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A time series analysis of oil production, rig count and crude oil price: Evidence from six U.S. oil producing regions

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ABSTRACT

With oil company valuations tied in part to oil well drilling to replace reserves at a rate that exceeds production, understanding the dynamic relationship between the development of oil rigs and oil production is important. This study focuses on the Bakken, Eagle Ford, Haynesville, Marcellus, Niobrara, and Permian regions, historically the six major oil producing regions in the U.S. Specifically, we apply time series econometric techniques of unit root, cointegration, and error correction modeling to examine the dynamic relationship among oil production, rig count, and crude oil prices for each of these six U.S. oil producing regions. The results of this study highlight the importance of identifying the regional variations in oil production, rig count, and crude oil prices and their interactions in both the valuation of oil firms and capital investment projects as it pertains to oil drilling activity.

1. Introduction

The value of an oil company engaged in E&P (exploration and production) depends critically on the ability to replace reserves at a rate that exceeds production [11]. As such, oil firms are routinely involved in drilling new wells to acquire additional reserves and producing from these reserves to generate revenues. Without new drilling (reserve additions), then under constant price and operating expense scenarios, net income would fall. This is because oil wells follow a distinctive pattern referred to as a decline curve by petroleum engineers and geologists [12]. The decline curve shows the predictable pattern of a well's production capabilities over time. In particular, the decline curve (or production profile) of the well shows the initial (maximum) production and how subsequent production drops off or decays over time. Consequently, for given commodity price and current technological and operational conditions, this implies that net income from a particular well falls over time [15].

The industry refers to oil reserves as a depleting asset. Thus, two distinct factors are important for oil companies seeking to maximize the present value of current and future profits. First, the company must find and develop reserves and, second, the company must produce and sell its hydrocarbons. However, many companies, from small independents to large integrated firms, operate in a variety of locations or different basins.[1] Differences in geological and geophysical characteristics among regions play a large role in both the quality and quantity of recoverable hydrocarbons. Similarly, age and condition of current infrastructure and capital in place (existing producing wells, rigs, pipeline, storage facilities, etc.) as well as new physical capital (assets and equipment) going on line, represent elements of both older and newer oil recovery methods (e.g., directional and horizontal drilling, hydraulic fracturing, well pad design and layout, etc.). Thus, it is not surprising that production rates and drilling activity will vary by region. However, the literature lacks studies comparing how production and drilling rig activity may respond to, or interact with, changes in the price of oil over time across various regions. This research documents and analyzes regional differences in oil production, drilling rig activity, and the price of oil. Specifically, we focus on the

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[1] Domestically traded public firms must file a Form 10-K each year per the U.S. Securities and Exchange Commission (SEC). Item 1 describes the production, deployment of assets, allocation of costs, and other financial and operating data for any regions in which a petroleum firm operates.

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six largest oil producing regions in the U.S. – Bakken, Eagle Ford, Haynesville, Marcellus, Niobrara, and Permian.[2] We examine the empirical relationship between oil production and rig count,[3] as rig count is generally considered to be a fundamental determinant of current and future production capabilities.[4] However, given the importance of oil prices as a key driver of drilling and production activity [2], we then examine the relationship among production, rig count and oil prices. The results will provide oil companies, and energy industry analysts, with new information to use when analyzing operational strategies and firm value.

Section 2 provides a brief review of the literature. The data, methodology, and results are discussed in Section 3 with concluding remarks given in Section 4.

2. A brief literature review

To date, a good deal of research has examined the time series behavior of commodity prices, in particular analysis of both spot and future oil prices, and implications for hedging and financial investment (e.g., [5,10]; among others). An equally vast body of research has studied the role of oil prices in the context of GDP and macroeconomic growth (e.g., [6,9]; among others). While these two strands of the energy economics literature are important for both finance and policy, they do not address the underlying features of oil production, capital investment, and/or energy company valuation.

Gulen et al. [8] address the economics of well production. Specifically, they focus on the economics surrounding drilling new natural gas wells in Texas' Barnett Shale. In a very comprehensive study, [8] document the sensitivity and economic viability of drilling new wells in this region to changes in natural gas prices. Additionally, a number of studies have been concerned with the evaluation of a well or well field using the technique referred to as *economic limit analysis*[5] [15], economic analysis of a particular shale play [16], and the use of petroleum accounting methods with respect to valuing an oil and gas company[6] [11]. These types of studies generally focus on costs and revenues and, thus, the economic profitability of oil and gas firms or specific projects. On a broader scale, a number of studies have been conducted on the economic impacts of the energy industry (e.g., [7,28]. Economic impact studies typically focus on jobs created and/or sustained by the industry, as well as, regional economic output, additions to Gross State Product, and government tax revenues generated.

