6-2011

Logistic Curves, Extraction Costs and the Effective Size of Oil Resources

Robert J. Brecha
University of Dayton, rbrecha1@udayton.edu

Logistic Curves, Extraction Costs and the Effective Size of Oil Resources

Robert Brecha, Ph. D., brecha@udayton.edu, Tel. +49 331 288 2557
Potsdam Institute for Climate Impact Research, P.O. Box 60 12 03; 14412 Potsdam, Germany
(Permanent address: Physics Dept. and Renewable and Clean Energy Program, Univ. of Dayton, Dayton, OH 45469-2314 USA)

Overview

The size of potential fossil fuel resources is an issue of perennial interest and controversy. Fundamentally, there appears to be a conflict in interpretation of available data for both past and future extraction histories. As fossil-fuel prices rose dramatically over the past several years, the question of resources once again became acute. In this paper we concentrate on conventional and non-conventional oil resources and make four main points, with the overarching theme that one can determine an *effective* oil resource that represents significantly less availability for consumption than usually posited by tallying resources in place.

First, looking at oil production data in terms of a logistic curve pattern of cumulative production is useful, as many authors have pointed out, but must be done with the awareness of significant predictive shortcomings. Second, a modest disaggregation of oil production regions and of oil types (conventional and non-conventional) can help give some insight into likely production trajectories for the future. Third, historical precedent shows that the large non-conventional oil resources will likely not be produced quickly enough to compensate for increasingly challenging production of conventional oil; the analysis of this point is at the heart of the current work. The fourth point is that one can include some basic assumptions for extraction costs in the logistic-curve approach and, together with data from the International Energy Agency arrive at estimates of how both marginal and average costs will increase with time. These will be compared with recent historical patterns.

Methods

In this paper we disaggregate world oil production into conventional and several non-conventional resources, and within the former category, into the two world production subsets, OPEC and Rest of World (ROW). Past production data for conventional petroleum are used as the basis for least-squares fits to a logistic model. Data for potentially available resources are compiled from the American Petroleum Institute, BP and IEA. With these data as a starting point, two separate analyses are carried out. In the first, a deterministic model is used to reproduce historical production patterns using a combination of logistic curves for conventional oil and for enhanced oil recovery (EOR), deep-sea and Arctic oil, heavy oil and tar sands, and for shale oil. Industry and historical data show that early growth rates of new petroleum sources (aggregated by type or region) are under 10%; we use this stylized fact as an input to the logistic function model, along with estimates for resource amounts. The second analysis is an optimization problem for minimizing overall production costs during the lifetime of the production cycle, constrained by the actual production data history. The same regions and oil types are used as above. Production estimates for the next half-century are made from these models, based on the fact that the logistic curves, once the input parameters are determined from past production, provide a deterministic path going forward.

For each analysis, both marginal and average extraction cost curves are constructed for the production pathways, with data from IEA taken as the basis for estimated extraction costs as a function of cumulative production quantities.

Results and Conclusions

From the models presented in this paper one may conclude that i) although the total resource base for conventional and non-conventional oil is large, production patterns show that there will likely be a maximum ultimately recoverable quantity, or effective resource, that is significantly smaller than the resource-in-place; ii) limited production growth rates for alternative conventional and for non-conventional resources lead to the necessity of early commencement of production for these resources, well before the conventional resource is exhausted; iii) due to the need for early production of non-conventional resources with relatively high extraction costs, the overall marginal extraction cost curve for oil tends to rise much more rapidly than average production costs, with the consequence under an assumption of functioning markets that the price of oil rises in excess of what might be expected on the basis of data indicating very large remaining conventional resources. Sensitivity of these results to assumptions made in the models will be discussed.

References

Relevant recent research beyond the large body of "peak oil" literature includes a logistic curve analysis used to model a multi-variate, non-time-series version of discovery to take into account economic and technology factors, thus refining the purely geological description of oil discovery (Reynolds 2002). Reynolds concludes that previous cumulative discovery and production largely explain oil discovery and production over time for the US with price being an inelastic factor. The same author also uses a stylized model of a mineral market economy to find that price is not be a reliable indicator of future scarcity of a commodity, and that sharp increases in extraction costs due to scarcity can be inherent in the industry (Reynolds 1999).

Holland develops four relatively simple economic models that show a peak in oil production without introducing market failures (Holland 2008). In these optimization models, an interplay between demand increase, technology improvement, discoveries and increasing scarcity leads to a peak in production, and to the conclusion that production peaks are not a reliable indicator of the amount of oil remaining and that prices are a better indicator of impending resource scarcity than production. Finally, deCastro, et al. use a systems modeling approach to examine the necessary rate of increase in production of non-conventional oil to allow growth in the world economy (deCastro 2009).

Reynolds, D.B. (2002) "Using non-time-series to determine supply elasticity: how far do prices change the Hubbert curve?" OPEC Review June 2002, 147-167.

Reynolds, D.B. (1999) "The mineral economy: how prices and costs can falsely signal decreasing scarcity" Ecological Economics **31**, 155-166

Holland, S. (2008) "Modeling Peak Oil", Energy Journal **29** 61-80.

de Castro, C., Miguel L.J., and Mediavilla M. (2009) "The role of non conventional oil in the attenuation of peak oil" Energy Policy **37**, 1825-1833.