Assessment of irrigation dam using real options and discounted cash flow approaches: a case study in Greece

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Abstract

This article extends the evaluation techniques of an irrigation dam in northern Greece, called “Petrenia”, by comparing the real options approach along with, a traditional one, the discount cash flow. By introducing first a Monte Carlo simulation, the various uncertainty factors can be simulated and alternative value options can be computed, feeding them later in the real options model. Results from the case study in Greece clearly demonstrate that the irrigation dam can be classified as a profitable investment, by applying traditional discount cash flow analysis, while by applying the real options approach the project cannot be classified as profitable. Taking into consideration the uncertainty factors, the real options approach reveals that the investment could be postponed and decision makers can keep the option of investing open. Sequentially, discount cash flow analysis accompanied by the real options approach facilitates decision making and improves the investment assessment analysis. In this particular project assessment, two uncertainty factors, variation in dam capacity and water price, restrict the profitability of the irrigation dam, according to the results of the real options approach.

Keywords: Dams; Investments; Net present value; Project assessment; Real options; Water management

1. Introduction

Huge investments, like irrigation dams, financed and supported by public funds, must be carefully evaluated, \textit{ex ante}, before a “go ahead” decision can be approved. Several dams are built throughout the world and the assessment of such investment should be better elaborated. In most of the cases, the discount cash flow (DCF) approach is followed, although several weaknesses have been identified. In this paper, a case study is presented by employing a combination of techniques, DCF and a real options approach. The case study refers to an evaluation of the “Petrenia” irrigation dam in northern Greece.


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It is planned to construct the “Petrenia” irrigation dam in a rural Greek area (eastern Chalkidiki-northern Greece) to irrigate around 1,000 ha of agricultural land (olive trees, vegetables, grape vines). The Petrenia irrigation dam will be financed by the Greek Ministry of Agriculture and the European Union. It is expected that the total construction cost will be recovered from beneficiaries collected from the water users. The Petrenia irrigation dam is classified as a large one, according to the definition of the International Commission on Large Dams (ICOLD, 1988) and its main characteristics are as follows: the total amount of water storage is equal to 3,900,000 m³, on an annual basis and aims to irrigate more than 700 ha of olive trees and 300 ha of other crops.

The main purpose of this work is to elaborate on the decision process in evaluating an irrigation dam project by employing both the real options approach and DCF techniques. The work mainly consists of two parts: first, the real options approach is discussed and second, an empirical application in an irrigation dam is attempted by employing the real options approach in combination with DCF techniques. The importance of incorporating the real options approach in irrigation dam evaluations is highlighted and fresh insights are gained.

The paper is organized as follows. First a literature review is offered followed by a brief description of the real options approach. Then, a description of the case study is presented and the results from the application are portrayed. Finally, the main conclusions and implications are drawn.

2. Literature review

Financial analysis of irrigation infrastructure investments is a very complex task mainly due to the required long planning horizon and immense demand of public funds. Traditional approaches, DCF techniques, are used extensively in evaluating investment opportunities simply by comparing the outcome between “with” the implementing of a specific investment and “without” undertaking the particular investment (Gittinger, 1986; Brealey & Myers, 1991; Luehrman, 1998). The DCF techniques are based on the assumption that future cash flows follow a constant pattern that can be accurately predicted. In addition the DCF techniques do not consider the irreversibility of any investment, now-or-never opportunity (Dixit & Pindyck, 1994).

Recent developments in investment analysis point out that DCF techniques have limitations when conditions of irreversibility and uncertainty are present because they lack the ability to account for various uncertainty factors (Morck et al., 1989; Dixit & Pindyck, 1994). More specifically, the net present value (NPV) rule assumes a fixed scenario in which an investor starts and completes a project and garners a cash flow during its lifetime without permitting the investor to react in the case of uncertainty. Actually, the present value of a project’s expected cash stream not only must be positive but also must exceed the cost of the project by an amount at least equal to the value of keeping open the investment option (Dixit & Pindyck, 1994).

