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Decision Support Tools for Assessing Petroleum Upstream Investments

أدوات دعم القرار لتقييم المشاريع الاستثمارية في المنبع البترولي

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Abstract:

The main aim of this paper is to provide a decision -support tool using a combination of real options analysis and portfolio optimization based on simulation and modelling principles to analyze and assess petroleum upstream projects. The provided method does not only takes in to account the risk concept, uncertainty and Managerial flexibility, but also can be used to select the optimal portfolio. Our results show that the use of real options analysis increases the value of the project, due to the flexibility that can be integrated into the decision process, and the use of portfolio optimization techniques helps the decision-makers to select the best set of projects, and the combination of the real options and portfolio optimization may reduce the project risks.

Keywords: Real Options; Petroleum upstream Projects; Portfolio Optimization; Uncertainty.

JEL Classification Codes: C61 ; D81 ; D92 ; G11 ; L71

ملخص:

تهدف هذه الورقة الى تقديم أداة لدعم القرار ، و هذا من أجل تحليل و تقييم مشاريع استكشاف وانتاج البترول وذلك عن طريق دمج كل من تحليل الخيارات الحقيقية و تحسين المحفظة اعتمادا على مبادئ المحاكاة و النمذجة، حيث أن الطريقة المقترحة لا تأخذ بعين الاعتبار مفاهيم المخاطرة، عدم

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اليقين والمرونة الإدارية فحسب، بل يمكنها أيضا تحديد المحفظة المثلى للمشاريع المدروسة، حيث تظهر النتائج أن استخدام تحليل الخيارات الحقيقية قد يزيد من قيمة المشروع ويرجع ذلك إلى المرونة التي يمكن دمجها في عملية صنع القرار كما يساعد استخدام تقنيات تحسين المحفظة صناع القرار على تحديد أفضل مجموعة من المشاريع، كما أن الجمع بين الخيارات الحقيقية وتحسين المحفظة قد يقلل من مخاطر المشروع.

كلمات مفتاحية: الخيارات الحقيقية؛ مشاريع استكشاف انتاج البترول؛ تحسين المحفظة؛ عدم اليقين.

تصنيفات JEL: C61; D81; D92 ; G11 ; L71.

1. INTRODUCTION

The global energy investment had reached 1.8 trillion USD in 2017, where oil and gas upstream investments had represented 25% by 450 billion USD (IEA, 2018, p23). Oil has been considered as a strategic product, not only due to its large-use but also its characteristic as an exhaustible energy source (Tamba, 2017, p01). Petroleum exploration and production E&P activity play a key role which is: allowing petroleum companies to renew their hydrocarbon resources in order to ensure the continuity of companies' long-term activities. The exploration and production industry is considered as an irreversible investment and risky activity (economic risk, geologic risk, country risk) (Lerche et al, 1999, p01-15 that is characterized by being an international activity, capital-intensive, long-term profitability, require high technology, critical to major economic factors and political events.

Petroleum companies' decision-makers sometimes face a whole of profitable projects, and regarding the fact of limited financial resources, they face difficulties to select the best set of project. The economic value of petroleum upstream projects is sensitive to many stochastic variables such as oil prices, capital expenditures, production profile...etc. Oil prices are considered as the main source of uncertainty related to the various factors that can affect them, either on the short-term such as volatility, production control, unconventional resources, or on the long-term like geopolitics and world wild economic growth (Lyons, Lorenz, & Plisga, 2011, ch7, p21). The traditional approaches that are used in the valuation of exploration and production (E&P) projects such as Net Present Value (NPV), Discounted Cash Flows (DCF), and others, usually take into account neither risk, uncertainty concept, nor the managerial flexibility that what makes these economic valuation criteria remain controversial(Mun, 2002, p06, 55; Abel Dixit, Eberly, & Pindyck, 1996, p33-34) and besides they cannot be used to verify if the portfolio obtained is optimal.

The construct of advanced option pricing was first articulated by many works like (McDonold & Siegl, 1986; Trigeogis, 1986; Pindyck, 1988), have emerged as scientific contributions for the establishment of the real options theory as a new approach of decision making. The term "Real Options" was coined for the first time in (Myers, 1977, p22) to describe the company growth opportunities that can be viewed as options. The majority of the previews studies (Pindyck & Dixit, 1994; Smith & Nau, 1995, Smith & McCardle, 1999; Guedes, 2016; Sabet & Heaney 2017) usually use the real options theory to evaluate real assets. Much of works of literatures since the real options theory coming to light have been combined this theory with other theories or techniques such as game theory, dynamic programming and portfolio optimization for example (Azevedo & Paxson, 2014; Chorn & Shokhor, 2006; Jain, Roelofs, & Oosterlee 2014),therefore to evaluate real assets that has specific characterization such as irreversibility, uncertainty and managerial flexibility, what makes the energy industry one of the sectors that has applied this theory (ROA) as a decision support tool.

