Risk and the Reserve/Production Ratio

*By Douglas B. Reynolds**

Risk is a factor in oil exploration and development that has not been fully incorporated into our analysis of OPEC and world oil market. Robin and Thaler (2001) show that an individual's marginal utility for wealth-gains decreases exponentially and that for wealth-losses increases exponentially. In other words, people are normally highly risk averse. But if an individual person, who is an economic agent, is highly risk averse, then an economic entity such as an oil company can also be risk averse. Each OPEC country has a National Oil Company (NOC) or a national bureaucracy, which controls all oil exploration and development. Since an NOC is an economic entity and could be highly risk averse, then we might see not only high reserve to production ratios for that country, but also very little new exploration or development.

Adelman (1986) shows that Saudi Arabia has less exploration and development than the United States even though oil reserves and potential oil production are greater in Saudi Arabia than in the United States. Reynolds (2000) suggests that the reason oil exploration and development investments are lower for some oil producer countries than for the United States is due to risk aversion. NOCs are risk averse to oil investment and, therefore, have lower oil production and in turn higher reserve to production ratios. Investments tend to be less aggressive and the pace of oil exploration and development is much slower than under a competitive environment. This, however, should not be interpreted as a bad thing. It is to the world's advantage that oil be conserved for the future. Oil is the most valuable energy commodity on earth and always will be. Therefore, any market environment that conserves oil should be applauded.

In contrast to OPEC producers, the United States has a well adjudicated property rights system and a competitive market, with many wildcat drillers. These wildcat drillers tend to have little to lose and are extremely risk loving. They push oil exploration to the limits of marginal cost. Oil supply models that compare a competitive U.S. market environment, with greater risk taking, to a risk averse market environment, such as OPEC countries operate in, can lead to the wrong oil supply forecast. It is important to incorporate the idea of risk loving and risk averse behavior into a model of oil supply. I will do that by using a modified Hubbert curve model, which is one of the most important models for oil supply.

In 1962 M. King Hubbert created a mathematical logistics curve, often called the Hubbert curve, which could be used to project future trends in oil discovery and production. Cleveland (1991), Reynolds (1999), Slade (1982), and Uhler (1976) give theoretical reasons for why the Hubbert curve works. Cleveland and Kaufmann (1991), Moroney and Berg (1999), and Kaufmann (1991), incorporate economic principles into Hubbert's equations. Pesaran and Samiei (1995), Campbell and Leherrere (1998), Edwards (1997), Campbell (1997), and Cleveland and Kaufmann (2001) use Hubbert's equations to forecast oil supplies for the United States and the world. On the other hand, Wiorkowski (1979), Ryan (1965), and Lynch (1994) have criticized Hubbert for not accounting for economic, technological and political changes in the oil market. The claim that in many instances it is not possible to forecast oil supplies using the Hubbert curve. Nevertheless, even with as much criticism as Hubbert received, his 1962 forecast for the peak in oil production for the U.S. lower 48 was only off by one year. Hubbert also theorized that his curve does take into account technological trends.

Since Hubbert's work has been resurrected as a viable forecast model, forecasters are starting to use it more. For example Campbell and Leherrere (1998) predicted a world oil shortage in the near future. The U.S. Energy Information Administration (EIA) also uses what looks to be a Hubbert curve analysis for their world oil supply forecast. The EIA, (EIA 2000), forecasts that oil production will not peak until at least 2030 and maybe into the 22nd century. I will also use a Hubbert curve to forecast world oil supplies and add a risk factor to take into account OPEC countries risk averse behavior. However, in order to better use the Hubbert curve it needs to be made into a cumulative production model rather than a time dependent logistics curve.

One of the problems with Hubbert's oil discovery and production logistics curve has been that it is time dependent. Because of this, if the demand for oil goes down or even increases more slowly, then the time path of production changes substantially from Hubbert's logistics curve. Once oil production goes below Hubbert's logistics curve it becomes difficult to track where the production limit is. An alternative Hubbert curve uses a simpler quadratic equation. This equation is derived by using the Hubbert time dependent oil production logistics curve and the time dependent cumulative oil production logistics curve and subsuming the time variable. The quadratic Hubbert curve is no longer time dependent but cumulative production dependent. The equation for the curve is:

$$QP = a \times CQP - (a/URR) \times CQP^2$$

where

QP = Quantity of Oil Produced during each year, i.e. the rate of oil production.
CQP = Cumulative Quantity of Oil Produced up to each year.
URR = Ultimately Recoverable Reserves.
a = a size parameter, which determines the height and width of the Hubbert curve.