The field of dam infrastructures entails many uncertainties, making strategic managerial decision making crucial. Thus, the evaluation of any dam investment has to be accompanied by an investigation of the effect of uncertainty and risk. Real options theory is explicitly based on the idea that most investment projects embed a series of alternative actions and uncertainties (Dixit & Pindyck, 1994). As discussed in Pindyck (1991), Dixit (1992) and Dixit & Pindyck (1994) investments with the aforementioned characteristics resemble financial call options. Theoretical advances in real options methodology have progressed very rapidly and have been assimilated in several empirical applications.
The real options approach arises because it offers a range of possibilities to examine either investing today, or waiting and perhaps investing later or when the conditions are more favorable.

One of the early motivations of real option theory was the uncertainty and irreversibility of natural resources development. However, although many studies have addressed natural resources investment analysis from a real options perspective, only a few of them were related to water context. It is important to note that the real options approach is used mostly in the literature on exhaustible resources and the present paper is attempting to extend its application to the water context.

The application of real options approach will not deem the traditional NPV obsolete, or replace it entirely. Actually, DCF techniques could be applied when there is no need to take into account how the ability to delay irreversible investment expenditure can affect the decision to invest. For example, reversible investments like real estate ones (Sivitanidou & Sivitanides, 2000), warranted capital investments without risk (Yeo & Qiu, 2003), small scale infrastructure projects without significant sunk costs (Keswani & Shackleton, 2006) and long range public forestry investments without uncertainty or future learning (Insley, 2002) are some of the cases where the DCF techniques could be applied. In contrast, real options evaluation could be applied as an additional analysis alongside current DCF techniques (Luehrman, 1998). In this way, the overall understanding of the investment decision is enriched and decision makers are equipped with a tool that helps them to explore the effects of uncertainty.

3. Methodology

The methodology section has been kept short describing the main elements of the model. In Table 1 the methodological framework for both the DCF technique and real options approach is illustrated. The first column lists the main functions of the empirical model and the second column presents the description of the key parameters of all the equations.

The choice between constructing a new infrastructure project or not can be based on the comparison of the incremental investment costs of the new infrastructure project and the present value of its incremental net revenue flow (Equation (1)). According to the acceptance rule, projects where incremental net revenues are greater or at least equal to incremental investment costs ($\text{NPV} = \text{PV} - I \geq 0$) are accepted.

The equation of the value of waiting and the value of investing describe the value of the opportunity to invest (Equation (2)). $H$ is the point where the value of investing and the value of waiting are tangential.

The parameter $\beta$ is a component of the equation for waiting and it is a function of two known or estimable parameters: $\rho$ and $\sigma^2$. As uncertainty about returns increases, $\beta$ gets smaller and the difference between the Marshallian trigger ($M$) and the optimal trigger ($H$) increases. A rise in the discount rate increases $\beta$ and reduces the difference between $M$ and $H$ (Equations (3) and (4)).

As discussed in Dixit (1992), investments with uncertainty and irreversibility have to be evaluated using a modified rate $\rho'$ which shows the effect of factoring in the value of waiting into the investment trigger (Equation (5)). This modified rate of return has to be used to determine the $H$ value which represents the difference between the Marshallian and the revised triggers.

A Monte Carlo simulation model is used to estimate the variance and the expected volatility of the value of investing in new dam construction technology. The estimation of the variance will be used to
Table 1. Equations and description of the parameters.

