Box 3.1. Life Cycle Constraints on Global Oil Production

Oil reservoirs have a life cycle with three main phases: youth, maturity, and decline. This box discusses these life cycle stages and the implications for global oil supply prospects.

After discovery and development, oil reservoirs enter a period of youth during which flow production increases. At maturity, production peaks and then starts to decline. Maturity patterns vary across fields. In some, production plateaus at its peak and decline sets in only much later.

The life cycle reflects a combination of geological, technological, and economic factors. From a geological point of view, there is the natural phenomenon of declining reservoir pressure or water breakthroughs once a substantial part of the oil in a reservoir has been extracted. Technological intervention can influence the timing of production peaks and the rate of decline through secondary and enhanced recovery methods, although applying these methods comes at a cost that generally increases with the extent of depletion.[1] At some point it becomes too costly to prevent decline through ever more intensive intervention.

Life cycle patterns have been well established for individual oil reservoirs and fields.[2] A widely debated issue is whether life cycle patterns are of more general relevance for regional and even global oil production. The proposition that global oil production has already peaked or will peak in the medium term is a generalization of the life cycle hypothesis. But such peak oil propositions are dependent on additional assumptions.

A first assumption is that large oil fields are discovered first. In part this seems to be supported by historical data (Figure 3.1.1, top panel). In fact, the "giant" fields in the United States, the Middle East, and Russia discovered before the 1970s have been the backbone of global oil production for decades (IEA, *World Energy Outlook,* 2008). Many of those

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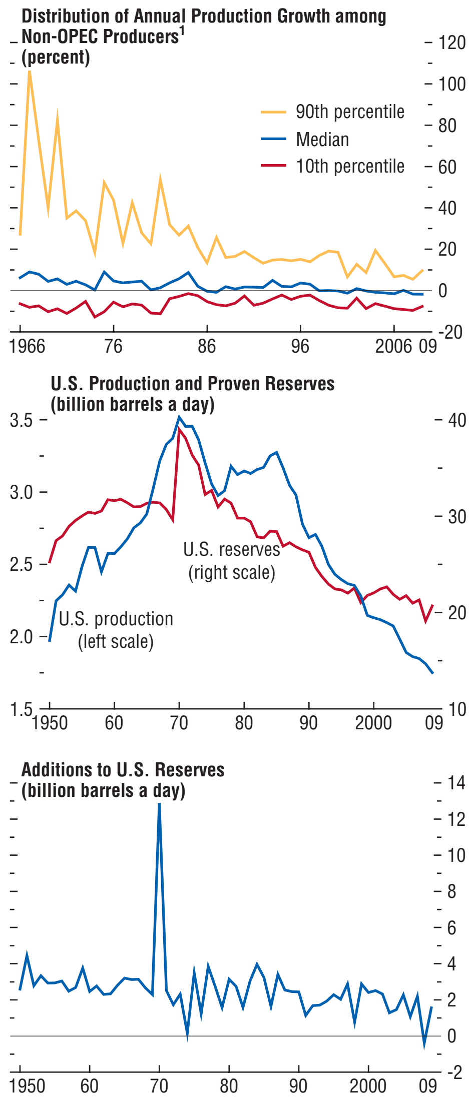
[1]The costs involve both capital costs—considerable investment is a prerequisite, especially for enhanced recovery—and operating costs, including the cost of the gas or water used in recovery.

[2]A field is a collection of reservoirs in geographical proximity based on a single geological structure. Sorrell and others (2010) provide a good overview of the evidence of life cycle patterns in oil production.

Figure 3.1.1. Life Cycle of Global Oil Production

Many giant oil fields have reached maturity. However, the decline rate of oil production has been relatively low because the marginal return from additional drilling has been high enough to support continued exploration and oil investment.



Sources: BP, *Statistical Review of World Energy*, June 2010; U.S. Energy Information Administration; and IMF staff calculations.
[1]OPEC = Organization of Petroleum Exporting Countries.

Box 3.1 *(continued)*

fields have reached maturity, and so the peak oil argument goes as follows: since large fields are less likely to be discovered, to offset the decline of current large fields we need an unrealistically high rate of small-field discovery.

