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The impact of spatial price differences on oil sands investments

Gregory Galay

Department of Economics and Finance, University of Guelph, Guelph, Ontario N1G 2W1, Canada

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ABSTRACT

In this article, a two-factor real options model is developed to examine the impact spatial price differences have on the value of an oil sands project and the incentive to invest. Large, volatile price differences between locations can emerge when demand to ship exceeds capacity limits. This may have a significant impact on production, investment, and policy in exporting regions. Here, we assume the price difference between two locations follows a stationary process implying crude oil markets are integrated as oil prices in different locations move together. The investment decision is formulated as a linear complementarity problem that is solved numerically using a fully implicit finite difference method. Results show the value of an oil sands project and the incentive to invest in a new project will increase when the mean price difference decreases. Surprisingly, the standard deviation of the price difference has very little impact on project value or the incentive to invest.

1. Introduction

The feasibility of a natural resource investment critically depends on its access to markets. Spatial arbitrage models have shown, the more remote a natural resource is the lower its net price will be (Samuelson, 1952; Takayama and Judge, 1971). Consequently, improving market access has been the motivation behind the decision to build additional pipeline capacity to export crude bitumen and its derivatives from Alberta. Fig. 1 plots monthly spot price data for West Texas Intermediate (WTI), Western Canadian Select (WCS), Mexican Maya, and the price difference between Mexican Maya and WCS from January 2005 to December 2015.[1] Prior to 2011, WCS and Mexican Maya tracked one another closely with Mexican Maya receiving a small location premium over WCS and large price differences were short lived. However, beginning in 2011, WCS and Mexican Maya diverged and WCS was heavily discounted relative to Mexican Maya. Proponents of additional pipeline capacity argue this large price difference is mostly attributed to inadequate transportation infrastructure and claim that both firms and governments would benefit from expanding pipeline capacity. Firms would gain access to international markets, higher world prices, and lower transport costs and governments would receive more tax revenue from higher royalties and income taxes.

This paper incorporates spatial price differences into a real options model to study the impact improved market access will have on the value of an oil sands project and the incentive to invest. Here, the value of an oil sands project is contingent upon uncertain oil prices and transport costs. We refer to the spatial price difference as transport costs to avoid confusion over price and spatial price differences. Transport costs include all factors that affect the spatial price difference including pipeline and rail tariffs, exchange rates, and capacity constraints. We assume oil prices follow a geometric Brownian motion (GBM) and transport costs follow a Ornstein-Uhlenbeck (OU) mean-reverting process. These assumptions are consistent with real options and oil price cointegration literature. Stationary process for transport costs implies the world oil market is 'one great pool' (Adelman, 1984) as crude oil prices in different geographical locations move together. Optimal stopping is used to identify the threshold prices when it is optimal to invest

E-mail address: ggalay@uoguelph.ca.

[1] WCS is the benchmark for heavy crude oil in Canada and it is located in Hardisty, Alberta. It is a blend of heavy crude oil, crude bitumen and diluents with an API gravity of 20.5°. Mexican Maya is a heavy crude oil similar in quality to WCS located in the Gulf Coast.

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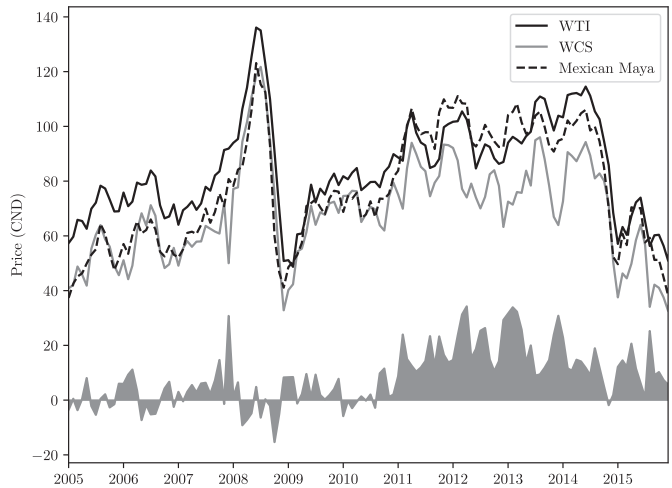

Fig. 1. Monthly crude oil spot prices and Mexican Maya-WCS price difference in Canadian dollars from January 2005 to December 2015. WTI data was collected from the EIA, Mexican Maya data was collected from Bloomberg, and WCS data was collected from Natural Resources Canada.

in a new project and abandon an operating project.[2] The optimal stopping problems result in free boundary problems that do not have known analytical solutions. Following Wilmott et al. (1993) and Insley and Rollins (2005), the free boundary problems are redefined as linear complementarity problems and we approximate the solutions numerically using a fully implicit finite difference method (IFDM). Model parameters are chosen to approximate a typical *in situ* oil sands project in Northern Alberta.

