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REAL OPTIONS FOR AGRICULTURAL INVESTMENTS

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Abstract: We present an overview of the real options methodology and its applications in agricultural decision making. We examine the current state of research on real options in agriculture as well as propose a range of possible extensions and further applications of diverse types of real options in agricultural investments and their policy implications.

Keywords: real options, agricultural investments, agricultural policy

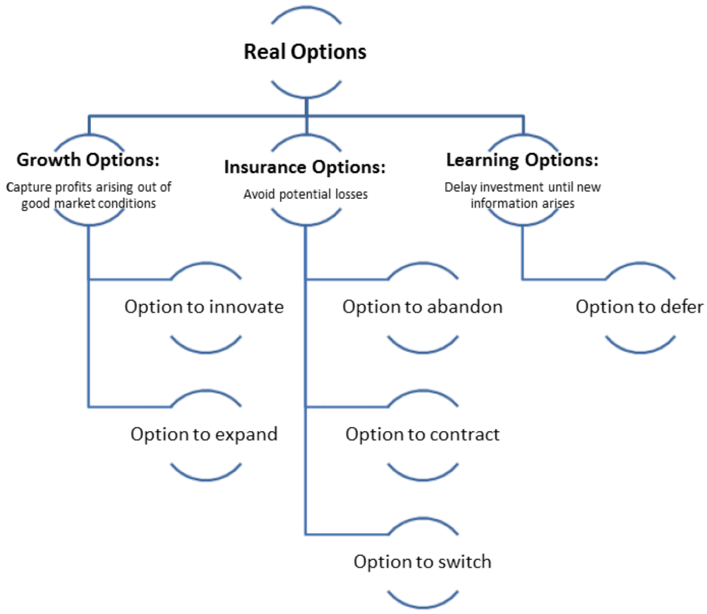
INTRODUCTION

Farmers nowadays are facing important strategic investment decisions (such as, for example switching from traditional to organic farming methods), which are to be made in uncertain environments, in which market growth, price moves, costs of development of new technologies or weather conditions may be unknown or difficult to assess [Dixit and Pindyck, 1994; Pindyck, 1991]. Thus, evaluating the adoption of any investment plan in agriculture must be accompanied by an investigation of the effect of uncertainty and risk. The classical methods of valuation require tools relying on forecasts of future cash flows, which often do not reflect the immanent uncertainty. The second problem is that the decisions about undertaking a particular project are taken once and for all - traditional discounted cash flow approach does not allow for recapitulation at a later stage. Although, in agricultural decisions it is often the case that investments are irreversible or difficult to be changed once have been made i.e. cutting the forest and using land for agricultural purposes instead cannot be easily changed (the forest can be even lost forever if the top soil is destroyed), but one needs a valuation method which is flexible enough to be applied to a broad range of agricultural problems. Theoretical advances in real options methodology have progressed very rapidly and have been assimilated in several empirical applications. Real options have been identified and valued in projects with high uncertainty, and a growing body of literature provides various examples of flexible investment strategies [Tzouramani and Mattas, 2004]. In recent years, real options have been adopted to analyze diverse branches of the economy: R&D investments [Childs and Triantis, 1999; Huchzermeier and Loch, 2001], intellectual capital investments [Bose and Oh, 2003; Kossovsky, 2002], patent valuation [Laxman and Aggarwal, 2003; Ming-Cheng and Chun-Yao, 2006] etc. all of which reveal similar characteristics to agricultural investment decisions, namely the high level of uncertainty. Only a limited number of studies, however, have implemented real options in agriculture. In this work, we focus on practical examples of how real options methodology can facilitate investment decision making in agriculture. The rest of the work is structured as follows. Section REAL OPTION METHODOOGY presents the overview of the real options valuation method. Section REAL OPTIONS IN AGRICULTURE presents an extensive survey of the literature related to the use of real options in agricultural decision–making processes. Section FURTHER APPLICATIONS presents further applications, for which we claim that the real options approach should be used. The last section concludes.

