A REAL OPTION APPROACH TO IRREVERSIBLE INVESTMENT IN PETROLEUM REFINERY UNDER REVENUE UNCERTAINTY

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Abstract

We use real option approach to analyse irreversible investment in petroleum refinery industry. We combine the “bad news principle” with real options model under revenue uncertainty to develop a hybrid model for the analysis of investment in petroleum refinery. Our results show that there are cases where irreversible investment in petroleum refinery cannot be justified under prevailing stochastic conditions.

KEY WORDS: Applications, Energy; Stochastic Models; Finance; Mathematical Economics

Introduction

According to OPEC World Outlook (2017, Chapter 5) there is a huge gap between required global refineries capacity and available capacity. But the reality is that investment in the expansion of refinery capacity is at a low pace. We use real options approach to analyse irreversible investment in petroleum refinery. We develop a hybrid real option model to analyse irreversible investment in refinery. The model combines the canonical real option model with the bad news principle. Historical data is used to calibrate the hybrid model.

The aim of this paper is to use real option technique to analyse irreversible investment in the petroleum refinery industry. Our interest is to explain the apparent paradox in the gap between available refinery capacity and required refinery capacity especially in developing countries. For example, Nigeria is a member of OPEC yet she imports petroleum product.

Literature Review

Schmit et. al.(2011) used real option analysis to study irreversible investment in ethanol plant. They used historical data from various studies to estimate the parameters of the models and illustrated the effects of the policy on the entry and exit environment.

Weibel and Madlener (2015) used real option technique to examine the feasibility and optimal sizing of hybrid power plant. Monte Carlo simulation methodology was used to examine the uncertainties associated with the investment. Thijssen (2015) developed a model for the analysis of a project constrained by revenues and construction uncertain. The model was used to determine if it is economically feasible to invest in the construct of a high-speed rail network in the UK.

Zhu et. al.(2015) used real options theory to develop a model for irreversible investment in oil fields outside the investor’s country. The variables included in the model are: oil price uncertainty, investment cost, exchange rate and investment environment. They employed simulation to obtain numerical results. Fonseca et. al (2017) also considered the impact of oil price volatility on decision making to study irreversible investments in oil field development.

Zeng and Zhang(2011) provides a review of real option literature including area of applications. They also pointed out the importance of real options techniques. A review provided by Schachter and Mancarella (2016) focused on real option methods used in smart grid systems. They identified the benefits and limitations of real options methodologies. Analytic method, lattice approach and simulation procedures for obtaining solutions to real option models were discused.

Consider an irreversible investment with a sunk cost *I.* Let X_t be the stream of revenues received at time *t* after the investment. X_t is a stochastic random variables. We shall assume that X_t can be described by a geometric Brownian motion. Thus we can write X_t as

$$dX_t = \alpha X_t dt + \sigma X_t dz \tag{1}$$

where α and σ are the mean and volatility of the random variable X_t. Let the value of the project at time *t* be V(*X*, *t*) while the value of the option to invest at time *t* is F(*X*,*t*). Let T be the optimal time of investment. The goal of the investor is to find T that maximizes the expected present discounted return of the investment. The expected present value of the investment is:

$$V(X,0) = E\{(V(X,T) - I)e^{-\rho T}\} \tag{2}$$

where ρ is the interest rate and E is the expectation operator. Real options theory states that the optimal time to invest is obtained by solving the constraint optimization problem

$$F(X) = supE\{(V(X,t) - I)e^{-\rho t}\} \tag{2}$$

subject to the boundary conditions and the stochastic process governing stochastic random variable X_t, which we have assumed to be a geometric Brownian motion. The boundary conditions are designed to ensure that the optimal investment time, T, is finite. The Bellman equation is E(dF) = ρ Fdt. If $\sigma = 0$, Dixit and Pyndyk (1994) states that the optimal time to invest is given by

$$T^* = \text{Max}\left(\frac{1}{\alpha}\log\left[\frac{\rho I}{(\rho - \alpha)\text{V}}\right], 0\right) \tag{3}$$

where ρ is the discount rate. If $\sigma \neq 0$, then Dixit and Pindyck (1994) states that the optimal investment trigger is given by

$$V^* = \frac{\beta}{\beta - 1} I \tag{4}$$

where β is the positive root of the equation $\frac{1}{2}\sigma^2\beta(\beta - 1) + \alpha\beta - \rho = 0$

We use these two results modified by the “bad news principle” to analyse irreversible investment in the petroleum refinery industry.

DATA COLLECTION, ANALYSIS AND APPLICATIONS

One of the main issues in the use of real option techniques is the calibration of real option models. Here we need to obtain values for α, σ, ρ, I and the stream of revenues. We shall estimate values for α and σ using published data for regional refinery margins as a surrogate for the streams of revenue. An estimated value of α and σ are 0.197878 and 0.61029 respectively. We shall use these values together with data on refinery in Nigeria.

