

Risk Aversion and OPEC: An alternative model for OPEC

By Douglas B. Reynolds
Associate Professor Oil and Energy Economics
University of Alaska Fairbanks

OPEC is thought to be a cartel. A test is conducted to see if one member of OPEC, Venezuela, has its production Granger Cause the cartel quota or whether the cartel quota Granger Causes Venezuelan production. The results show both occur. Having OPEC quotas Granger Cause Venezuelan oil production makes sense since there are times when OPEC coordinates outputs in a tit-for-tat game. However it doesn't make sense that Venezuelan oil production Granger Causes OPEC quotas, unless OPEC is not very powerful. Clearly this is the case. Furthermore, during the 1970s when there was no quota for Venezuela, its production declined even as prices compared to the 1960s were twice as high. When oil prices went down in the 1980s and 1990s Venezuelan production increased, especially when it opened up production to Production Sharing Agreements (PSAs). That evidence precludes a bureaucratic production syndicate hypothesis. This suggests an alternative explanation for OPEC is needed based on Institutional Economics. One explanation for OPEC is that each member of OPEC has that institutional control of each country's production is at play where risk aversion to changing its oil production status quo is caused by the Cautious Shift Phenomenon. If the Cautious Shift Phenomenon explains OPEC members' production, then a model for world oil production based on risk averse institutions shows that peak oil may have occurred in 2005.

CLASSIFICATION: C700 Game Theory and Bargaining Theory: General
Q410 Energy: Demand and Supply
Q480 Energy: Government Policy

KEYWORDS: Risk, Venezuela, Oil Supply, OPEC

Doug Reynolds
University of Alaska Fairbanks
School of Management
PO box 756080
Fairbanks, Alaska 99775-6080

Phone: (907) 474-6531
Fax: (907) 474-5219
Email: FFDBR@UAF.EDU

Risk Aversion and OPEC: An alternative model for OPEC

I. Introduction

Ever since the first oil price shocks of 1973, OPEC has been an enigma. The usual explanation for low oil production capacities among OPEC members is that OPEC operates as a cartel. However, with ten or more members making up OPEC's producers, it is difficult for such a cartel to be successful. Van Huyck et. al. (1990) and other game analyses suggest agents playing cooperative games have a difficult time trusting each other especially if a small amount of uncertainty occurs, which is the case for OPEC. Based on those games, it should be extremely hard for OPEC to cooperate to change oil prices. Furthermore, as Adelman (1986b) implies, OPEC members face the risk of losing oil value now due to technological innovation later should they attempt to refrain from production. Therefore, due to the potential competition, the future risk of technological substitutes for oil, and the difficulty of coordinating in a game, there should be little if any supply reductions by OPEC members.

However in the existing literature on OPEC, Kaufmann, et. al. (2004) and Loderer (1985) do show that oil prices have been affected by OPEC actions, at least to a small degree. Furthermore, Adelman (1986a) shows that there is less investment in Saudi Arabia and Kuwait than what would normally be the case in the United States, which suggests an effort to reduce output. What's more, there was less investment in Saudi Arabia after 1973 than what was normal for it before 1973. However, if OPEC is affecting the market price, it is still unclear what market manipulating model—cartel, price leader or some form of oligopoly—best represents OPEC.

In this paper Venezuela oil production in comparison to OPEC' stated quota for Venezuela is looked at. A test is conducted to see if Venezuelan production Granger causes the OPEC quota for Venezuela or vice versa. The results show both occur. However, during the 1970s when there was no quota for Venezuela, Venezuelan oil production declined even as prices compared to the 1960s were twice as high. Therefore, the 1970s cannot be characterized as a cartel since there was no quota. When oil prices went down in the 1980s and 1990s Venezuelan production increased and the OPEC quota increased, mostly in response to, rather than as a cause of, Venezuelan oil production. This suggests an alternative explanation for OPEC is needed. One explanation for OPEC is that each member is risk averse to changing its status quo due to the Cautious Shift Phenomenon.

The paper is organized as follows. The next section looks at the theories of OPEC, then the tool (quota system) that OPEC can use to affect prices is considered. The fourth section looks at capacity constraints by OPEC members to see if a quota tool of OPEC could be being used or not. In that section, an indexed Hubbert production curve is introduced for individual producers including Venezuela. Then Venezuela 's production relationship to the OPEC quota is tested for Granger Causality. The fifth section looks at an alternative explanation for OPEC: The Cautious Shift. Decision making at the margin and internal versus external risks will be considered. In the sixth section, we examine the typical decision rule for an oil explorer at the margin and consider how risk plays into the decision to invest. In the seventh section, we look at internal versus external risks that an OPEC member will choose. In the eighth section, is shown the risk averse world oil production model that explains why 2005 was the peak for world conventional oil production.

II. What is OPEC

A number of models explaining OPEC behavior have been proposed. Johany (1980) proposed a low discount theory. Ezzati (1976), Cremer and Salehi -Isfahani (1991) and Teece (1982) proposed target revenue models. Moran (1982) and Adelman (1993) among others proposed political explanations for the cause of the 1970s and 1980s oil price shocks. Griffin (1988), and Al-Sultan (1993) proposed several types of collusive behavior, and Pindyck (1978) proposed a Hotelling (1931) model. Attempts to verify these models are shown in Griffin (1985), Green (1988), Jones (1990), Dahl and Yucel (1991), Griffin and Nielson (1994), Gulen (1996), Alhajji and Huettner (2000a and 2000b), Spolimbergo (2001), and Ramcharran (2002), but without definitive success. As far as collusive quotas are concerned, Gault et. al. (1999) could not firmly establish a single statistically significant model for how the assignment of quotas is done within OPEC.

Smith (2005) looks at several of the models for OPEC including a target revenue model, a Bertrand-Edgeworth Model, a Stackelburg Model, a Cournot model, and a perfectly competitive model. The author concludes that few interesting hypotheses for OPEC have been rejected. He states that, “it is possible to find bits of behavioral evidence in the historical record that are consistent with a wide range of alternative hypothesis—therefore making it difficult to reject any.” Smith however does suggest an alternative model for OPEC: it is a *bureaucratic production syndicate* that somehow allocates quotas but which faces high costs of making decisions. Thus due to the high cost of decision making, OPEC members are reluctant to make changes in their allocation of quotas unless the outcome of the reallocation is substantially better for all members. Since that is rarely the case, OPEC seldom changes its outputs.

One of the problems with the idea of a bureaucratic production syndicate with seldom changing output allocations is that OPEC had no quotas from 1974 to 1981 and therefore it conducted no coordinated output reductions or output allocations during that time even though oil prices averaged twice as high in real terms than compared to the previous ten years. It may be true that OPEC members saw a reduction in their oil outputs right around the 1973 oil price shocks making it look as if OPEC was trying to be a cartel or look as if they were actively engaging in production cutbacks, but most likely much of this reduction in supplies was due to the take-over and nationalization of oil and gas assets that took place around that time.¹ Reductions were due to institutions. As the national companies took over the oil fields, there was an inevitable reduction in production as new local and possibly inexperienced managers were put in place and as risk aversion, explained below, emerged. Still since no output agreements were mandated and everyone was free to produce as much as they wanted, then unless it can be proven that OPEC had a secret allocation protocol the bureaucratic production syndicate model has to be rejected.

Therefore, given Smith’s and Loderer’s results and given the incentive for cheating that exists and given that no production quotas existed prior to 1982, there is no solid evidence for any model that can explain OPEC decision-making or market effects over the entire course of OPEC’s existence. Smith does however show convincing evidence that OPEC members are not merely free market competitors. Smith shows that monthly and quarterly production changes for oil producers relative to other OPEC and non-OPEC producers does not exhibit compensating change. In other words, if OPEC were a cartel, each member would change outputs to compensate for other OPEC and non-OPEC variations in output more than 50% of the time, but that does not happen. More surprising, if OPEC members were not complying with any organizational directives at all or were simply participating in a Cournot Oligopoly or in a competitive market, then they would have at least a 50-50 chance of arbitrarily compensating their own production levels vis-à-vis other OPEC and non-OPEC members. That does not happen either. Rather, compensating quantity changes happen significantly less often than a 50-50 chance, which Smith believes is indicative of a bureaucracy that inefficiently runs the group. Smith’s results indicate that there has to be more to OPEC than just a group of competitive producers or even a type of oligopoly. Something is constraining output.

It is possible though that OPEC engages in a tit-for-tat game between its price leader Saudi Arabia and the rest of OPEC. For example Geroski, Ulph, and Ulph (1987), Dahl and Yucel (1991), Alhajji and Huettner (2000a and 2000b), and Griffin and Nielson (1994) and Dibooglu and Algudheu (2007) do show a tit-for-tat game strategy within OPEC. However while a tit-for-tat game strategy to reduce outputs and punish cheaters can work in the short term, there is still incentive to cheat over the long term and expand production capacity. If everyone knows that in each successive play of the game there will be cheating, and that in order to take advantage of the inevitable cheating in the next play it is best to attain a higher capacity to get more of the pie when it is split, then each member should aggressively be engaging in capacity expansion over the long haul. Indeed game theory suggest that it is extremely difficult for such tit-for-tat games to work over the long run. Yet there is little expansion. Moreover, there was no tit-for-tat game for OPEC prior to 1981, since no quota agreements existed.

