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Calculation of risk-neutral value for future exploration in the western part of the Sava Depression

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Abstract

Risk management is an integral part of business policy of a company engaged in the exploration and production of hydrocarbons. In order to be able to numerically present and analyse the risk of investment in individual geological areas, it is necessary to calculate the risk-neutral value. The calculation of the risk-neutral value of monetary units applied to investigate additional amounts of hydrocarbons in the existing structures of the western part of the Sava Depression. The calculated value of $2.32 \cdot 10^6$ risk-neutral USD (United States Dollar) for the exploration geological probability value (500 000 m3 of geological reserves of hydrocarbons) is the investment maximum in the western Sava Depression exploration area for the company's 50 million USD hydrocarbon exploration budget.

Keywords: Sava Depression; Probability of Success (POS); Risk Neutral Value (RNV); risk management

1. Introduction

Projects aimed at hydrocarbon exploration at existing or new locations is a very risky activity of companies whose main activity is exploration and production of hydrocarbons. A feature of research projects is the overestimation of the monetary value of hydrocarbon reserves in the event of non-consideration of possible risk in the project. To avoid such a case, it is necessary to calculate a Risk Neutral Value (RNV).

Risk management is a fundamental task of any company engaged in hydrocarbon exploration and production. **Cozzolino (1977)** applied risk to basic economic calculations when deciding to invest in hydrocarbon exploration and production. **Rose (1987)** was the first to use an approximation of the utility function in calculating a risk-adjusted value. **Malvić et al. (2007)** described the calculation for the calculation of the neutral value and the application of the algorithm in the JAVATM package for examples in the Drava Depression. The first application of the calculation of RNV in Croatian part of Pannonian Basin System (CPBS) and is made in the example of Bjelovar Subdepression (**Rusan and Malvić, 2009**). By applying the method of RNV and probability of success (POS) for the area of Bjelovar Subdepression, economic and geological indicators for possible sustainable development of hydrocarbon exploration in that area obtained, and standards for such analysis set in other parts of CPBS. **Malvić et al. (2020)** are applied modification POS and calculate the risk-neutral value for future water injection on reservoir "L" of field "A" in Sava Depression. A relatively small number of literature citations used in this type of paper, due to the confidentiality of data of companies engaged in production and exploration of hydrocarbons. These papers were used as a theoretical basis for calculating the risk-neutral value.

2. Methods

2.1. Research area (western part of the Sava Depression)

The Sava Depression is in the southwestern part of the Pannonian Basin System. The area of the western part of the Sava Depression (**Figure 1**) is about 8000 km^2, while the area of vertical projections of hydrocarbon reservoirs discovered so far is about 930 km^2 (**Ivšinović, 2019**).

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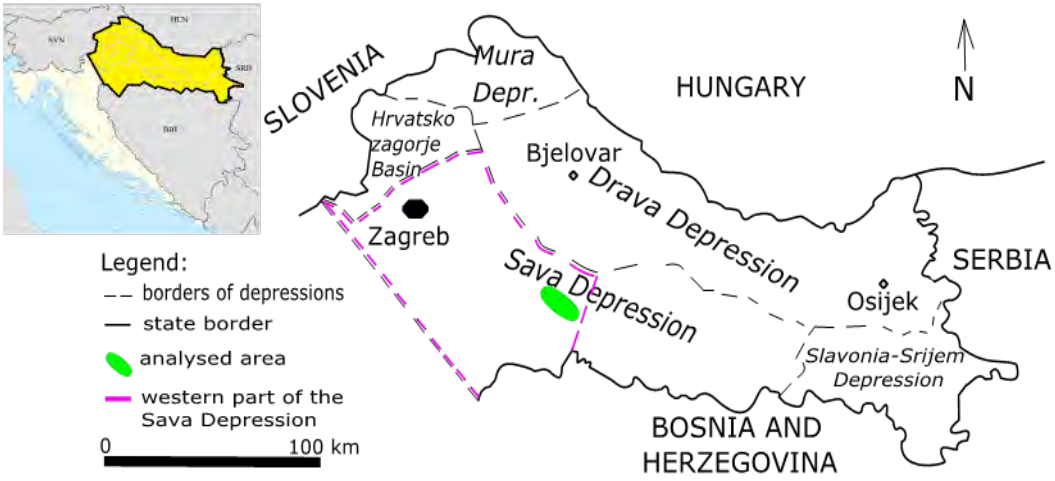

