THE POLITICAL ECONOMY OF OIL DEPLETION

by

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THE POLITICAL ECONOMY OF OIL DEPLETION

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To my family and friends. To me.
Above all to my mentor Alireza Naghavi.

Outline

1. INTRODUCTION

1.1 The importance of oil

Oil is present in almost all activities of our daily lives. It is the fundamental source of energy of this era, and it is involved in the production of many goods necessary to maintain the current standard of living.

The importance of oil for the society has also made it a politic tool. All countries depend on oil for carrying on their activities, and some developing countries are the most important oil producers in the global scene, as the countries of the Persian Gulf.

However this resource is a non-renewable one, and its presence on earth is limited.

During the last 50 years the issue of the end of oil has been investigated more than once, but until recent times most researchers have considered the issue as a long term problem, not really affecting current operations.

Observing movements of recent periods instead a lot of researchers have come back to the problem, underling that the end of oil is nearer than most believe. Price trends could be a proof of that.

Moreover the actual situation is characterized by a steady increase of consumption of oil, mainly due to the development of countries, and the growth of population.

The model on which researchers base their projections is the one developed by Hubbert during the 1950s, which proposes a bell shaped curve. The peak of this curve is the issue investigated in order to have correct projections of the future of oil.

World is not running out of oil in a literal sense, as when oil production will stop there will still be the presence of the resource underground, however, it won’t be economically feasible to extract it.

The core of this issue becomes the correct management of the resource left, and the political implications of it.

As presented here a correct management of the oil extraction is fundamental in order to achieve the higher flow of resource without damaging the oil basins, in order to recover the most oil possible with the current technology.

Although there are different opinions about the end of oil, the critics of projections driven by researchers who follow Hubbert do not seem to have a strong basis. They are more based on hopes on new discoveries, on a heavy improvement of technology, or on new sources of non conventional oil.

These three aspects instead can’t affect in a strong way the timing of peak oil. In fact oil discoveries peaked on 1962, and the most of the oil utilized right now is extracted from old oilfield, as the current period is characterized by the discovery of only small basins. In addition all the surface of earth has already been investigated in order to find new oilfield. Also an improvement in technology can’t shift the peak in a significant way, as this could occur only by huge quantities of oil produced.

The argument of new sources for unconventional oil seems not to have an important future, for both economic and environmental implications.

Hence taking into account what Hubbert has predicted, what world has to do is to correct manage the resources left and to also calibrate political behaviours, in order to contain the consequences of high oil prices due to the scarcity of the resource.

On the side of oil producers they have to find a new path of growth as they have completely oil based economies.

Oil producing countries seem to have already moved in such a direction, trying to develop new sectors, as the manufacturing one, the one of real estate, and banking.

They also seem to be concerned with the implementation of the use of renewable resources, as the project of UAE demonstrates.

The more awareness of the problem has probably been reached at the beginning of 2008, when the price of oil has reached, and then passed the value of 100$.

In this occasion the world has asked OPEC to increase production in order to lower the price, but received a negative answer.

This behaviour carries for the most the idea that OPEC may really lay in a situation of decline.
Also the main oil producer, Saudi Arabia, has declared it is not going to increase its production as done in many previous occasions.
As Saudi Arabia has always played an important role in output oscillation, and has always increased production when needed, this negative reaction of the swing producer of OPEC has generated consciousness of the real problem the world is going to face.
To face the problem of oil depletion world is developing new sources of energy, and it seems the future will be characterized by an hydrogen economy, as hydrogen is the economically best answer.
As hydrogen is not a source of energy, but only an energy carrier, it's necessary to implement the use of solar, and mainly, nuclear energy in order to produce it in the more convenient way.

1.2 Structure

In the second chapter I present the model developed by Hubbert, and the works of his followers, and I also present the criticism on this thought.
Then I show the model of Hotelling, which is the most used to predict the economics, consumption and production forecasts of a non-renewable resource. As I show this model doesn't apply well to oil, I present another model of oil management, the one of Banks.
In the third chapter I present the different theories about the consequences of oil spikes on recessions and on other macroeconomic variables, and the origin of the oil shocks.
Then I present the structure of oil market, investigating the real role that OPEC assumes.
Finally I show the influence that a spike in oil prices can have on the exchange rate market, considering Dollar and Euro as the two currencies affected.
In chapter four I describe the situation of Middle Eastern oil producers, investigating firstly the possible causes of the lack of their

growth, and then the scenario forecasted for their development beyond oil, considering the rate of openness and the flows of FDI to the region.