An alternative explanation for the actions of OPEC is explained by Reynolds (1999a), who introduces the concept of risk aversion to OPEC. This is not risk aversion to losing oil’s value due to future energy technology

¹ In 1970, Libya raised taxes, which can also stifle aggressive investment. In 1971 more OPEC governments raised taxes, and Algeria, Libya and Venezuela began nationalizing assets. In 1972, OPEC raised oil prices and Iraq nationalized its oil with OPEC support. Also Kuwait, Qatar, Saudi Arabia and the UAE started taking equity stakes at that time. In 1973, Iran replaced its equity sharing agreements with service contracts. In 1974, Saudi Arabia took controlling interest in Aramco. Kuwait nationalized its oil operation in 1976.

in the Adelman (1986b) sense, but risk aversion to making risky exploration investments. This analysis relies on Friedman and Savage's (1948) idea of risk in economic models along with Markowitz's (1952) idea of the utility of wealth, as well as Kahneman and Tversky's (2002) idea of prospect theory. If oil producers are risk averse to exploration and development, then that could induce less exploration and development leading to low oil supplies.

III. The Tool of OPEC

Since Kaufman et. al. show evidence that OPEC is raising oil prices at least somewhat, we must find a tool that OPEC can use to carry out that slight market manipulation. For example the U.S. Federal Reserve has a tool to change interest rates, which is through monetary policy. Similarly OPEC must use changes in the world's oil supply to affect oil prices. OPEC agreements may include price targets, but OPEC can only achieve those targets by changing the physical oil supply and in particular by changing OPEC oil supply. That is the only tool it has.

However, if OPEC were in control of the oil market the way a central bank controls money markets, then whenever OPEC announces a price target, not only should the rest of the market immediately move to that price target, but the cartel should also be able to adjust its output to force the world price to match its target very quickly. However, Loderer shows that from 1974 to 1981, OPEC announcements for new price changes had no immediate affect on the world spot price for oil. However after 1981 OPEC decisions did immediately affect the spot price, but only for a limited time and only very slightly. That suggests that OPEC did not manipulate the oil market from 1974 to 1981. Furthermore as stated, OPEC had no quotas or quantity restrictions for its members between 1974 and 1981 so there was no tool in place that OPEC could have used to change prices.

Officially, OPEC announced price targets during the 1974 to 1981 period, but since these prices were lower than spot prices, then, contrary to what a cartel or bureaucratic syndicate would do, OPEC tried to expand output not reduce it. Plus looking at official news releases during this period, most OPEC members wanted high prices, but Saudi Arabia the main producer wanted low prices. This is indicative of a price leader model. If Saudi Arabia was a price leader during this period then it would prefer prices to be high but not too high, which means Saudi Arabian calls for lower prices make sense. This is because if prices were too high, the demand for oil would eventually fall over the long run, as Adelman (1986b) suggests, due to the incentive to seek substitutes for oil and eventually Saudi Arabia would lose money. But if the demand for oil fell in the long run, the price followers would assume that the price leader would reduce its output to keep prices from falling and the threat of falling prices wouldn't affect them. This may be why OPEC had a hard time determining the price they wanted to target from 1974 to 1981. However, since there were no quota restrictions on any OPEC members at the time, there was no mechanism for OPEC to use to achieve its price goals.

So since OPEC used no tool to change the price of oil from 1974 to 1981 and since Loderer gives evidence that OPEC did not control prices during this period, then this shows OPEC as a whole did not successfully affect oil prices either as a cartel or as a bureaucratic production syndicate at that time. Yet oil prices were on average 200% higher in real terms than the previous decade and more interestingly total OPEC production from 1973 to 1977 before the Iranian revolution was flat. So on the one hand there was no tool that OPEC actively used to manipulate oil prices, yet on the other hand, oil prices were high and production levels within OPEC members stayed flat even though their proven reserves were substantial.

Starting in 1981, though, OPEC attempted to engage in classic tit-for-tat output reductions. In May 1981 there was an official announcement that everyone in OPEC except Saudi Arabia would reduce their output. Importantly that announcement immediately affected spot prices. Thus the supply tool was working. This output reduction agreement was the first output agreement since 1973 where OPEC actually used its quantity reduction tool to affect prices and where it had an immediate effect on spot prices. But then after a slight price increase, prices proceeded to fall. In fact, Loderer found that most of the agreements from 1981 to 1983—which were always agreements about output cutbacks rather than prices—immediately affected the price of oil by raising it, but only for a short while before prices began to fall again. Thus it may be that starting in May 1981 OPEC did finally act as a tit-for-tat oligopoly.

Nevertheless, if a tit-for-tat oligopoly, or possible cartel or bureaucratic production syndicate was strong enough from 1981 to 1983 to actually affect spot market prices, then how could prices in general have collapsed? If the oligopoly was so weak from 1974 to 1981 that it had no discernable affect on spot prices after each of its decisions then why were prices so high? Undoubtedly OPEC had less affect on prices than did the world supply

of and demand for oil. In other words, from 1974 to 1981, it was the world's high demand for oil that pushed against a weak supply that caused prices to increase, not OPEC actions. After 1981 OPEC's lack of ability to maintain high prices was due to oil demand destruction going on at the time and due to the increasing share of fringe oil producers. Thus OPEC should be seen as a competitor rather than a strategic manipulator in world oil markets.

Indeed we might ask, if OPEC was a market manipulator after 1981 then what market power did they have? One way to measure market power is to use an oil market worldwide Herfindahl-Herschman Index (HHI) that assumes OPEC and the Soviet Union are single producers. Using data from the EIA for 1982, OPEC as a single producer controlled 28% of the world oil supply. The Soviet Union, which often sold oil on the world market and which created incentives to reduce internal communist consumption with internal price increases, see Gustafson (1989), controlled 21% of the world supply. The Soviet Union therefore actively engaged in world oil markets by increasing exports both with attempts to increase its supply and reduce its internal demand. If we include each oil producing country as a single unified producer (even for the United States) then the HHI for 1982 was less than 1700 indicating the world oil market was "moderately concentrated" according to U.S. Department of Justice (2008) definitions.

After the price collapse of 1986, though, there were many sustained periods of price increases which were instigated by OPEC as Kaufmann et. al. show. Therefore OPEC agreements, which Alhajji and Huettner (2000a and 2000b) and Dibooglu and Aljudhea (2007) show as a tit-for-tat oligopoly, definitely affected prices. Smith also finds a marked decrease in the probability of compensating changes after the quota system is put in place in 1982 which would indicate that OPEC is definitely different before 1982 then it was from 1982 onward. Therefore the pre- and the post-May 1981 data may require two separate models to explain OPEC.

IV. Is OPEC's Oil Production Capacity Constrained: the example of Venezuela

Based on Van Huyck and game theory, we should see oil countries cheating on any and all OPEC agreements especially in the long run. Members should expand their oil supply capacities at will in order to better negotiate for higher quotas inside OPEC, or in order to have better bargaining power within a production syndicate or a tit-for-tat game, or even to maximize their oil's value before alternative energy technology takes that value away. Yet OPEC members and even some non-OPEC members seem to have constrained production outputs. Consider specific examples of OPEC members and some non-members lack of expansion.

First look at the United States as an example how quickly expansion can take place. U.S. offshore oil production evidence, EIA (2005), from 1990 to 2002, shows that even though U.S. offshore oil exploration, development and production is relatively more costly than on-shore oil exploration, development and production, nevertheless the U.S. did manage to expand its offshore oil production by about 5% per year during those years. That was during a time when oil prices often dipped below \$10 per barrel in nominal terms and were never more than \$30 per barrel. In fact they stayed below the \$20 market much of the time. The U.S. off-shore oil reserves as of 2005 were at 5 billion barrels or a 9.7 year reserves to production ratio which has not changed much over the years. That suggests that if a high cost region like the U.S. offshore oil region can have expanding oil production, and having no reduction in proven reserves, in a competitive market over a ten year period, then so should any one of the smaller or medium sized OPEC oil producers, who are fringe cheaters—competitors—at the margin. Those producers would normally be price takers in a cartel with cheating, and they mostly have rather large proven reserves from which to utilize.

Therefore individual OPEC members should theoretically be engaging in output capacity expansions faster than they have done. And Venezuela provides an example. In the 1980s Venezuela hovered at oil production levels of around 2 million barrels a day until it opened up its oil fields in the 1990s to outside oil companies through the use of profit sharing agreements (PSAs) and expanded its oil supply capacity at about a 4% increase per year. Since few OPEC members were expanding output capacities during the 1990s at such a pace—even though most members have stated proven reserves in excess of a reserve to production level of 50 years—then that suggests cheating by OPEC members by expanding capacity in the long run could have been easily done.

