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Oil projections in retrospect: Revisions, accuracy and current uncertainty

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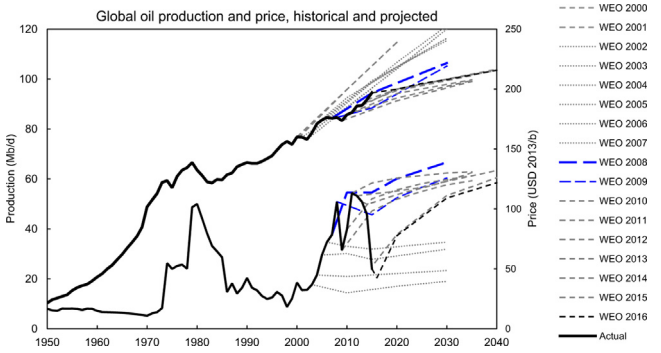
HIGHLIGHTS

- Projections of oil production, price and investments in WEO 2000–2016 are evaluated.
- Revisions are largest for OPEC and unconventional and due to demand and supply factors.
- Accuracy is high for Non-OPEC conventional, and low for OPEC and unconventional oil.
- Empirical prediction intervals are derived to show uncertainty of current projections.
- Previous retrospective studies of IEA and EIA energy projections are reviewed.

GRAPHICAL ABSTRACT



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ABSTRACT

Scenarios and projections are important for decision and policy making. Accuracy of past projections can be useful for both scenario users and developers, for insight on current projection uncertainty, and for guiding improvement efforts. This paper compiles projections of oil production, oil prices and upstream investments from the years 2000 to 2016 from the annual World Energy Outlook by the International Energy Agency, and investigates revisions and accuracy of past projections and implied uncertainty of current ones. Revisions of world oil production, price and investments have been motivated by a combination of demand and supply factors. Downward revisions are mainly allocated to OPEC, while recent upward revisions are due to unconventional oil, in particular US tight oil. Non-OPEC conventional projections have been stable. Price and investments have been revised mostly upwards. Projection accuracy follows the size and directions of these revisions, with high accuracy for Non-OPEC (mean absolute percentage error of 4.8% on a 5 year horizon) and low for OPEC (8.9%) and unconventional (37%). Counteracting error directions contribute to accurate total World oil supply projections (4%) while price projections have low accuracy (37%). Scenario users should be aware of implied uncertainty of current oil projections. In planning and decision making, uncertainty ranges such as those presented here can be used as benchmarks. Scenario developers should focus improvements efforts on three areas in particular: tight oil, OPEC and new technology.

1. Introduction

Scenarios and projections play a key support role in decision and policy making. In the energy field much effort has been spent on deriving projections of future production and prices of oil. This interest can be justified since oil is still the world's largest energy source, providing 33 percent of global primary energy consumption [1], and arguably also the most important one due to its dominance in

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transportation, where it stands for 94 percent of the energy used [2]. Furthermore, oil production and its price dictate magnitudes and directions of international trade flows as well as the profitability of some the world's largest companies. In the longer term, oil developments effect the security of nations as well as the global environment due to its non-renewable and fossil nature. Yet, less effort has been spent on evaluating these projections in systematic ways, although requests have been made [3,4] and important lessons learned from general energy retrospective studies [4–10].

According to O'Neill and Desai [11] analysis of performance of past projections can be useful for two main reasons: (i) to inform scenario users about implied uncertainty of current projections based on historical accuracy, and (ii) to identify accurate and inaccurate parts of projections to inform modelers and scenario developers where improvement efforts can be aimed, and to what extent accuracy increases can be expected in the future. The purpose of this paper is to shed light on these two points by a case study of annual oil projections published between the years 2000 to 2016 in the World Energy Outlook (WEO) by the International Energy Agency (IEA), a publication that is often regarded as the most authoritative source of energy analysis and long term scenarios [12].

Besides being directly relevant to oil scenario users and oil modelers this study should be useful for the wider energy modeling community concerned with incorporating uncertainty in the modeling practice [13], for example by the characterization of input uncertainty [14] of key parameters such as the oil price. The results can also contribute to the longstanding debate of potential future oil supply constraints [15] as well as the more recent peak demand prospect [16]. In particular, these results can be used to evaluate past questioning of IEA WEO oil projections [17,18].

