IE347 – Engineering Economy

Case Study – Oil Firm

"Academic integrity is expected of all students of METU at all times, whether in the presence or absence of members of the faculty. Understanding this, I declare that I shall not give, use, or receive unauthorized aid in this study."

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Introduction

For the drilling company to decide on when to drill new wells in the fields of South-Eastern Turkey, many factors have to be considered to maximize the profit. This study will focus on the time value of the investments and profit, and how to utilize it in order to make strategic decisions when it comes to drilling new wells.

At first, the company has 16 wells that have been operating for five years. It is now time 0 and the decision to be made is wether to start the drilling of a seventeenth well now, next year, or the year after. The well starts producing a year after the drilling debutes, in other words if now, at time 0, the company starts digging the well, the production won't start untill year 1.

As the abandonment cost of the field is a factor in this decision, it is assumed that as soon as the lease was signed, the company directly started drilling 16 wells. Meaning, that for all current concerns, the cash flows of the work-overs and the respective uniform series will be treated as if beginning 5 years *before* year 0.

Secondly, the company wants to know in the case that they start drilling well 17 now, when can the drilling following wells be justified, as in when is it more profitable to drill wells 18, 19, 20…

Knowing that the company wants to keep a steady production rate of 20,000 barrels a day, it isn't profitable to base the drilling plan on this alone. Hence this will be considered as a factor separately, if two or more present values from different drilling plans are equal, the one that makes next year's production rate 20,000, or closer to it, will be chosen. In other words, the drilling plan that maximizes the production rate in the close future, will be preferred.

The plant has several costs to consider, including a drilling cost and tying cost, of $2M and $1.75M respectively. The firm also has to consider regular cash flows, that include annual maintenance per well at $200k per year and a workover done every 7 years at $1.25M. The abandonment costs of the facilities are incurred per well and are 10% of the total drilling and facility costs, which include the work-over every 7 years and the annual maintenance.

The shutdown point is 500 barrels per day, and it will be assumed that the firm will shutdown if it *expects* that next year it will produce less than that threshold amount. This helps in decreasing loss in the final year, since the firm believes that anything below 500 barrels per day will result in a loss. It will be assumed that a year will be 365.25 days, since oil production facilities do not stop on holidays or weekends.

The drilling of a new well will increase production by 2000 barrels per day in that year. The current decline rate is 17%, meaning that the flow rate will decrease by 17% for every year the firm is open. After a new well is dug, it will increase the decline rate by 1% for each new well built. This allows for a tradeoff between sooner, higher flow rate of oil and a higher decline rate in the future, meaning the firm will shut down earlier.

Finally, the last matter will be dealt with again after considering oil's inflation rates.

Question 1

Part 1

To compare each alternative, it is best to see the potential profit that would be from each case. It is also noteworthy to compare each alternative with the do-nothing (DN) option, since if a higher profit can be attained from doing nothing, then nothing will be done. All costs and income generated or incurred from before year 0 are not to be considered, since they will appear in every alternative and are thus redundant.

The shutdown point is calculated from year 0 and onto the point where less than 500 barrels per day are to be expected. The flow rate of oil is a geometric decreasing series, where the flow rate is given as $FR_k = 18{,}000(1-17\%)^{k-1}$, where k corresponds to a certain year. For a shutdown point, n, and $FR_n < 500$, then $n < \frac{\ln\left(\frac{500}{18{,}000}\right)}{\ln(1-17\%)} + 1$. Since the firm wants to cease production before the threshold is reached, the maximum integer that is less than the given boundary will be chosen as the firm's shutdown point, namely, $n = \left\lfloor \frac{\ln\left(\frac{500}{18{,}000}\right)}{\ln(1-17\%)} + 1 \right\rfloor$

The calculations are given as such:

$$P_{DN} = [Revenue] - [Shutdown\ Costs] - [Maintenance\ Costs]$$

- $Revenue = 365.25(18{,}000)(30 - 5.25 - 3.75)(P|A, 17\%, 15\%, n)$
- $Shutdown\ Costs = 16(10\%)\left[\$200k \times n + \$1.25M \times \left\lfloor\frac{n+5}{7}\right\rfloor\right]$
  - The term $\left\lfloor\frac{n+5}{7}\right\rfloor$ gives the number of workovers done over the years.
- $Maintenance\ Costs = 16\left[\$200k(P|A, 15\%, n) + \$1.25M(F|P, 15\%, 2)\left(1 + \left(P\middle|A, i_{\frac{eff}{7yrs}}, \left\lfloor\frac{n+5}{7}\right\rfloor - 1\right)\right)\right]$
  - The term $\left(P\middle|A, i_{eff/7yrs}, \left\lfloor\frac{n+5}{7}\right\rfloor - 1\right)$ calculates the workovers done except the first one at finds the present worth at year 2. The added "1 +" is to add the maintenance done at year 2 exactly.
  - The term $(F|P, 15\%, 2)$ givens the PV at year 0

