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A micro-based model for world oil market

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ABSTRACT

In this paper, we study the supply–demand drivers of the price of oil over the last two decades. We address the problem of endogeneity using a novel SVAR approach, which allows us to incorporate technological restrictions that occur at the micro level in the production of crude oil to solve the identification problem in a reduced-form regression analysis that seeks to disentangle the drivers of oil prices. We explore the relationships between oil prices, rig counts, oil production and an index of world economic activity, and provide results for a heterogeneous set of countries. We find that when oil prices peaked in mid-2008—reaching almost US$150 compared to US$14 in 1998, a large proportion of the price move can be explained through a purely demand and supply factors.

1. Introduction

For more than a decade, academics and policymakers have pondered the question of which factors drive oil prices, both in the short and long run. Prices have ranged widely in the past two decades, from around 14 dollars per barrel ($/b) in the middle of 1998 to nearly 150 $/b in the middle of 2008, and back to significantly lower levels over the following years, sparking a heated debate to determine the reasons for these moves.

Some have argued that price increases are the result of high global demand, driven by the growing emerging market economies, such as China or India. Others have argued that it is merely a matter of supply, with producers being unable to keep up with demand from consumers (Barsky and Kilian, 2004). Still another group argues that the price increases observed were mostly a result of speculation in financial markets (Smith, 2009). From a practical point of view, it is possible to argue that all three hypotheses are likely to be partially correct, and that the answer to the question of what is the ultimate driver is an empirical one (Ringlund et al., 2004).

However, the problem of estimating the importance of each hypothesis and identifying their impact upon the price dynamics is extremely difficult. Oil prices, oil production, and oil demand are all endogenous variables. Most of the current literature takes an aggregate approach and uses reduced-form regression analysis, and use exclusion restrictions to solve the estimation problem (Kilian, 2008b,c,a; Kilian, 2009; Basher et al., 2012; Wang et al., 2014; Chen et al., 2016).

Sometimes embedded assumptions and approaches are questionable, rendering their assessments of the processes that drive the movement of oil prices disputable. Left out of this aggregate/reduced-form approach are the technological, geological and institutional limitations that exist in the production of oil. Evidently, the macro approach has not considered significant restrictions that

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are plainly observable at the micro level. This is the gap that this paper intends to fill. Our aim, therefore, is to add to the literature an important set of physical restrictions to the modeling of oil price.

Recent works by Chen et al. (2016) and Wang et al. (2014) discuss the need for structural break model approaches to capture the 2008 financial crisis. Ultimately our results do not contradict those of these authors. However, we find no reason to apply a structural break different in nature than the productivity changes discussed in the earlier sections of the paper to account for the 2008 financial crisis. In fact, we find that several countries show a production per rig ratio break date around 2008, including the world index, which aligns with their approach. Their results align with ours in that there is some persistence of price shocks which do not become permanent.

Production of oil consists of several steps: exploration, drilling, extraction, and commercialization. When demand for oil increases and prices rise, the supply chain responds by increasing exploration efforts and drilling activity, which is followed by increased production levels. We do not claim that production is the result of current, or even recent, drilling activity. Our claim is that in order for oil production to expand, a series of steps have to be fulfilled as physical prerequisite. The most important one is that new oil wells have to be developed, which is a process that requires drilling activity. That sequence implies that current oil production cannot respond immediately to changes in the oil price. There is a lead time to increase capacity and bring production on stream, always assuming that there is no spare production capacity.

For the purposes of estimation, drilling activity provides access to a rich array of data. The oil industry keeps precise records on where each drilling rig is located, whether it is active or not, and how it is being used. This information is available at the country level; in the United States, this is even available at the state and field levels. We use the restriction that production cannot be expanded without some drilling activity beforehand. This is indeed an exclusion restriction, but it is one that arises from the technological limitations of oil production[1]. This is the essence of our identification strategy. Using this information we intend to disentangle the drivers of oil prices through a simplified but intuitive approach to the modeling of oil supply and prices.

In this paper, we document the relationship that exists between drilling activity and the supply of oil or, put another way, the lag between the beginning of the drilling process and the actual output and marketing of oil. We also document how the change in the price level affects drilling activity. This is a micro-supply side view of the petroleum market; it is an essential ingredient to understand how the market works in general, and how we solved for the problem of identification.

