



UPDATE

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What Price Should be Paid to Keep U.S. Dependence on Foreign Oil in Check?

by
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The long-run U.S. oil supply, and hence oil security, depends significantly on additions to proven reserves—a process which is importantly influenced by the long-run, expected oil prices, in addition to geological or technological factors. It is shown that if U.S. oil import dependence is to be kept in check, steady annual oil price increases of 1.6-4.5% are essential.

Once again, U.S. energy security has become the center of intense debate both in policymaking and public opinion circles. The debate has prompted concerns about U.S. future domestic oil and gas supplies and its dependence on imported oil. The bases for these concerns cannot be properly addressed without first answering the more specific question: *In the face of steady economic growth and growing oil consumption, what price should the United States pay for keeping its dependence on foreign oil in check?*

To answer this question, in turn, requires a good understanding of the relationship between oil price changes and additions to proven reserves. Yet, this relationship has not been adequately explored either by previous scholarly studies or by energy supply forecasting agencies. For example, the U.S. Department of Energy which uses oil reserves estimation techniques that rely mainly on reservoirs' production history and geological and engineering principles, and fails to incorporate economic factors.

In an *economic* (as opposed to geological) concept of reserves, the economic size of reserves of a depletable resource,

instead of being assumed fixed and known, depends on expectations of future price, reserves discovery and development costs, and the state of technology.

I have modeled additions to proven reserves as a conventional production process in which drilled wells act as a primary input to convert some of the stock of oil-in-place into the economic category of proven reserves. The model attempts to incorporate the three salient economic, geological and technological effects that influence the process of additions to proven reserves. These are, respectively, the effect of oil price on drilling activity level, the effect of reserves depletion on discovery and development costs, and the effect of technological progress on those costs.

Factors Influencing Reserves Additions

Additions to reserves are an outcome of combined geological, technological and, above all, economic factors which are hard to model. The growth of oil reserves stems from two broad sources: the discovery of new fields and additions to reserves in known

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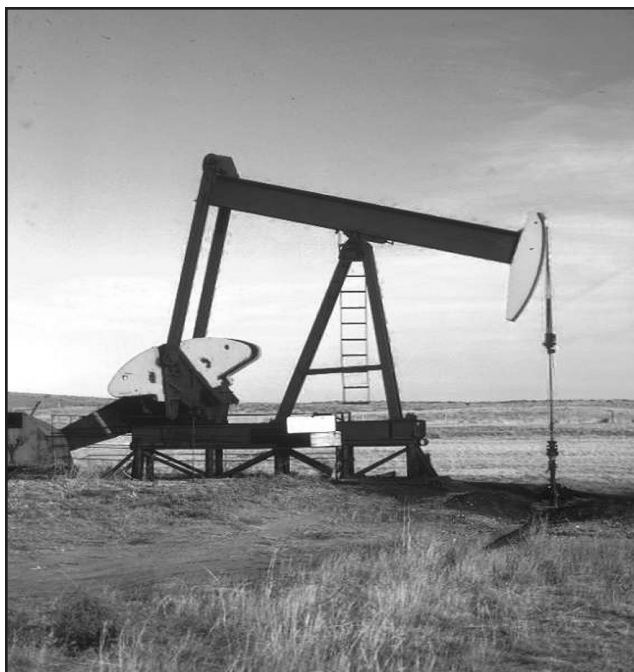
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Additions to proven reserves is a price sensitive production process in which the drilling of wells leads to conversion of some oil-in-place to the economic category of proven reserves.

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fields. The first source, which is the result of drilling exploratory wells, is characterized by a high degree of uncertainty and provide a rather insignificant contribution to the U.S. total reserves additions. (The U.S. average success rate in exploratory drilling was about 15 percent by 1970, rising to about 25 percent by early 1990s, and to nearly 40 percent by 1998 due to a number of recent technological advances in oil exploration.) Over the period 1949-1995, the average annual addition to proven reserves from new field discoveries was only 250 million barrels, or about 11 percent of the average total reserves additions. This study has not been concerned with reserves additions due to new field discoveries and instead concentrates on additions resulting from extensions of reserves in known fields.