<table>
<thead>
<tr>
<th>Equation</th>
<th>Description</th>
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| (1) $PV = \int_0^t e^{-e^t} E[(P_t Q_{w,t} - C_{w,t}) - (P_t Q_{w,t} - C_{w,t})] dt$ | $I = $ incremental investment costs. $PV = $ present value of its incremental net revenue flow. $e = $ real discount rate. $t = $ time period. $E = $ expectations operator. $P = $ output price. $Q = $ output quantity. $C = $ variable costs of production. $w = $ indicates production "with" the investment. $o = $ indicates production "without" the investment. $BR = $ value of waiting. $R/\rho - K = $ value of investing. $V(R) = $ value of the opportunity to invest. $B = $ shifter which fixes the position of $w_1 w_2$. $\beta = $ shifter which determines the slope of $w_1 w_2$. $H = $ optimal investment trigger. $\rho = $ decision maker’s discount rate. $\sigma^2 = $ expected volatility in the value of investing over the life of the investment. $\rho' = $ modified rate which includes the effects of uncertainty and irreversibility. $V = $ value of the opportunity to invest. $\mu = $ constant drift rate. $\sigma = $ constant variance rate. $dz = $ increment of Wiener process, $z(t)$.
| (2) $V(R) = \begin{cases} BR^\beta & \text{if } R \leq H \\ R/\rho - K & \text{if } R \geq H \end{cases}$ | $Q = $ output quantity. $C = $ variable costs of production. $w = $ indicates production "with" the investment. $o = $ indicates production "without" the investment. $BR^\beta = $ value of waiting. $R/\rho - K = $ value of investing. $V(R) = $ value of the opportunity to invest. $B = $ shifter which fixes the position of $w_1 w_2$. $\beta = $ shifter which determines the slope of $w_1 w_2$. $H = $ optimal investment trigger. $\rho = $ decision maker’s discount rate. $\sigma^2 = $ expected volatility in the value of investing over the life of the investment. $\rho' = $ modified rate which includes the effects of uncertainty and irreversibility. $V = $ value of the opportunity to invest. $\mu = $ constant drift rate. $\sigma = $ constant variance rate. $dz = $ increment of Wiener process, $z(t)$.
| (3) $B = (H - \rho K)/H^\beta$ | $Q = $ output quantity. $C = $ variable costs of production. $w = $ indicates production "with" the investment. $o = $ indicates production "without" the investment. $BR^\beta = $ value of waiting. $R/\rho - K = $ value of investing. $V(R) = $ value of the opportunity to invest. $B = $ shifter which fixes the position of $w_1 w_2$. $\beta = $ shifter which determines the slope of $w_1 w_2$. $H = $ optimal investment trigger. $\rho = $ decision maker’s discount rate. $\sigma^2 = $ expected volatility in the value of investing over the life of the investment. $\rho' = $ modified rate which includes the effects of uncertainty and irreversibility. $V = $ value of the opportunity to invest. $\mu = $ constant drift rate. $\sigma = $ constant variance rate. $dz = $ increment of Wiener process, $z(t)$.
| (4) $\beta = \frac{1}{2} \left[ 1 + \sqrt{1 + \frac{8\rho}{\sigma^2}} \right] > 1$ | $Q = $ output quantity. $C = $ variable costs of production. $w = $ indicates production "with" the investment. $o = $ indicates production "without" the investment. $BR^\beta = $ value of waiting. $R/\rho - K = $ value of investing. $V(R) = $ value of the opportunity to invest. $B = $ shifter which fixes the position of $w_1 w_2$. $\beta = $ shifter which determines the slope of $w_1 w_2$. $H = $ optimal investment trigger. $\rho = $ decision maker’s discount rate. $\sigma^2 = $ expected volatility in the value of investing over the life of the investment. $\rho' = $ modified rate which includes the effects of uncertainty and irreversibility. $V = $ value of the opportunity to invest. $\mu = $ constant drift rate. $\sigma = $ constant variance rate. $dz = $ increment of Wiener process, $z(t)$.
| (5) $\rho' = \frac{\rho}{\sigma^2} \rho$ | $Q = $ output quantity. $C = $ variable costs of production. $w = $ indicates production "with" the investment. $o = $ indicates production "without" the investment. $BR^\beta = $ value of waiting. $R/\rho - K = $ value of investing. $V(R) = $ value of the opportunity to invest. $B = $ shifter which fixes the position of $w_1 w_2$. $\beta = $ shifter which determines the slope of $w_1 w_2$. $H = $ optimal investment trigger. $\rho = $ decision maker’s discount rate. $\sigma^2 = $ expected volatility in the value of investing over the life of the investment. $\rho' = $ modified rate which includes the effects of uncertainty and irreversibility. $V = $ value of the opportunity to invest. $\mu = $ constant drift rate. $\sigma = $ constant variance rate. $dz = $ increment of Wiener process, $z(t)$.
| (6) $\frac{dV}{V} = \mu dt + \sigma dz$ | $Q = $ output quantity. $C = $ variable costs of production. $w = $ indicates production "with" the investment. $o = $ indicates production "without" the investment. $BR^\beta = $ value of waiting. $R/\rho - K = $ value of investing. $V(R) = $ value of the opportunity to invest. $B = $ shifter which fixes the position of $w_1 w_2$. $\beta = $ shifter which determines the slope of $w_1 w_2$. $H = $ optimal investment trigger. $\rho = $ decision maker’s discount rate. $\sigma^2 = $ expected volatility in the value of investing over the life of the investment. $\rho' = $ modified rate which includes the effects of uncertainty and irreversibility. $V = $ value of the opportunity to invest. $\mu = $ constant drift rate. $\sigma = $ constant variance rate. $dz = $ increment of Wiener process, $z(t)$.