Chapter five deals with the situation occurred after the price of oil reached 100$, and its causes.

I have stressed the role of Saudi Arabia, and the possible explanation of the Saudi reaction, analyzing the problems that could have affected Saudi production so far. I also stress the importance of the correct management of Saudi oil, thinking in a long run perspective, with respect to the model of Banks mentioned in chapter number two.

In my conclusions I also briefly present the possible suggestions for the use of renewable resources. I analyze the global scenario that may occur with the actual and forecasted situation of oil, and its political implications.

2. MODELS OF OIL DEPLETION AND OIL MANAGEMENT.

2.1 The Hubbert method

Most of those who predict an imminent decline of oil production refer to Marion King Hubbert as their mentor.

At the beginning of 1920s some geologists predicted that oil would end in a few years, but the great discoveries of 1930s in Texas and in the Persian Gulf took the attention off this problem, thinking that supply and demand could grow till a far future with no worry about depletion in the short-term; but during 1950s Marion King Hubbert began a so famous geophysical because of his theory of a near oil depletion.

He has developed a theory with which he predicted the USA peak of production in 1970, and then his model has been developed, by himself and by other researchers, to predict the trend of global oil production.

The original Hubbert model involved some mathematic techniques, and he faced a lot of criticism for that because of the difficulties to interpret his way of thinking in the model.

But the core of his model and his full methodology could be explained by simple equations.

Firstly I will present here the first part of his work, so the prediction of U.S. oil production.

To estimate the future trends of that he used just a strait line on a graph, where the axes were the cumulative oil production in the horizontal one (Q), while in the vertical one it was possible to find the ratio of annual production in a given year to cumulative production up to the year (P/Q).

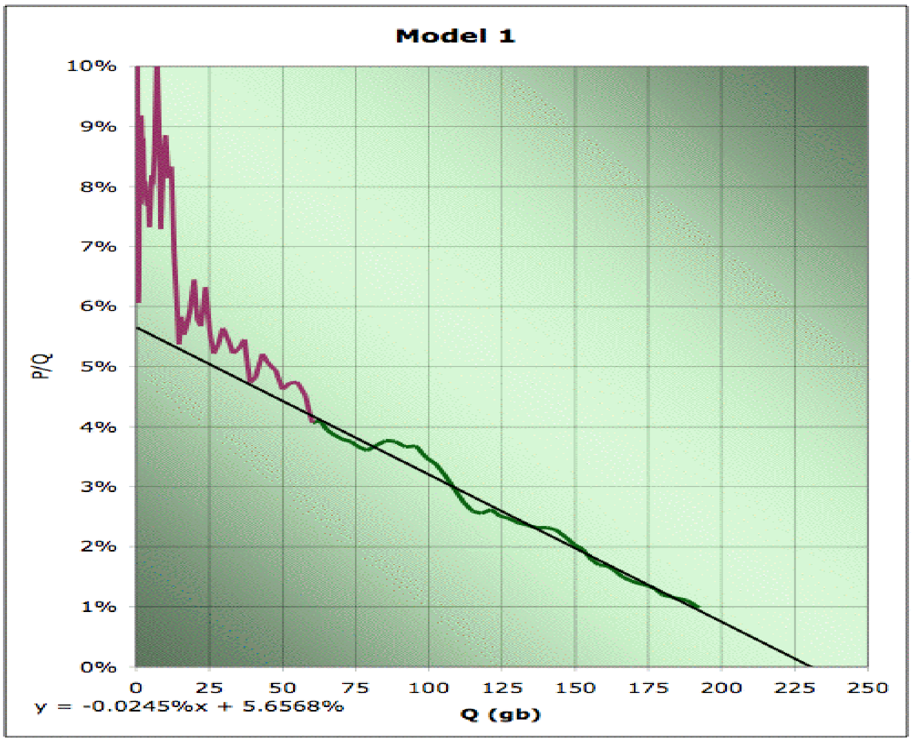

Figure 1- Hubbert linearization for the U.S. lower 48 crude oil production. (The oil drum)

In this first graph Hubbert noted that from the year 1958 it was possible to follow a strait line path of the U.S. production, and he assumed that the first part of the graph (years till 1958) shouldn't be considered because of the distortion of the curve they could produce for the inevitable low cumulative production of the first years of extraction.