(Belailey et al 2003) review discounted cash-flow approach and show how real options valuation can exceed certain shortfalls of DCF, and not only they explain the two main models for evaluating options, Black and Schools and Binomial lattice models, but also provides the manner of their application by giving examples from the petroleum industry. The first demonstration of a combination of two mathematical techniques dynamic programming and real option valuation algorithm was by (Chorn & Shokhor, 2006) to achieve the policy development in the petroleum industry. (Abid & Kaffel 2009) evaluates the option to defer the development of the oil field using a methodology through which can determine the continuous-time stochastic processes for major risk factors of a petroleum project. (Jain et al, 2014) combines the real options theory and mean-variance portfolio optimization to assess the future nuclear power plant portfolio. (Fonseca et al, 2016) employs real options valuation approach to assess an African petroleum field using a binomial method, where the project's volatility is necessary; however, he has used a non-parametric GARCH model for forecasting oil prices volatility as a proxy for the project's volatility. (Guedes & Santos 2016) used real options analysis to assess offshore petroleum exploration and production projects through evaluating the available options in E&P projects such as exploration options, appraisal options, scaling options and abandonment options.

The Mean-Variance Model (MVP) was introducing by (Markowitz, 1956) has been applied widely to select the best set of petroleum projects. (Orman & Duggan 1999) has illustrated how petroleum upstream companies use Markowitz's portfolio optimization framework for selecting their portfolio of exploration production investment and compare this method to the traditional approaches used in upstream projects selection. (Casta et al, 2008) provides a methodology to select the optimal portfolio in the oil and gas industry through proposing an extension of the MV model. Based on the MV model of Markowitz, (Belaid & De Wolf, 2009; Xue et al, 2014) highlights a manner of selecting petroleum upstream investments through optimizing the quadratic problem of MV model.

2. Methodology:

2.1 Real Options for upstream petroleum project assessment:

The assessment of petroleum exploration and production projects using real options technique must take in consideration the major sources of uncertainty, in this paper, we have considered Reserves, oil prices, operation and capital costs as the main source of uncertainty in the economic assessment process. To achieve our objectives we need to follow some necessary techniques that usually employed for petroleum upstream project assessment.

2.1.1 Reserves estimation using volumetric method:

According to (Lyon et al, 2016, ch07, p5), the real reserves are never been determined until the production is stopped and the field is abandoned, otherwise the reserves are just an estimate. The volumetric method requires knowing specific information about the reservoir properties such as the estimate of the gross volume rock which containing hydrocarbons, the water saturation, the porosity value and the reservoir volume factor at initial condition (Allen & Seba, 1993, p37). The Original Oil in Place (OOIP) is calculated based on the following equation (1):

$$OOIP = \frac{7758\ A.h.\varphi\,(1 - S_w)}{B_o} \quad (1)$$

Where 7758 is the conversion to barrels from acres-feet, *A* is the area in acres, *h* is the thickness in feet, φ is the porosity fraction of void space in volume of reservoir, S_w is the is the water saturation as a fraction of fluid content and B_o gives the oil formation volume factor.

Estimated Ultimate Recovery EUR is defined as the amount of oil expected to be recovered from the reservoir or, in other words, the amount technically possible to produce, expressed in equation (2), where R_f is the recovery factor, which is can be resolved from the performance of similar reservoirs.

$$\mathrm{EUR} = \mathrm{OOIP} * R_f \quad (2)$$

2.1.2 Production profile forecasting

After the estimation of "OOIP" and determine the "EUR", we can forecast the production profile, therefore we have using (Lund 2000) model which is a tank model or zero-dimensional, where the reservoir is a three-dimensional by nature; the equation (3) presents the production profile and the maximum production level is described by equation (4) :

$$Q_{r,t} = N_t Q_{w,0}\left(\frac{EUR - \sum_{t=0}^{n} Q_t}{EUR}\right) \quad (3)$$

$$Q_t = Min\{Q_{r,t}, MaxCap\} \quad (4)$$

Where $Q_{r,t}$ the production at time t, EUR is the Estimated Ultimate Recovery, $Q_{w,0}$ initial production capacity of a well, N_t is the number of producing wells at time t, Q_t is the field production at time t, and MaxCap is the maximum capacity of the plant.

2.1.3 Oil prices modeling:

Oil prices are considered as one of the main sources of uncertainty in economic assessment of petroleum exploration and production projects, related to the various factors that can affect them, either on the short-term such as volatility, production control, unconventional resources, or on the long-term like geopolitics and world wild economic growth (Lyon et al, 2016, ch07, p21),therefore there are two main stochastic processes ,the first one is Mean-Reverting process or Ornstein–Uhlenbeck process which is based on the idea of the effect of supply and demand results in a mean reversion property, but one of the limits of this process is it can produce negative prices, the last one is Geometric Brownian Motion process which is using for modelling the financial derivatives, the main disadvantage of this process is that it can under or over-evaluate the commodity prices (Lima & Suslick 2006 p131; Aba Oud & Goard, 2015 p190). In this paper we have chosen the GBM to model oil prices as follows:

$$dP^{\mathrm{oil}} = \mu_p P^{\mathrm{oil}} dt + \sigma_p P^{\mathrm{oil}} dZ \quad (05)$$

The solution of the stochastic differential equation (05) described by the equation (06)

$$P_t^{\mathrm{oil}}(m) = P_0^{\mathrm{oil}} e^{\left(\mu_p - \frac{\sigma^2}{2}\right)t + \sigma_p W_t} \quad (06)$$

Where μ_p the oil price drift rate, σ_p is the oil price diffusion rate, P_t^{oil} is the oil price, and dZ is the increment of Wiener process, m is the number of trials.

