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A parsimonious model of tax avoidance and distortions in petroleum exploration and development

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ABSTRACT

We present a simple model of petroleum exploration and development that can be applied to study the performance of alternative tax systems and identify potential distortions. Although the model is highly simplified, it incorporates many factors and some of the key tradeoffs that would influence an investor's investment behavior. The model recognizes the role of enhanced oil recovery and treats the impact of taxation on exploration and development in an integrated manner consistent with an investor's joint optimization of investments at both stages of the process. The model is simple and user-friendly, which facilitates application to a broad range of problems.

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1. Introduction

We propose a new model that complements existing methods for studying petroleum tax policy. The model incorporates the impact of taxes on several margins of investment, including the scope of exploration; the scale, timing, and intensity of initial development of new discoveries; the timing and intensity of secondary or enhanced recovery operations; as well as the investor's ultimate decision to abandon the field. The model differs from previous analyses in several respects. First, it extends the traditional exponential decline model to incorporate enhanced oil recovery (EOR) beyond the primary stage of production. Although a significant portion of annual petroleum reserve additions comes from the application of enhanced recovery techniques to existing fields, few studies have examined how tax distortions affect this activity.[1] It also extends the exponential decline approach by allowing the operator to determine the scale of development and primary recovery factor independently from the rate of extraction. Second, the model links exploration incentives directly to the value of prospective discoveries and treats tax shields and carryovers between the two stages consistently. In addition, the optimal scope of exploration is informed by Bayesian updating of expected exploratory success based on the record of past drilling. Finally, and perhaps most importantly, the model recognizes that an investor's behavioral reaction depends on possibly subtle interactions that connect the various margins of investment.

The importance of the last point follows from the observation that an investor normally shifts investment away from activities that are heavily taxed and towards activities that are lightly taxed. In petroleum exploration and development, there are many such possibilities. A simple example taken from the ensuing analysis illustrates this point: It may be supposed that a high royalty rate would cause early abandonment of a field and reduce total production. That conclusion is undoubtedly correct if investment across all other margins is held constant. But, a high royalty may also reduce the intensity of the investor's initial development program, which may in turn cause production to decline at a slower pace, thereby *extending* the life of the field. In addition, however, the high royalty may discourage application of enhanced recovery as the field ages, and an investor who anticipates this may elect to increase investment in initial capacity as a more profitable alternative to

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[1] According to Energy Information Administration (2013) statistics, 32.9 billion barrels were added to the volume of petroleum reserves in the U.S. between 1977 and 2012 through secondary and enhanced recovery methods (so-called “revisions”), whereas 34.9 billion barrels came from the discovery of new reservoirs.

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enhanced oil recovery (EOR). The total impact of the royalty on resource recovery, the investor's rate of return, and government revenues depend on the resolution of these interrelated investment problems, and may actually result in *longer* field life and a *higher* recovery factor—as we demonstrate in subsequent analysis. The nature and size of the distortion will depend on a set of coordinated behavioral responses by which the rational investor attempts to mitigate the overall burden of the tax. An integrated model that recognizes the tradeoffs that link various margins of investment may therefore be required to assess the overall effect of the tax.

The complexity of tax avoidance behavior can hardly be overstated, but we hope to demonstrate that a better understanding of its effects can be obtained by applying a relatively simple model. The proposed model builds on previous analyses, is user-friendly and completely transparent, taking the form of an Excel spreadsheet in which all intermediate results and calculations are displayed—which illustrates precisely how the fiscal regime affects investor behavior and provides an external check on the validity of results. The model is also flexible, with parameters that can easily be benchmarked to match selected real-world analogs (e.g., onshore versus offshore, conventional reservoirs versus tight-formations, high-cost versus low-cost operations) and used to test the performance and robustness of specific real-world tax regimes across diverse environments.