Table 1 shows petroleum products imported into Nigeria. The Table shows that the volume of Premium Motor Spirit (PMS) and House Hold Kerosene (HHK) imported into Nigeria is substantial. These pieces of information indicate that there is urgent need for new refineries in Nigeria. Indeed Nigerian government issued a number of licences to organisations to establish refineries. These refineries have not taken up. Only one is at the construction state.

Table 1: 10-Year PPMC's products Import (Metric Tons)

Year Product	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
PMS	5,792,449	4,596,145	5,988,567	5,031,288	487,375	5,873,996	4,387,019	4,860,813	5,926,513	8,018,721
HHK	1,335,022	909,542	1,170,993	1,608,464	151,009	2,058,298	2,175,388	2,177,451	1,503,776	302,108

Source: Nigerian National Petroleum Corporation (NNPC) 2016 Annual Statistical Bulletin

Table 2 shows the utilizations of government owned refineries in Nigeria. The maximum capacity utilization is 41.34 at WRPC in 2009. The utilization level in each of the refinery is low compared to global best practice. One of the reasons for this low utilization level is pipeline breakdown. Table 3 shows data on pipeline breakdown for ten years.

Table 2: Refinery Capacity Utilization in Nigeria (%)

Years Refinery	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
KRPC	-	19.56	22.17	20	22.17	29.12	29.33	9.24	2.98	9.24
PHRC	24.87	17.84	15.23	9	17.33	11.95	9.18	17.28	4.66	17.28
WRPC	-	38.52	41.34	43	27.99	27.88	35.99	12.03	7.07	12.03

Source: Nigerian National Petroleum Corporation (NNPC) 2016 Annual Statistical Bulletin

Vandalization and system failure are the two sources of pipeline breakdown as indicated in Table 3. From the data available, the empirical probability that pipeline failure will be due to vandalization is 0.9855. This is the main source of "bad news." Vandalization has resulted low utilization and huge loss making operations by the refineries.

Table 3: Pipeline Incidence 2007-2016. (Number of breakdown each Year).

Years - Source	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	Total	Probability
Vandali-zation	3,224	2,285	1,453	836	2,768	2,230	3,505	3,700	2,783	2,534	23,866	0.985547
System Deteri-oration	20	33	27	24	19	26	65	32	49	55	350	0.014453
Total	3,244	2,318	1460	860	2,787	2,256	3,570	3,732	2,832	2,589	24,216	1.000000

Source: Nigerian National Petroleum Corporation (NNPC) 2016 Annual Statistical Bulletin

Applications of the investment triggers stated above combined with negative flow of revenues point to the postponement of investment in the refinery.

Conclusion

The real option techniques provide investment triggers that are more demanding that the net present value procedure. The methodology provides option to postpone investment. Many investors who obtain licence to build new refineries are taking the option to postpone investment. Several factors may be responsible for this. It is important for those governments having the desire to establish local refineries to adopt a critical analysis based on real option technique. In Nigeria, pipeline vandalization ("bad news") combined with real options investment trigger suggest postponement of the decision to invest in local refineries. Indeed many organisations offered licence to build refineries have chosen the option to wait.

References

Dixit, A. K. and Pindyck, R.S.(1994), Investment under uncertainty. Princeton University press, Princeton New Jersey.

Fonseca, M. N.; Pamplona, Edson de Oliveira; Valerio,Victor Eduardo de Mello; Aquilaa,Giancarlo; Rocha, Luiz Célio Souza; and Junior; Paulo Rotela (2017) "Oil price volatility: A real option valuation approach in an African oil field" Journal of Petroleum Science and Engineering 150 (2017) 297–304

OPEC(2017) Organization of the Petroleum Exporting Countries World Oil Outlook 2040

Schachter, J. A. and Mancarella, P.(2016) A critical review of Real Options thinking for valuing investment flexibility in Smart Grids and low carbon energy systems. Renewable and Sustainable Energy Reviews 56 (2016) 261–271

Schmit, T. M.; Luo, J and Conrad(2011) Estimating the influence of U. S. ethanol policy on plant investment decisions: A real option analysis with two stochastic variable. Energy Economics. Doi:10.106/j.enco.2011.07.013.

Thijssen, J. J. J.(2015 A MODEL FOR IRREVERSIBLE INVESTMENT WITH CONSTRUCTION AND REVENUE UNCERTAINTY. Journal of Economic Dynamics & Control 57, 250-266

Weibel, S. and Madlener, R.(2015) Cost-effective design of ringwall storage hybrid power plants: A real options analysis. Energy Conversion and Management 103 (2015) 871–885

Zeng S. and Zhang S.(2011) Real Options Literature Review. iBusiness, 2011, 3, 43-48 doi:10.4236/ib.2011.31007 (http://www.SciRP.org/journal/ib)

Zhu, L., Zhang, Z. and Fan, Y.(2015). Overseas oil investment projects under uncertainty: How to make informed decisions? Journal of Policy Modeling 37 (2015) 742–762