2.1.4 Costs Modeling:

In this part we will model the petroleum exploration and production projects’ main costs which are Capital Expenditures “Capex” and Operational Expenditures “Opex”, where the Opex containing two elements, fixed Opex which is proportional to the Capex, and variable Opex is related to the oil production rate. We are considering Capex following triangular distribution, the fixed Opex is considering deterministic, but for the variable Opex is modelled used GBM process as follows:

$$dOpex^v = \mu_{opex} Opex^v dt + \sigma_{\mathrm{Opex}} Opex^v dZ \quad (07)$$

The solution of the stochastic differential equation (07) described by the equation (08)

$$Opex_t^v(m) = Opex_0^v e^{\left(\mu_{opex} - \frac{\sigma_{Opex}^2}{2}\right)t + \sigma_{Opex} W_t} \quad (08)$$

Where μ_{opex} is the drift rate of variable Opex, σ_{Opex} is the diffusion rate of *variable* Opex, and $Opex^v$ is the *variable Opex*.

2.1.4 Economic Modeling:

Petroleum upstream projects have a specific Economic model due to the government tax system to simplify we have proposed a simple concessionary regime.

2.1.4.1 The standard Net Present Value:

The present value of upstream project at time t is:

$$PV_t(m) = \frac{Q_t\left(P_t^{oil} - Opex_t^v\right) - Opex_t^f - TT_t}{(1+r)^t} \quad (09)$$

The equation (10) shows that the total government-take is the total income tax plus royalties: The equation (10) shows that the total government-take is the total income tax plus royalties:

$$TT_t = IncomTax_t + Royalty_t \quad (10)$$

$$Royalty_t = P_t^{\mathrm{oil}} Q_t \,\alpha \quad (11)$$

$$\begin{aligned} &if\ \left(P_t^{oil} - Royalty_t - Opex_t - DTS_t\right) > 0 \\ &\quad IncomTax_t = \beta\left(P_t^{oil} - Royalty_t - Opex_t - DTS_t\right) \\ &else \\ &\quad IncomTax_t = 0 \end{aligned}$$

Where the PV_t is the project's present value at time *t*, $Opex_t^f$ is the fixed Opex, TT_t is the total government-take at time *t*, and *r* is the discount rate, DTS_t is Depreciation at time *t*, α is the royalty tax rate, β is the income tax rate.

2.1.4.2 The net present value including flexibility:

A. Option to switch on/off:

The equation (13) represent the present value of the project including the option of switching on/off (temporarily) if the project generate negative results. However, during the project lifetime we have considered that the costs of the switch on/off option are neglected.

$$\mathrm{PV}_t^f(m) = \mathrm{Max}\left\{\frac{Q_t\left(P_t^{oil} - Opex_t^v\right) - Opex_t^f - TT_t}{(1+r)^t}, 0\right\} \quad (13)$$

Therefore the flexible NPV is as follows:

$$\mathrm{NPV}_f(m) = \sum_{t=0}^{n} \frac{\mathrm{Max}\left\{Q_t\left(P_t^{oil} - Opex_t^v\right) - Opex_t^f - TT_t, 0\right\} - \mathrm{Capex}_t}{(1+r)^t} \quad (14)$$

The real option value ROV_f of the project is the difference between the NPV and the flexible net present value NPV_f.

$$ROV_f = NPV_f - NPV \quad (15)$$

B-Option to Continue /Abandon:

The equation (16) illustrates one-way continuity or abandonment decision (Irreversible decision), regarding the fluctuation of the major variables that affect the economic value of the project.

$$\mathrm{NPV}_{Co/Ab}(m) = \mathrm{Max}\left\{\left(\sum_{t=0}^{n} \frac{Q_t\left(P_t^{oil} - Opex_t^v\right) - Opex_t^f - TT_t - Capex_t}{(1+r)^t}\right), 0\right\} \quad (16)$$

The real option value $ROV_{co/Ab}$ of the continuity or abandonment is the difference between the NPV and Continue/Abandon net present value $\mathrm{NPV}_{Co/Ab}$.

$$ROV_{Co/Ab} = NPV_{Co/Ab} - NPV \quad (17)$$

C- Compound Option:

The Compound option value is the resultant of the combination of the two previous options (Switch on/off and Continue/Abandon), which expressed by the equation (18);

$$\mathrm{NPV}_{Compound}(m) = \mathrm{Max}\left\{\left(\sum_{t=0}^{n} \frac{\mathrm{Max}\left\{\left(Q_t\left(P_t^{oil} - Opex_t^v\right) - Opex_t^f - TT_t\right), 0\right\} - Capex_t}{(1+r)^t}\right), 0\right\} \quad (18)$$

The real option value added by the Compound option is the difference between the NPV and Compound net present value $\mathrm{NPV}_{Compound}$.

$$ROV_{Compound} = NPV_{Compound} - NPV \quad (19)$$

2.2 Mean-Variance portfolio optimization:

The mean-variance approach is widely used in the quantitative analysis of portfolio selection. The mean-variance portfolio optimization framework requires return distribution for individual petroleum upstream project and uses the statistical measures of expectation and variance of return to describe the return and risk of an investment, respectively. The objective is either to minimize portfolio risk for a given return or, to maximize the expected level of return for a given level of risk.