The distribution of expected returns from investing, annualized and projected into perpetuity, solve the equation of $\beta$ 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). Therefore, the value of the opportunity to invest also follows a GBM process, given by Equation (6) (Black & Scholes, 1973; Louberge et al., 2002; Kassar & Lasserre, 2004).

The relationship between $dz$ and $dt$ is given by $dz = e^t \sqrt{dt}$, where $e$ has zero mean and unit standard deviation ($e$ is $N(0,1)$ and $E(e e_i) = 0$, for $t \neq s$). Therefore, changes in $V$ over time are a function of a known proportion growth rate parameter $\mu$, and $\sigma$, which is governed by the increment of the Weiner process, $dz$ (Dixit & Pindyck, 1994). 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 ($\mu$) of the GBM process is estimated by $\mu_V \approx 1/N \sum_{j=1}^{N} \left[ \Delta \ln V_j \right]$ where, $E[\Delta \ln V_j] \Rightarrow 0$ and the variance in the opportunity value to invest is estimated by $\sigma_V \approx 1/N \sum_{j=1}^{N} \left[ \Delta \ln V_j - \mu_V \right]^2$ where, $E[(\ln V_j - \mu_V)^2] > 0$.

To calculate the statistics $\mu_V$ and $\sigma_V$ 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.
4. Results

First, a DCF technique (NPV) was applied using primary data from a survey (792 questionnaires—about 10% of the total population) and secondary data from: (a) the statistical service of the Greek Ministry of Agriculture and (b) several earlier studies (feasibility study, environmental study, financial study and study of the socioeconomic impacts) (Karamouzis & Papamichail, 1998; Michailidis, 2004). The contingent valuation method (willingness to pay values) was used to derive estimates regarding minor expenses or revenues (social values) that cannot be extracted from direct data resources. In particular, the contingent valuation estimators comprise just 2.3% and 1.7% of the total benefits and costs, respectively.

Cost projection estimates indicate that the “Petrenia” irrigation project is expected to require an outlay of 7,947,761.55€ during the construction phase. This includes an outlay of 3,815,113.72€ for the irrigation canals, design and construction of the underground components of the project, financed by the Greek Ministry of Agriculture. The project is required to provide 10% of annual pre-tax revenue for payback during the operating stage. The annual operation cost (120,815.85€) includes salaries, materials, any conservation expenses and payments for several other services. The operation of the “Petrenia” dam will cover more than 90% of the region’s total irrigation needs until the year 2020. On the other side, the estimates of total direct annual revenues are equal to 890,388.85€ including all water uses.