To preview the results, we find that a decrease in transport costs increases the value of the oil sands project, investments in new projects happen earlier, and operating projects are abandoned later. These results are consistent with the claims made by supporters of the policy to expand pipeline capacity. Surprisingly, we also find that changes in transport cost uncertainty has virtually no effect on the value of the oil sands project or on the decision of when to invest and when to abandon. Typically, the value of an option increases as uncertainty increases as upside potential increases while the option limits downside loses.

1.1. Literature review

Evaluating natural resource investments using real options analysis is a standard approach in the literature. Brennan and Schwartz (1985) apply option pricing theory to the problem of valuing uncertain investments. They determine the combined value of the options to shut down and restart a copper mine when spot prices are uncertain and the convenience yield is constant. Paddock et al. (1988) combine option-pricing techniques with a model of equilibrium in the market for the underlying asset to value offshore petroleum leases. Bjerksund and Ekern (1990) value a Norwegian oil field with options to defer and abandon. Clarke and Reed (1990) consider the option to abandon a currently producing oil-well when oil prices and extraction rates are uncertain. Conrad and Kotani (2005) determine the trigger prices to initiate investment in the Arctic National Wildlife Refuge under different assumptions about the evolution of crude oil prices. Morck et al. (1989) value forestry resources under stochastic inventories and prices. Insley (2002) and Insley and Rollins (2005) consider the optimal tree harvest problem when tree harvesting can be delayed and output prices follow known stochastic processes. Conrad (2000) determines the order and timing of wilderness preservation, resource extraction, and development when amenity value, the value of the resource, and return from development all follow known stochastic processes.

Recently, a number of papers have analyzed the management of oil sands projects and the rate of oil sands development using real options analysis. Almansour and Insley (2016) extend the Brennan and Schwartz (1985) model to include cost uncertainty and study the optimal management of an oil sands project. *In situ* oil sands projects face high levels of cost uncertainty from fluctuations in natural gas prices, natural gas is an important input in the extraction process. Almansour and Insley (2016) extend the Schwartz and Smith (2000) two factor commodity price model by incorporating a deterministic seasonality component. In their paper, commodity prices follow a non-stationary stochastic process made up of three factors: a long-run factor (non-stationary process), a short-run factor (stationary process), and a deterministic function that represents seasonality in the prices. Surprisingly, they find the value of the oil sands project is significantly negatively affected by stochastic costs and the value of the project decreases as cost volatility increases.

Kobari et al. (2014) evaluate the rate of oil sands expansion under different environmental cost scenarios in a dynamic, game-theoretic model. Their model considers a multi plant/multi-agent setting with price and cost uncertainty. Like Almansour and Insley (2016), cost uncertainty is driven by uncertainty in natural gas prices. The price of oil follows a mean-reverting process with an increasing long-run average price. The cost of natural gas depends on a deterministic seasonality component and a mean-reverting stochastic component. They consider two environmental cost scenarios: an increasing environmental cost scenario and a decreasing environmental cost scenario. Their results show that decreasing environmental costs cause new investments to be delayed compared to increasing environmental costs but decreasing environmental costs have little effect on projects that have already been constructed.

Almansour and Insley (2016) and Kobari et al. (2014) both assume that the price of crude oil and natural gas in Northern Alberta follows the same dynamics as international crude oil and natural gas benchmarks.[3] These assumptions ignore crude oil price differences and factors that affect price differences such as the availability of pipeline capacity, exchange rates, weather, and the cost of diluent.[4] Carney et al. (2013) expect Canadian crude oil prices to remain depressed and more volatile than international benchmarks until sufficient capacity is in place. They believe this is an important issue facing Canada's energy sector and a major factor restraining business investment. This paper hopes to contribute to this literature by focusing on the effect spatial price differences have on a firm's investment decision. Due to the cost of investing in new pipeline projects, understanding how oil sands producers will respond to a decrease in spatial price differences is important for oil transport firms proposing new pipeline projects and for policymakers weighing the cost and benefit of these new pipeline projects.

The rest of the paper is organized as follows. Section 2 presents the general valuation model when price and transport costs are uncertain. Section 3 values a typical *in situ* oil sands project and discusses the results. Section 4 summarizes and concludes the paper.

[2] Insley and Wirjanto (2010) compare dynamic programming and contingent claims approaches for valuing risky investments. They find contingent claims is preferred when data exists that allows for the estimation of the market price of risk or the convenience yield. However, in this setting, it might not be possible to create a perfect hedge as transport costs risk (i.e. crude oil price spreads) may not be actively traded in markets.

[3] Almansour and Insley (2016) use weekly WTI futures and Henry Hub (HH) natural gas futures data from January 1995 to August 2010 to calibrate their model and Kobari et al. (2014) use daily WTI futures and HH natural gas futures data from February 2, 2009 to May 10, 2012 to calibrate their model.

[4] Diluent is any lighter hydrocarbon added to heavy crude oil or bitumen in order to facilitate its transportation in crude oil pipelines.