Note, that QP is statistically independent of CQP because they have different units of measurement, one is a rate and the other is a quantity. The independence of QP from CQP, similar to the independence of QP from time, allows a statistical analysis using the quadratic Hubbert curve similar to his logistics curve. The new quadratic Hubbert curve has characteristics that make it easier to use. For example, if actual oil production is below the quadratic Hubbert curve, it is easier to see where consumption falls relative to the limits of supply. Plus it is easier to see how far demand can increase before it reaches the Hubbert limit. Therefore, this new Hubbert curve is the supply limit. Putting both supply and

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consumption (demand) on the same graph will allow us to see how far away the Hubbert curve supply limit is from demand.

Campbell and Laherrere use a Hubbert curve to estimate total world oil supplies at 1.8 trillion barrels and a peak in oil production before 2005. If they are right, in less than five years oil prices will increase to spectacular heights. An oil crisis of immense magnitude will ensue. However, even if the URR is much larger than what Campbell and Laherrere predict, we may still reach a Hubbert curve limit sooner than expected due to OPEC countries' risk averse natures. When risk aversion is included into a Hubbert analysis then Campbell and Laherrere's prediction may turn out to be much truer than expected. First consider an alternative Hubbert analysis using the EIA's world oil supply forecast. The EIA estimates a medium URR using geological data and scientific methods at 3 trillion barrels. The EIA's medium estimate for increases in oil demand is 2% per year. Putting together supply and demand, the EIA's best estimate is that world oil supply will peak in 2037. An alternative estimate forecasts the peak in 2030. If the EIA's estimated URR is correct and the world follows a U.S.-type Hubbert curve, then we can see where supply and demand were relative to each other in the past. Figure 1 shows the EIA model in terms of a quadratic Hubbert curve. The assumption is that reserve to production ratios will be at 10 to 1 as it has been in the United States for many decades.

The problem with using a U.S.-type Hubbert curve or assuming a low reserve to production ratio is that the United States has a competitive market with a large number of risk loving agents. As explained above, the United States is unique in its competitive marketplace. In many of the largest world oil producing regions, only one NOC is allowed to look for oil, or to determine who will and who will not explore for and develop oil within the country, and at what profit. Having a single economic entity in charge of all oil activities will normally reduce risk taking and create a very risk averse environment. Clearly with a single entity in charge, the Hubbert curve model, or any model, must take into consideration that risk averse behavior, which will radically reduce oil exploration, development, and production for any given region.

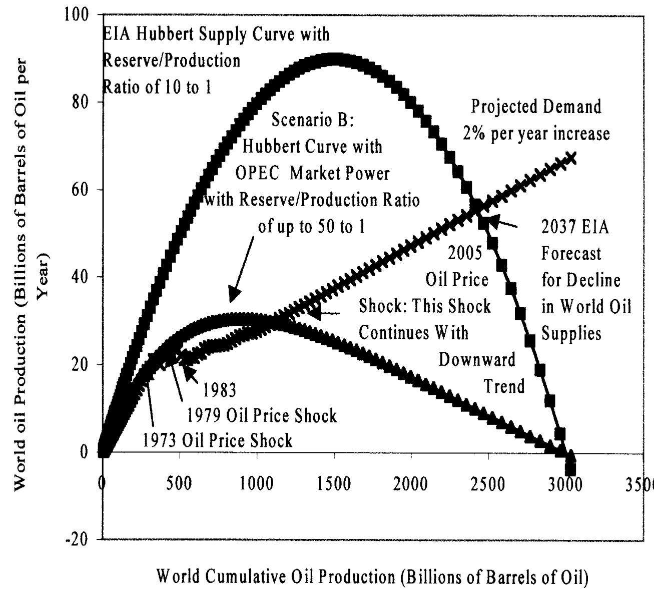
If a normal U.S.-type Hubbert curve cannot be used to analyze world oil supplies because actual supplies will be much lower than a 10 to 1 reserve to production ratio would allow, then how can world oil supplies be modeled? The best model for world oil supplies may simply be to track the maximum supply points in the past and forecast that path to the estimated URR. Looking at 1973 and 1979, we see extremely sudden declines in demand. The changes occurred because oil prices suddenly shocked upward. However, was it the price changes that caused the demand trend to change, or was it a supply limit that forced prices to increase and demand to fall. It is surprising to find oil prices rising so suddenly when oil consumption was well below the EIA modeled Hubbert curve limit. Indeed, the very fact that oil prices suddenly skyrocketed and stayed high suggests that the Hubbert curve at a 10 to 1 reserve production ratio is not in fact the limit of oil production, but that the Hubbert curve limit is much lower. Remember, many oil producing countries in the world produce oil at a 50 to 1 or even a 100 to 1 reserve/production ratio. This is a level of oil production 80% lower than for a 10 to 1 ratio. This means that a standard Hubbert curve should not be used to forecast world oil supply potential.

