



Resource extraction with a carbon tax and regime switching prices: Exercising your options[☆]



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ABSTRACT

This paper develops a model of a profit maximizing firm with the option to exploit a non-renewable resource, choosing the timing and pace of development. The resource price is modelled as a regime switching process, which is calibrated to oil futures prices. A Hamilton-Jacobi-Bellman equation is specified that describes the profit maximization decision of the firm. The model is applied to a problem of optimal investment in a typical oils sands *in situ* operation, and solved for critical levels of oil prices that would motivate a firm to make the large scale investment needed for oil sands extraction, as well as to operate, mothball or abandon the facility. Regime shifts can have an important effect on the optimal timing of investment and extraction. The paper examines the effect of several carbon tax schemes on optimal timing of construction, production and abandonment. A form of Green Paradox is identified.

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1. Introduction

Commodity prices are typically highly volatile and characterized by cycles of boom and bust. Not surprisingly, investments in resource extraction tend to mirror these cycles. One example can be found in investment in the high cost oil sands reserves in Alberta, Canada. Beginning in the 1970's, investment in the extraction of the oil sands was an on-again off-again proposition depending on the strength of oil prices. World crude prices since 1986 and capital expenditure in the oil sands since 1973 are shown in Figs. 1 and 2 respectively. Buoyant oil prices in the past decade up until mid-2014 have been associated with unprecedented investment in oil sands extraction. The collapse of oil prices in the latter part of 2014 resulted in many cancellations and delays of spending plans and total capital expenditures dropped sharply in 2015. However, oil sands production (Fig. 3) has shown a fairly steady upward trend with no indication that producing projects have curtailed production in response to low oil prices.

The run-up in oil prices and resultant strong investment in oil sands extraction of the past two decades raised concerns nationally and internationally about the impact of such large scale operations on the local environment including water quality for nearby residents, wildlife habitat and general ecosystem health. Added to the more localized environmental impacts are widespread concerns about increased carbon emissions from expanding production from oil sands reserves, which has a high carbon content compared to other sources of crude production (Lattanzio, 2014). The Alberta government was criticized for not having adequate regulatory oversight in place to ensure that environmental impacts are kept at acceptable levels. Oil sands operators have felt the pressure of strong negative public opinion expressed around the world and there is a sentiment that they have lost their "social license to operate".¹

In the past decade, development of oil sands reserves has been threatened by new sources of supply such as oil and natural gas from

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¹ The environmental concerns raised by oil sands extraction are well documented by the Pembina Institute <http://www.pembina.org/>. The alarm over a lack of regulatory oversight was raised in the 2006 report "Canada's Oil Sands Rush" (Woynilowicz et al., 2005) and the 2008 report "Taking the Wheel" (Severson-Baker, 2008).

