The Impact of Stochastic Extraction Cost on the Value of an Exhaustible Resource: An Application to the Alberta Oil Sands

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Production and investment decisions for energy producers are complicated by highly uncertain energy prices as well as by uncertain costs for developing and producing a resource. To date the attention of researchers has focused mainly on the impact of uncertain output prices with less attention paid to the impact of uncertain costs. For some energy resources, uncertain production costs play a key role in extraction decisions. For example oil production from the oil sands in Alberta requires a significant amount of natural gas. Natural gas prices are characterized by high volatility and high correlation with other energy prices, particularly oil prices. This paper studies the impact of uncertain extraction costs on optimal extraction decisions for a non-renewable resource, using the Alberta oil sands as an example.

The analysis in the paper models natural gas and oil prices as correlated stochastic processes, which requires specifying the nature of the co-movement between the two prices. Since natural gas and oil are substitutes in key markets, one might expect to observe a long run relationship between their prices. In particular the ability of industrial processes to switch to the cheaper fuel would be expected to limit the extent to which oil and natural gas prices would diverge from each other. However, the paper shows that it is difficult to detect a long run statistical relationship between oil and natural gas prices. This is in contrast to a rule of thumb which has been used in the industry of a 10:1 ratio between the price of oil in $/barrel and the price of natural gas in $/mmbtu.

Accordingly, in modelling the dynamics of oil and gas prices, two models are proposed, one which incorporates a long-run link between the two markets and the other which has no such link. In both models, oil and gas prices are correlated, but in the linked model it is specified that over the long run the ratio of oil and gas prices is pulled to an equilibrium level. These two models are estimated statistically using data for West Texas Intermediate crude futures and Henry Hub natural gas futures.

The paper then presents a model of the value of an operating oil sands project and its optimal production profile assuming either of the price models prevails for natural gas and oil prices. In the valuation model it is assumed that producers seek to maximize the expected net present value of their resource over time, choosing when to produce, temporarily suspend production, or eventually to permanently abandon the project. Project value is determined as well as critical prices for oil at which it would be optimal to restart a closed project, suspend an open project or abandon a project altogether.

A key result of the paper is that incorporating an explicit model of stochastic costs yields very different results than the simple 10:1 rule of thumb sometimes used in the industry for the relationship between oil and natural gas prices. The paper focuses on the impact of natural gas price volatility as well as the correlation between natural gas and oil prices on the value of the project and optimal decisions. A higher natural gas price volatility, which represents more uncertain future costs, is found to reduce the value of the project. The negative effect of natural gas price volatility is higher when the correlation between gas and oil prices is higher. The intuition is that higher correlation between gas and oil reduces the benefit of high oil prices since costs will also tend to rise.

The above result holds for both price models. The main difference that arises between the two models is in the sensitivity to natural gas prices. More specifically, in the specification which included a long run relationship between oil and gas prices, project value and optimal decisions are much less sensitive to natural gas price volatility.

A final observation is the strong impact that the slope of the implied forward curve has on the optimal decision regarding shutting down or abandoning the project. Forward curves consistent with declining expected oil prices relative to natural gas prices, resulted in critical prices to shut down or abandon the project which were quite insensitive to natural gas price volatility or to the correlation between oil and gas prices. In contrast implied forward curves consistent with rising oil prices relative to natural gas resulted in critical prices that were very sensitive to natural gas price parameters.

The results of the paper point to the importance of careful consideration of the nature of uncertainly for both the output price and the prices of key inputs known to be volatile. A recommendation for analyzing the economics of energy projects such as the oil sands is to consider more than one characterization of the price process for cost, in order to observe its impact. The use of a simple rule of thumb may lead to poor decisions. Furthermore, the slope of the forward curve implied by the data significantly affects the optimal decision. This points to the need for ongoing analysis of project economics as market conditions, as reflected in futures prices, change over time.