In Venezuela's case the oil expansion caused Venezuela to push above its quota theoretically allowing it a higher piece of the OPEC pie for subsequent quota negotiations. Therefore, if expansion and cheating is possible with Venezuela, than it should also be possible with other OPEC members. More to the point, if Venezuela could

do it, why wasn't everyone in OPEC doing it? Such capacity expansion would be an easy way to gain revenue. Yet no other OPEC member except possibly Qatar was expanding their production capacity as fast as Venezuela in the 1990s, even though Adelman and Shaki (1989) show costs for most OPEC and many non-OPEC countries were low and even though these countries have high levels of proven reserves. For example, Iran was able to increase its oil production by only 1% per year during the 12 years from 1990 to 2002. Iran currently has stated reserves of 130 billion barrels or a 114 year reserve to production ratio. The United Arab Emirates increased its oil production by only .5% per year during the same period, yet U.A.E. has stated reserves of 97.8 billion barrels for a 112 year reserve to production ratio. Finally Nigeria was only able to increase its production by 1.3% during the same period. Nigeria has stated reserves of 34 billion barrels which gives it a 44 year reserve to production ratio. Even Mexico seems to follow a similar pattern of non-expansion as OPEC members even though it isn't a part of OPEC.

One way to make such a comparison is to use what is called a quadratic Hubbert curve see Al Jarri and Startzman (1999) and Reynolds (1999b). The standard Hubbert model, Hubbert (1962), specifies a logistics model that can be solved as a cumulative production model subsuming the time variable. For production the model is as follows:

$$QP = b_1 * CQP + b_2 * CQP^2 \quad [1]$$

Where:

QP = the Yearly Production Rate

CQP = the Cumulative Production

Equation 1 gives a simplified Hubbert curve that can be used to determine if other countries are as aggressive as the United States in oil exploration and development. By comparing different countries to the U.S. using Equation 1 and indexing the expected Ultimately Recoverable Reserves (URR), the CQP value at $t = \infty$, of the different countries, using cumulative production and proven reserves and, if available, probable reserves, it is clear that a number of countries are below what they could normally expect to produce had they had an open competitive market like that of the U.S.. See figure 1-5. The indexed Hubbert curves URRs are proportional to cumulative production and official proven reserves, except for Mexico which also includes probable reserves. Therefore the evidence shows that these countries have restrained supplies. However, a model must explain this constraint and still be consistent with Loderer's and Smith's evidence.

Looking at Venezuela in particular, I test whether Venezuela's oil production Granger causes the OPEC quota for Venezuela or whether the OPEC quota for Venezuela Granger Causes Venezuela's oil production. The data is from EIA monthly oil production for individual OPEC members and OPEC's own quota data. If OPEC is a cartel, then it should be the case that the OPEC quota Granger Causes Venezuela's oil production not vice versa. The evidence shows for a month by month test for causation six months ahead of current production that we cannot reject no Granger causality in either direction. The F-test for the hypothesis that the OPEC Quota does not Granger Cause Venezuelan Oil production is 43. The F-test for the hypothesis that Venezuelan oil production does not Granger Cause OPEC Quota is 85. Therefore we reject both hypotheses and find that the quota affects production and vice versa. But it is still odd to have production affect the quota. In fact looking closer at the quotas and production it is clear that there are only a few instances when Venezuela did follow the quota, most of the time it was the quota following Venezuela's production.

A bigger problem to solve is that since Venezuela did engage in capacity expansion in the 1990s with PSAs, then why couldn't Venezuela's own oil company, Petroleos de Venezuela, unilaterally expand its production without PSAs or without outside international oil companies (IOCs)? If you are going to expand capacity, then just do it yourself. Why bring in IOCs to do it, and give away any of the profit, unless you cannot do it yourself? Therefore a model needs to explain why Petroleos de Venezuela could not expand its own production by itself without the use of PSAs. None of the models of OPEC can explain that.

