Oil and Gas Exploration and Production – Phase 3

RFP #: TF – F3.H3

Simulation & Risk - Homework 3

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1st December, 2017

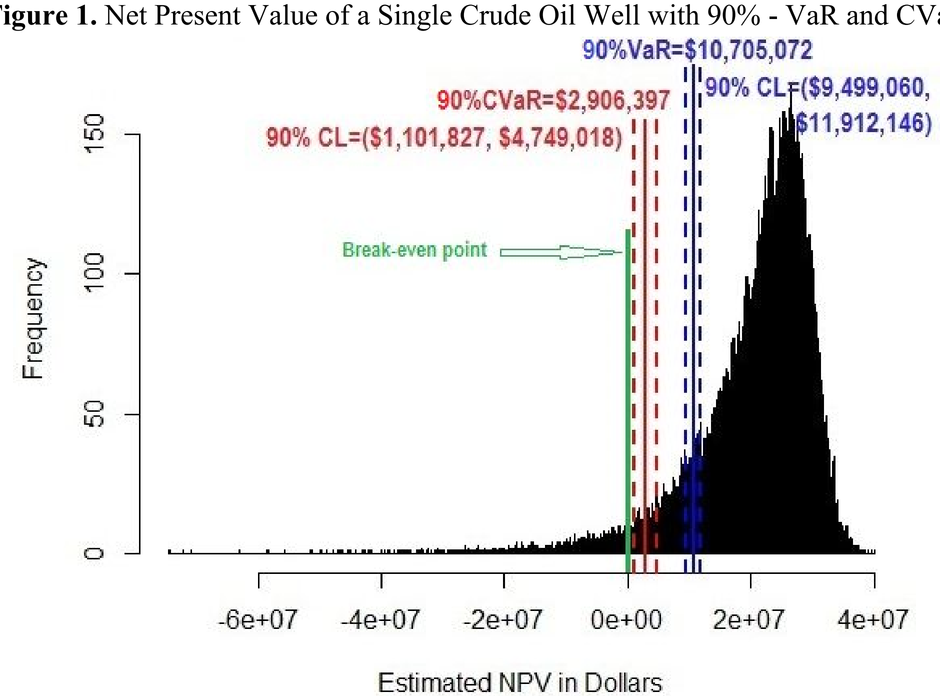
Executive Summary

We were tasked by the Compagnie Pétrolière et Gazière, Inc. to simulate the 90% **Value at Risk** (*VaR*) with **Conditional Value at Risk** (*CVaR*) of net present value (*NPV*) and their respective 90% confidence intervals (*CI*) and plot them over simulated distributions of the NPV of a single crude oil well in 2018 operating until 2040. We utilized a kernel density estimator to simulate the distribution of the annual rate of drilling cost inflation, and projected costs from 2006 to 2018 to arrive at the 2018 drilling cost, a one time fixed cost assumption. Furthermore, revenue was calculated for operations from 2018 to 2040 using triangular distributions for price and quantity of oil produced, with no annual fixed or variable cost component and no discounting for time value of money. The VaR and CVaR were calculated from the simulated NPV and their CI was calculated from bootstrapped samples of VaR and CVaR.

Results and Recommendations

90% VaR for the project is the maximum possible loss (*or minimum possible profit*) for the project at 90% probability (*i.e., P_{VaR}%*). 90% CVaR or 90% Expected Shortfall is the expected loss given the loss is higher than VaR. It is traditionally a loss amount (negative returns) stated as a positive figure. As per our simulation, the 90% VaR for NPV for a single oil well during the 23 year operation period is $10.7 million in profit. The 90% CI for the 90% VaR, is $9.5 million profit at the lower bound and $11.9 million profit at the upper bound, in profit. The 90% CVaR during the same period was $2.9 million in profit, with 90% CI for the 10% CVaR, being $1.1 million profit at the lower bound and $4.75 million profit at the upper bound. Figure 1 shows the 90% VaR and 90% CVaR along with their respective 90% CIs. The break-even point, where the NPV is zero, is also shown in the figure. The probability of break-even is 2.47% as per our simulation.