So he drew the line starting on 1958, and he argued that the point where that line crosses the horizontal axis is the one where annual production of U.S. will fall to zero, so when the last well in the United States will run dry.

In this kind of graph the point expresses this end in terms of quantity, precisely 228 billion barrels. .

The line crosses the vertical axis too, in an intercept called *a* that is a sort of an interest rate; in the particular case of U.S. *a* is 0.0536 that means the 5,36% per year: *a* is an idealized beginning of production, clearly when cumulative production was equal to zero.

To explain this graph is sufficient to take a linear equation of a line, so Y=*a*+*m*X, where Y is represented by P/Q, X is Q, *a* keeps the meaning, and *m*, so the slope of the line, is represented by (a/Qt); so the equation becomes P/Q=a-(a/Qt)Q. It's easy to note that there is the sign minus explained by the indirect relationship between the growth of Y and X. The last step is to multiply both parts of the equation by Q, so it will be P=a-(1-Q/Qt)Q, that represents the algebraic statement of the Hubbert theory, and that describes a bell-shaped curve, or better, a logistic curve.

It's important to note that the factor (1-Q/Qt) is the fraction of the total oil that remains to be produced, and this states that P, so the annual production, is linearly dependent on the fraction of oil that remains. It shows that is impossible to have an unlimited exponential growth despite of the equality to 1 of the term (1-Q/Qt), or its inexistence.

There has been a lot of criticism on this thought, because of the importance that a lot of researchers give to other components, such as technology and incentives.

Empirical facts sustain the Hubbert theory demonstrating that even if it's not the only factor affecting P, the unproduced fraction of oil is surely the most important one.

From the last equation it is simple to derivate the number of years per billion barrels, simply using the reciprocal of it, so it'll be 1/P=1/[a+(1-Q/Qt)Q], that still represent a bell-shaped curve which is symmetrical in time because of the linear dependence of the production rate on the unproduced fraction of oil, as said; by that it's possible to see that U.S. peak should occurred around 1972: it was on 1970.

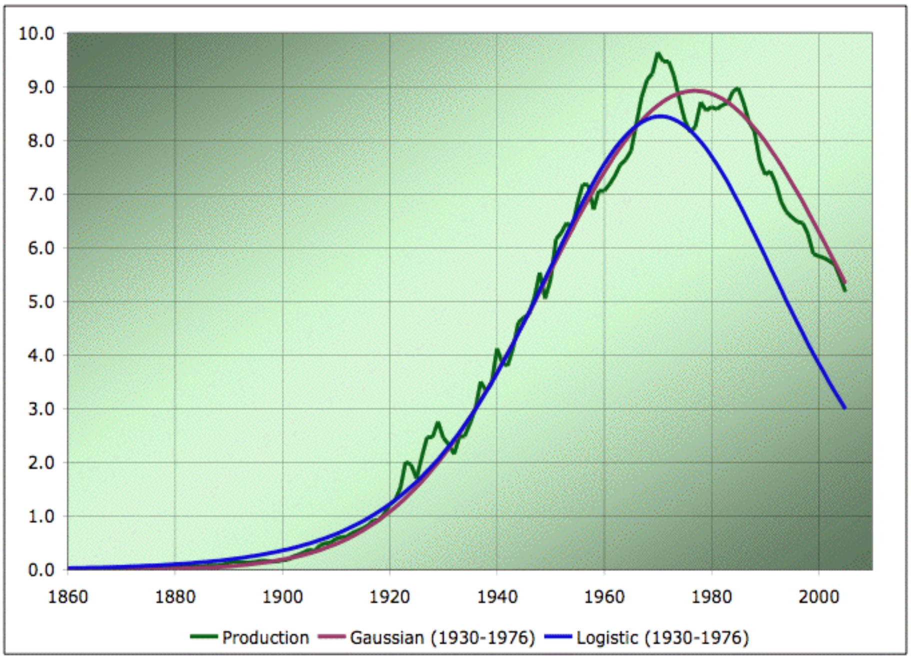

Figure 2- U.S. Crude oil production. (The oil drum)

The area under the curve drawn represents Qt, and the peak comes in the middle of the curve, when a half of oil has been produced. This is the simple mathematical explication of what Hubbert studied about U.S..