REAL OPTIONS METHODOLOGY

Based on Black and Scholes [1973], Myers [1987] developed the idea of a real option, as the right but not the obligation to purchase a real asset. In analogy to financial options, a real option which gives the owner the right, but not the obligation to make a specific investment at a specific price in the future. The two most common styles of options are European and American options. The former may be exercised only at the pre–specified expiration date of the contract, whereas the latter can be exercised at any time before the expiration date. Each style reflects a specific investment situation: the former works for investments that need to be taken at a specific time (e.g. investment in pest control of crops, investment in planting a specific type of a crop), the latter for opportunities that can be exercised in a less specified future (e.g. switching o organic farming methods, building a greenhouse etc.) By construction, the real options approach allows explicit inclusion of the uncertainty in the decision-making process. The real options approach considers multiple decision pathways as a consequence of uncertainty in choosing optimal strategies or options along the way when new information becomes available [Mun, 2006]. Figure 1 presents the overview of types of real options.

Figure 1: Main types of real options



Source: own work

Each type of a real option corresponds to a analogous financial option e.g. option to delay investment to the future can be seen as an American call option from the perspective of the investor e.g. a farmer: like the owner of a call, the farmer has the right, but not the obligation to pay a fixed sum I and to receive a stochastic cash flow with a discounted value V (t). Standard discounted cash flow approach prescribes to conduct the investment as long a $V - I > 0$, whereas this formula does only account for the intrinsic value of the investment, and neglects the continuation value[1]. To include the uncertainty associated with the investment, the real option approach would prescribe that the value of the investment changes over time according to

$$(dV(t))/V = \mu dt + \sigma dz, \qquad (1)$$

a standard Brownian motion, where σ is the variance, and *dz* is the increment of the Wiener process, for which it holds that

$$dz = \varepsilon_t \sqrt{dt}, \qquad (2)$$

[1] For additional details, please refer to financial options literature e.g. Black and Scholes [1973], or real options literature e.g. Trigeorgis [1996].

where ε_t ~ (0, 1). Therefore, changes in the value of the investment are a function of μ and σ, which is governed by the increment of the Wiener process *dz* [Dixit and Pindyck, 1994]. The new decision rule, taking into account the future changes of value is a solution to the corresponding Bellman equation

$$F(V,t) = max\left\{V(t) - I, \frac{1}{1+kdt} * E(F(V+dV, t+dt)|V(t))\right\} \quad (3)$$

where *F* denotes the value of the option to invest, *k* is a discount rate, and *E* indicates the expectations operator. Since finding the maximand of (1) requires solving a partial differential equation, in case of complicated real options, in particular most of the American style options, an analytical solution might not be possible to find, in which case, one can refer to numerical methods, such as the binomial lattice method or Monte–Carlo simulation.

Let us turn to a detailed description of the real options by types. According to classification found in Figure 1 "a growth option" allows a decision–maker to secure profits if the market conditions occur to be better than expected. This can be accomplished by reinvesting the capital e.g. expanding the scale of production or entering new market sectors. Additional sources of the growth options comprise R&D and innovation, intellectual property and change in the market position. Growth options are the equivalent to a financial call option. This kind of option can be used whenever a farmer decides to expand his operations. Once a project is undertaken, he may have the flexibility to alter it in various ways at different times during its life. When a farmer buys vacant, undeveloped land, or when he builds a new facility in a new location to position itself to develop a large market, he essentially acquires an expansion option.

"Insurance options" allow the management to scale down or abandon certain investments in order to avoid potential losses. Therefore, it is mainly seen as risk–reducing option. The value of the option stems from the opportunity to postpone or abandon unprofitable investments. Insurance options are equivalent to financial put options. In agriculture, insurance options can be found in various situations. A prominent example for an insurance option would be a pre–payment strategy in the wine industry or long–term contracts for delivery of certain types of crops. From a progressive point of view, insurance options are used in situations in which it becomes obvious that variable costs exceed market prices. The option to switch can also be seen as an insurance options. In this, they include situations in which one can use agricultural land in diverse way e.g. switch to a different type of a crop or plant a coppice instead of growing crops.

Finally, "learning options" allow the decision-maker to "wait and see". In other words, they allow the decision-maker to defer decisions regarding investments. The value of the option stems from the opportunity to wait for the resolution of uncertainties before committing resources to investment. A specific type of learning options, the deferral option, or option of waiting to invest, derives its value from reducing uncertainty by delaying an investment until more information has arrived. These types of options are of particular importance in agricultural investments. The scope of applications of the deferral option in agriculture is described in more details in the next two sections.