Although it represents an advance in certain respects, the model also makes many compromises and is subject to significant limitations. We focus exclusively on the tax regime in the oil-producing country, but the effective tax rate facing any given investor may depend on many external factors that we have ignored. These would include the investor's home country tax regime and international tax treaties, methods of project finance, and the scope of the investor's investments elsewhere. There are also additional margins of investment in real-world petroleum projects that we have not included: the distinction between secondary versus enhanced oil recovery is one. Only by describing the sequence of major investments in more detail would one know whether those additional substitution possibilities have an important impact on tax distortions. We recognize but do not incorporate the fact that a ring fence that restricts the concurrent deduction of exploration costs may create incentives to accelerate extraction in order to speed up those deductions.[2]

Perhaps the most important limitation of the present model is that we take a deterministic view of future prices and ignore the impact of risk. The investor is assumed to be risk neutral with respect to exploratory outcomes and to hold a perfect forecast of future oil prices. Consequently, our results do not capture distortions that arise from differences in the way alternative fiscal regimes allocate risk between investor and government. The deterministic approach also ignores potential fiscal impacts on the value of the investor's real options. This simplification is adopted for purposes of tractability: by assuming deterministic prices we are able to easily solve a fairly rich model of the investor's tax avoidance behavior and to identify the distortions that result. But that simplicity comes at the cost of overlooking important aspects of fiscal design that pertain to the allocation of risk. Some methods for incorporating uncertainty are discussed later, but their implementation goes beyond the scope of the present paper.

We illustrate the workings of the model by application to six generic fiscal regimes, each one composed of the most common tax instruments: income taxes, royalties, production-sharing payments, and resource rent taxes. The specified regimes are hypothetical and do not match the specific provisions of any particular country. They are intended simply to demonstrate the functionality of the model and to highlight certain characteristics of the differing tax systems. Given the flexibility of the model, it would be straightforward to extend the study to include any particular real-world regime, including hybrid versions that comprise combinations of the instruments mentioned above, but that is not pursued here. A general outline of the model is provided below.

1.1. Resource development

Analysis of the extraction phase of operations is built on a new model of oil field development that integrates decisions regarding primary and enhanced recovery. The model is a direct extension of the traditional exponential decline model of oil field development often seen in the literature.[3] Initial investments to install productive capacity are taken not only based on relevant costs, knowledge of future oil prices, and the fiscal environment, but also with the knowledge that additional investments may be taken in the future, as production declines, to enhance total recovery. The effect of investments taken to enhance recovery is to multiply the volume of remaining recoverable reserves by a fixed factor (determined by reservoir characteristics and technology, and which might vary from one basin to another). In the analysis reported below, we examine cases where the potential of EOR is to increase the recovery factor from roughly 33% in the primary phase of operations to roughly 45–55% overall.

Thus, at the development stage the private investor (hereafter "IOC" for International Oil Company) faces three decisions: (1) how much initial capacity to install, (2) at what rate to extract from those reserves, and (3) when, if ever, to commence enhanced recovery operations. We also consider the IOC's incentive to postpone initial field development, based on expectations that prices will be higher in the future, or costs lower. Throughout the analysis we focus primarily on differences in the way alternative tax instruments and fiscal regimes impact these decisions.

The model of oil field development is simple, but designed to capture important operational tradeoffs that might be influenced by the method of taxation. For example, the margin between primary and enhanced recovery is resolved within the model. Investing in enhanced recovery too early is prohibitively expensive, but waiting too long will produce a relatively small increment to reserves. We assume the IOC has fixed expectations regarding prices and technology and elects the development program that maximizes after-tax net present value (NPV).[4] Attributes of that program in terms of the size and timing of initial investment, the overall recovery factor, the initial extraction (decline) rate, the timing of enhanced recovery, and ultimate abandonment of the field are all optimized within the model and recorded for each economic scenario (oil price level, cost level, field size) and fiscal regime under consideration.

The model is implemented and all optimizations performed within a relatively simple Excel spreadsheet. All cash flows (investments, operating costs, revenues, tax, and fiscal liabilities) are projected on an annual basis. Although adapting the model to a quarterly schedule would be straightforward, it is not clear that additional insights would necessarily follow.

1.2. Resource exploration

The oil field development model just described can be applied on a stand-alone basis to evaluate a previously discovered but undeveloped field. Or, it can be embedded in a larger model of exploration and discovery to study the impact of alternative fiscal regimes on exploration incentives and behavior. Exploration is assumed to be directed at a discrete petroleum prospect (e.g., geological formation) and consists of a series of exploratory wells, each with known cost. A well may produce a dry hole (non-commercial discovery), or one of three field types (small, medium, or large). For purposes of illustration, we assume those

[2] This issue could be explored without changing the structure of the model, but an iterative optimization procedure would be required.

[3] See for example Smith and Paddock (1984), Adelman (1990), and Smith (1995a).

[4] The model is well behaved, meaning that the profit function is convex and a unique optimum always exists. As noted previously, we exclude the value of operating options; i.e., the flexibility to revise future investment plans as prices change.

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