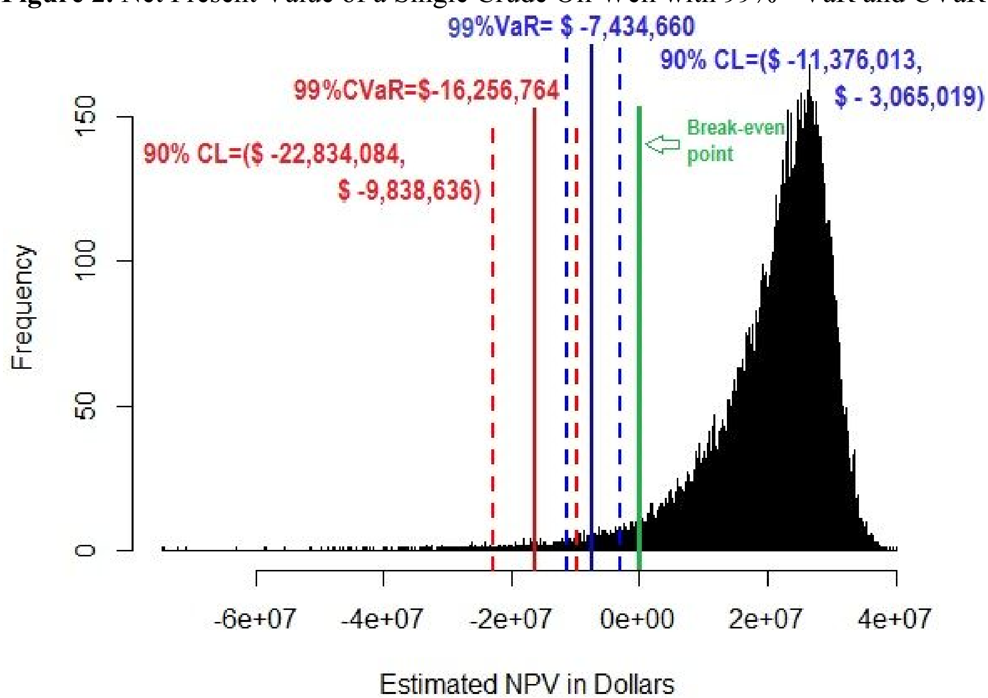
Figure 1. Net Present Value of a Single Crude Oil Well with 90% - VaR and CVaR



The VaR and CVaR as a profit figure, gives a sense of how low the profit might be in the worst case scenario. This helps to quantify the risk management strategies like an oil price hedge to prepare for low profit scenarios. However the downside risk is not always a price risk, it can also be an operational risk where the company is unable to extract the planned quantity of oil from the well.

We recommend, shifting the VaR probability below the break-even probability as it gives a better sense of how big the losses can get in the worst case scenario, ideally measuring solvency implications of black swan events. We simulated VaR and CVar at 99% (*which implies (1-P_{VaR}) is below the 2.47% break-even point*) as an alternative. As per our simulation, the 99% VaR for NPV is $7.4 Millions in loss. The 90% CI for the 99% VaR, is $11.4 million loss at the lower bound and $3 million loss at the upper bound. The 99% CVaR during the same period was $16.25 million in loss, with 90% CI for the 1% CVaR being $22.8 million loss at the lower bound and $9.8 million loss at the upper bound.

Figure 2. Net Present Value of a Single Crude Oil Well with 99% - VaR and CVaR



Analysis

We used **kernel density estimator** for geometric rate changes in cost of drilling, because normal testing is not ideal for a small sample size of only sixteen. We used the simulated geometric changes in cost and compounded these changes on the 2006 oil well drilling cost, for over 12 years, to arrive at the 2018 drilling cost simulations.

We used random number generator from **triangular distribution**, for both price per barrel and number of barrels, as per recommendation. The number of barrels produced distribution is fixed for all years in the study with minimum of 10K barrels, maximum of 17K barrels, and mode of 15.5K barrels. The oil price per barrel distribution changes with the 2016 AOF reference crude oil forwards, between 2018 and 2040 inclusive of both years.

To find the confidence interval, we bootstrapped VaRs and CVaRs from 10,000 samples of size 1,000 each. The 5% le and 95% le points of 10,000 VaR-CVaR sample is the simulated lower and upper bound, of the 90% CI of VaR and CVaR. The 90% CIs for both 90% VaR-CVaR and 99% VaR-CVaR, were simulated using the same bootstrap process.

Next Steps

Compagnie Pétrolière et Gazière, Inc.should consider moving towards 99% VaR as it give a better sense of large loss conditions. The company must hedge for possible losses in case of a 99% VaR breach. Hedging for an average lumpsum amount of $16MM losses is advisable. This hedge would be a complex one as the risk faced by the company is not just a price risk but also an operational one due to uncertainty in the quantity drilled and cost of drilling. Setting aside a corpus of $9MM to $23MM would be advisable to prepare for threat to solvency of the company due to crude oil price shocks and operational risks..