Figure 1: Geographical position of the western part of the Sava Depression (**Malvić et al., 2020**)

Hydrocarbon reservoirs have been proven in all formations except in the youngest Lonja Formation. A typical geological column of the western part of the Sava Depression is shown in **Figure 2**.

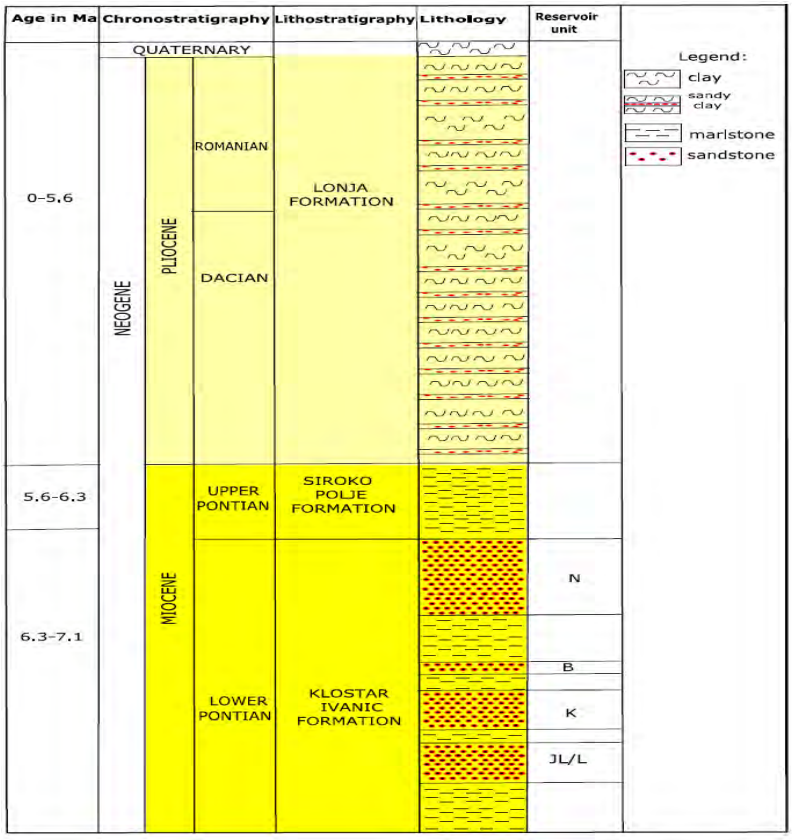

Figure 2: Typical geological column of the investigated area (**Ivšinović and Malvić, 2020**)

The original value of POS for possible new hydrocarbon discoveries within the Upper Miocene deposits (the Kloštar Ivanić Formation) is 42.18% (**Ivšinović et al., 2020**).

2.2. Risky neutral value of possible discoveries

The risk-adjusted value is derived from the utility function with respect to the level of investment and the level of acceptable risk. The derived value depends on the size of the investment, the level of risk and the investor's profit, and for the risk-adjusted value is **Equation 1:**

$$RAV = -\frac{1}{r(u)} \cdot \ln\left[POS \cdot e^{-r(u)(R-C)} + (1-POS) \cdot e^{r(u) \cdot C} \right] \quad (1)$$

Where are:
RAV - *risk-adjusted value,*
R - *total profit (million USD),*
C - *cost (million USD),*
POS - *geological probability of success,*
e - *mathematical constant, Euler's number,*
r(u) - *first approximation of the utility function.*

The risk-averse function (rtc) is a value that is usually taken 1/5 and 1/6 of the total annual budget for hydrocarbon exploration (**Malvić and Rusan, 2009**). Different authors describe the calculation methodology: **Cozzolino (1977), Rose (1987), Malvić et al. (2007), Malvić and Rusan (2009) and Ivšinović (2019)**. Below are the mathematical **Equations 1 to 7** contained in the calculation methodology of RNV for the western part of the Sava Depression.