The investor in this case has the financial ability to invest in a set of *k* projects, the return represented by the random variable NPV_i, and the w_i represent the weight of the total investment to allocate in the $i-th$ project. The expected return of this portfolio is as following:

$$E(\mathrm{NPV}_p) = E\left(\sum_{i=1}^{k} w_i \mathrm{NPV}_i\right) \quad (16)$$

So,

$$E(\mathrm{NPV}_p) = w_i E(\mathrm{NPV}_1) + \ldots + w_k E(\mathrm{NPV}_k) \quad (17)$$

The portfolio variance is calculated by:

$$\mathrm{Var}(\mathrm{NPV}_p) = E\left[\left(\sum_{i=1}^{k} w_i \mathrm{NPV}_i - E\left(\sum_{i=1}^{k} w_i \mathrm{NPV}_i\right)\right)^2\right] \quad (18)$$

So,

$$\mathrm{Var}(\mathrm{NPV}_p) = \sum_{i=1}^{k} \sum_{j=1}^{k} w_i w_j \sigma_i \sigma_j \rho_{\mathrm{ij}} \quad (19)$$

As NPV_p represents the portfolio return, σ_i is the standard deviation of the the project *i*, ρ_{ij} is the correlation coefficient inter-projects, w_i is the weight of the project *i*, the weights must be positive and there sum equal one.

$$\sum_{i=1}^{k} w_i = 1 \ \& \ L_i \le w_i \le U_i \quad i = 1, \ldots k \quad (20)$$

L_i and U_i represents the lower and upper bands of the $i-th$ weight, respectively.

The mean-variance model is a quadratic problem that given by:

$$\text{Max Z} : \sum_{i=1}^{k} w_i \mu_i - \sum_{i=1}^{k} \sum_{j=1}^{k} w_i w_j \sigma_i \sigma_j \rho_{ij}$$

Sub to:

$$\sum_{i=1}^{k} w_i = 1,$$
$$\sum_{i=1}^{k} w_i Capex_i \leq MaxCapex,$$
$$\sum_{i=1}^{k} w_i NPV_i \geq Min\ \mu,$$
$$\sum_{i=1}^{k} w_i EUR_i \geq MinEUR,$$
$$L_i \leq w_i \leq U_i, i = 1, \ldots k$$

The mean variance model represented by equation (20) has two main objectives (bi-objective), the first is maximizing the return, and the second is minimizing risk, $\mu_i$is the expected NPV of $i-th$the project, Capex_i the Capital Expenditures of the project i, MaxCapex the maximum financial resources capacity, the $Min\ \mu$ is the threshold of the desired net present value of the portfolio, $MinEUR$ is The minimum reserve threshold required for the selected portfolio.

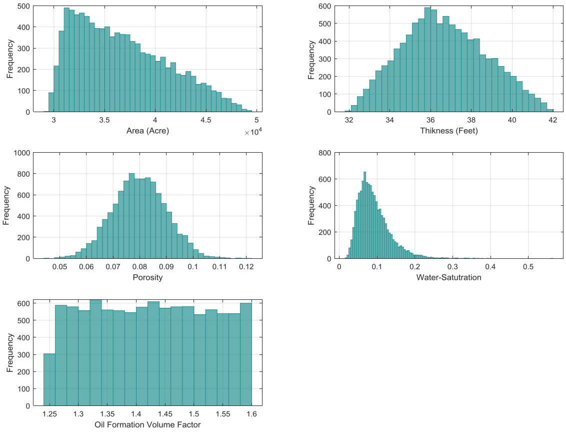
3. Result and Discussion:

This section is devoted to applying the combination of real options valuation and portfolio optimization (M-V model) following the steps that we have illustrated in the Methodology section to assess hypothetical but realistic petroleum upstream projects.

3.1 OOIP, EUR and Production Profile:

The **Fig.1** displays the inputs that required to estimate the OOIP of the first project, as the figure has shown the area and the net pay thickness follow a triangular distribution, while the porosity, water saturation and oil formation volume factor follow normal, log-normal and uniform distributions respectively.

Fig.1. The inputs required to estimate the original oil in place of the project one using the Volumetric method



The **Fig.2** illustrates the expected curves and the distribution of the OOIP of each project, and as it shows, all the cases have an estimated probability of oil present of 100%, in other words 100% of probability these projects are containing a finite amount of oil greater than zero, the project one as the expected curve displays, the probability to have a volume in place equal or greater than 405 MMbbl is 90% and 50% and 10% of probabilities for volume in place equal or more than 524 MMbbl and 681 MMbbl respectively.

The **Fig.3** set out the production profile estimated based on the (Lund, 2000) model, for each project the difference between its production profile and others mainly due to the EUR, Number of wells and their initial production rate, and the maximum capacity of the plant, as can be seen from the figure below (**Fig.3**), the project five has a maximum capacity of 450 Mbbl per month (4.5 MMbbl per year), in which the production started with the maximum capacity of the plant until the decline phase showed up after 60 months of production, due to the decline of the reservoir pressure that was maintaining the project production (Natural Recovery).