REAL OPTIONS IN AGRICULTURE

In this section we provide an overview of recent applications of the real option method in agricultural decision–making. As the literature on real options in agricultural investments is fairly scarce, the following survey is structured chronologically rather than subject to the topic covered. It can be, though, seen that the first strand of real options applications for agriculture concentrates on the irreversible investments, whereas more recent works broaden the scope into more diverse applications. One of the first works that applied the real option approach in agriculture is Purvis et al. [1995] who analyze the technology adoption of a free-stall dairy housing under irreversibility and uncertainty and its implications for the design of environmental policies. The free-stall investment involves significant start–up costs and limited potential for recouping the investment capital quickly should it become necessary to disinvest [Purvis et al. 1995]. Authors use data from early adopters in central Texas and calculate expected returns from investing in a 1000-cow free-stall facility. Subsequently, they compare the expected returns from the technology change as compared to the prevailing technology, open-lot dairying, assuming that the returns are influenced by two stochastic factors: milk production and feed costs. Authors conclude the analysis with relevant policy implications: they identify that adoption of the new technology can be precluded by the risk associated with investment and uncertainty regarding the investment cost. Moreover, authors quantify the magnitude of these factors and provide policy recommendation of subsidizing producers willing to adopt the new technology in order to obtain an optimal level of investment.

Winter-Nelson and Amegbeto [1998] analyze present a model of investment under uncertainty to analyze the effect of variability of prices on the decision to invest in soil conservation and apply it to the case of adoption of Fanya Juu terraces in eastern Kenya. Authors claim that changes in policy that lead to increase in the output prices encourage agricultural investment, however, simultaneous increase in price volatility could reduce incentives to invest. Real options model is in this case the most appropriate method of analysis as it directly incorporates the underlying investment risk. They test the hypothesis and find confirmation of the assumptions, which then leads to policy implications. Empirical study shows that commodity market liberalization changes the value of options enough to influence terrace adoption in Kenya. This result also highlights the need of economic institutions to moderate the price movements during and after market reforms.

Yet another application of real options for the case of irreversible investments with high sunk costs comes from Price and Wetzstein [1999], who analyze the market for perennial crops. In particular, production of perennial crops such as peaches requires a large sunk cost of orchard establishment and high uncertainty of future yields and prices. Similarly to previous cases, addition of the uncertainty to the model results in different decisions than ones arising from a standard NPV approach. Incorporating price and yield uncertainty, the irreversibility of the investment decision, and the value of the option to delay production enters into the decision, results in a 120% increase in the entry threshold and a 3% decrease in the exit threshold from the thresholds found conventionally [Price and Wetzstein, 1999]. Another agricultural application of a model of irreversible investment under uncertainty can be found in Tegene et al. [1999], who analyze landowner's decision to convert farmland to urban use. Application of the real option method leads to a conclusion that even under certainty about future returns to urban use, it may be optimal to delay conversion in order to realize returns to agriculture until they are exceeded by urban returns net of conversion costs, even if urban value already exceeds agricultural value Tegene et al. [1999]. Moreover, it seems that conservation easements are currently underpriced and that farmland owners might be reluctant to sell easements at the prices offered. In fact, conventional valuation procedures may also systematically overprice easements by inadvertently exaggerating the urban returns (based on comparisons with already-converted parcels) that could be realized on yet-to-be converted parcels of agricultural land.

Finally, Khanna et al. [2000] applies an option-pricing model to analyze the impact of uncertainty about output prices and expectations of declining fixed costs on the optimal timing of investment in site-specific crop management (SSCM). It also analyzes the extent to which the level of spatial variability in soil conditions can mitigate the value of waiting to invest in SSCM and influence the optimal timing of adoption and create a preference for custom hiring rather than owner purchase of equipment. Numerical simulations show that while the net present value (NPV) rule predicts that immediate adoption is profitable under most of the soil conditions considered here, recognition of the option value of investment indicates that it is preferable to delay investment in SSCM for at least 3 years unless average soil quality is high and the variability in soil quality and fertility is high. The use of the option value approach reveals that the value of waiting to invest in SSCM raises the cost-share subsidy rates required to induce immediate adoption above the levels indicated by the NPV rule [Khanna et al. 2000].

The second strand of research initiated in the beginning of 2000s, further developed the idea of real options in agriculture, beyond the cases of irreversible investments. Among miscellaneous topics, current agricultural and environmental topics such as organic farming, fisheries sustainability and pest control are covered. Work by Kuminoff and Wossink [2005] is the first attempt to analyze the farmer's decision to convert from traditional to organic farming using the real options approach. Using county data on organic and conventional corn and soybean production in the U.S., authors develop a theoretical model to assess the dollar compensation required for the conversion to organic farming. Authors relate their result to policies that can ease adoption of organic farming, and estimate with the example of the Conservation Security Program adopted in the U.S., the size and the duration of the necessary payments to the farmers.