However, views on the scope for future discoveries differ considerably. The most recent assessments by the U.S. Geological Survey released in 2000—a standard reference—suggest that there are between 1 and 2.7 trillion barrels of conventional oil still in the ground that are technically recoverable. The range reflects different probabilities attached to the discovery of new reservoirs of oil that is technically recoverable and the growth of reserves in fields already in production.[3] The lower bound of the band reflects oil that is technically recoverable and consists mostly of current proven reserves. The fact that important oil discoveries continue to be made and that many promising areas have not yet been extensively explored suggests that this lower bound is likely pessimistic for a baseline projection.

The second assumption concerns the extent of the drag from declining production in mature fields. The main issue is whether past patterns in so-called observed decline rates provide a good basis for forecasts. There is a distinction between the natural decline rate, that is, the rate without any postpeak intervention, and the managed decline rate, with intervention after the peak. Some analysts see little scope for changing past patterns. In their view, production-weighted global decline rates, which are currently estimated at some 4 percent, are expected to increase further in the future as decline in large mature fields accelerates. However, observed decline rates are a function of technology and investment, factors that usually are not considered in the curve-fitting approaches used to predict decline rates. The use of secondary and enhanced recovery techniques is costly, and so investment in decline management will be a function of current and expected market conditions. Given that oil prices were low between the mid-1980s and the early 2000s, it is plausible that forecasts based on past patterns are not valid in a high-price environment. With prospects for continued high oil prices, field management and attempts to increase recovery rates are likely to play a more prominent role than in the past, implying lower global rates of decline. Moreover, technological developments have improved the scope for enhanced recovery at lower cost.

The experience with oil production in the United States provides some grounds for cautious optimism. U.S. oil production peaked in 1970, as some geologists had predicted it would (middle panel).[4] This corroborates the view that decline is difficult to overcome once it begins. Nevertheless, overall, U.S. oil production has declined by less than many predicted using curve fitting (see Lynch, 2002). The average rate of decline has been steady at about 1 percent a year since the 1970s.

The relatively low decline rate reflects a number of factors. Most important, the marginal return from additional drilling, as measured by reserve additions, has been high enough to support continued exploration and oil investment (bottom panel). This happened despite the presumption that discovery and development activity are increasingly less likely to result in reserve growth the more an area has already been explored and developed—as should be the case for the United States.[5] Finally, the U.S. experience also highlights the important influence of market conditions and incentives on exploration and investment and the importance of relatively low barriers to entry in the oil sector.[6] This has led

[3]Historically, the upgrading of reserve estimates because of increased knowledge about reservoir properties and the effectiveness of the installed capital after the beginning of production has been an important source of measured reserve growth. Cumulative production in many fields that are still producing is already well above initial reserve estimates.

[4]The prediction of a production peak between 1965 and 1970 in the lower 48 U.S. states by the late M. King Hubbert is well known.

[5]In the well-known model of Pindyck (1978), additional drilling and development have positive marginal returns. But these benefits from additional investment must be weighed against increasing marginal costs from diminishing returns from all past exploration and developing efforts. These costs are believed to be increasing with the cumulative past efforts (see, for example, Uhler, 1976; or Pesaran, 1990).

[6]Kaufmann (1991) notes that oil market conditions explain a significant part of the deviations of actual oil production from the levels predicted by so-called Hubbert curves.

Box 3.1 *(continued)*

exploration and subsequent reservoir development to respond strongly to price signals.[7] In fact, exploration activity has remained higher in the United States than in some areas with more potential.

The conclusion is that there are constraints on global oil production from life cycle patterns in oil production. The main reasons for these constraints are the broadly synchronized maturing of major large oil fields that have been the backbone of global oil production. Nevertheless, there remain important questions about the strength of these constraints. The U.S. experience suggests that managed decline is possible, especially in areas with many and large fields, including for example Saudi Arabia. It also underscores the risks of restricting investment in the oil sector, which can hamper the process of exploration and development.

[7]Dahl and Duggan (1998) survey the evidence.