Net present value is the value obtained by discounting the difference between income and investment for each year over the observed period. When calculating the net present value, a fixed discount rate less the value of the invested capital is assumed **(2)**:

$$NPV = \frac{NT}{(1+i)^k} \quad (2)$$

Where are:
NPV - *net present value of potential reserves,*
NT - *cash flow (USD),*
i - *discount rate,*
k - *number of years.*

Expected monetary value is the profit that an investor makes by investing in oil and gas exploration projects **(3)**:

$$EMV = NPV \cdot (1-POS) \quad (3)$$

Where are:
EMV - *expected monetary value (USD),*
NPV - *net present value of potential reserves,*
POS - *geological probability of success.*

The first approximation of the utility function is the company's annual investment in research and development of a particular area, and is calculated according to **Equation 4**:

$$r(u) = \frac{1}{GU} \quad (4)$$

Where are:

GU - *annual investment (million USD),*
r(u) - *first approximation of the utility function.*

Risk-neutral dollars are calculated from an exponential function that decreases with respect to risk, and expression **(5)** for converting real dollars into risk-neutral dollars is:

$$U(x) = rtc \cdot \left(1 - e^{\frac{-NPV}{rtc}} \right) \tag{5}$$

Where are:
U - *useful units in millions of neutral dollars,*
NPV - *net present value of potential reserves,*
e - *mathematical constant, Euler's number,*
rtc - *risk-averse function.*

Expected utility units adjusted for values taking into account geological probability, and expected utility units are calculated according to relating **Equation 6:**

$$EU = U(x) \cdot POS - RAV \cdot (1 - POS) \tag{6}$$

Where are:
EU - *expected utility units,*
U - *useful units in millions of risk-neutral dollars,*
POS - *geological probability of success,*
RAV - *risk-adjusted value.*

The corresponding equivalents are a variable value that describes the utility in terms of potential return on investment, and relating **Equation 7** is:

$$CE = -rtc \cdot \ln\left(1 - \frac{EU}{rtc} \right) \tag{7}$$

Where are:
CE - *appropriate cash equivalents in millions of risk-neutral dollars,*
rtc - *risk-averse function,*
EU - *expected utility units.*

3. Results and Discussion

An example of the calculation is in area of the western part of the Sava Depression (**Figure 1**) is the Lower Pontian sandstone reservoir of the Klostar Ivanic Formation, which have total geological oil reserves of 556,000 m^3. The predicted hydrocarbon recovery assumed 30% (primary and applied secondary production methods). The average oil price was taken at 390 USD/m^3 (for 2019). Revenues from the sale of hydrocarbons were generated during 10, 15 and 20 years of production. The cost of drilling two vertical wells (one research and one confirmatory) is $6.6 \cdot 10^6$ USD. The future net value of the quantities of hydrocarbons produced, which is used to calculate the neutral value, is $59.0 \cdot 10^6$ USD. In **Table 1**, the values from **Equation 1-7** are calculated.

Table 1: Calculated risk-neutral monetary risk values for multiple scenarios for the western part of the Sava Depression

Hydrocarbon production period (years)	10	15	20
Discount rate (%)	10	10	10
Net present value (10^6 USD)	22.74	14.12	8.77
Geological probability of success (POS)	0.42	0.42	0.42
Expected monetary value (10^6 USD)	13.19	8.19	5.09
CAPEX for hydrocarbon exploration (10^6 USD)	50	50	50
Risk-averse function	10	10	10
Useful units (10^6 USD)	8.97	7.56	5.84
The first approximation of the utility function	0.02	0.02	0.02
Well drilling costs (10^6 USD)	6.61	6.61	6.61
Risk-adjusted value (USD)	5.87	2.75	0.65
Expected utility units (USD)	0.35	1.57	2.07
Appropriate cash equivalents (RNUSD)	0.36	1.71	2.32