The data used in this paper comes from Baker Hughes Inc.[2], an oil services company that provides the count of active oil rigs for the 65 most important oil producing countries (with the exception of Russia) on a monthly basis. We use the classification that distinguishes between those rigs used for crude oil and natural gas activities. Baker Hughes began publishing data with this distinction in January 1995. Baker Hughes registers rotary rigs[3]; while not the only type of rigs available in the market, they are certainly the most used worldwide. Although this reduces the number of countries that can be included in the estimation, it is not methodologically relevant. We were able to study the claimed drilling–production relationship for a large group of producers.

For our study, we took prices from the most widely used crude price the West Texas Intermediate (WTI), settled in Cushing Oklahoma on a monthly basis. We expressed price in real terms using the US CPI provided by the Bureau of Labor Statistics. We also tested the sensitivity of our analysis to this choice of WTI, by comparing with Brent-driven results, which rendered low differences. Finally, we used the average production per country, provided on a monthly basis by the International Energy Agency (IEA), for the relevant period. The monthly crude supply is found in the IEA MODS database (Monthly Oil Data Service).

On the basis of that information, we found that a portion of the price moves can be attributable to moves explained by market fundamentals. This is true even at its peak during mid-2008. Additionally, structural price shocks implied by our model (i.e., the bubble component) are very volatile and are also serially correlated. This correlation, however, is short-lived on average. This evidence is consistent with the hypothesis that long-term price deviations are the results of market fundamentals rather than just speculative behavior. By no means do we intend to claim that this is the sole influencing factor, but instead another factor to consider in the complex modeling of oil dynamics.

Two auxiliary results also support this view. Investments in the oil sector respond to changes in prices with a delay that ranges from 1 to 9 months (Hvozdyk and Mercer-Blackman, 2009; Ajzen and Fishbein, 1980). In turn, crude oil production half-life response to changes in oil-related investments (i.e., drilling activity) is reached with a delay that ranges from 1 to 7 months of the actual investments. Given the nature of the oil industry, the capacity for very short-term response to market price signals is limited, meaning that fundamental adjustments do take place, but not immediately. Therefore, the capacity of speculative movements to affect permanently oil price is constrained by the dynamics of the crude oil production process.

Estimating the associated response of crude oil production to changes in the number of rigs is a difficult task to document; since 1999, oil field productivity has been falling worldwide especially in the OECD countries. This decline in productivity is related to the exhaustion of OECD reservoirs (particularly those in the US, North Sea and Mexico) observed after a sharp increase in the production per active rig during the 1990s.

Given the lack of appropriate data, it is difficult to separate changes in productivity that are due to geological rather than technological reasons. Therefore, we decided to filter our data and concentrate on the short run effect drilling has on production, allowing us to separate the secular decline in productivity from the short run price–drilling–production effects.

Our approach focuses on physical restrictions of oil production and prices, which translate into econometric model restrictions which induce a more parsimonious model approach. This econometric approach was also used by Basher et al. (2012), but in the context of the joint estimation for demand and supply of oil as they relate to financial rather than physical characteristics, such as interest rates, equity prices, exchange rates and oil prices, cleverly extending previous work by Kilian (2009).

For the remainder of the analysis we organized this paper as follows: Section 2 discusses the data sources in further detail. Section 3 describes the challenges the data presents and the approaches taken in this paper. In particular, we highlight the changes in oil field productivity that have taken place in the last decades. Section 4 discusses the empirical justification for our chain of causality. It is divided in two sub-sections: (i) the relationship between price and drilling activity as a proxy for investment in the oil industry; and

[1] There are several microeconomic behaviors in the oil industry that have not been fully exploited in the estimation of aggregate oil price models. The aspect of the drilling decision is one of them. Inventories, for instance is another such aspect. If a price increase is the result of a bubble in the price level, it would only be natural to expect that inventories will react, i.e. it pays to hold on to oil. Inventories fluctuate incredibly in the data — at 7% a month on average and with fluctuations as large as plus minus 15%, and this only in the United States.

[2] http://investor.shareholder.com/bhi/rig_counts/rc_index.cfm.

[3] According to Baker Hughes Inc., a rotary rig rotates the drill pipe from surface to drill a new well (or sidetracking an existing one) to explore for, develop and produce oil or natural gas.