Extensions are recoverable reserves that result from changes in the productive limits of known reservoirs. After the discovery of a reservoir, additional wells are normally drilled to outline the productive limits of the reservoir. In the process, more reserves may be found than initially indicated at the time of discovery. Reserve additions from this source are likely to decline rapidly as cumulative additions due to extensions increase, since a significant portion of extensions usually occurs within the first few years after the reservoir discovery. Extensions can result

from either exploratory or development drilling. The degree of risks and returns associated with each of these modes of drilling differs substantially.

Exploratory drilling usually involves few wells that are drilled beyond the geographical limits of recent discoveries in order to find new reservoirs or open up neglected, deeper strata in old reservoirs. With exploratory drilling, the probability of discovery is relatively small but the size of discovery can be relatively large since it would be the first drilling effort in the region.

On the other hand, development (or “infill”) drilling involves many wells that are usually drilled in years subsequent to discovery of a reservoir, in order to either reach previously untapped portions of the reservoir or to access spaces wherein the natural force of the reservoir is insufficient to mobilize the oil-in-place. In this mode of drilling, the probability of adding to existing reserves is relatively large but the expected size of additional reserves is likely to be small. Furthermore, as cumulative development drilling and, hence, cumulative addition to reserves increases, reserves additions resulting from new development wells are likely to decline simply because there will be less recoverable resources in place.

In deciding how to allocate their drilling activities between exploratory and development drilling, producers make a trade-off between expected return and expected risk, depending on their attitudes toward risk. Everything else being equal, the more that producers are risk averse, the greater their preference for development drilling. Given the producers’ attitude toward risk, both the level and mode of drilling will depend on a number of economic factors. Among the most important are likely to be expected oil prices and drilling costs. Expectation of a lower future price is not only likely to reduce the total number of wells to be drilled, but also to give producers an incentive to shift from riskier exploratory drilling to relatively less risky development drilling.

Over the period from 1949 to 1995, the average additions to proven reserves from all sources was 2.35 billion barrels a year, which amounted to 8.2 percent of proven reserves on average. In the United States, historically, most of the additions to oil reserves (nearly 90 percent on average over the 1949-1995 period) can directly or indirectly be attributed to development drilling which has resulted in increased recovery rates from existing fields. (This average consists of 28.6 percent due to extensions, 6.5

percent due to new discoveries in existing fields, and 54 percent due to revisions and/or adjustments.)

Several important features should be noted regarding drilling costs. First, both total and incremental costs of drilling wells are likely to vary from one production district to another depending on geological characteristics of each district. Second, average cost per well in a producing district may rise with the total number of wells drilled in that district in a given period of time due to limited supplies of skilled labor and specialized capital equipment in the short run. This effect may be offset to some extent by economies of scale. Third, development drilling costs have the additional feature of rising with the cumulative amount of reserves withdrawn, reflecting a shrinking size of the remaining oil-in-place as a base for reserve additions. Fourth, improvements in drilling technology over time can exert a favorable effect in reducing drilling costs. \hat{E}

With this background, I have studied the decision-making of a typical firm which forms its expectations of future prices and determines its desired level of development drilling, and hence additions to proven reserves, so as to maximize the expected profits from its drilling activity. Based on that model, I have been able to derive a relationship between additions to proven reserves from existing fields and the main determining economic and technological factors. I have then estimated the relationship for the U.S. over the period 1951-1995.

Main Results

The statistical estimations suggest several interesting points:

(1) In forming their expectations of future oil prices, producers do not rely merely on the current price but attach rather significant weights to very recent past prices too. This may in part reflect oil producers' perception of oil price volatility in the short-run, which stems, for example, from political uncertainties in the oil-exporting nations or uncertainties in domestic regulatory policies.

(2) More interestingly, I obtain an estimate of the short-run price elasticity of reserves addition of around 0.11 and a long-run price elasticity of around

0.16. Accordingly, the quantitative impact of oil price on reserve addition, although rather small, is by no means insignificant. For example, a 10 percent (or nearly \$1.20 per barrel) increase in the average real oil price (which was \$12.20 per barrel over the sample period) would immediately bring about nearly one percent (or about 12 million barrels a year) increase in average addition to proven reserves. Furthermore, the impact of a price increase on reserve addition is fully born out in a very short period of time.

