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The future of oil: Geology versus technology☆

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ABSTRACT

We discuss and reconcile the geological and economic/technological views concerning the future of world oil production and prices, and present a nonlinear econometric model of the world oil market that encompasses both views. The model performs far better than existing empirical models in forecasting oil prices and oil output out-of-sample. Its point forecast is for a near doubling of the real price of oil over the coming decade, though the error bands are wide, reflecting sharply differing judgments on the ultimately recoverable reserves, and on future price elasticities of oil demand and supply.

1. Introduction

Future real oil prices are notoriously difficult to predict in real time, particularly over the medium and long run. Economists, government officials, and market oil specialists all experience this first hand, generally obtaining oil price forecasts that display no improvement, or only a marginal improvement, over the no-change forecast. However, the no-change forecast itself does a very poor job of predicting oil prices. This is particularly the case during sharp increases in prices, such as in the mid-1970s and the 2000s, together with the abrupt oscillations during the Great Recession in 2007–2009, which professional forecasters were slow to recognize. This result is well-known within the oil industry and the academic literature.

Several papers have shown, however, that the real price oil has some predictability in the short run. In a recent paper, Alquist, Kilian, and Vigfusson (2013) report that out-of-sample monthly forecasts from a reduced-form vector autoregressive model (VAR) of the global oil market are more reliable than forecasts from the random walk model at short horizons.[4] Nevertheless, at medium and long

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4 The forecasting performance is sensitive to variable selection and the lag length. In particular, Alquist et al. (2013) find, like Baumeister and Kilian (2012), that the real price of oil, defined as US refiners' acquisition cost for imported crude oil, is easier to forecast than the real price of West Texas Intermediate (WTI) crude oil. These results are based on mean square predictive errors.

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horizons of one year and above, no-change forecasts systematically beat all models studied, and also professional forecasters. This result is also found by Baumeister and Kilian (2012, in press), who extend the analysis to include real time forecast restrictions at the monthly and quarterly frequencies, respectively. The econometric models of Alquist et al. (2013) and Baumeister and Kilian (2012, in press) use macroeconomic and financial indicators, as well as global crude oil production, as predictors of future oil prices. Many of these indicators are highly correlated with fluctuations in aggregate demand, so that the forecasts capture changes in the price of oil caused by variations in demand. In order to identify the roles of oil demand and oil supply shocks, Kilian (2009) proposes a structural VAR model of the global crude oil market. The model distinguishes between three drivers of real oil prices: global demand for industrial commodities, precautionary demand for oil, and oil supply, with the latter capturing the possibility of supply disruptions due to political events in oil producers, the dominant supply shock in historical data. The paper finds that the two demand shocks have been very important as drivers of oil prices, while supply shocks have had a negligible effect.

However, there is an alternative explanation for the recent persistent price movements that has received very little attention in the economics literature, despite there being considerable evidence to support it. This is the idea that one key driver of recent events may have been a highly persistent or even permanent shock to oil production that is due to geological limits on the oil industry's ability to maintain the historical growth rate of production. The extent to which the literature discounts or embraces this possibility is critical for its interpretation of recent events in the oil markets.[5]

The most prominent economist who does not discount this possibility is James Hamilton. Hamilton (2009) finds that temporary disruptions in physical oil production have already played a major role in explaining the historical dynamics of oil price movements. Furthermore, he argues that stagnating world oil production, meaning a very persistent reduction in the growth rate of oil production, may have been one of the reasons for the run-up in oil prices in 2007–08.[6] According to Hamilton (2009), the main reasons why oil supply shocks affect output is their disruptive effects on key industries such as automotive manufacturing, and their impact on consumers' disposable incomes. In other words, the main effect is on the aggregate demand. As for aggregate supply effects, there may be large short-run impacts due to very low short-run elasticities of substitution between oil and other factors of production. It is often argued that such elasticities of substitution would tend to get larger over longer horizons, as agents find possible substitutes for oil, fueled by high prices that stimulate the technological change that can increase both the recovery of oil and the availability of substitutes for oil. Hamilton (2013), however, argues that the main reason for the historic growth in oil production has been the exploration of new geographic areas, rather than the application of better technology to existing sources, and that the end of that era could come soon. His paper goes on to explore the potentially very problematic implications of a slower future growth in oil production for future GDP growth.

Other than Hamilton, most proponents of the geological view of future oil production are found among physical scientists. They argue that oil reserves are ultimately finite, easy-to-access oil is produced first, and therefore, oil must become harder and more expensive to produce as the cumulated amount of oil already produced grows. According to many scientists in this group, the recently observed stagnation in oil production in the face of persistent and large oil price increases is a sign that a physical scarcity of oil is already here, or at least is imminent, and that it must eventually overwhelm the stimulative effects of higher prices. Furthermore, based on extensive studies of alternative technologies and resources, they state that suitable substitutes for oil simply do not exist on the required scale, and that technologies for improving oil recovery must eventually run into limits dictated by the laws of thermodynamics, specifically entropy.

This view of oil production has its origins in the work of the geoscientist Hubbert (1956, 1962, 1967). Hubbert (1956) fitted historical production data to a symmetric bell-shaped curve and predicted correctly that US oil production would peak in 1970. Subsequently, Hubbert (1962, 1967) projected the ultimate quantity of oil to be recovered, and the rate at which it would be produced in the lower 48 US states. Hubbert (1962) adjusted logistic curves to cumulative production and discoveries, while Hubbert (1967) proposed an analysis of the quantity of oil discovered per foot of well drilled (yield per effort, YPE), fitting a negative exponential in order to form forecasts of the ultimate oil recovery (UOC). Hubbert's gloomy projections both spurred awareness and attracted criticism from the oil industry, government agencies, and academics. Some of the criticisms were related to the fact that the models were only based on physical oil production and discovery, and ignored the role of economics and technological changes. The response of Hubbert, and of subsequent studies validating his work, was that geological features were ultimately the main drivers of oil discovery, production and distribution, and that factors other than those were already embedded in the historical series used in the model.

The empirical success of Hubbert's seminal approach motivated various important academic studies that incorporated additional economic, institutional and/or technological factors into the original model, and that proposed alternative estimation methods. A partial list includes the studies by Cleveland and Kaufmann (1991), Kaufmann (1991), Kaufmann and Cleveland (2001), and Pesaran and Samiei (1995). Cleveland and Kaufmann (1991) extend Hubbert's (1962) model to account for the non-random historical drilling pattern in the oil industry in the lower

5 Kilian's (2009) analysis does not consider the possibility of shocks to the supply of oil that are driven by terminal geological limits.

6 In particular, Hamilton (2009) argues that the main dynamic was strong demand, at a low price elasticity of demand, meeting stagnating world oil production. Hamilton also finds that the flow of investment dollars into commodity futures contracts was important, but not the key factor, in explaining the late 2000s increase in real oil prices, the largest in history. By contrast, Baumeister and Peersman (2013), Kilian (2008, 2009), and Kilian and Hicks (2013) stress the role of oil demand shocks rather than oil supply shocks in causing the 2007–2008 oil price surge.