Fig.2. Expected Curves of original oil in place of all projects estimated using the volumetric method

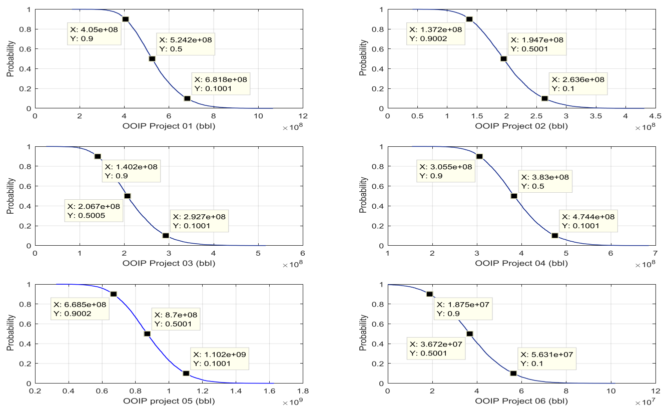
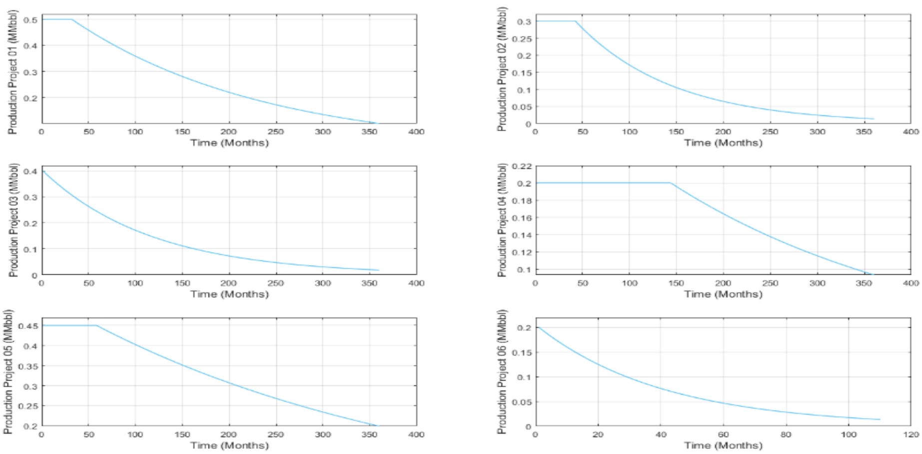


Fig.3. Production profile estimated using Lund 1999) model



3.2 Real options valuation:

This stage represents the second step after the estimation of both OOIP and production profile, therefore the input of the previous step (the production profile) being an input in this stage, the **Fig.4** represents the fifth project's capital expenditures which follows triangular distribution (a) and the oil prices (b) simulated using the GBM .

The Variables such as production profile, Capex, oil prices, Opexes, royalty tax, income tax and WACC represent the inputs to Monte Carlo simulation to compute the distributions of all project in both cases with and without options, **Table.1** compares the project values and there risks for the four cases (standard net present value, net present value with switch on/off option, net present value with Continue/Abandon option and net present value with Compound option).

Table.1 The Expected values and the standard deviation of all projects and for the four cases.

	Project 1	Project 2	Project 3	Project 4	Project 5	Project 6
E(NPV)	93,06	95,39	-41,64	40,39	26,67	-189,80
STD(NPV)	431,25	221,55	226,93	275,94	431,99	67,72
E(NPVf)	94,26	100,12	-30,47	41,26	26,97	-187,79
STD(NPVf)	430,15	218,60	219,43	275,07	431,65	66,63
E(NPVAb/Co)	203,13	130,84	71,42	121,42	173,10	0,24
STD(NPVAb/Co)	339,34	188,71	140,93	211,91	325,99	3,97
E(NPVComp)	203,25	132,50	72,69	121,46	173,11	0,24
STD(NPVComp)	339,32	188,64	141,30	211,90	325,99	3,97

Fig.4. Distributions of Capex of the fifth project (a) and the oil prices simulated using GBM fifteen paths (b)

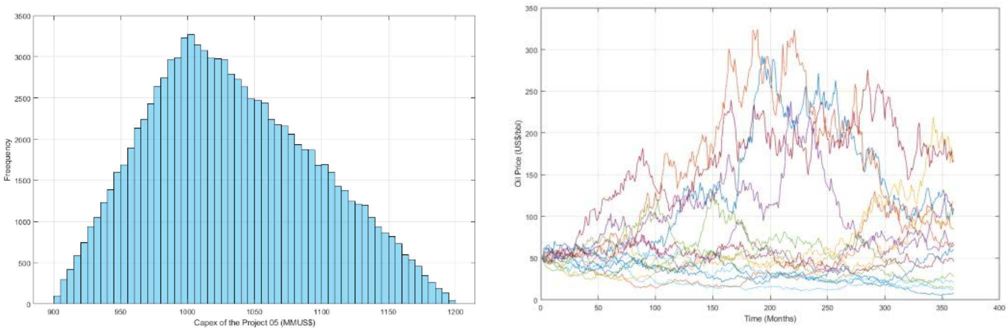
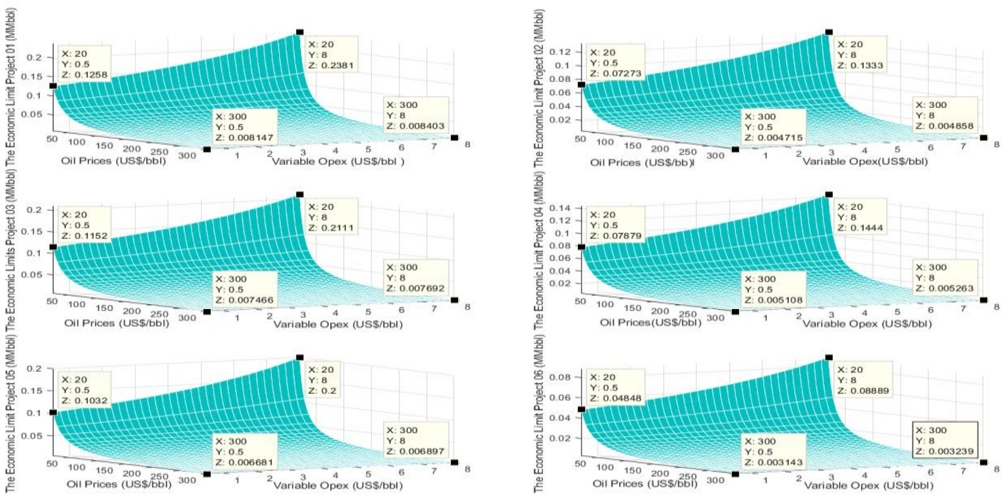