For P when the well 17 is dug out at years 0, 1, or 2:

$$P_t = [Revenue] - [Shutdown\ Costs] - [Maintenance\ Costs] - [Drilling\ Costs]$$

- $Revenue = \begin{cases} 365.25(20{,}000)(30 - 5.25 - 3.75)(P|A, 17\%, 15\%, n) & t = 0 \\ 365.25(30 - 5.25 - 3.75)[18{,}000(P|A, 17\%, 15\%, t) \\ +(18{,}000(1-17\%)^t + 2{,}000)(P|A, 17\%, 15\%, n-t) & t = 1,2 \end{cases}$

- $Shutdown\ Costs = 16(10\%)\left[\$200k \times n + \$1.25M \times \left\lfloor\frac{n+5}{7}\right\rfloor\right]$
$$+10\%\left[\$200k \times n + \$1.25M \times \left\lfloor\frac{n}{7}\right\rfloor\right]$$
    - The first term is exactly the same as the DN case, the second is well 17's shutdown cost.
- $Maintenance\ Costs = 16\left[\$200k(P|A,15\%,n) + \$1.25M(F|P,15\%,2)\left(1 + \left(P\middle|A, i_{\frac{eff}{7yrs}}, \left\lfloor\frac{n+5}{7}\right\rfloor - 1\right)\right)\right] + \$200k(P|A,15\%,n) + \$1.25M(F|P,15\%,t)\left(P\middle|A,15\%,\left\lfloor\frac{n-t}{7}\right\rfloor\right)$
- $Drilling\ Costs = \$2M + \$1.75M$

According to the data from the attached excel file, and after comparing the total profit from starting the drilling of the well 17 in year 0, 1, 2, then challenging these values with the do-nothing option, it is quite obvious that well 17 should be drilled now. The production rate next year will be 20,000 barrels a day as well.

- P_{DN} = \$385,499,528.02 for $n = 20$
- P_0 = \$413,074,384.18 for $n = 19$
- P_1 = \$306,843,473.72 for $n = 19$
- P_2 = \$246,510,251.98 for $n = 19$

And W_0 yields the highest profit hence is the chosen one.

Part 2

To determine whether a well is worth opening or not, the potential profit should exceed the case where the well is not opened. This means the present worth at the time, k, should be higher than the present worth at k if the well weren't opened. It is best to start with trying to see the potential profit if the well were opened at year 0. As such, the alternatives for well 18 at year 0 is compared with the current method of 17 wells.

The result is that the profit for well 18 at year 0 is \$438,718,219.49, which is about \$25M higher than the current returns. For well 18 at year 1, the returns are \$437,893,213.92, the former choice better. In a similar way, the profit for well 19 and well 20 will be calculated are compared to the alternative, do-nothing case.

Well\\k	0	1		Compare with DN.
Well 19	\$462,769,176.38	\$461,880,420.93	>	\$438,718,219.49
Well 20	\$484,943,772.51	\$484,459,094.48	>	\$462,769,176.38

Table 1: Present worth at time k for the opening of wells 19 and 20 and compared with the case where that well was not opened.

Considering the complexity of the problem, it is extremely difficult to pinpoint the number of wells at which it will stop being profitable to add additional wells. As such, the decision should be taken one by one for each well. It seems for now that it is best to open 4 wells (including well 17) at year 0. At some point, it is expected that adding one more well will decrease returns, but the complexity of the problem makes determining that well problematic. Similarly, a more rigorous way of determining at what year to open each well, it would make most sense to calculate the returns for every possible year. However, wells 17 through 20 have demonstrated that delaying the drilling will decrease winnings, meaning that it seems that the earlier the digging the better.

Question 2

As it is well known, inflation rate has increased in the oil and combustibles industry, due to political and socio-economic issues around the world. It has also consequently raised the global inflation rate. In order to account for the potential profits that can be earned as a result of this inflation rate, a forecasting model is needed.