Figure 1

US and Iranian Indexed Oil Production

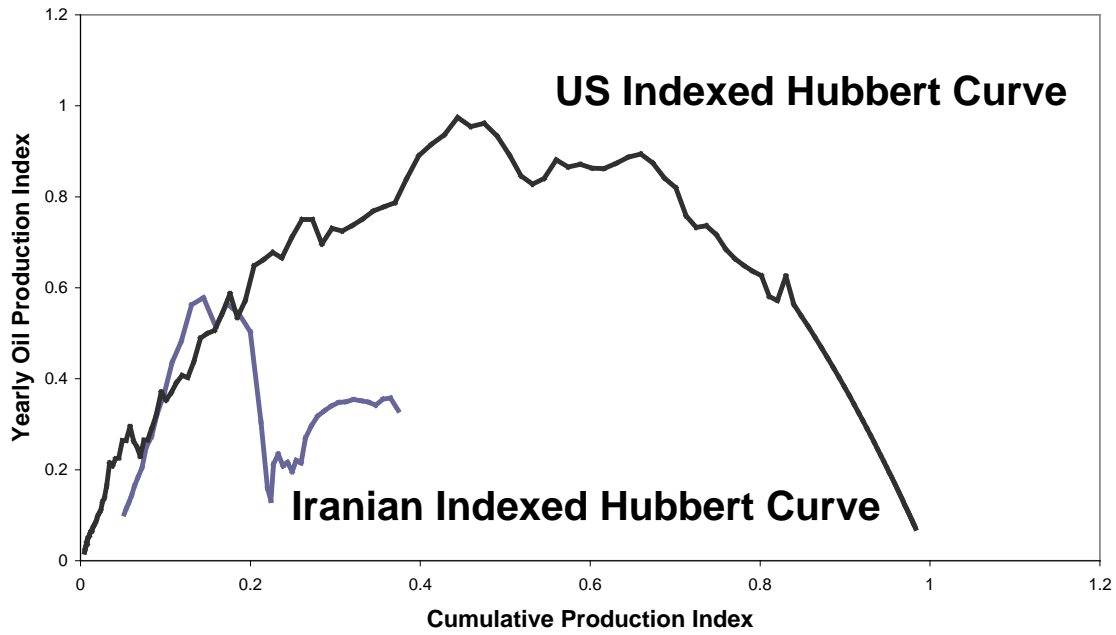


Figure 2

Kuwait and US Indexed Hubbert Curves

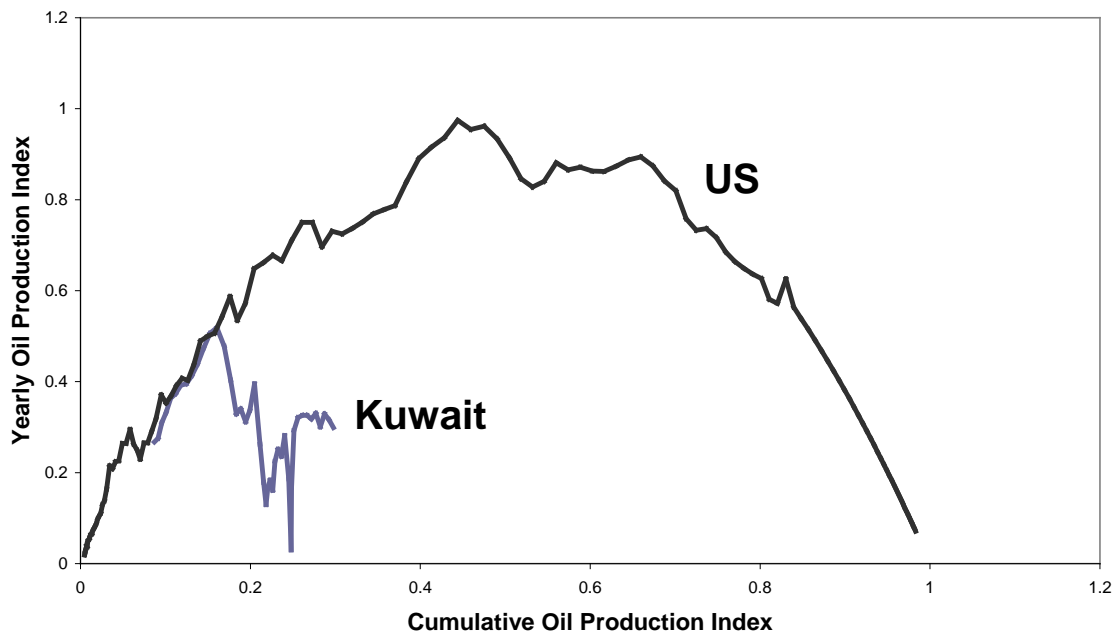


Figure 3

Mexico and US Indexed Hubbert Curves

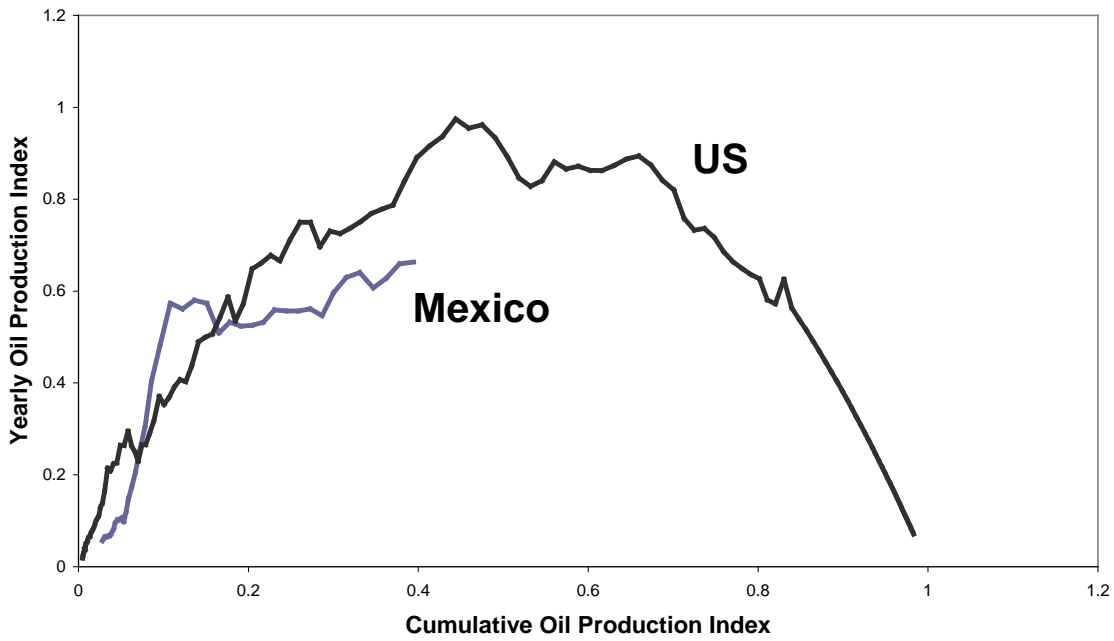


Figure 4

Nigerian and US Indexed Hubbert Curve

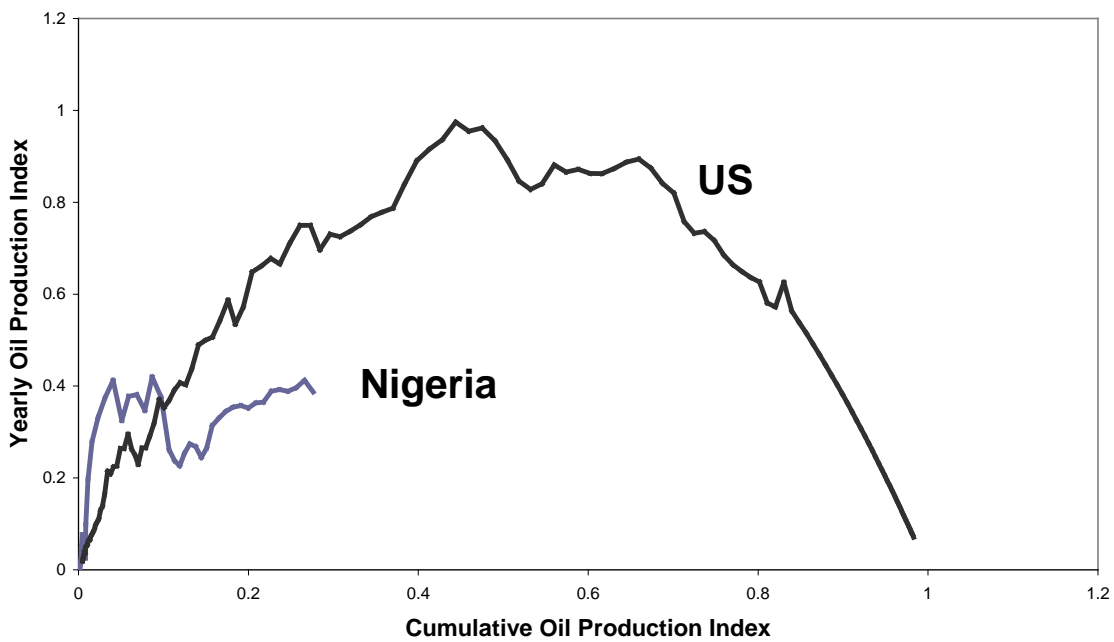


Figure 5

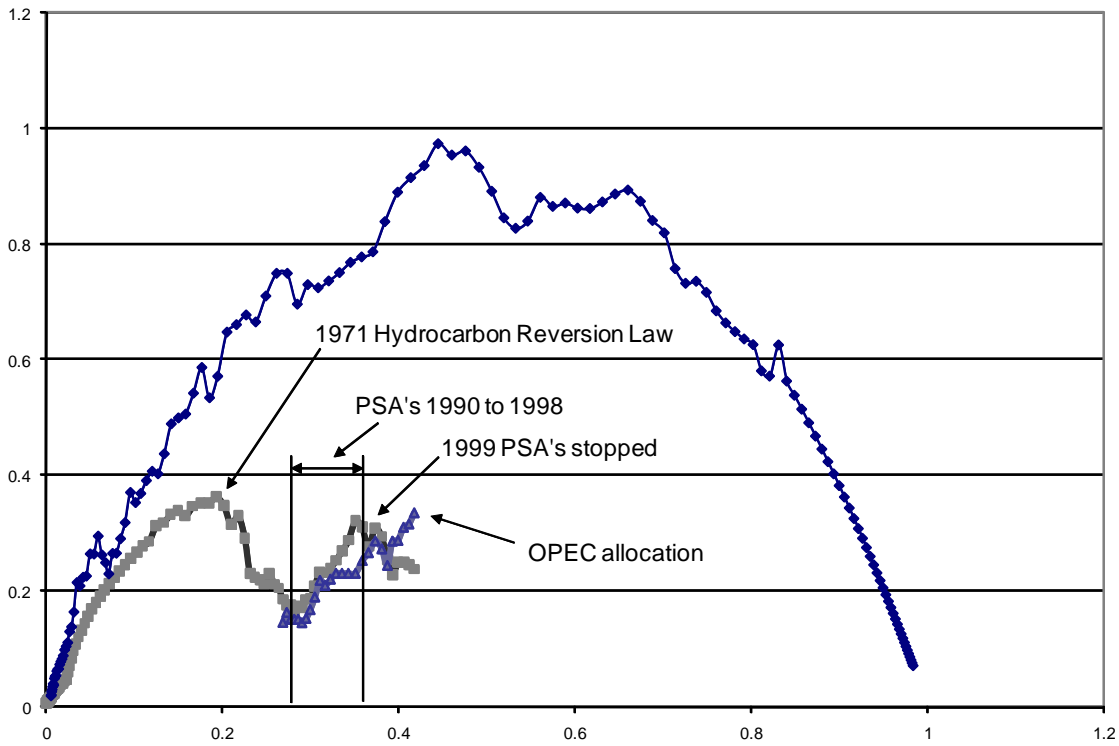
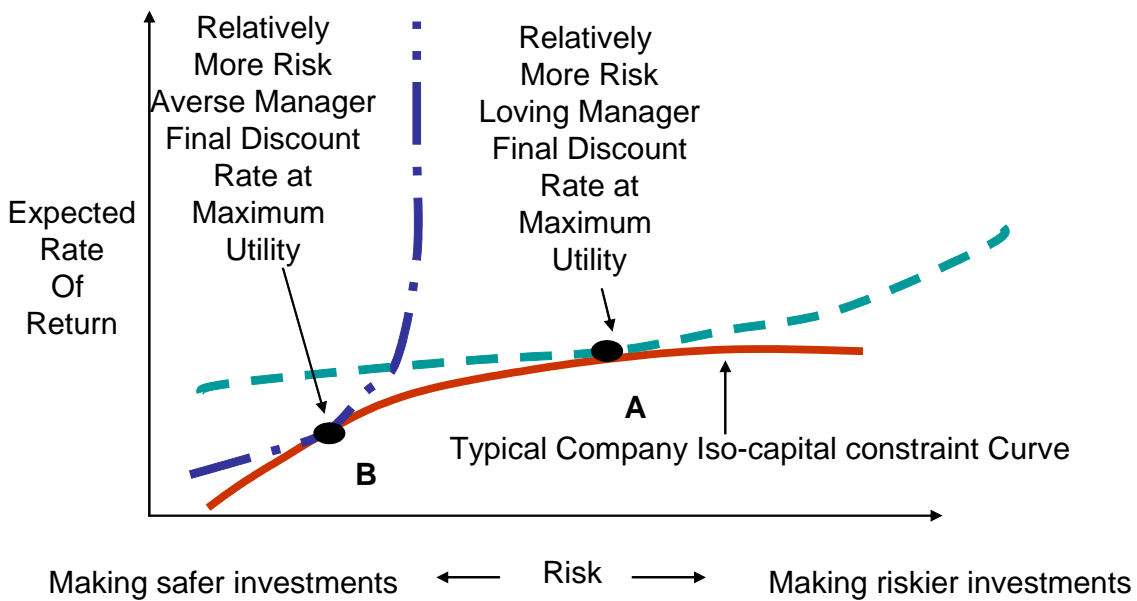


Figure 6 Decision analysis at the margin, should you invest in one more project?



V. An alternative cause for OPEC actions—the Cautious Shift

The most important question concerning OPEC is not what it is, but rather why does not each of the members cheat on any and all OPEC agreements and simply expand their production capacity at will especially over the long run as Venezuela did in the 1990s. An alternative hypothesis is needed. The alternative hypothesis must explain OPEC member behavior and the behavior of some non-members like Mexico where each government owns an oil monopoly. One such theory is the Cautious Shift Phenomenon.