Fig.5. Economic limit of the all projects



As the **Table.1** set out the mean value of the projects increase while the standard deviation (the risk) decrease with the integration of options (flexibility), for the project two the switch on/off option add to the standard net present value 4.73 MMUS$ while the compound option add more than 134 MMUS$ to the standard net present value and in the other hand the standard deviation of the same project goes from 221.55 MMUS$ in the standard valuation to 218.6 for the switch on/off case.

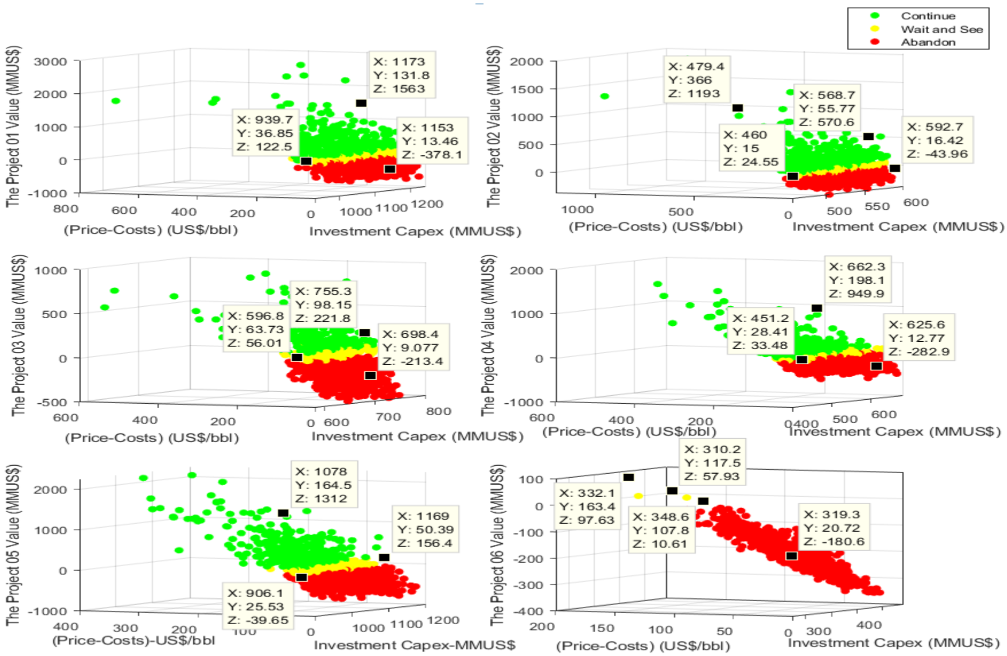


Fig.6. The net present value of all projects versus simulated paths of oil prices, operational costs and capital expenditures, the red region represents abandon policy (negative results), green grid represents continue policy (positive results), while the yellow represents the Wait-and-see policy in which the return on investment less than 15%.

The economic limit depends mainly by oil prices, Opexes and royalty tax, the **Fig.5** shows the threshold quantity of oil extracted for each project at which the project generates no more positive results. However, it can be observed from the **Fig.5** that the economic limit is directly proportional to variable Opex, while it is inversely proportional to oil prices.

Fig.6 displays the variation of projects value in function of the capital expenditures and the difference between oil prices and operational costs, in which the x-axis represents the capital expenditures of the project, the y-axis represents the difference between oil price and operational costs, while the z-axis represents the projects value, at which the green grid points represents the states at which the project's value not only greater than zero but also the project has return on investment greater than 15%, therefore the decision policy at this case is should continue, while the yellow grid points is considered as a risky states due to its closeness to the red region, even though, the project generate positives results but has less than 15% return on investment, thus the decision policy, in this case is just wait and see, however, the red points region the project generate negative results, therefore the project should be abandoned. For example the project six has only two possible scenarios where the project generate positive value and more than 15% as return on investment, and they are (310.2, 117.5, 57.93) and (332.1, 163.4, 97.63) as mean values for the whole lifetime of the project, while all the rest results are either wait-and-see or abandoned states. What stands out of this figure is if we know how the project's value behaves in function of capital expenditures, oil prices and operational expenditures, the flexibility can be easily integrated the decision's process.

3.3 Portfolio Optimization:

In case when a company faces limited financial resources and it has to choose amongst several projects, in this case, the portfolio optimization can be used to select the optimal set of projects, in other words maximizing the expected value and minimizing the risk.

The efficient frontier is considering as the weighing machine between return and risk in the selection of the optimal set of assets in which the efficient frontier has the highest expected values for the same amount of risk compared with non-efficient portfolios.