These results make it clear that oil price increases are essential for the growth of proven reserves. This

point is better appreciated once we note that, based on the estimated reserve addition relationship, even if one assumes a steady rate of technological progress and ignores the negative depletion effect, then with the oil price remaining unchanged at its 1995 level, the cumula-

tive additions to reserves (due purely to technological progress) will be only about 8 percent over 10 years. On the other hand, ignoring the technological progress but allowing for the negative depletion effect, a one percent steady annual increase in oil price brings about a 44 percent cumulative reserve additions over the same 10-year period. This raises a question the answer to which can provide valuable insight about the role of oil prices in shaping the dynamics of U.S. dependence on imported oil: *What is the annual constant real rate of oil price increase that is needed to keep the share of oil imports in total oil consumption, the reserve-production ratio, and hence the reserve-consumption ratio constant over time?*

“This study makes it clear that increases in oil prices of 1.6-4.5% per year are essential...to keep U.S. foreign oil dependence in check...”



Under a business-as-usual scenario, the model predicts that the share of U.S. oil imports in consumption will rise from their 1995 level of 58% to over 72% by 2010.

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Table 1: Rate of Annual Price Increase Required to Keep U.S. Oil Import Dependence Intact

	GDP Growth	
	2%	3%
Income elasticity=1.0		
Price elasticity=0.5	3.62	4.53*
Price elasticity=0.75	2.19	3.30
Income elasticity=0.75		
Price elasticity=0.5	2.26	3.40
Price elasticity=0.75	1.64**	2.47
<p><i>Income elasticity is the percent increase in oil demand due to a one percent increase in consumer income. Price elasticity is the percent decrease in oil demand due to a one percent increase in the oil price.</i></p> <p>* This value reflects the high-case scenario with oil demand characterized by high income elasticity of 1, a high GDP growth rate of 3%, and a low price elasticity of 0.5.</p> <p>** This value reflects the low-case scenario with a GDP growth rate of 2% a year and a low oil demand.</p>		

The long-run price elasticity of reserve addition (estimated to be 0.16) is a key element in answering this question. More specifically, I have derived a simple formula that shows that the required rate varies directly with the growth rate and the income elasticity of oil demand and, inversely, with the price elasticities of reserve addition and oil demand. One may think of this rate as a premium that needs to be paid in order to prevent U.S. dependence on foreign oil from rising in the future in the face of steady rates of economic growth and, hence, higher oil consumption. Table 1 presents the magnitude of the required rate of oil price increase calculated for different stipulated values of long-run GDP growth rate ($g=2\%$, $g=3\%$), oil demand price elasticity ($b=0.50$, $b=0.75$) and income elasticity ($a=0.75$, $a=1.0$). The required price increase will be as low as 1.6 percent a year in the low-case scenario specified by an expected steady economic growth rate of two percent a year and an oil demand characterized by a high price elasticity of 0.75 and a low income elasticity of 0.75. In the opposite (high-case) scenario, characterized by a high rate of economic growth (three percent a year) and a high oil demand (price elasticity of 0.5 and income elasticity of 1.0), the needed rate of oil price increase rises to about 4.5 percent a year.

Even under this latter scenario, the required rate of price increase seems modest, or at least not unduly large; it implies a doubling of the real oil price in 15 years. On the other hand, suppose the oil price is kept constant at its 1995 level and that we rely exclusively on the technological progress rate of 0.57 percent a year to develop new oil reserves. Then, even if the negative reserve depletion effect is ignored, with a steady three percent annual growth rate in oil consumption, the share of oil imports in consumption is estimated to rise by nearly 1.5 percent a year. At this rate of increase, imports would rise from their 1995 level of 58 percent to over 72 percent by 2010. Of course, allowing for the negative depletion effect, the implied degree of foreign oil dependence will most likely be much higher than that.

Conclusion

This study shows that increases in oil prices of 1.6 - 4.5 percent a year are essential for sufficient growth of proven reserves to keep U.S. foreign oil dependence in check in the face of steady growth of economic activity and, hence, oil consumption. Bearing in mind that oil prices are not determined domestically, these findings accentuate the importance of alternative policies to ensure sufficient future domestic oil supply. Such policies may include less stringent leasing regulations for oil prospecting firms or fiscal measures (tax credits/subsidies) to boost drilling activity and to encourage research and development investments aimed at technological innovation and adoption in oil development and exploration. Rationale for these policies is reinforced if private firms undervalue the increased national oil security resulting from increased proven reserves.

For more detail on the article, the author suggests: "The Impact of Oil Price on Additions to U.S. Proven Reserves," Y.H. Farzin, *Resource and Energy Economics*, 23, 2001, pp. 271-291.

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