Figure 1 shows an alternative Hubbert curve called Scenario B. The Scenario B curve is created by finding a formula that fits the 1973 high point of oil production, the 1979 high point of oil production, and the currently estimated URR. The equation used for this curve is

$$QP = [a \times CQP - (a/URR) \times CQP]^2 \times 0.78[(CQP/URR) + 1]^{-ex}$$

Where ex = 2.5

Figure 1
Forecast OPEC Supply and World Oil Demand As a Function of Cumulative Production



Other exponents for *ex* less than or greater than 2.5 do not fit the 1973 and 1979 high points as well. Scenario B assumes that the maximum world oil production is lower than what a 10 to 1 ratio would give. One way to look at Scenario B is to assume that political or other economic factors have caused it. I believe it is OPEC countries risk averse environment that caused NOC's to have lower exploration and development efforts that caused Scenario B. Therefore, it is the Scenario B Hubbert curve that caused the 1973 and 1979 oil price shocks rather than the oil price shocks causing Scenario B. Note that although the second price shock was slightly lower than Scenario B suggests, this was due to Iran's slight reduction in production and Saudi Arabia's reductions thereafter. The most striking thing about Scenario B is that demand will reach and exceed supply in the next five years creating an oil price shock, even with URR at three trillion barrels. If URR is even higher at say six trillion barrels, Scenario B can be redrawn and the price shock is only delayed by another five years. Therefore, we should not expect higher URR estimates to delay for long the inevitable world oil price shock.

The reason the Scenario B curve is so much lower than a regular Hubbert curve is because of the inherent risk averse nature of NOCs. No matter how much an NOC is cajoled, reorganized or provided with internal incentives, it will still be a single entity making oil exploration and development decisions one project at a time. The company will by nature be risk averse because each individual oil project it decides on will be judged a gamble in isolation from all other considerations. In other words, the NOC does not judge individual project decisions by comparing it to other risks in the economy or by comparing it to the countries overall wealth. Rather the entity judges each risk in isolation and becomes very risk averse to make any move. This makes the oil entity, just like many individuals, very hesitant to expand its activities and investment.

What Scenario B suggests is that the world is in danger of an upcoming oil supply shock of epic proportions. What is more, there will be confusion over why such an oil shock will happen. Oil price shocks in the past occurred during or around significant political evens such as a war. However, I must stress that in no way could a one month Arab/Israeli war or a six month Iranian revolution cause an oil price increase of such a sustained magnitude as what happened in 1973 and 1979. The price increases were caused by fundamental economics. They were caused independently of political events and were due to the risk averse nature of OPEC's NOC's. However, political events do tend to push markets into chaos a little faster than they normally would. In today's highly charged political and terroristic environment, there will no doubt be future significant events as great as the World Trade Center horror. These events will not be the cause of future oil price increases but they will exacerbate them. Political and economic events that happen simultaneously will be interpreted as being cause and effect. Political events will be judged the cause rather than the underlying economic reality. Plus political events will exacerbate the economic events. What we can assume, though, is that there will be a huge oil price adjustment within five years. Oil prices of upwards of $200 to $300 per barrel are not out of the question. We need to prepare now for that event.