The derived NPV is equal to 1,135,849.88€ suggesting that this particular investment is economically feasible. The sensitivity analysis (after ± 20% fluctuation of each factor ceteris paribus) for the NPV shows that the “Petrenia” irrigation dam is, in any case, an acceptable investment.

Then, the real option approach was applied following the theoretical lines described in the empirical model section. The mean and the variance of net annual returns of the “Petrenia” irrigation dam were determined by 25,000 Monte Carlo iterations by using @RISK software (Palisade, 2000).

The hydrologic resources available each year and the water price were selected as two of the most important uncertainty sources for the “Petrenia” irrigation dam (Michailidis, 2004). It is very important to note that the real option approach is based on the influential assumption that the uncertainty factors does not vary “with” and “without” the project. Thus, in the case of the “Petrenia” irrigation dam, as the hydrologic resources are unaffected by the project administrators the selling price of the single water unit is the only uncertainty source which does not vary “with” and “without” the project. In particular, the water capacity of the “Petrenia” irrigation dam has been modeled as a gamma distribution, by using @BEST FIT software (Palisade, 1998), while the selling price of the single water unit (m³) has been modeled as a triangular distribution. The expected mean water capacity (water production minus evapotranspiration) is 6,022,286 m³ per year with a standard deviation equal to 4,353,497 m³ per year. The most likely price, administered by the central municipality corporation, is 0.36€ per m³, with an expected price range between 0.32€ and 0.40€ per m³ owing to rainfall disparities from year to year. The expected mean of the net annual returns \(E(R)\) is equal to 222,657.20€ with a standard deviation of 1,114,225.00€.

One hundred iterations (simulations) were used to derive the parameters \(\mu_r\) and \(\sigma_r\). The initial investment cost is equal to 4,400,000€ and the investment cost of irrigation canals amounts to 3,815,000€. The annuity (a transformation of the discounted values on an annual basis) has been computed assuming a long-run loan of 50 years and 6.5% rate of interest. The Marshallian trigger \((M)\) of the initial cost is equal to 540,236.52€ (Table 2). The investment’s net annual returns \((\beta/\beta - 1)\) must be at least 1.5087 times greater of the corresponding Marshallian trigger; that is, higher than 815,070.41€ (Figure 1).
Thus, the results from the real options approach could not justify the “Petrenia” irrigation dam as an economically efficient investment, although the results of NPV signal the opposite. In particular, although the simulated annual returns $E(R)$ have to be larger than 815,070.41€, according to the optimal investment trigger ($H$), the expected mean of the net annual returns $E(R)$ is equal to 222,657.20€. Conclusively, although the application of both the real options approach and NPV could lead to a different outcome, they offer additional insight into investment decisions. In this particular investment, the decision makers might consider delaying the investment and keeping the option open for the future.

Sensitivity analysis indicates that the value of waiting increases as the discount rate decreases. In particular the value of waiting $\rho V(H)$ and the Marshallian point increase as the discount rate of return decreases from 6.5% to 5.0%. In addition, the modified optimal investment policy is influenced by the changes in the discount rate of return. Estimates in Table 3 show that the annual value of investment

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Values</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\sigma^2$</td>
<td>0.0223</td>
<td>Variance of the opportunity to invest</td>
</tr>
<tr>
<td>$\beta$</td>
<td>2.9656</td>
<td>Constant depended on the discount rate</td>
</tr>
<tr>
<td>$\beta/\beta - 1$</td>
<td>1.5087</td>
<td>Relation between Marshallian and optimal triggers</td>
</tr>
<tr>
<td>$B$</td>
<td>$2.4175 \times 10^{-17}$</td>
<td>Multiplicative constant</td>
</tr>
<tr>
<td>$\rho$</td>
<td>6.50%</td>
<td>Discount rate</td>
</tr>
<tr>
<td>$\rho'$</td>
<td>9.81%</td>
<td>Modified discount rate</td>
</tr>
<tr>
<td>$M$</td>
<td>540,236.52€</td>
<td>Marshallian investment trigger</td>
</tr>
<tr>
<td>$H$</td>
<td>815,070.41€</td>
<td>Optimal investment trigger</td>
</tr>
<tr>
<td>$H - M$</td>
<td>274,833.89€</td>
<td>Difference between optimal and Marshallian triggers</td>
</tr>
<tr>
<td>$\rho V(R)$</td>
<td>274,833.89€</td>
<td>Value of delay (waiting value)</td>
</tr>
</tbody>
</table>