The calculation was made for three cases of production: 10, 15 and 20 years; with a discount rate of 10% per annum. Risk averse function is calculated as 1/5 of Capital expenses (CAPEX) investments in research and is $10.0 \cdot 10^6$ US dollars. The first approximation of the utility function for investment research and according to **Malvić and Rusan (2009)** for the value of annual investment in research of 50 million USD for the area of Bjelovar Subdepression and is 0.02. Due to the similarity of the area of Bjelovar Subdepression and the western part of the Sava depression in the case of calculation (RNV), the same value of the first approximation of the utility function of 0.02 will be used. To ensure the expected 30% recovery, a longer period of hydrocarbon production is required, so the values for 10 and 15 years of hydrocarbon production will be taken for comparison data (**Table 1**). For a geological reserve of 556,000 m^3, a POS value of 0.42 for the western part of the Sava Depression and a hydrocarbon production time of 20 years, the expected monetary value is $8.77 \cdot 10^6$ USD. The value of $2.32 \cdot 10^6$ dollar corresponding equivalents is the investment maximum in the explored area of the western part of the Sava Depression (**Figure 1**) considering the annual budget of the hydrocarbon exploration company of $50.0 \cdot 10^6$ USD with a risk-adjusted value of 42.4%.

The period observed in calculating the corresponding equivalents for the value of exploratory POS is 10, 15, and 20 years of hydrocarbon production from the reservoir. The best case is the one whose value of the corresponding equivalents is the largest. In the case of calculating the corresponding equivalents (**Table 1**) for the POS exploration area of the western part of the Sava Depression, 20 years of hydrocarbon production were taken with 2.32 million risk-neutral dollars and the expected monetary value of 5.09 million USD. Hydrocarbon exploration under these conditions is cost-effective given the expected risk. The calculation of the risk-neutral value on the example of exploration and adjusted POS for the area of the Western Sava Depression indicates a large impact of risk on hydrocarbon exploration and production. The results showed that in the investigated area it is possible to estimate the annual amount for research and development of 50 million USD is sufficient for work in the western part of the Sava Depression. Risk be reduced by merging two or more companies in project, because then the total risk is shared.

4. Conclusions

To calculate the risk-neutral monetary value of the investment for the exploratory regional POS, three cases of hydrocarbon production period of 10, 15, and 20 years used for calculation. The highest value of the corresponding monetary equivalents was obtained in the case of 20 years of hydrocarbon production and amounts to $2.32 \cdot 10^6$ USD as the investment maximum in the investigated area of the western part of the Sava Depression for the discovery of reservoirs with geological reserves of 500,000 m^3 of hydrocarbons. This implies that the company dispose of a budget for exploration of hydrocarbons in the completely western part of Sava Depression of 50 million USD. In the case of risk sharing between two or more companies, the risk-neutral value of each of them is reduced, but the expected monetary value must then be divided.

5. References

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SAŽETAK

Izračun rizično neutralne vrijednosti za buduće istraživanje u prostoru zapadnoga dijela Savske depresije

Rizik i upravljanje rizikom je sastavni dio poslovnih politika tvrtki koje se bave istraživanjem i pridobivanjem ugljikovodika. Kako bi se rizik ulaganja u pojedine geološke prostore moglo numerički prikazati i analizirati, potrebno je izračunati rizično neutralnu vrijednost. Izračun rizično neutralne vrijednosti novčanih jedinica je primijenjen za istraživanje dodatnih količina ugljikovodika u postojećim strukturama zapadnog dijela Savske depresije. Izračunata vrijednost od $2{,}32 \cdot 10^6$ neutralnih USD (500 000 m^3 geoloških rezervi ugljikovodika) za vrijednost istražne geološke izglednosti je maksimalno ulaganje u istražno područje zapadnog dijela Savske depresije za proračun tvrtke od 50 milijuna USD namijenjenih za istraživanje ugljikovodika.

Ključne riječi: Savska depresija; POS; rizično neutralna vrijednost; upravljanje rizicima

Author's contribution

Josip Ivšinović (PhD, Field Development Project Expert) completed the entire research and publishing process.