Appendix

#R Code.

```
library(xlsx)
PriceProj <- read.xlsx('C:/Users/Sam Koshy/Desktop/MSA - Fall/502/Fall 3/Simulation &
Risk/HW/2/Analysis_Data.xlsx', 1, startRow = 4)
DrillingCost <- read.xlsx('C:/Users/Sam Koshy/Desktop/MSA - Fall/502/Fall 3/Simulation &
Risk/HW/2/Analysis_Data.xlsx', 2, startRow = 4)
# Drilling Costs from 1991-2006 - 16 obs
cost <- DrillingCost[31:46, 5]
library(graphics)
library(ks)
cost
PriceProj
hist(cost,breaks=8)
#Simulation using kernel density estimator
new.density <- density(cost, bw='SJ-ste')
new.density
set.seed(9385)
rate.value=matrix(exp(rkde(fhat=kde(cost, h=0.08908), n=12*100000)),nrow=100000)
#Cost of Drilling in 2018
co=2238.6*1000*apply(rate.value,1,prod)
#Barrels
library("triangle")
Barrels= matrix(rltriangle(n=23*100000, a=10000, b=17000, c=15500),nrow=100000)
#Price
Price=rep(0,100000)
for (i in rep(1:23)){
  Pricei=matrix(rltriangle(n=100000, a=PriceProj[i,3], b=PriceProj[i,2], c=PriceProj[i,4]),nrow=100000)
  Price = cbind(Price,Pricei)
}
Price=Price[,2:24]
#Revenue
Revenue=Barrels*Price
TotRev= apply(Revenue,1,sum)
#Net Present Value
NPV=TotRev-co
quantile(NPV)

#VaR & CVaR @ 10%
library(scales)
VaR.percentile = 0.10
VaR = quantile(NPV, VaR.percentile)
CVaR <- mean(NPV[NPV < VaR])
```

```
# Confidence Intervals for VaR & CVaR - Bootstrap Approach
n.bootstraps <- 10000
sample.size <- 1000
VaR.boot <- rep(0,n.bootstraps)
CVaR.boot <- rep(0,n.bootstraps)
for(i in 1:n.bootstraps){
  bootstrap.sample <- sample(NPV, size=sample.size)
  VaR.boot[i] <- quantile(bootstrap.sample, VaR.percentile, na.rm=TRUE)
  CVaR.boot[i] <- mean(bootstrap.sample[bootstrap.sample < VaR.boot[i]], na.rm=TRUE)
}
VaR.boot.U <- quantile(VaR.boot, 0.95, na.rm=TRUE)
VaR.boot.L <- quantile(VaR.boot, 0.05, na.rm=TRUE)
dollar(VaR.boot.L)
dollar(VaR)
dollar(VaR.boot.U)
CVaR.boot.U <- quantile(CVaR.boot, 0.95, na.rm=TRUE)
CVaR.boot.L <- quantile(CVaR.boot, 0.05, na.rm=TRUE)
dollar(CVaR.boot.L)
dollar(CVaR)
dollar(CVaR.boot.U)
hist(NPV, breaks=5000, main=paste("Figure 1. Net Present Value of a Single Crude Oil Well with 10% -
VaR and CVaR"), xlab = 'Estimated NPV in Dollars', ylab = 'Frequency')
abline(v=0, col='green', lwd=2)
abline(v=VaR, col='blue', lwd=2)
abline(v = VaR.boot.L, col="blue", lwd=2, lty="dashed")
abline(v = VaR.boot.U, col="blue", lwd=2, lty="dashed")
abline(v=CVaR, col='red', lwd=2)
abline(v = CVaR.boot.L, col="red", lwd=2, lty="dashed")
abline(v = CVaR.boot.U, col="red", lwd=2, lty="dashed")
#Break-even-point-percentile and Quartiles of NPV
sum(NPV<(0))/100000  #This means the break even is at 2.47% hence VaR should be below this

#VaR & CVaR @ 1%
library(scales)
VaR.percentile1 = 0.01
VaR1 = quantile(NPV, VaR.percentile1)
CVaR1 = mean(NPV[NPV < VaR1])
VaR1
CVaR1
# 90% Confidence Intervals for Value at Risk & Conditional VaR - Bootstrap Approach
n.bootstraps <- 10000
sample.size <- 1000
VaR.boot <- rep(0,n.bootstraps)
CVaR.boot <- rep(0,n.bootstraps)
for(i in 1:n.bootstraps){
  bootstrap.sample <- sample(NPV, size=sample.size)
  VaR.boot[i] <- quantile(bootstrap.sample, VaR.percentile1, na.rm=TRUE)
  CVaR.boot[i] <- mean(bootstrap.sample[bootstrap.sample < VaR.boot[i]], na.rm=TRUE)
```

```
}
VaR1.boot.U <- quantile(VaR.boot, 0.95, na.rm=TRUE)
VaR1.boot.L <- quantile(VaR.boot, 0.05, na.rm=TRUE)
dollar(VaR1.boot.L)
dollar(VaR1)
dollar(VaR1.boot.U)
CVaR1.boot.U <- quantile(CVaR.boot, 0.95, na.rm=TRUE)
CVaR1.boot.L <- quantile(CVaR.boot, 0.05, na.rm=TRUE)
dollar(CVaR1.boot.L)
dollar(CVaR1)
dollar(CVaR1.boot.U)
hist(NPV, breaks=5000, main=paste("Figure 1. Net Present Value of a Single Crude Oil Well with 10% -
VaR and CVaR"), xlab = 'Estimated NPV in Dollars', ylab = 'Frequency')
abline(v=0, col='green', lwd=2)
abline(v=VaR1, col='blue', lwd=2)
abline(v = VaR1.boot.L, col="blue", lwd=2, lty="dashed")
abline(v = VaR1.boot.U, col="blue", lwd=2, lty="dashed")
abline(v=CVaR1, col='red', lwd=2)
abline(v = CVaR1.boot.L, col="red", lwd=2, lty="dashed")
abline(v = CVaR1.boot.U, col="red", lwd=2, lty="dashed")
```