The paper consists of four main parts. First, revisions of past projections of oil production, price and investments published in WEO 2000–2016 are quantified and, if available, stated motivations of these revisions are presented. Second, accuracy of past projections are calculated and whether accuracy has increased or not in recent projections is investigated. Third, implied uncertainty of current projections, based on the simple premise that future uncertainty is at least as large as historical projection errors, is illustrated by applying derived empirical prediction intervals to WEO 2016 projections. Finally, in the discussion, projection accuracy and uncertainty are discussed and recommendations for scenario users and scenario developers are made.

The paper contains a literature review and in line with previous studies [11,19–33] it adds empirical evidence in the form of detailed projection evaluation to the broader literature concerned with evaluation and improvement of energy models, projections and scenarios [4–10,34] and their use in policy and decision making, for example [35–37]. The present study fills two important gaps in the existing literature by providing (i) an in-depth oil sector specific retrospective and (ii) a unique examination of IEA WEO oil projections. Many previous retrospectives only look at projections of aggregate consumption of certain fuels or total energy use. This paper improves the focus on the oil sector by investigating projections of total use, production, price and investment, with further disaggregation of global production projections in the five categories: World oil supply, World conventional oil production, World unconventional oil production, OPEC conventional oil production and Non-OPEC conventional oil production. This detail makes it possible to reveal the source of underlying uncertainty by, for example, distinguishing between demand and supply driven errors. Besides calculation of historical accuracy of different disaggregations, this paper also investigates revisions of projections and their stated motivations as a further mean to better understand uncertainty and its sources.

Lastly, there is an important distinction between the exploratory and predictive use of energy scenarios and projections. Today most energy modelers promote published scenarios as possibilities of what might happen rather than predictions. This is arguably a necessary approach since making definite forecasts of such complex systems as the global energy system can be deemed impossible as it includes, among many things, assumptions on human behavior and innovation. Indeed, the WEO reports frequently stress that presented scenarios and projections are not forecasts, they are merely intended to demonstrate how markets could evolve under certain conditions [38]. How close these scenarios are to actual outcomes depends not only on how well underlying models and assumptions represent how energy systems and markets work, or on the occurrence of disruptive events, but also on users' reaction to these scenarios. This third point is highlighted in the foreword to the WEO 2015 report by Fatih Birol, chief executive of IEA: *"the reason that we look into the future is to trigger key policy changes in the present"* [38]. This statement echoes a key purpose of long term energy scenarios according to Craig, Gadgil and Koomey [10] who declared that scenarios, at their most successful, influence how people act by showing the consequence of not acting. These disclaimers aside, the central scenarios of the WEO reports are widely used as a baseline case for future energy planning, at least in the short to medium term, possibly in the absence of any better guidance. According to the organization itself, WEO scenarios are used by both the public and the private sector as framework for policy, planning and investment decision making [39]. For the case of this paper, the projections of the central scenarios presented in the WEO reports are treated and evaluated as forecasts, even though they are not strictly forecasts by definition or by intention of their developers. Yet, since they are often used as such in real world planning this kind of evaluation can still be relevant and informative. The analysis can be framed as an investigation of the uncertainty involved when using the central scenarios as predictions, and of possible ways to reduce it. To highlight this approach, the term forecast is avoided, instead scenario and projection are used, where a scenario refers to a consistent set of assumptions that can produce a range of different projections of specific parameters.

2. Literature review

2.1. Evaluation of forecasts and projections

This literature review first provides an overview of key theoretical and broader works in the field of evaluation of energy forecasts and projections. In the second part it provides a complete review of the existing literature performing detailed quantitative retrospective studies of IEA and US Energy Information Administration (EIA) energy projections.

A landmark work in forecast evaluation and accuracy is Ascher's 1978 book [5] that examines forecasts in areas of population, economics, energy, natural resources, transportation and technology from the 1930s until the 1980s, both quantitatively and qualitatively. Several important observations valid across different fields are found. For example, all trends examined, including technological and natural resource trends, are heavily dependent on socio-economic factors. Also the level of sophistication and complexity of methodology are found to have relatively little influence on accuracy, while core assumptions on the other hand have high impact. In fact, despite evolution of method sophistication, there is no clear evidence of forecast accuracy increasing over time. Instead assumptions is pointed out as the most important factor, highlighting the importance of qualitative factors and judgment. In particular Ascher points out *assumption drag*, the persistence of invalid assumptions already contradicted by data, as an area for improvement and the importance of the ability to quickly include new information and altered circumstances. Finally, Ascher makes an important methodological contribution for dealing with evaluation of current forecasts where the outcome exists in the future. He shows that the dispersion of forecasts reflects uncertainty and related minimum error.

Another famous retrospective was made by Landsberg [6] who revisited the comprehensive assessment of demand and supply of US