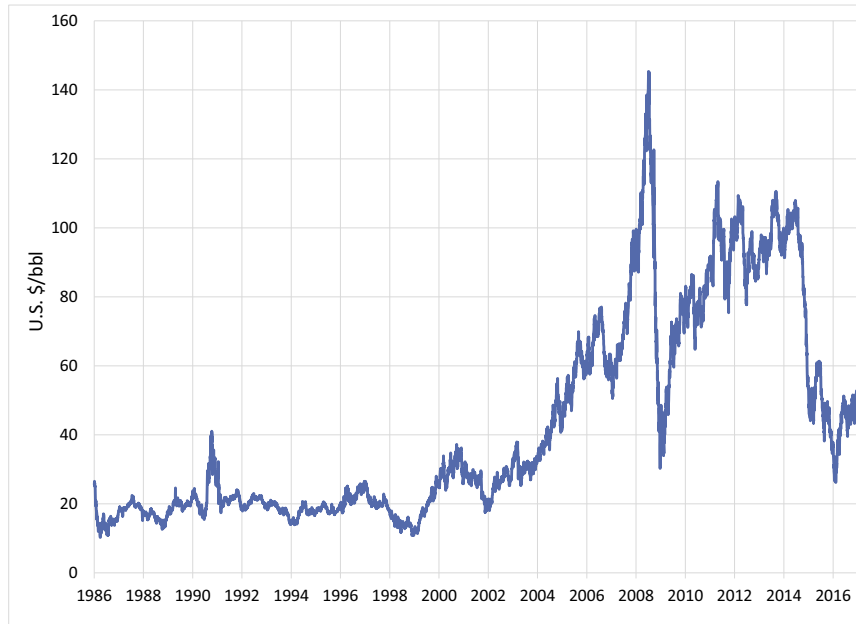


Fig. 1. West Texas intermediate crude oil spot price, U.S. \$/barrel, daily, Jan 1 1986–December 29 2016 Cushing, OK. Source: U.S. Energy Information Administration.

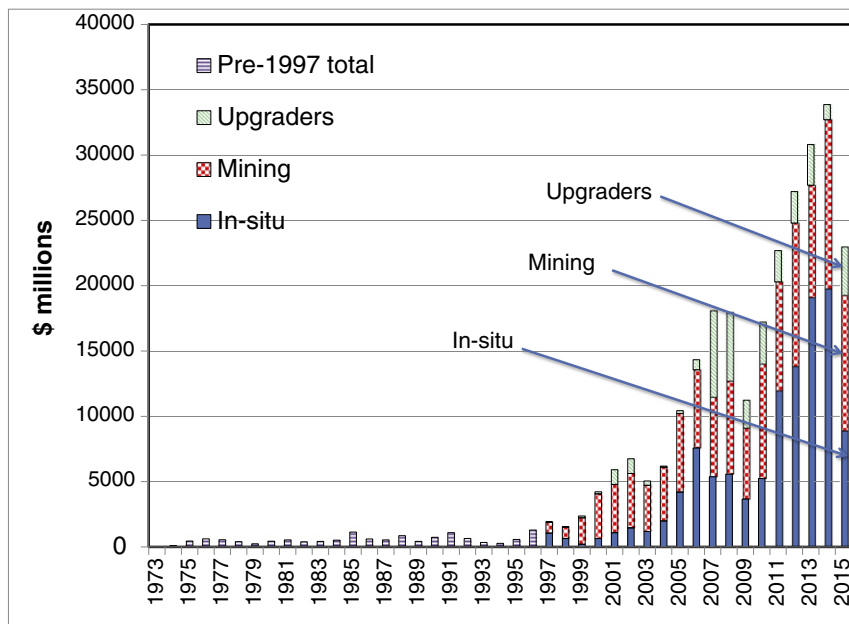


Fig. 2. Alberta oil sands capital expenditures, 1973–2015, millions of C\$. Data source: Canadian Association of Petroleum Producers.

shale deposits, which have been made accessible by newly developed technologies. The dramatic fall in the price of oil in late 2014 is a reflection of the rapidly changing economics of the fossil fuel industry. Media reports have referred to Canadian oil as being “a good choice for roller coaster fans.”² Oil firms have adapted their investment and operating strategies to the “roller coaster.” In a May 2015 interview one energy company executive stated that his company had been assuming \$50 per barrel for crude oil for the benchmark

WTI, but added that “We didn’t believe \$100 oil was going to last forever and we don’t believe \$50 will last forever.”³

While the recent experience of oil sands development is particularly dramatic, parallels can be found in other resource extraction industries such as copper, potash, and gold. Industries ramp up investment when prices are buoyant, with resultant environmental impacts and public concern. In this paper, we investigate the economics of non-renewable natural resource extraction taking account the boom and bust cycle of commodity prices. In particular we examine the

² See for example, two 2012 *Globe and Mail* headlines: “Canadian oil: a good choice for roller coaster fans,” (Nathan VanderKlippe in the *Globe and Mail*, August 24, 2012) and “Economics biggest threat to embattled oil sands,” (Martin Mittelstaedt in the *Globe and Mail*, January 18, 2012).

³ “Rachel Notley reaching out to the energy sector”, Kyle Bakx, May 12, 2015, CBCnews, Business, <http://www.cbc.ca/news/business/rachel-notley-reaching-out-to-energy-sector-1.3070996>

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