Fig.7 displays the frontier efficient (a) and there optimal fractions (b) for the standard net present value case (without flexibility) under budget, net portfolio present value threshold, and reserves threshold constraints, and for both cases (a) and (b) the project two dominating the portfolios with high value, due to its risk-return combination (as **Table.1** indicates), while for the

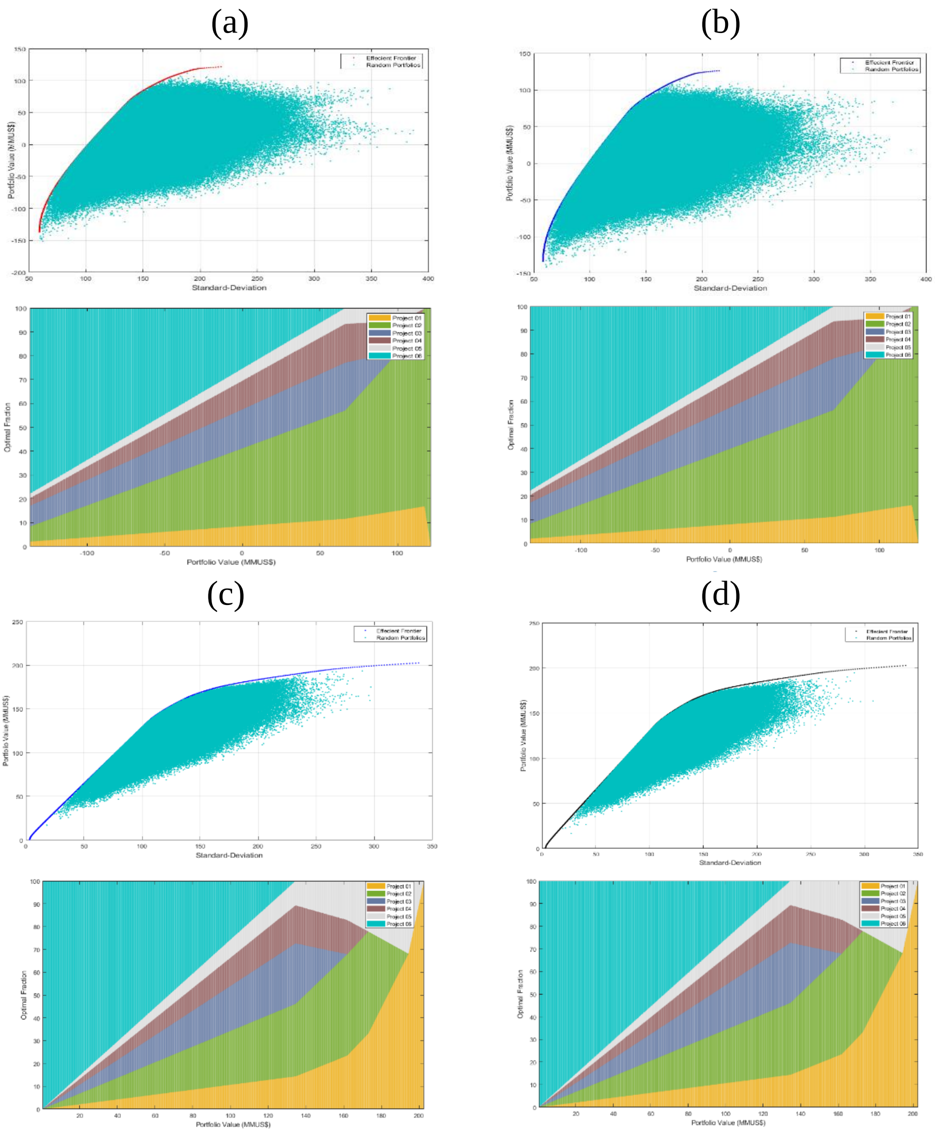
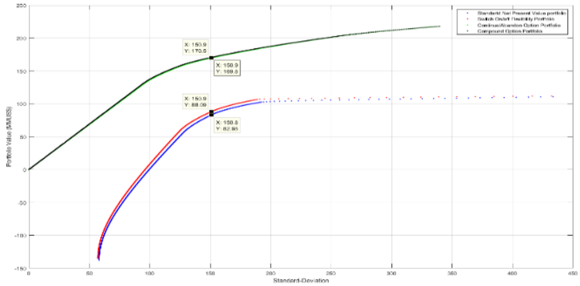


Fig.7. Efficient frontier and its optimal fractions (a) for the case of standard net present value, (b) net present value with switch on/off option, (c) net present value with Continue/Abandon option, while (d) is for the net present value with Compound option case.

rest two cases the portfolios with the highest value are dominated by the 1st project because it has the highest value amongst all the six projects in this two cases (**Table.1**).

Fig.8. the Comparison between the efficient frontiers for the four cases



What can be clearly seen in the **Fig.8**, is that for the same amount of risk (standard deviation equal 150.9) we have different portfolios' values for the four cases, at which the switch on/off option add more than 5MMUS$ to the standard net present value portfolio, while continue/abandon and compound
options add to the standard case more than 86.8 and 87.5 MMUS$ for the same standard deviation.

