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Have we run out of oil yet? Oil peaking analysis from an optimist's perspective☆

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Abstract

This study addresses several questions concerning the peaking of conventional oil production from an optimist's perspective. Is the oil peak imminent? What is the range of uncertainty? What are the key determining factors? Will a transition to unconventional oil undermine or strengthen OPEC's influence over world oil markets?

These issues are explored using a model combining alternative world energy scenarios with an accounting of resource depletion and a market-based simulation of transition to unconventional oil resources. No political or environmental constraints are allowed to hinder oil production, geological constraints on the rates at which oil can be produced are not represented, and when USGS resource estimates are used, more than the mean estimate of ultimately recoverable resources is assumed to exist.

The issue is framed not as a question of "running out" of conventional oil, but in terms of the timing and rate of transition from conventional to unconventional oil resources. Unconventional oil is chosen because production from Venezuela's heavy-oil fields and Canada's Athabascan oil sands is already underway on a significant scale and unconventional oil is most consistent with the existing infrastructure for producing, refining, distributing and consuming petroleum. However, natural gas or even coal might also prove to be economical sources of liquid hydrocarbon fuels.

These results indicate a high probability that production of conventional oil from outside of the Middle East region will peak, or that the rate of increase of production will become highly constrained before 2025. If world consumption of hydrocarbon fuels is to continue growing, massive development of unconventional resources will be required. While there are grounds for pessimism and optimism, it is certainly not too soon for extensive, detailed analysis of transitions to alternative energy sources.

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1. Introduction

Petroleum is the most critical energy resource for modern economies, supplying about 40% of the world's primary energy and nearly all of the fuel for the world's transportation systems. Over the past 30 years, world oil use has increased by 47% despite oil price shocks and economic downturns. Over the next 30 years oil demand is expected to grow by 60% as the transportation systems of developing economies become increasingly motorized (International Energy Agency (IEA), 2002a, Table 2.1). This growing reliance on oil and the continuing lack of economical substitutes for petroleum-based transportation fuels has generated concern about the future adequacy of the world's petroleum resources.

The debate over oil resources is generally framed in terms of "pessimists" who foresee an imminent peaking of world oil production (e.g., Bentley, 2002; Deffeyes, 2001; Campbell and Laherrere, 1998) versus "optimists" who expect innovation and market forces to make the question of oil resource limitations irrelevant (e.g., Odell, 1999; Adelman, 2003). Of course, many fall somewhere between these two viewpoints (e.g., Davies and Weston, 2000; Wood et al., 2000; Cavallo, 2002). The pessimists' analysis is based on "peaking curves" for individual petroleum deposits, using methods derived from the seminal analysis

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of Hubbert (1956) who accurately predicted the peaking of US oil production. The pessimists are sometimes referred to as "geologists" because of their belief that geology will be more important than economics or technology in determining when oil production will peak. The optimists are often referred to as "economists" because of their belief that markets and technological change will make the scarcity of oil an irrelevancy.

The debate is important because a sudden, unanticipated and permanent decline in world oil production would severely damage world economies, probably for a decade or longer. In addition, the transition from oil to some other source of energy for transportation is almost certain to have important economic, environmental and security implications. A transition to more carbon intensive fossil energy sources would increase the likelihood of major climate changes. As several have pointed out, the longer-term problem of climate change depends on the world's decision to burn or not to burn the world's vast fossil resources of coal and unconventional oil and gas and release the carbon to the atmosphere. There is not enough carbon in all the world's conventional oil and gas resources to raise atmospheric carbon concentrations above the threshold of 450 ppm (Grubb, 2001, p. 838). Knowing more about when and how rapidly such a transition might occur could allow nations to plan for a more desirable path.

This paper describes a quantitative analysis of oil peaking from the perspective of an optimist including the potential for developing alternative sources for liquid fuels. To date, most quantitative analysis of the oil peaking issue has been done by the pessimists. This is logical, since from the optimists' perspective, why waste time analyzing an irrelevancy? A premise of this study is that if a quantitative analysis of the oil peaking issue from the optimists' viewpoint shows that it is neither so distant in time nor so gradual that negative impacts can be safely neglected, then understanding oil peaking and the consequent transition to alternative sources of energy should be a critical priority for energy policy research.

The analysis makes an effort to incorporate uncertainty along three dimensions: (1) alternative scenarios of future oil demand, (2) alternative assessments of the extent of world oil resources, and (3) risk analysis of rates of technological change, reserve growth, resources discovery and Middle East oil production.

2. Background

Concerns about resource availability can be traced back in time at least as far as Thomas Malthus' *An Essay on the Principle of Population*, which argued that population growth would be limited by the availability of tillable land (e.g., Tilton, 2003). More recently, Meadows et al. (1972) explored the potential impacts of resource scarcity and pollution on world economic and population growth using simulation modeling. Their study is most famous for its prediction that "under the assumption of no major change in the present system, population and industrial growth will certainly stop within the next century, at the latest." (Meadows et al., 1972, p. 126). What is frequently overlooked is the study's finding that major changes in technology and environmental policy could alter that conclusion.

M. King Hubbert (1962) observed that individual oil fields followed an approximately bell-shaped curve of rising and then declining production. Extending this concept to the region of the lower 48 United States, he correctly predicted that US oil production would peak within a decade; it peaked in 1970. Since then, "pessimists" such as Campbell and Laherrere (1998), Bentley (2002) and Deffeyes (2001) have further developed Hubbert's methods, applied them to the entire world, and generally concluded that world oil production will peak by 2010.

3. What is oil?

In any assessment of oil resources, the first question that must be answered is, "What is oil?" (Laherrere, 2001). In this analysis, two kinds of oil are distinguished: conventional and unconventional. Conventional oil includes liquid hydrocarbons of light and medium gravity and viscosity, occurring in porous and permeable reservoirs. Here, oil available with enhanced recovery is considered conventional; Rogner (1997) and Laherrere (2001) take a different view. Also, conventional oil resources here include natural gas liquids. Unconventional oil comprises deposits of greater density than water (heavy oil), viscosities in excess of 10,000 cP (oil sands), and occurrences in tight formations (oil shale). Ultimately, the distinction between conventional and unconventional resources is based on technology and economics. Fifty years ago, offshore crude oil was considered an unconventional resource (Adelman, 2003). Some today consider Canadian oil sands to be conventional oil, although here they are classified as unconventional here due to the cost and complexity of operations, water scarcity, and the need for dilution or upgrading before the product can be shipped (Economist, 2003).

Unconventional oil is not the only potential source of energy to replace petroleum. Liquid hydrocarbon fuels can be made from any resource containing carbon, including coal or biomass. Much attention has recently been given to the possibility of powering transportation vehicles with hydrogen fuel cells (US Department of Energy (US DOE), 2002). This analysis allows a transition only to unconventional petroleum, not because that is the only possibility, but for simplicity and because it is almost certainly the path of least resistance in terms of infrastructure, economics and policy. Indeed, the development of Canadian oil sands and Venezuelan heavy oil suggest that the transition to unconventional oil is underway.

Another premise is that world oil resources are known well enough to permit a meaningful analysis of their

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