K. 2007. Using real options theory to irrigation dam investment analysis: an application of binomial option pricing model, *Water Resources Management* 21: 1717–1733. doi:10.1007/s11269-006-9122-3

Michailidis, A.; Mattas, K.; Karamouzis, D. 2008. A socioeconomic assessment of an irrigation dam by introducing real options approach, *Water Policy* 11(4): 481–488. doi:10.2166/wp.2009.057

Michailidis, A.; Koutsouris, A.; Mattas, K. 2010. Information and communication technologies as agricultural extension tools, *Journal of Agricultural Education & Extension* 16(3): 249–263. doi:10.1080/1389224X.2010.489767

Morck, R.; Schwartz, E.; Stangeland, D. 1989. The valuation of forestry resources under stochastic prices and inventories, *Journal of Financial and Quantitative Analysis* 24: 473–487. doi:10.2307/2330980

NSSG – National Statistical Service of Greece 2009. Inventory of Greek Agriculture. Athens [in Greek].

OECD – Organization for Economic Cooperation and Development 2006. OECD broadband statistics, December 2005. Available from Internet: <http://www.oecd.org/document/39/0,3343,en_2649_34225_36459 431_1_1_1_1,00.html>.

Palisade Corporation. 1998. *@BEST FIT: Distribution Fitting Software Package*. Version 2, Newfield, NY.

Palisade Corporation. 2000. *@RISK: Risk Analysis and Simulation Add-In for Microsoft Excel: A Software Package*. Version 4, Newfield, NY.

Rogers, E. 1995. *Diffusion of innovations.* 4th ed. New York: The Free Press.

Ross, S. A.; Westerfield, R. W.; Jordan, B. D. 2000. *Fundamentals of corporate finance*. Irvin McGraw-Hill (Fifth edition), Boston.

Sun, Y.; Wang, H. 2005. Does Internet access matter for rural industry? A case study of Jiangsu, China, *Journal of Rural Studies* 21: 247–258.

Tzouramani, I.; Mattas, K. 2004. Employing real options methodology in agricultural investments: the case of greenhouse construction, *Applied Economics Letters* 11(6): 355–359. doi:10.1080/1350485042000189550

Ucal, I.; Kahraman, C. 2009. Fuzzy real options valuation for oil investments, *Technological and Economic Development of Economy* 15(4): 646–669. doi:10.3846/1392-8619.2009.15.646-669

Verdegem, P.; Verhoest, P. 2009. Profiling the non-user: Rethinking policy initiatives stimulating ICT acceptance, *Telecommunications Policy* 33: 642–652. doi:10.1016/j.telpol.2009.08.009

INOVACINIŲ ŽEMĖS ŪKIO PLĖTROS PROJEKTŲ VERTINIMAS NAUJOMIS INVESTICINĖMIS PRIEMONĖMIS

A. Michailidis, F. Chatzitheodoridis, G. Theodosiou

Santrauka. Straipsnyje aprašomos naujos investavimo į žemės ūkio plėtrą vertinimo priemonės. Sukurta realių alternatyvų metodologija, kuri pritaikyta inovatyviame „Wema“ žemės ūkio projekte. Empiriniai rezultatai atskleidė, kad pagal tradicinį kriterijų – grynąją dabartinę vertę – „Wema“ projektą įgyvendinti įmanoma. Tačiau projekto dalyviai, šiuo metodu vertindami neapibrėžtumus, gali priimti klaidingą sprendimą ir projektą atmesti. Tai akivaizdžiai rodo, kad vertinant žemės ūkio plėtros projektus, grynosios dabartinės vertės kriterijų reikia derinti su realių alternatyvų metodologija.

Reikšminiai žodžiai: žemės ūkio plėtra, inovacija, investavimas, Monte Karlo metodas, realios alternatyvos, modeliavimas.

Anastasios MICHAILIDIS is a Lecturer of Agricultural Extension at Aristotle University of Thessaloniki. His research interests include agricultural extension, agricultural education, adoption-diffusion of innovations, water resources management and information-communication technologies. His education includes a B.Sc. in Agriculture, a M.Sc. in Agricultural Economics and a Ph.D. in Agricultural Economics. He has published more than 50 papers in international refereed journals, in collective volumes and proceedings.

Fotios CHATZITHEODORIDIS is an Assistant Professor in rural and regional development in Technological Educational Institution of Western Macedonia, Greece and at the same time he teaches in University of Central Greece. Chatzitheodoridis is economist and holds a PhD in environmental studies (University of Aegean) and has been working for the Greek Ministry of Rural Development and Foods and Aristotle's University of Thessaloniki. His research interests revolve around sustainable rural development focusing on topics such as environment, project design and evaluation, with emphasis on systemic and participatory approaches.

George THEODOSIOU is an Assistant Professor of Economic Analysis. His education includes a B.Sc. in Economics from University of Piraeus, a M.Sc. in Marketing from University of Clermont and a Ph.D. in Agricultural Economics from University of Thessaly. His research interests include Econometrics, Marketing, Agricultural and Social Policy, Rural Development and Interdisciplinary work. He has published many papers in international refereed journals, in collective volumes and proceedings. He has also contributed to several international conferences and served as a referee to international journals.