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Forecasting the limits to the availability and diversity of global conventional oil supply: Validation☆

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ABSTRACT

Oil and related products continue to be prime enablers of the maintenance and growth of nearly all of the world's economies. The dramatic increase in the price of oil through mid-2008, along with the coincident (and possibly resultant) global recession, highlight our continued vulnerability to future limitations in the supply of cheap oil. The very large differences between the various estimates of the original volume of extractable conventional oil present on earth (EUR) have, at best, fostered uncertainty of the risk of future supply limitations among planners and policy makers, and at worse lulled the world into a false sense of security. In 2002 we modeled future oil production in 46 nation-units and the world by using a three-phase, Hubbert-based approach that produced trajectories dependent on settings for EUR (extractable ultimate resource), demand growth, percent of oil resource extracted at decline, and maximum allowable rates of production growth. We analyzed the sensitivity of the date of onset of decline for oil production to changes in each of these input parameters. In this current effort, we compare the last eleven years of empirical oil production data to our earlier forecast scenarios to evaluate which settings of EUR and other input parameters had created the most accurate projections. When combined with proper input settings, our model consistently generated trajectories for oil production that closely approximated the empirical data at both the national and the global level. In general, the lowest EUR scenarios were the most consistent with the empirical data at the global level and for most countries, while scenarios based on the mid and high EUR estimates overestimated production rates by wide margins globally. The global production of conventional oil began to decline in 2005, and has followed a path over the last 11 years very close to our scenarios assuming low estimates of EUR (1.9 Gbbl). Production in most nations is declining, with historical profiles generally consistent with Hubbert's premises. While new conventional oil discoveries and production starts are expected in the near term, the magnitudes necessary to increase our simulated production trajectories by even 1.0% per year over the next 10 years would represent a large departure from current trends. Our now well-validated simulations are at significant variance from many recent "predictions" of extensive future availability of conventional oil.

1. Introduction

1.1. Summary and rationale of original effort

In 2004, we published research assessing the range of possible futures for the global supply of conventional oil using a consistent modeling protocol across a range of uncertainty in four parameters: resource availability or EUR (extractable ultimate resource), demand growth rate, the ratio of cumulative production to EUR at which decline begins, and maximum possible growth rate of annual production [1]. This present paper compares a decade of subsequent empirical production data to 36 global-level simulations to evaluate their accuracy from 2002 to 2012 and to determine which scenarios and associated EUR settings still make sense. In the process, we also identify recent trends in production of conventional oil as defined here. At that earlier time, we did not intend to make a single prediction of the rate of oil production over time or the "peak" or decline-point date – because such predictions are

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Definitions/glossary

bbl	Barrels – 42 US gallons
Gbbl	Giga barrels, or billion barrels
Mbbl	Mega barrels, or million barrels
Tbbl	Tera barrels, or trillion barrels
decline point	the point at which oil production in the model begins terminal decline
decline rate	the annual rate of decline in oil production in a field or region
depletion rate	the annual rate at which a field or region is depleted, defined here as the ratio of annual production to the volume of oil remaining at the start of that year. This is sometimes referred to as the decline rate, but we use the term depletion rate to avoid confusion with the previous term
EIA	United States Energy Information Administration
empirical data	data derived from historical EIA data and representing actual observation, for comparison to forecasted data
EOR	enhanced oil recovery
EROI	energy return on investment. The ratio of the amount of energy returned or made available by a resource or technology to the amount of energy invested to make it available
EUR	extractable ultimate resource. The total volume of oil that will ultimately be extracted from an oil field or region. This is sometimes termed ultimately recoverable resource, or URR
forecasted data	simulated data created by our model by projecting oil production into the future based on certain parameter settings
IEA	International Energy Agency
model scenario	a specific combination of model parameter settings that results in a distinct set of forecasted data
USGS	United States Geological Survey

fraught with uncertainty. We had decided that a more robust planning tool could be created by encompassing the future with a range of forecasts generated by a range of parameter settings encompassing the different estimates "out there". Our intention was to provide a broad enough range for the model controls such that the actual trajectory of production would fall somewhere between the projections of the individual scenarios. This strategy allowed us to assess the sensitivity of the forecasted date of peak production to changes in the input settings. For example, how much does the date of peak production change if EUR is increased by 50 or 100%, or if the maximum rate of production increase is 5% per year vs. 15% per year?

We first provide a summary of the modeling methods and results from that earlier paper to ease interpretation of the material presented here.

1.2. Model description and primary results from 2004 (with minor clarifications)

The models were based in part on the empirical observation that production of individual oilfields tended to increase over time until approximately 50% of the extractable oil had been removed, before beginning a permanent decline. Most of the pioneering work and observations related to this were done by M. King Hubbert in the 1950's, who accurately predicted the 1970 date of peak oil production in the lower 48 United States [2]. Subsequent analyses by Brandt [3], Duncan [4], and Nashawi et al. [5] tend to confirm Hubbert's initial intuition that the peak would occur when approximately 50% of the resource had been extracted. Hubbert himself, however, was flexible as to whether the oil production peak would occur when half of EUR had been extracted, and even allowed the possibility of several peaks.

We modeled 46 important oil producing nations (accounting for 99% of crude oil production in 2001) individually for the period 2002–2060, with global production in any given year equaling the sum of production in those nations. Model scenarios were created using Microsoft Excel™ spreadsheet software, and the production observed for 2001 was the common starting point for all scenarios.

Under our basic model protocol, we assume that oil production increases annually in each pre-peak nation in order to satisfy internal demand and to help satisfy the global demand for imports from net-consuming nations. Oil production is assumed to increase each year until 50% (or 60%) of extractable oil has been removed and to decline thereafter by the rate of EUR depletion existing at the time of peak. A simple function was included to smooth the peak of the production curve.

The models simulate the potential production of oil over time as a function of certain constraints – not the exact suite of underlying factors determining production rates. Actual production of oil results from a suite of "above and below ground" factors that influence how quickly oil is found and extracted. "Below-ground" factors include geologic and geographic factors such as the location, water depth, size, porosity, compartmentalization, and pressure of the physical reservoir, as well as resource characteristics such as viscosity. "Above-ground" factors are factors other than the characteristics of the reservoir or oil, and may include ownership and management of the reservoir, the socio-political environment, the availability of adequate investment funds, and random events such as hurricanes or accidents. These factors acting together over time manifest themselves in the emergent properties determining the trajectory of oil production – recovery factors, EUR, maximum realized rates of extraction, the proportion of EUR extracted at which decline begins, and the subsequent rate of that decline. This strategy allowed us to focus on the sensitivity analysis of our model parameters, without being concerned with uncertainties about the underlying factors influencing production at any given time – which were assumed to be encompassed by our range of parameter settings.

The 36 model scenarios we tested were defined by combinations of the following four parameters.

- Three country-specific estimates of original in-place EUR for oil – ranging from 1.9 to 3.9 Tbbl globally. These estimates represented the range found in the literature from the lowest (Aleklett and Campbell [6]), to the United States Geological Survey's (USGS) mean and 5% probability estimates from their 2000 assessment [7].
- Two sets of EIA-based estimates for the rates of increase in demand for oil at the national level (low and high), which drove the need for additional oil production in pre-peak nations [8].
- Two levels for the ratio of cumulative production to EUR at which the decline in oil production would begin: 50% and 60%.