Stoner (1961 and 1968) originally proposed the Risky Shift Phenomenon after experiments showed that individuals, when placed in a group, take more risks than they would when by themselves. See also Kogan and Wallach (1964) and Wallach, Kogan, and Bem (1962). The level of risk taking changes when people are in different environments. The Risky Shift Phenomenon may explain why a mob can become unruly since individuals in the mob engage in risky illegal activities in a group setting that they would not otherwise engage in. This has been further developed into the Group Polarization Effect by Levine and Moreland (1998) where groups can be pushed by a dominant personality to become more risk loving or even more risk averse in certain situations. See Isenberg (1986) and Kerr et. al. (1996).

Interestingly, Stoner originally was trying to prove that people would exhibit a Cautious Shift rather than a Risky Shift, since he believed that people would become more cautious when making decisions in front of a group. Stoner's motivation is based on General James M. Gains who talked about military generals being more risk averse in history. For example Kowert and Hermann (1997) note that throughout history high ranking generals, who were identified as vacillating in their later careers, were noted for their daring and determination as junior officers. Thus it seems that as people increase their responsibilities, they exhibit a cautious shift and this may affect business decision making as well.

The idea of the cautious shift does show some validity in business. Shupp and Williams (2008) show group risk aversion for high risk lotteries. March and Shapira (1987) show that company managers may shift their level of risk taking depending on circumstances. Swalm (1966) shows managers appear to have an excessive aversion to any outcome that could yield a net loss. Viscusi, Magat, Huber, (1987) show managers are extremely reluctant to accept responsibility for even a small increase in the probability of a disaster. Miller and Ross (1975) argue that managers assess risk based on the worst possible outcome. Kahneman and Lavallo (2002) suggest that managers tend to make bold forecasts and yet take timid choices. Also Kahneman and Tversky (2002) show that individuals over emphasize extreme outcomes.

In the case of a government owned oil company, Ramsey (1980) shows interesting results that an asymmetry may exist whereby a business loss by a government company could result in a larger decline in the constituents' utility than an analogous gain would raise it. This may be due to the fact that increased government revenue would be subdivided into a myriad of different projects, effectively diluting whatever benefits the extra profits give. On the other hand, losses generated by a government-owned oil company have a clear source—higher taxes or program cuts—and the main constituents affected may feel that their tax money had been wasted on a questionable endeavor. This asymmetry in utility changes for gains and losses of national income follows Kahneman and Tversky's (2002) prospect theory and is a political consideration that may make monopoly national oil companies more risk averse than private enterprises.

Another interesting example of risk aversion is the US Gulf of Mexico's outer continental shelf lease bids. Smith (1982) shows that larger oil companies that bid on leases there were placing higher bids than smaller companies which suggests that the larger companies were less risk averse (taking more risks) than the smaller companies. However, an alternative explanation implied by Baun et. al. suggests that economies of scale are at play. Large companies are seemingly less risk averse but in reality are pursuing economies of scale. Economies of scale allows them to submit higher lease sale bids because if they win more leases, they can expand their operations enhancing cost cutting by having greater specialization in the drilling and development of wells. More leases reduce costs. Therefore, the big companies higher bids suggest a pursuit of economies of scale, not a characteristic of lower risk aversion. Thus it can still be the case that the larger an oil and gas company is, the more risk averse it is and therefore, large government owned oil companies are very risk averse. However, unlike the US Gulf of Mexico, most oil producing countries have single monopolies owning and controlling their oil, suggesting that those national companies do not need to pursue economies of scale as quickly as large American

firms do in the United States since in these other oil producing countries there is no danger of losing oil leases to small players.

In general, the difference between Stoner's risky shift and alternative arguments for a cautious shift may have to do with how much money is on the line or in the case of generals how many lives are on the line. Another interesting difference is that the decisions about risk in Stoner's experiment are made in front of a group but decisions in business are often made in isolation away from a group and then revealed later only after the results are apparent. Thus a business manager, unlike Stoner's subjects, must choose in private risky decisions that affect corporate stock holders and the firms' workers and that will be revealed only later. Therefore, since a manager often makes decisions in private and since the decisions are only revealed after the results of the decision are apparent, and since bad outcomes will probably be presented as more horrifying than good outcomes are presented as euphoric, then this could lead to a cautious shift in decision making.

However, if even free market businesses are cautious or their managers display a cautious shift, then why would oil production on the U.S. side of the Gulf of Mexico show an increase in production between 1990 and 2002, whereas the Mexican side did not increase by much? The answer is competition. Competition within a region creates an alternative risk to deal with. If you don't find the oil someone else will and you will lose it. Once you do find the oil, most lease agreements require a firm to develop the lease or else the firm will lose the lease.

This brings up the idea of monopoly national oil companies (MNOC), where an MNOC is not just any national oil company, it is a national oil company that does not face domestic competition—it is a monopoly within that country. For example Brazil's Petrobras, or Norway's Statoil are not actually MNOCs since they have to compete with other oil companies for new leases and wells at the margin. Even if Petrobras is the major operator in over 90% of upstream Brazilian fields, still it is not an MNOC due to the Brazilian competitive free market at the margin. A true MNOC faces absolutely no competition. Based on the concept of MNOC's, it is possible that OPEC members are very risk averse, which can explain Smith's (2005) results for why compensating production changes occur less often than a 50-50 chance even during the 1974 to 1981 period when everyone was free to expand oil production at will and prices and proven reserves were high.

Using the idea of a cautious shift, it can be implied that OPEC members, and even some non-OPEC members, are relatively more risk averse to changing production outputs. In other words it is not OPEC's production quotas that are difficult to change, as in a bureaucratic production syndicate, but rather it is the actual production capacity itself that is difficult to change due to fear of making a mistake. Each OPEC member has difficulty changing its own capacity and output due to the MNOC's own natural risk aversion to exploration and development rather than due to a cartel production cut back or even due to the high cost of running a bureaucratic production syndicate. Thus the results of Smith could be due to a cautious shift. Furthermore it could explain why OPEC members with MNOCs do not cheat more robustly and expand their oil production capacities even though under every conceivable economic model they should all be doing just that. It also could explain why some non-OPEC members do not expand production.

VI. Cautious decision making at the margin

Adelman and Shaki show that most OPEC oil producers have low average oil development costs. However even though low average costs of development are important, what are even more important are the costs of oil supply expansions at the margin. That is, the cost of expanding oil production at the margin can be quite high even if average costs are low. Every oil and gas company including every MNOC must decide to explore, develop and produce oil *one project at a time*, and a big factor in determining costs at the margin is risk: what is the probability that this marginal project will be successful or not, will find oil or not? Therefore each project's risk must be judged in isolation. It must then be compared to other risky or less risky investments for MNOCs and to social program investments, i.e. the marginal opportunity cost. However the cost at the margin depends explicitly on expected results of activity at the margin and your view on how much risk is acceptable, rather than on accounting costs of capital and labor alone. The *subjective* probability of the decision making operator, and how much weight you put on that probability, is the biggest factor that will determine whether the cost of each marginal project is low or high. See Reynolds (2002). But that means subjectivity on risk taking is an important ingredient for determining what a cost is.

Newendorp and Schuyler (2000) show how this decision making at the margin works. Figure 6 shows a typical decision rule for a single oil exploration or development investment, i.e. a marginal project. There are three curves. One curve is the iso-utility curve of a relatively more risk averse entity. The second curve is the iso-utility curve of a relatively more risk loving entity. The third curve is the iso-capital constraint curve. The capital constraint is based on the fact that at an given moment, a company has only so much capital available to work with, where that capital can be allocated to one high risk or one low risk investment at that point in time of the decision making process. It is therefore possible to use more or less risk as an input into the production function to increase oil reserves, but the use of risk as an input into oil production is subject to the law of diminishing returns. With a capital constraint, you can either commit to a risky exploration project with a high expected present value or to a safe project with a low expected present value, but you can't commit to both. The relatively more risk loving entity will use relatively more risk as an input into production in order to increase their oil investment expected value. The opposite will happen for the relatively more risk averse entity.

One interesting example of the risks of oil development has to do with oil field engineering itself. For example it is possible to develop a particular oil field's capacity above the so called maximum efficient rate (MER) in which case an oil field's ultimate recoverable reserves can be destroyed due to over exploitation, such as too much water flooding. See for example Nystad (1988 and 1987) and Salahor (1998). Ultimately recoverable reserves and the net present value of the oil field can be reduced as the initial rate of production is pushed too high. Therefore it can be risky to push oil production close to the MER. Such managerial risks can cause MNOCs to reduce production below the profit maximizing output, and even cause oil production to seldom change.

A more common risk is oil exploration or development itself, where new projects may turn out to be unsuccessful. Consider for example two ways that an MNOC will finance its operations and how it will affect the people of that country.

1.) An MNOC can finance new projects by using government revenue. This implies that one or another government program will have to be cut, or taxes raised, or more of the existing profit margins be retained by the MNOC—a *de facto* revenue reduction—in order to secure the extra funds. Therefore the people of the country are directly involved in the cost of the investment and will be upset at those cuts. Even if the country gives the MNOC a budget for exploration and development, the budget will always be reviewed to determine how much is really necessary. This leads to less risk taking in expanding the MNOC oil supply.