[2] examine the impact changes in futures prices have on drilling activity, as measured by changes in the number of rigs actively employed. While their study emphasizes a global comparison of the U.S. versus the rest of the world, there is one particularly important finding as it relates to our study. They confirm the importance of forward-looking behavior by oil producing companies with respect to capital formation. Along these same lines, [20] examine capital formation in the oil industry within the context of uncertainty. They highlight the role that oil price uncertainty and underground risk play in the exploration efforts of the Norwegian offshore region. They find that exploration activity responds asymmetrically to changes in price, with instantaneous adjustment to price drops and slower adjustment to price increases. The finding is somewhat expected as offshore rig investment is extremely costly as compared to investment in onshore or land-based rig and well development. Moreover, none of the drilling investment studies directly takes into account current production.

This study extends the existing literature in two important ways. First, we examine the time series relationship between oil production and rig count, accounting for the price of oil. Secondly, we conduct the analysis for six major oil producing regions within the U.S.

3. Data, methodology, and results

3.1. Data

Monthly data covering the period January 2007 to February 2014 are used in this study. Specifically, we examine RC (rig count), total oil production (bbl/day) (TP), and the price of WTI (West Texas Intermediate) at Cushing. Rig count and production data are from the U.S. Energy Information Administration (http://www.eia.gov/petroleum/) and are obtained for each of the six regions – Bakken, Eagle Ford, Haynesville, Marcellus, Niobrara, and Permian. WTI is from the Federal Reserve Bank of St. Louis Economic Database (http://research.stlouisfed.org/fred2/).[7]

Fig. 1 shows the location of the six major oil producing regions in the U.S. As stated previously, these regions account for about 95 percent of the tight oil produced in the U.S. Below we provide a basic description of each of these regions.

3.1.1. Bakken

The Bakken is located in North Dakota and Montana[8] and is the largest continuous oil resource in the lower 48 states (United States Geological Survey, www.usgs.gov). According to the Energy and Environmental Research Center at the University of North Dakota, (http://www.undeerc.org/bakken/), the Bakken consists of three distinct members. While the upper and lower members are considered world-class source rocks, they have very low permeability, meaning that recovery is more difficult and/or costly. The middle member, while not as organically rich as the other two, is

[2] See US Energy Information Administration, Drilling Productivity Report, http://www.eia.gov/petroleum/drilling/. In August 2014, the EIA recognized the Utica region of Ohio as the seventh major producing region in the U.S. However, as we are conducting a times series analysis, we focus on the traditional six major regions for which a long time series of data are available.

[3] While there are different types of rigs (i.e., drilling vs. workover), we focus specifically on drilling rigs so as to capture possible additions to reserves and current levels of production. The purpose of a workover rig is related to maintenance and repair of existing wells, thus workover rigs are not directly tied to new drilling activity or to current production. Further, once a well is completed, rigs may produce both oil and natural gas with many producing both types of hydrocarbons. In fact, more than half of the rigs in the US produce both oil and natural gas (EIA, Drilling Productivity Report, http://www.eia.gov/petroleum/drilling).

[4] Baker Hughes reports rig counts and notes the “active rig count acts as a leading indicator of demand for products used in drilling, completing, producing and processing hydrocarbons.” (http://www.bakerhughes.com/rig-count).

[5] Economic limit analysis (ELA) is commonly used to evaluate when a well reaches a point in which further operation is uneconomic (i.e., no longer profitable). The point in time that this occurs is referred to as the economic limit of the well. ELA utilizes the well's production profile or decline curve along with data on operating expenses and oil prices, assuming current technology and regulatory environment. See Ref. [23] for a simplified explanation of ELA.

[6] Oil and gas accounting is unique in that there are two accepted methods for the treatment of costs associated with exploration and development of new reserves, namely, full cost and successful efforts. The former capitalizes all costs associated with these activities while the latter capitalizes only the successful efforts and expenses unsuccessful efforts. Thus, the methods have different impacts on current reported net income and the balance sheet. Moreover, accurate valuation of oil and gas companies typically takes into account measures of reserves and relies on scientific reports compiled by *Petroleum Engineers*.

[7] In what follows, the analyses were conducted in both natural log as well as non-log forms and the results were qualitatively similar. We present the results for the non-log form here; however, the results for the natural log models are available upon request.

[8] The Bakken formation extends further north to Saskatchewan, Canada; however, the current study focuses only on the U.S.