Fig. 1. Optimal investment policy.
increases at a greater rate than the decrease in the discount rate of return, which means that it is better to delay the construction of the “Petrenia” irrigation dam.

The value of waiting and the optimum investment trigger ($H$) can be illustrated using the diagram (Figure 1) described by Dixit (1992). The corresponding $V(R)$ function is drawn thicker, with the convex part $w_1i_2$ of the curve for waiting to the left of $H$ and the straight line $i_2i_3$ for the net worth of the project to the right of that point. The Marshallian trigger $M$ is where the value of investing just becomes positive, that is, where the straight line $i_1i_3$ crosses the horizontal axis. The optimum trigger $H$ is obviously to the right of this. The curve $BR^\beta$ (value of waiting: $i_2w_2$) lies above the line $R/\rho - K$ (value of investing: $i_2i_3$) to the right of $H$ and waiting again is the preferred policy for higher values of $R$.

5. Concluding remarks

Huge investments, like an irrigation dam, financed by public funds must be very carefully designed and studied before a “go ahead” decision can be approved. Researchers have devised several approaches to facilitate such decisions; among them DCF techniques (NPV) are the mostly used. Nevertheless, in applying traditional DCF techniques to such water management analyses, inherent uncertainty problems could influence the ultimate decision. Therefore, combining the DCF techniques with new advanced methodologies could significantly alleviate the weakness of the DCF techniques.

This paper offers an example of applying the real options approach in comparison with a DCF technique, the NPV criterion, to a large scale irrigation dam project. Empirical results revealed that, according to the NPV criterion, the construction plan of the particular irrigation dam is economically feasible. In contrast, results from the real options approach prove that the same investment is not feasible. Although the results seem to be contradictory, they can bind together very well and shed light on an investment decision.

Thus, when uncertainty in annually available hydrologic resources and water price is assumed, the results of the real options approach change significantly, as the investment is profitable only if NPV is larger than 815,070.41€. This means that investment can be postponed until uncertainties regarding the aforementioned factors dissipate or the NPV equals the optimal investments trigger ($H = 815,070.41€$).

A negative relationship between the value of waiting and the discount rate has been demonstrated in the performed sensitivity analyses. Actually, the value of waiting and the Marshallian point increase as the discount rate of return decreases. In addition, the modified optimal investment policy is influenced by the changes in the discount rate of return. In particular, the annual value of investment increases at a greater rate than the decrease in the discount rate of return, which means that it is better to delay the construction of the “Petrenia” irrigation dam under the current circumstances.

Table 3. Sensitivity analysis of the discount rate of return.

<table>
<thead>
<tr>
<th>$\rho$</th>
<th>6.50%</th>
<th>5.00%</th>
<th>8.00%</th>
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<tbody>
<tr>
<td>$\rho'$</td>
<td>9.81%</td>
<td>8.25%</td>
<td>10.44%</td>
</tr>
<tr>
<td>$M$</td>
<td>540,236,52€</td>
<td>447,218.52€</td>
<td>637,680.59€</td>
</tr>
<tr>
<td>$H$</td>
<td>815,070,41€</td>
<td>778,221.30€</td>
<td>913,541.60€</td>
</tr>
<tr>
<td>$\rho V(H)$</td>
<td>274,833,89€</td>
<td>331,002.77€</td>
<td>275,861.01€</td>
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