References

For references contact the author.

Student Conferences *(continued from page19)*

ics, presented a paper on "Deregulation in the North American Natural Gas Industry: what lessons for Mexico?"

At the second and final session on *The Electricity Sector,* Virginie Pignon, Ph.D. Student in Economics discussed "Electricity Transmission Tariffs in the Nordic Countries: An Assessment of Pricing Rules," Marie Laure Guillerminet, Ph.D. Student in Economics, discussed "Investment and Financing in an Institutional Environment in Mutation: the Case of an Electronuclear Equipment," Pierre Taillant, Ph.D. Student in Economics, discussed "Technological Competition and Lock-in in the Photovoltaic Solar Electricity Production" and Stine Grenaa Jensen, Ph.D. Student in Economics discussed "A Simple Integrated Power Market Model Including Tradable Green Certificates and Tradable Emission Permits."

The abstracts of the presentations from the Mexican student conference will be in the next issue of the newsletter of the Mexican Association for Energy Economics. In order to obtain free proceedings of either one of the student conferences please contact Alberto Elizalde Baltierra (elizaalb@hotmail.com) or Stine Grenaa Jensen (stine.grenaa@risoe.dk).

Controlling Carbon Dioxide *(continued from page 29)*

[2] Greenhouse gases, as defined by the United Nations Framework Convention on Climate Change (UNFCCC), are "those gaseous constituents of the atmosphere, both natural and anthropogenic, that absorb and re-emit infrared radiation." These are carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFC's), perfluorocarbons (PFC's), and sulfur hexafluoride (SF_6). Each gas is assigned a "global warming potential," which is a value that allows for comparison in terms of carbon units. The most important constituent of global warming models, in terms of its impact, is water vapor.

[3] Since water is far more effective at absorbing outgoing infrared radiation than is CO_2, most of the temperature increase predicted by the models arises from increased water vapor in the atmosphere triggered by CO_2 rather than the CO_2 itself. A slight warming of the coldest air masses allows them to hold substantially more water vapor and greatly increases their insulating effect. By contrast, more water vapor at tropical latitudes, and in the summer months, increases cloud cover. Clouds reflect incoming solar radiation, however, and this tends to have a cooling effect. Another factor making CO_2 more potent at warming higher latitudes is that CO_2 absorbs a greater proportion of the longer wavelength radiation emitted from colder surfaces.

[4] Figure 1 simplifies the analysis by ignoring the role of the OPEC cartel in the world fossil fuel energy market. The Appendix (to the companion paper) shows how the discussion in this section can be extended to allow for the actions of OPEC in setting the price of oil and thus indirectly of coal and other energy resources. The analysis of this section applies to the case where the supply chosen by OPEC is independent of the tax rate on fossil fuel. More generally, the analysis in this section under-states the efficiency costs of taxing the use of fossil fuel. Monopoly pricing by OPEC would already reduce the consumption of fossil fuel below the efficient level. Additional taxes on fossil fuel consumption would only exacerbate the efficiency losses resulting from monopoly pricing.

[5] If average temperatures do increase, laboratory experiments have shown that the stimulatory effect of CO_2 on photosynthesis is likely to be enhanced.

[6] Sir Fred Hoyle (1996) has noted the difficulties this creates for people concerned about current projected levels of global warming (K stands for degrees Kelvin, or degrees above absolute zero):

"Given the choice, I imagine nobody would opt for a world without any greenhouse, that is a world with a mean temperature of about 259K. And probably few would opt for an ice-age world with a mean temperature of 275K to 280K. To this point, the greenhouse is seen as good. Further still, a clear majority continues to see the greenhouse as good up to the present-day mean of about 290K. But, at the next 1.5K a drastic change of opinion sets in: the greenhouse suddenly becomes the sworn enemy of environmental groups, worldwide, to the extent that they rush off to Rio and elsewhere and make a great deal of noise about it. I find it difficult to understand why. If I am told that computer calculations show immensely deleterious consequences would ensure, then I have a good laugh about it. In private, of course, since I am always careful to be polite in public." (p. 185)

[7] These cost estimates derive from the survey of a number of models presented in a special issue of *The Energy Journal* (Weyant, (1999)).

Bibliography

For bibliography contact the authors.