2.) A second way for the MNOC to get financing is to engage in a joint venture or a production sharing agreement (PSA) contract with an outside international oil company (IOC) in order to start a new project. In that case the IOC would come up with the financing, but there would have to be some sort of stipulation of a reward for taking the risk. However even if the MNOC allows IOCs to enter the country and invest, there is still the risk that the outsiders will take too much of the profits of the new project away from the host country. In that case the MNOC will want to negotiate hard to keep as much of the rent as possible for the MNOC while still giving the IOC just enough incentive to induce them to come. Therefore negotiations with outside oil companies can also be risky: If the MNOC gives the outsider too much of a reward should the new project be successful, then the people of the country lose the profits from their oil. On the other hand, if the MNOC gives the outsider too little reward, the outsider will not give the financing for a new project in which case the country loses a new source of revenue. All that negotiation takes time and reduces aggressive risk taking. Therefore, the people of the country still face risks even when the financing comes from outsiders and the cautious shift still reduces new investments.

In the two cases above it is a government agent that must decide how money for a risky venture will be acquired and invested. But in both cases there is a risk that the country will lose money. Bureaucrats who make decisions that involve creating a possible loss for their people in exchange for a possible future gain will be afraid to take any risky investment chances. They must choose in private an outcome that will be revealed later, and they must bear possibly heavy criticism should it fail. That will instigate a cautious shift. The result is a lack of investment and a tendency to keep the status quo.

Interestingly, because the MNOC is a monopoly it faces no competition from other oil companies for the countries undiscovered assets since it knows that if it does not find the oil, no one else will. As Ramsey suggests, this leads to low rates of exploration and development. This gives the country the luxury of knowing that a mistake of not finding or developing oil quickly enough will never be revealed. The only mistake that will be revealed is if they have an unsuccessful and costly new project or if an IOC takes too much profit away from the

country. Thus an MNOC, which has no chance of evaluating its success or failure vis-à-vis other oil companies within the country's boundaries, will tend to under invest. So all of the risk is derived from the cost of investment expenditures, or the loss of country asset profits to international companies, and not from the lack of new supplies.

Looking closely at Venezuela's production, we see that it was during the nationalization days in the 1970's and 1980's that production went down, right when there were no quotas. Then once quotas were placed on Venezuela in the 1990s production went up. But it went up because of the PSA environment not due to anything OPEC was doing. Then in the 2000's production went down again just when nationalization was back in full swing. So it was never OPEC but the institutions of Venezuela itself that changed its supply.

VII. Internal and External Risk

In addition to risk affecting normal internal decisions on production, risk can affect the interaction within OPEC. OPEC members, who would normally be risk averse to exploration and development without the OPEC organization will become even more risk averse to exploration and production changes when faced with the consequences of their decision in a tit-for-tat game. Therefore OPEC members, who are faced with the threat of a Saudi Arabian reprisal if they increase their oil production, may be even more afraid than normal to make any changes at all to their production outputs. If Saudi Arabia is even weakly successful in implementing its tit-for-tat strategy, then this could scare other members into high levels of risk aversion in regard to new exploration and development.

The cautious shift hypothesis therefore gives a possible scenario for the two different eras that both Loderer and Smith identify. In the 1974 to 1981 era, there were no quotas and little risk of Saudi reprisals on OPEC members since Saudi Arabia's oil production was at its maximum. So OPEC members did not have to follow quotas or even price targets. This means that the only risk to each producer was an "in-country" or internal risk of simply being afraid to take normal business risks to expand output. After 1981 when production cuts started and eventually quotas were assigned, then there was both an internal risk of normal business risks of investing and an "outside-country" or external risk of a Saudi tit-for-tat reprisal against cheating as well as the possibility that quotas would be reassigned. Faced with the new higher level of risk after 1981, this changed OPEC member behavior substantially enough to show different frequencies of compensating change.

The external risk is then caused by two fears. One fear is that if an OPEC member is having trouble maintaining its quota—i.e. its capacity is actually declining due to a lack of new investment into exploration and development due to risk aversion—then it fears that the rest of OPEC could impose a new tighter quota on that particular member for years to come even if the country eventually finds more oil. The tighter quota would reduce future profits. Therefore, even if an OPEC member has extra capacity to use, or that it can develop right now, it may refrain from creating that capacity lest their oil fields start going more quickly into decline, and that country eventually gets assigned a lower OPEC quota. Therefore, the country refrains from aggressively expanding production now in order to not have its quota reduced later. In fact, it could be the case that members are using the quota system as an excuse for not investing in new exploration and development to cover up their fear of investing in new capacity that is risky. This gives each government a ready reason to maintain the status quo and not be taking risks of expanding output and producing more oil for the benefit of the people of their country.

Another fear creating risk aversion in a quota system is that any change in output can trigger a reaction by Saudi Arabia to increase oil output and reduce oil prices. This would reduce oil revenues as in a tit-for-tat game. Government bureaucrats could be afraid to aggressively engage in a capacity expanding tit-for-tat strategy. The only reason to adjust your production then is if you can be sure to have a sizable increase in revenues before you go head to head with Saudi Arabia. Although even in a tit-for-tat game, the loss, should the Saudis increase their own oil output and reduce your revenue, would probably be minimal since the Saudis would not want to sustain low prices for long. The perception of the loss though may be great enough to create additional cautious behavior on the part of oil operators causing countries to keep output low.

This also fits Smith data where Smith finds that the pre-quota frequencies of compensating change are higher than the quota era frequencies, both for monthly and quarterly observation and in relationship to other OPEC members and non-OPEC members. However, Iraq's behavior since 2002 where it was allowed to go above its quotas shows that it is acting more like a competitive producer rather than a country monopoly oil

producer. This could be due to the lack of clear public ownership and control of the Iraqi national oil company during successive interim governments. In the case of Iraq, the successive ruling governments have not been strong enough to affect the politics of oil outputs and investment. Therefore, the national company working in Iraq is simply a competitive entity on the open market and has been divorced from the risk averse political machine that will soon enough be controlling it.

Another thing that is out of the ordinary in Smith's data is that Mexico, Russia, Norway, and the United Kingdom all exhibit OPEC like behavior at different times in that they have compensating changes in output vis-à-vis the other non-OPEC producers of less than 50% of the time. This signifies that they too are following some sort of production changing mechanism. Note that Mexico, Norway, the United Kingdom and Russia have or have had MNOCs running their countries oil production. That means their host governments had at times complete control of the oil production within their respective countries and their oil production could have been driven by risk aversion.

VIII. Conclusion

OPEC does not look to be a market manipulator. Rather it looks to be a set of players where each member restricts its production due to its own intrinsic institutions that create risk aversion. That means world energy supplies will be constrained by individual country institutions and the world should expect low oil supplies and high energy prices. In Figures 7 and 8, I create a world quadratic Hubbert curve based on past events in the oil market. Using a Richards (1959) function that Hubbert originally used, we can see why world oil production has peaked in 2005.

Past world conventional oil production is plotted in Figures 7 and 8 versus cumulative production. Two important points in time where oil price shocks occurred are the 1973 shock, when cumulative production was at roughly 350 billion barrels, and 1979, when cumulative production was at roughly 450 billion barrels. The usual explanation for these price movements is that political events caused them. An alternative explanation is that a risk averse Hubbert supply constraint caused them. If a Richards function, such as $QP = b_1 * CQP + b_2 * CQP^{1+\lambda}$, where, $-\infty < \lambda < \infty$, is fitted to the two points in time and an ultimately recoverable reserve of around 3 trillion barrels is used, see USGS 2000, then 2005 is the only possible point of peak oil that fits the function. The world is past peak oil.