Optimal pesticide control of crops is a subject of works by Saphores [2000] and Mbah et al. [2010]. The former paper formulates an optimal stopping model for applying pest control measures when the density of a pest population varies randomly. A delay between successive pesticide applications is introduced to analyze the farmer's expected marginal cost of reentry. This model is applied to the control of a foliar pest of apples via a pesticide, and solved numerically. A sensitivity analysis shows that the pest density that should trigger pesticide use can vary significantly with the pest density volatility. Incorporating pest randomness into decision rules helps better manage the chemicals applied to soils and crops [Saphores, 2000]. The latter work by Mbah et al. [2010] who develop a framework to examine the economically optimal timing of pest treatment. The real option analysis suggests that the decision to treat should only be undertaken when the benefits exceed the costs by a certain amount and not if they are merely equal to or greater than the costs as standard net-present-value (NPV) analysis would prescribe. This criterion leads to a large reduction in fungicide use which is associated with significant economic and environmental benefits. Authors then investigate the effect of the model for disease progress on the value required for immediate treatment by comparing two standard models for disease increase. Analyses show that the threshold value of benefits required for immediate release of treatment varies significantly with the relative duration of the agricultural season, the intrinsic rate of increase of the disease and the level of uncertainty in disease progression.

A fistful of other topics has been additionally analyzed up to now; Musshoff [2012] examines the decision to grow short rotation coppice on agricultural land in Germany, Fenichel et al. [2008] analyses precautionary fisheries management; in Odening et al. [2005] option–pricing theory is applied to an investment problem in hog production; finally Luong and Tauer [2006] explain with the use of the real option theory a significant growth in coffee production in Vietnam in the recent years.

FURTHER APPLICATIONS

In the previous section we examined the current strand of research of real options for agricultural applications. The presented overview highlights the broad scope of possibilities of application of the real options method in this context. This part of the work is dedicated to presenting possible further applications and research that can help modernize decision making in agriculture. The previous section has also highlighted the main advantage of the real options methodology over other valuation methods, as it allows to make predictions which include the value of risks associated with investments. Table 1 presents an extract of main uncertainty and risk factors facing agricultural production and types of insurance procedures against each of them, which will be also described in more detail later on. As a matter of fact, whenever any of these risks/uncertainties appear as a factor of a valuation of opportunities stemming from investments, one should refer to real options methodology, as it allows to directly incorporate them into the value of the decision. In the traditional NPV approach, estimation of the discounted stream of profits does not explicitly include the volatility of the stream of profits, resulting from the identified risks. In the presence of substantial risks, that affect agricultural production, as identified in Table 1, exclusion of this information from the model should be considered inappropriate and may results in wrong decisions. An example of how real options incorporate directly the issue of uncertainty, has been presented e.g. in Winter-Nelson and Amegbeto [1998].

The following overview is structured according to the main types of real options as presented in Figure 1. Among the presented literature items, what can be qualified as ”growth options” are applications presented in Winter-Nelson and Amegbeto [1998], Price and Wetzstein [1999], Khanna et al. [2000] and Luong and Tauer [2006]. All of these works deals with the value of irreversible investments which can, but not necessarily will, lead to an increase in productivity of the farmer. This type of reasoning can be applied to many agricultural decisions, in which a farmer is presented with an opportunity to build his strategy on a substantial investment, often associated with high sunk costs, but leading to an increase in productivity. Other than straightforward options to expand production, an obvious example of growth options in agriculture are innovations. A farmer can decide to adopt a multitude of innovations, which would increase his productivity, whereas we concentrate here on embodied innovations, for which it is feasible to quantify their impact. Agricultural innovations can be categorized into certain classes, each of which can be valued with real options analysis. Product innovations, though not happening very often, happen occasionally e.g. safflower which was introduced in the 1950s. With biotechnology, one may expect innovations that will be new, value–added final products that can be produced by the agricultural sector. More commonly, agriculture is often impacted by process innovations. A yield–

increasing innovation, that is introduction of new high-yield varieties, is the most often encountered. Among these, one can distinguish between innovations that increase the mean–yield and those that influence the variability of the yield. Both of these changes, as seen in Equation (1), will be clearly reflected in the value of the real option. Notice, the substantial advantage of the real option method over the traditional NPV approach, for which the value of the variability altering innovation will not be captured at all. Cost–reducing innovations, such as a new and improved type of harvesting equipment which may be most noted for its labor-saving effect or a new irrigation technology having a water–saving effect, can be both quantified and used as input data for the growth option analysis. Given the inelastic demand for the main agricultural commodities and some products, one way to increase value added in agriculture, which can be quantified and valued with the real options methodology is improvement of product quality.