4. CONCLUSION

The reserves estimation, oil prices, and capital costs play a pivotal role in the assessment of petroleum upstream projects. Oil prices are considered as one of the main sources of uncertainty, due to the multiplicity of factors that can affect theme and energy prices in general such as production control, unconventional resources, geopolitics, and world wild economic growth. The economic value of E&P projects involves an amount of uncertainty, owing to the sensitivity to many stochastic variables, the fluctuation of these variables is critical in investment decision of whether continue, expand, abandon, or be delayed. The traditional approaches that are used in the valuation of E&P projects such as DCF methodology take into account neither uncertainty nor the managerial flexibility besides its optimal portfolio selection limits, the decision support tools provided in this paper has an important literature contribution due to its integrality at which it starts from the OOIP estimation until the selection of the optimal portfolio taking the risk and the managerial flexibility into account, the results obtained show that the integration of the flexibility to the decision process (ROA) may increase project's value comparing with the traditional NPV based on the nature of real options analysis which is avoiding the negative results through wait for more profitable oil prices, while under the fact that petroleum companies face a set of projects at which, they must select the best project combination in order to maximize profits and minimize risks.

5. Bibliography List:

Abel, A. B., Dixit, A. K., Eberly, J. C., & Pindyck, R. S. (1996). Options, the value of capital, and investment. The quarterly Journal of economics, 111(3), 753-777.

Abid, F., & Kaffel, B. (2009). A methodology to evaluate an option to defer an oilfield development. Journal of Petroleum Science and Engineering, 66(1-2), 60-68.

Azevedo, A., & Paxson, D. (2014). Developing real option game models. European Journal of Operational Research, 237(3), 909-920.

Bailey, W., Bhandari, A., Faiz, S., Srinivasan, S., & Weeds, H. (2003). Unlocking the Value of Real Options (Oilfield Review).

Belaid, F., & De Wolf, D. (2009). Sélection du portefeuille de projets d'exploration production en utilisant la méthode de Markowitz.

Chorn, L. G., & Shokhor, S. (2006). Real options for risk management in petroleum development investments. Energy Economics, 28(4), 489-505.

Costa Lima, G. A., Suslick, S. B., Schiozer, R. F., & Repsold, H. (2008). How to select the best portfolio of oil and gas projects. *Journal of Canadian Petroleum Technology*, *47*(05).

Dixit, A. K., Dixit, R. K., & Pindyck, R. S. (1994). *Investment under uncertainty*. Princeton university press.

Energy, W. (2018). Executicve Summary of the World Energy Investment, 2018. *Int. Energy Agency*.

Fonseca, M. N., de Oliveira Pamplona, E., de Mello Valerio, V. E., Aquila, G., Rocha, L. C. S., & Junior, P. R. (2017). Oil price volatility: A real option valuation approach in an African oil field. Journal of Petroleum Science and Engineering, 150, 297-304.

Guedes, J., & Santos, P. (2016). Valuing an offshore oil exploration and production project through real options analysis. Energy Economics, 60, 377-386.

Guedes, J., & Santos, P. (2016). Valuing an offshore oil exploration and production project through real options analysis. Energy Economics, 60, 377-386.

Jain, S., Roelofs, F., & Oosterlee, C. W. (2014). Decision-support tool for assessing future nuclear reactor generation portfolios. Energy Economics, 44, 99-112.

Lerche, I., & MacKay, J. A. (1999). Economic risk in hydrocarbon exploration.

Lund, M. W. (2000). Valuing flexibility in offshore petroleum projects. *Annals of Operations Research*, *99*(1-4), 325-349.Elsevier.

Lyons, W. C., & Plisga, G. J. (2011). Standard handbook of petroleum and natural gas engineering. Elsevier.

Markowitz, H. (1956). The optimization of a quadratic function subject to linear constraints. Naval research logistics quarterly, 3(1-2), 111-133.

McDonald, R., & Siegel, D. (1986). The value of waiting to invest. The quarterly journal of economics, 101(4), 707-727.

Mun, J. (2002). Real options analysis: Tools and techniques for valuing strategic investments and decisions (Vol. 137). John Wiley & Sons.

Myers, S. C. (1977). Determinants of corporate borrowing. Journal of financial economics, 5(2).

Orman, M. M., & Duggan, T. E. (1999). Applying modern portfolio theory to upstream investment decision making. *Journal of petroleum technology*, *51*(03), 50-53.

Pindyck, R. S. (1988). Capital risk and models of investment behaviour. In Economic modelling in the OECD countries (pp. 103-117). Springer, Dordrecht.

Sabet, A. H., & Heaney, R. (2017). Real options and the value of oil and gas firms: An empirical analysis. Journal of Commodity Markets, 6, 50-65.

Smith, J. E., & McCardle, K. F. (1999). Options in the real world: Lessons learned in evaluating oil and gas investments. Operations research, 47(1), 1-15.

Smith, J. E., & Nau, R. F. (1995). Valuing risky projects: Option pricing theory and decision analysis. Management science, 41(5), 795-816.

Tamba, J. G. (2017). Crude oil production and economic growth: Evidence from Cameroon. Energy Sources, Part B: Economics, Planning, and Policy, 12(3), 275-281.

Trigeorgis, L. G. (1986). Valuing real investment opportunities: an options approach to strategic capital budgeting: a thesis (Doctoral dissertation, Harvard University, Graduate School of Business Admiistration.

Xue, Q., Wang, Z., Liu, S., & Zhao, D. (2014). An improved portfolio optimization model for oil and gas investment selection. *Petroleum Science*, *11*(1), 181-188.