Figure 7

**Forecasted Supply and Demand for World Crude Oil
As a function of cumulative production, including risk factors**

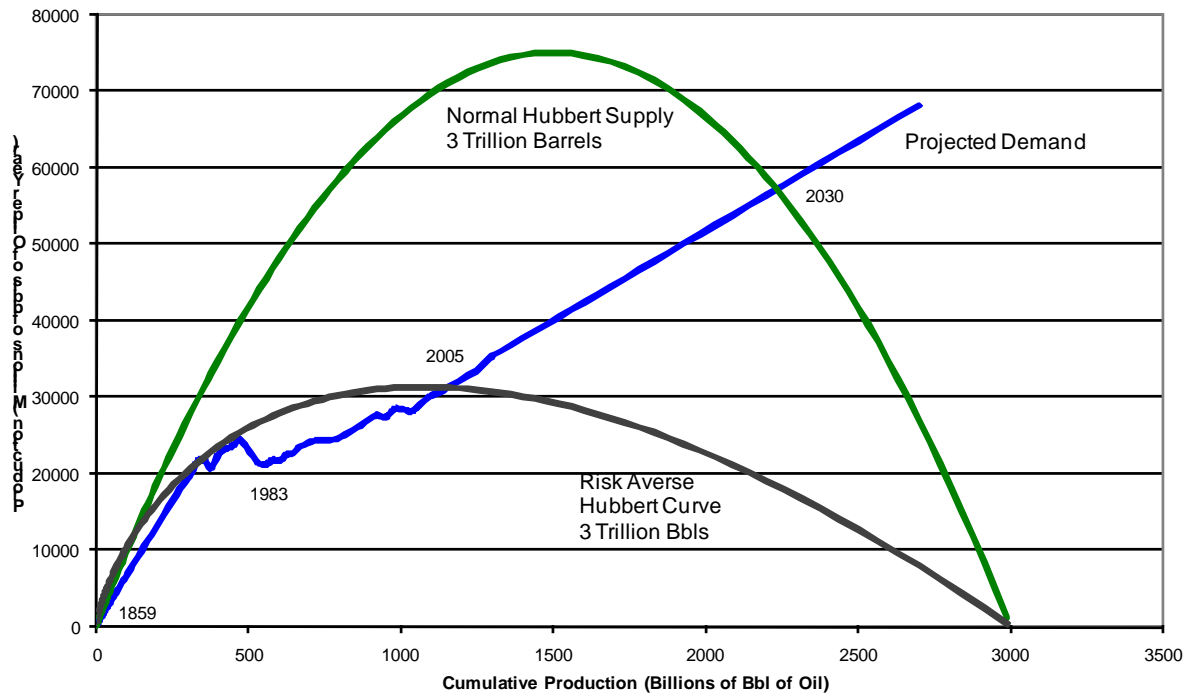
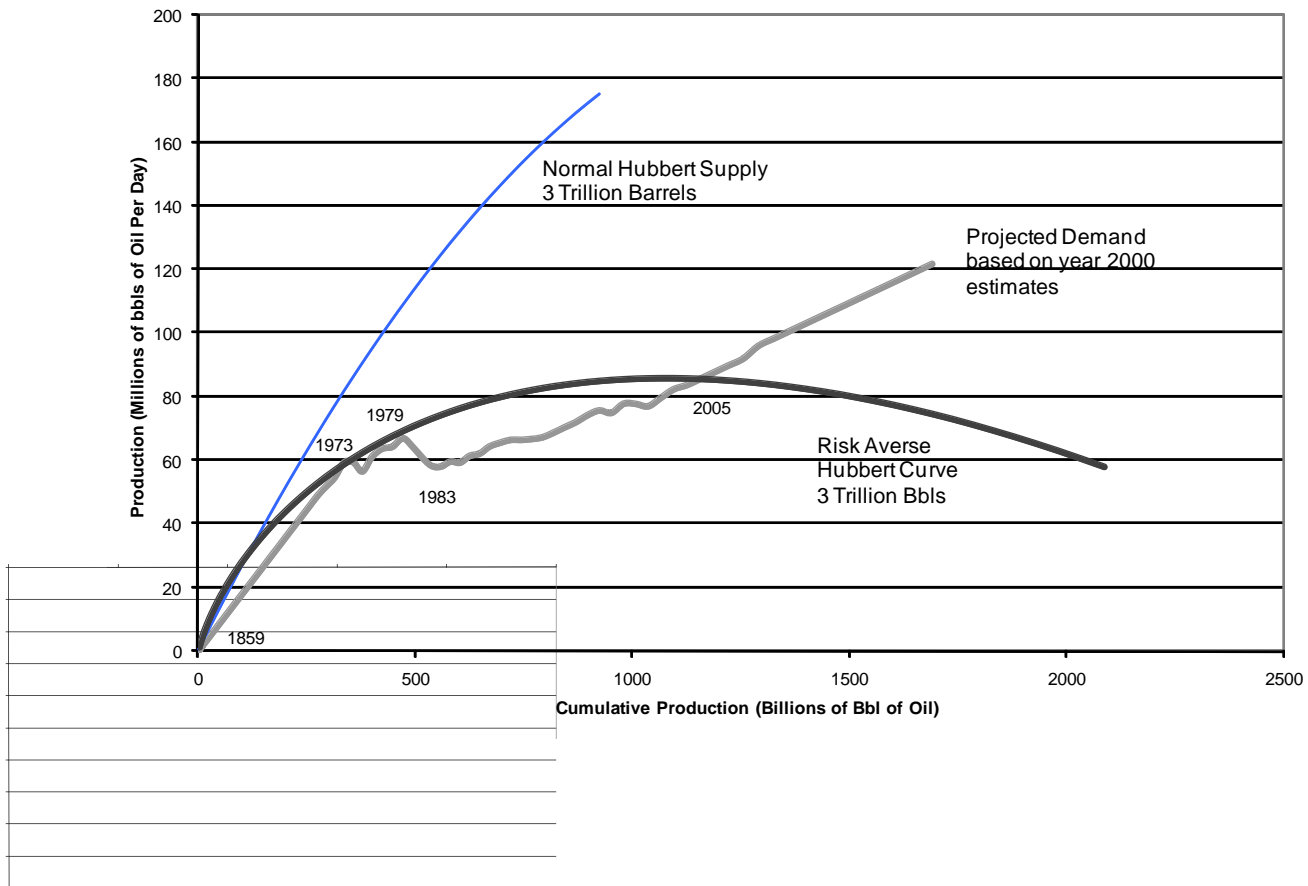


Figure 8

Forecasted Supply and Demand for World Crude Oil



References

- Adelman, M.A. (1993). *The Economics of Petroleum Supply*, MIT Press, Cambridge.
- _____ (1986a). "Scarcity and World oil Prices," *The Review of Economics and Statistics*, Volume 8, pp. 309-329.
- _____ (1986b). "Oil Producing Countries' Discount Rates," *Resources and Energy*, December, pp. 387-397.
- _____ and Manoj Shaki (1989). "Oil Development–Operating Cost Estimates, 1955 – 1985" *Energy Economics*, vol 11, pp 2-10.
- Alhajji and Huettner (2000a). "The Target Revenue Model and The world Oil Market: Empirical Evidence from 1971 to 1994," *The Energy Journal*, vol. 21, no. 2, pp. 121-143.
- Alhajji and Huettner (2000b). "OPEC and The World Crude Oil Markets from 1973 to 1994: Cartel, Monopoly, or Competitive?" *The Energy Journal*, vol. 21 no.3. pp. 31-60.
- Al Jarri, Abdulrahman S. and Richard A. Startzman (1999). "U.S. Oil Production and Energy Consumption: A Hubbert Modeling Approach to Forecast Long Term Trends in Various Components of U.S. Energy Consumption with an Emphasis on Domestic Oil Production" in J.R. Moroney ed., *Advances in the Economics of Energy and Resources*, Volume 11, *Fuels for the Future*, JAI Press, Stamford, Connecticut, pp. 37 -58.
- Al-Sultan, Abdulrahman M. (1993). "Alternative Models of OPEC Behavior," *Journal of Energy and Development*, vol. 18, no. 2, pp. 263 -281.
- Baum K. E. Munson J. R., Marshall J. A., Vroomand D. K. (1998). "Turnkey drilling : Bringing cost predictability to a risky business," SPE drilling conference: Dallas TX, 3-6 March 1998, pp. 593-601
- Congdon, Barney, Caryl Fagot, and Debra Winbush, (2003). "Gulf Deepwater Activity Continues at High Rate," U.S. Department of the Interior Minerals Management Service, Gulf of Mexico OCS Region, NEWS RELEASE, <http://www.gomr.mms.gov/homepg/whatsnew/newsreal/030212.html>.
- Cremer, Jaczue and Djavad Salehi-Isfahani (1991). *Models of The Oil Market*, Harwood Academic Publishers.
- Dibooglu, Sel, and Salim N. Algudhea, (2007). "All time cheaters versus cheaters in distress: An examination of cheating and oil prices in of OPEC," *Economic Systems*, no. 31 p. 292-310.
- Dahl, Carol and Mine Yucel (1991). "Testing Alternative Hypothesis of Oil Producing Behavior," *The Energy Journal*, 12(4), pp. 117-138.
- EIA, U.S. Department of Energy, Energy Information Administration, (2004). "Mexico Country Analysis Brief," at <http://www.eia.doe.gov/emeu/cabs/mexico.pdf>, November 2004.
- EIA, U.S. Department of Energy, Energy Information Administration, (2005). *International Energy Outlook*, at <http://www.eia.doe.gov/>.
- Ezzati, Ali (1976). "Future OPEC Price and Production Strategies as Affected by its capacity to absorb oil revenue," *European Economic Review*, August, 8, pp. 107 -138.
- Friedman, Milton and Leonard J. Savage, (1948). "The Utility Analysis of Choices Involving Risk" *Journal of Political Economy*, August, Volume 56.
- Gault, John, Charles Spierer, Jean-Luc Bertholet, and Bahman Karbassioun (1999). "How does OPEC allocate Quotas," *Journal of Energy Finance and Development*, vol.4, no. 2, pp. 137-148.
- Geroski, P.A., A.M. Ulph, and D.T. Ulph (1987). "A Model of the Crude Oil Market in which Market Conduct Varies." *The Economic Journal*, vol.97 (conference), pp. 77-86.
- Green, David Jay (1988). "The World Oil Market: An Examination Using Small-Scale Models," *The Energy Journal*, Vol. 9, no. 3, pp. 61-77.
- Griffin, James M. (1985). "OPEC Behavior: A Test of Alternative Hypotheses," *American Economic Review*, 75(5), pp. 954 – 963.
- _____, and William S. Nielson (1994). "The 1985-1986 Oil Price Collapse and Afterwards: What Does Game Theory Add?" *Economic Inquiry*, vol. 32, pp. 543-561.
- Gulen, S. Gurcen (1996). "Is OPEC a Cartel? Evidence from Cointegration and Causality Tests," *The Energy Journal*, 17(2), pp. 43 -57.