Table 1: Types of risks in agriculture.

Type of risk	Risk	Insurance Instrument
Political	Direct subsidies Biofuel Price setting (e.g. intervention prices) Environment regulations	
Production	Diseases Weather conditions Yield Pest	Insurance Insurance
Market	Sales Commodity prices Product quality Production factors prices	Commodity forward exchange
Personal	Absence of staff	
Assets	Fire Theft Damages	Insurance Insurance Insurance
Soil / Environment	Environmental damages Contamination	

Source: own work

New genetic engineering varieties are expected to significantly augment product quality, for example, by enhancing shelf life, improving the nutrient content, and improving appearance, and a growth option to invest in the improved technology, can in this case be valued with a model that accounts for all these factors, as well as their variability. Finally, the public is increasingly concerned about food safety, worker safety, ground water contamination by pesticides, and other types of negative external effects of agriculture. The development of technologies that improve environmental quality or at least reduce damages relative to existing technologies is becoming a major research and policy priority. In order to fully describe the economic value of investment in the environmental innovations, policy makers as well as researchers could refer to real options methodology of assessment.

Learning options arise whenever a farmer is facing a decision that is affected by such a high uncertainty of future events, that it might be profitable to defer the investment until new market information is available. These cases were also highlighted in the cited literature e.g. in Saphores [2000] and Mbah et al. [2010], who adopt the idea that pest control should be adapted, always when new information about the previous round of a spraying has arrived. Of particular importance in agricultural investments are political decisions, which strongly affect the environment in which a farmer operates. Among these, typical examples include production quotas for agricultural products set by the European Union, the effects of the financial crisis on the future composition of the direct subsidies to agriculture, the current values of intervention prices at which national intervention agencies in the EU are obliged to purchase commodities, and others. Real options analysis offers, in each case, a methodology to find the value of deferring any investment decisions until the crucial information is available.

Finding insurance options in agricultural applications, other than the straightforward options to abandon investments or switch the type of activity, is a bit trickier. In financial terms, owning an insurance option is equivalent to a form of hedging behavior. There exist various financial instruments, which can be used as diverse forms of hedging also in agricultural context. For example, it is a common practice of wine producers, to sell their product before it actually starts to exist. Another example of a typical insurance behavior in agricultural applications is the use of weather derivatives. There are, however not many obvious agricultural examples of 'real' rather than financial hedging behavior, but identification of such opportunities would be of great value to any farmer. A typical example of a real insurance option stems from crop fertilization. A farmer, who over fertilizes his crops is insuring himself against a variety of possible weather conditions that may arise: whenever the weather conditions are good, the plants will use the additional portion of a fertilizer, and if they are bad, the excess of fertilizer will not harm the yield (it creates an externality on other farmers, but this is not important for an individually rational decision). Further example of a real insurance option of great importance in modern agriculture, in particular in the organic farming sector, is vertical integration. Vertical integration allows the farmer to fix the prices for his product, and in this sense it insures him against unfavorable market conditions.

CONCLUSIONS

In this work, we have presented an overview of the real options methodology and its applications in agricultural decision making. We also examined the current state of research on real options in agriculture as well as proposed a range of possible extensions and further applications of diverse types of real options in agricultural investments. Each of the identified options corresponds to either an individual farmer's decision making, or an agricultural problem which could be considered a policy issue. Among the latter category, the cited works of Kuminoff and Wossink [2005], Fenichel et al. [2008] and Musshoff [2012] raise vast topics in modern agricultural policy making: organic farming, fisheries management, the adaptation of farming land to different uses and so on. In each of these examples, real options methodology highlights how misleading policy decisions are, when they are solely based on the traditional net present value approach in an industry, which is exposed to so many factors of uncertainty and high volatility of outputs. Policy makers should, in any case, modernize the way they think about cost–benefit analysis in a way that directly allows for inclusion of the flexibility and uncertainty in the decision–making process.

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