The inflation rates of oil prices directly affect the selling price of each oil barrel. Effectively, the higher the inflation rate, the better it is for the company, considering that its MARR (which will be assumed to be the market interest rate) is unphased by the inflation rate. The forecast model takes data from 13 years, from 2010 until 2022, and analyzes its dynamicity. The data, retrieved from Investing.com (2023), is visualized alongside the respective forecast in figure 1. The exact figures are presented in table 2:

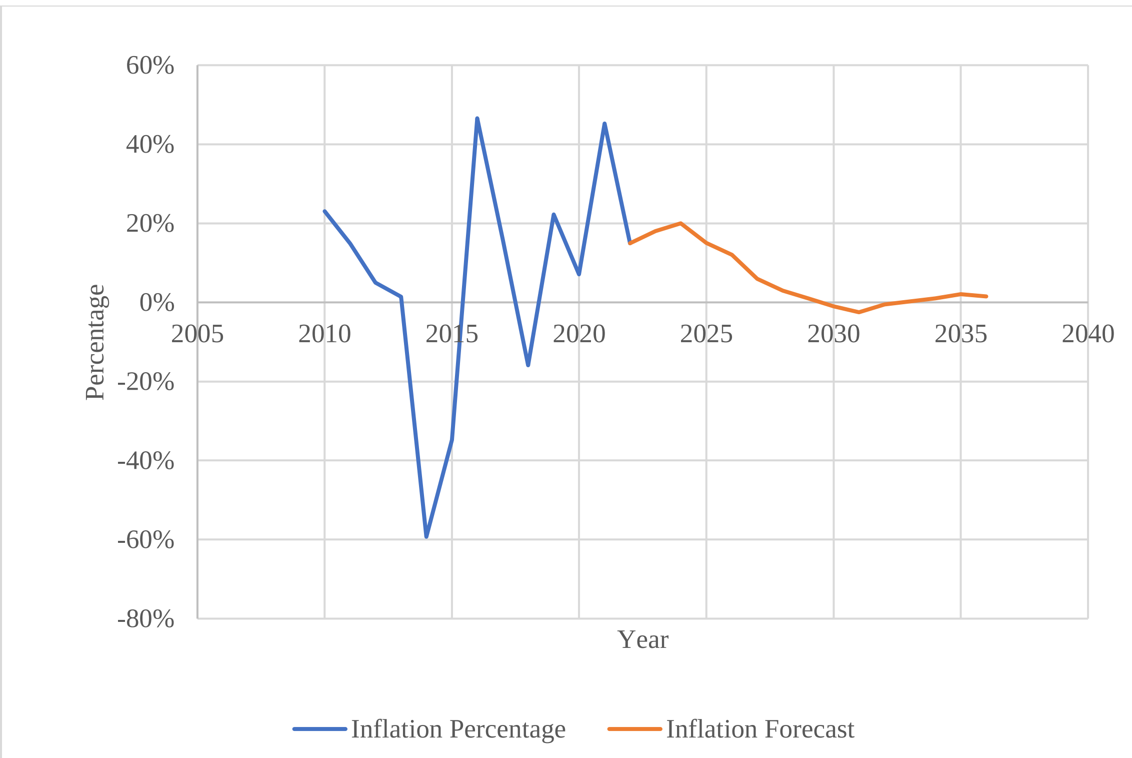

Figure 1: Inflation percentages from years 2010 to 2022 and forecasts over the horizon 2023 till 2036.

Year	Inflation Percentage
2010	23%
2011	15%
2012	5%
2013	1%
2014	-59%
2015	-35%
2016	47%
2017	16%
2018	-16%
2019	22%
2020	7%
2021	45%
2022	15%

Year	Inflation Forecast
2023	18%
2024	20%
2025	15%
2026	12%
2027	6%
2028	3%
2029	1%
2030	-1%
2031	-3%
2032	-1%
2034	1%
2035	2%
2036	2%

Table 2: Data and Forecast of Inflation in the Prices of Oil.

The inflation rates have fluctuated very heavily and a steady incremental trend is visible in recent years. So, why was it not assumed and forecasted that prices will keep increasing?

The problem arising when using a strictly quantitative model is that it cannot take into account the causes of the trends and fluctuations. The recent trends in the increase of oil prices suggest that the following years will also witness a high increase in the oil inflation rate. However, the current issues that are causing the price increases will not last forever, it is illogical to assume a constant upward trend. As such, it will be assumed that the inflation rate will start in the increase for a few years then reach an equilibrium.

The model, does indeed, assume that once current political problems cease, then no more will arise in the following years. This is a very inaccurate assumption, but there is no other way to predict such problems and how they will affect global prices. At the very least, the severe fluctuations that the quantitative model would have assumed will keep the prices even in the long run.

Recalculating the returns from opening well 17 in years 0, 1, or 2, whilst considering the fluctuations in the price of oil, and assuming that the MARR and the market interest rate being at 15% constant, the findings are as follows:

- $P_{DN} = \$632{,}748{,}220.43$
- $P_0 = \$675{,}029{,}425.77$
- $P_1 = \$678{,}580{,}781.14$
- $P_2 = \$679{,}011{,}554.59$

As a result, after considering inflation of prices, it is best to open well 17 in year 2, as opposed to year 0 when not considering inflation. It makes sense to do so considering that prices are high in these years.

References

Investing.com. (2023, January 19). *Brent Oil Futures*. https://www.investing.com/commodities/brent-oil