- Gustafson, Thane (1989). *Crisis Amidst Plenty: The Politics of Soviet Energy under Brezhnev and Gorbachev*, Princeton University Press, Princeton, NJ.
- Hotelling, Harold (1931). "The Economics of Exhaustible Resources," *Journal of Political Economy*, Volume 39, Number 2, April, 1931. pp. 137 - 175.
- Hubbert, M.K. (1962). *Energy Resources, A Report to the Committee on Natural Resources: National Academy of Sciences, National Research Council*, Publication 1000-D, Washington, D.C..
- Isenberg, Daniel (1986) "Group Polarization: a Critical Review and Meta Analysis," *Journal of Personality and Psychology*. 50, 1986, 1141-1151.
- Johany, Ali (1980). *The Myth of the OPEC Cartel*, N.Y. Wiley and Sons.
- Jones, Clifton T. (1990). "OPEC Behavior under Falling Prices: Implications for Cartel Stability." *The Energy Journal*, vol. 11, no. 3, pp. 117-129.
- Kahneman, Daniel, and Dan Lavallo (2002). "Timid Choices and Bold forecasts: A Cognitive Perspective on Risk taking," in Kahneman, Daniel and Amos Tversky (2002). *Choices, Values, and Frames*, edited by Daniel Kahneman, Amos Tversky. Cambridge University Press, pp. 393-413.
- Kahneman, Daniel and Amos Tversky (2002). *Choices, Values, and Frames*, edited by Daniel Kahneman, Amos Tversky. Cambridge University Press.
- Kaufmann, Robert K., Stephane Dees, Pavlos Karadeloglou, and Marcelo Sanchez, (2004). "Does OPEC Matter? An Econometric Analysis of Oil Prices," *The Energy Journal*, Vol. 25, no. 4, pp. 67-90.
- Kerr, Norbet L., Robert J. MacCoun and Richard H. Thaler (1996), "Examining Risk Preference Under High Monetary Incentives: Reply," *Journal of Political Economy*, 98, December 1990, 1325-1348.
- Kogan, Nathan and Michael A. Wallach, (1964). *Risk-Taking: A Study in Cognition and Personality*, New York, Holt, Rinehart, Winston.
- Kowert, Paula and Margaret G. Hermann (1997). "Who Takes Risks? Daring and Caution in Foreign Policy Making," *Journal of Conflict Resolution*, vol. 41, no. 5, pp. 611-637.
- Leiby, Paul N., David Bowman, and Donald W. Jones, (2002), "Improving Energy Security Through an International Cooperative Approach to Emergency Oil Stockpiling," Environmental Sciences Division, Oak Ridge National Laboratory, Working paper, March 29, 2002.
- Levine, J.M. and R.L. Moreland (1998). "Small groups," In D. Gilbert, S. Fiske, & G. Lindzey (Eds.), *The handbook of social psychology* (4th ed.). Boston, MA: McGraw-Hill.
- Loderer, Claudio (1985). "A Test of the OPEC Cartel Hypothesis: 1974-1983," *Journal of Finance*, vol. 40, no. 3, pp. 991-1008.
- March, James G. and Zur Shapira (1987) "Managerial Perspectives on Risk and Risk Taking," *Management Science*, Vol. 11, No. 11, November 1987, pp. 1404-1418.
- Markowitz, Harry (1952). "The Utility of Wealth," *Journal of Political Economy*, 60 April, pp. 151 -158.
- Miller, D. and M. Ross (1975). "Self Serving Biases in Attribution of Causality: Fact or Fiction?" *Psychological Bulletin*, vol. 82, pp. 213-225.
- Moran, Theodore (1982). "Modeling OPEC Behavior: Economic and Political Alternatives," in Griffen and Teece, eds. *OPEC Behavior and World Oil Prices*, London, George Allen and Unwin, pp. 94 -130.
- Norgaard, R.B., (1990). Economic Indicators of Resource Scarcity: A Critical Essay. *Journal of Environmental Economics and Management*. 19(1): 19 - 25.
- Newendorp, Paul, and John Schuyler (2000). *Decision Analysis for Petroleum Exploration*, 2nd Edition, Planning Press, Aurora, Colorado.
- Nystad, A.N. (1988). "On The Economics of Improved Oil Recovery: The Optimal Recovery Factor from Oil and Gas Reservoirs," *The Energy Journal*, Vol 9, No. 4, October, pp 49 - 61.
- _____, (1987). "Rate Sensitivity and The Optimal Choice of Production Capacity of Petroleum Reservoirs," *Energy Economics*, Vol 9, No. 1, January, pp 37 - 45.
- Pindyck, Robert S. (1978). "Gains to Producers from the Cartelization of Exhaustible Resources," *Review of Economic Statistics*, 60(2), pp. 238 -251.
- Ramsey, J. (1980). *Bidding and oil leases*. Greenwich, CT: JAI Press.
- Ramcharran, Harri (2002). "Oil Production Responses to Price Changes: An empirical Application of the Competitive Model to OPEC and non-OPEC Countries," *Energy Economics*, vol. 24. no. 2 pp. 97-106.

- Reynolds, Douglas B. (1999a). "Modeling OPEC Behavior: Theories of Risk Aversion for Oil Producer Decisions," *Energy Policy*, Volume 27, pp. 901-912.
- _____. (1999b) "The Mineral Economy: How Prices and Costs Can Falsely Signal Decreasing Scarcity," *Ecological Economics*, Volume 31, Number 1, pp. 155-166.
- _____. (2002). *Scarcity and Growth Considering Oil and Energy: An Alternative Neo-Classical View*, The Edwin Mellen Press, 240 pages.
- Richards, F.J., (1959). "A Flexible Growth Curve for Empirical Use." *Journal of Experimental Botany*. Volume 10: pp. 290 - 300.
- Shupp, Robert S. and Arlington Williams. (2008). "Risk Preference Differentials of Small Groups and Individuals," *The Economic Journal*, Volume 118, Issue, January, pages: 258-283.
- Salahor, Gordon. (1998). "Implications of Output Price Risk and Operating Leverage for the Evaluation of Petroleum Development Projects," *The Energy Journal*, 19(1), pp. 13 -46.
- Smith, James L. (2005). "Inscrutable OPEC? Behavior Tests of the Cartel Hypothesis," *The Energy Journal*, vol. 26, no. 1, pp. 51-82.
- _____. (1982). "Risk Aversion and Bidding Behavior for Off-Shore Petroleum Leases," *The Journal of industrial Economics*, Volume 30, Number 3, March 1982, pp. 251 – 269.
- Spolimbergo, Antonio (2001). "Testing the Hypothesis of Collusive Behavior Among OPEC Members," *Energy Economics*, vol. 23, pp. 339-353.
- Stoner, J. A. F. (1961). *A comparison of individual and group decisions involving risk*. Unpublished Master's Thesis, Massachusetts Institute of Technology.
- _____. (1968). "Risky and cautious shifts in group decisions: the influence of widely held values," *Journal of Experimental Psychology* 4:442-59
- Swalm, R.O. (1966). "Utility Theory: Insights into Risk Taking," *Harvard Business Review*, Vol. 44, pp. 123-136.
- Teece, David J. (1982). "OPEC Behavior, an Alternative View," in Griffen and Teece, eds. *OPEC Behavior and World Oil Prices*, London, George Allen and Unwin, pp. 64 -93.
- U.S. Department of Justice (2008). "THE HERFINDAHL-HIRSCHMAN INDEX," web site, <http://www.usdoj.gov/atr/public/testimony/hhi.htm>, accessed on March 28, 2008.
- United States Geological Survey, USGS, (2000). U.S. Geological Survey World Petroleum Assessment 2000 – Description and Results, By USGS World Energy Assessment Team.
- Van Huyck, John B. Raymond C. Battalio, Richard O. Beil (1990). "Tacit Coordination Games, strategic Uncertainty, and coordination failure," *The American Economic Review*, Volume 80, Number 1, March, pp. 234-248.
- Viscusi, W. Kip, Wesley A. Magat, and Joel Huber, (1987). "An Investigation of the Rationality of Consumer Valuations of Multiple Health Risks," *RAND Journal of Economics*, RAND, vol. 18, no.4, pages 465-479.
- Willrich, Mason and Melvin A. Conent, (1977). "The international Energy Agency: An Interpretation and Assessment," *The American Journal of International Law*, Volume 71, Number 2, April, pp. 195-223.
- Wallach, M. A., N. Kogan and D. J. Bem, (1962). "Group influence on individual risk taking." *Journal of Abnormal and Social Psychology*, vol. 65, pp. 77-86.