Using the Hubbert method for all the world, and considering the events of history, now can be drawn a line as well as for U.S., and it's seen that world oil production settles down after 1983 to a straight line, so it's seen that the line has an intercept *a* of 0.05 and a Qt, so where the line meets the horizontal axis, of 2 million barrels, predicting the peak around 2006 for some actual researchers.

So Hubbert firstly noted that the production of a basin does not follow the trend of a growth till a stable level, continues for a long time on that level and then suddenly declines to zero when all the oil has finished, but it follows a bell-shaped curve, generally a logistic one, in which the area under the curve is equal to the estimates of the amount of total oil available. During the first phase the production increases rapidly because the first oil that is extracted is the easiest one to find, and then it becomes more difficult to reach and extract the one that remains, reaching the peak of production generally when half of the oil present in the basin has been extracted, then production starts to decline till a point where there is still oil in the basin, but it’s not economically convenient to extract due to high costs.

So the Hubbert curve (then the production rate) for a single area starts at zero, increases exponentially during the early period and then declines negative exponentially to zero.

Updating and complicating the base model it’s possible to say that the curve could have one or more maxima and it could be symmetrical or not.

Even though observing large areas would be noted that the irregularities of small areas tend to cancel one another, so the smooth curve has a single practical maximum, although it still can be no symmetrical. In fact the ascending curve depends on skills or luck of explorationists, but the descending side depends upon facts, as political events.

Studying the discoveries of oil in the United States, Hubbert noted that they follow a bell-shaped curve as well as production, and that the production curve follows the discoveries one after a time lag different in each region, so once the peak of discoveries and the time lag are known, it becomes easy to find the production peak; clearly the area under the production curve cannot exceed the one under the discoveries curve.

It is now known that world’s oil discovery curve peaked in 1962 and then declined as a Hubbert curve predicts, and without restrictions as the Arab oil embargo of 1973, following this model, world production would have peaked in the mid-1990s.

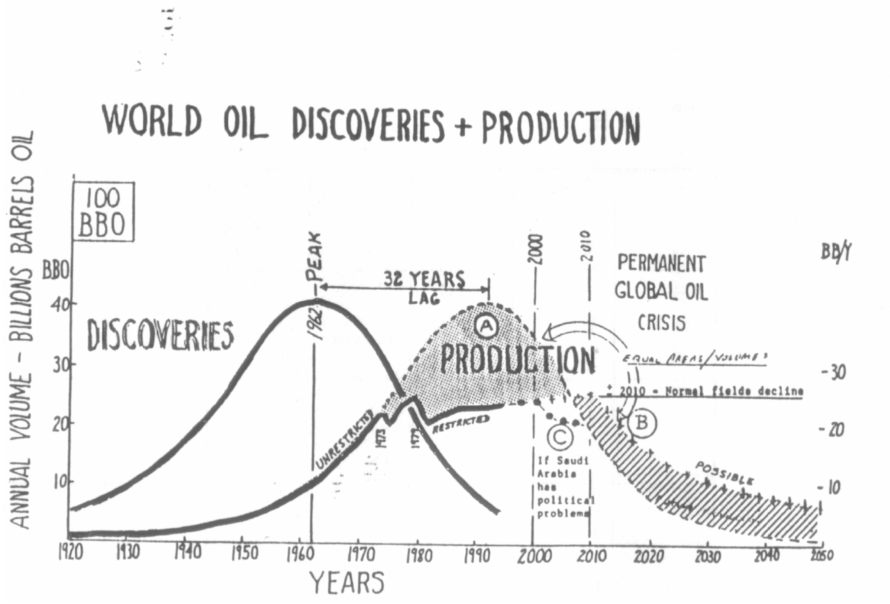

Figure 3 - World oil discoveries and production- an example of Hubbert decline. (Ivanhoe)

It is possible to see in this graph that until global production is unrestricted the global production curve follows the discoveries one suggesting that global production would have peaked in the mid-1990s.

The restriction of Arab oil embargo of 1973, which caused the first global oil shock, changes the shape of the curve, and global production flattens out, due to worldwide more efficient energy use after the second oil shock in 1979 due to Iran-Iraq war. Since 1989 global consumption and production has been increasing steadily.

The light dashed line is the unrestricted production Hubbert curve and it has the same shape of the discoveries curve. In this graph we can see that the production curve (+++++) has been replaced after the year 2010 by an oil field decline curve, then the Hubbert peak, so when global demand will exceed global production, should be on 2010.World production will continue at a dwindling rate after that year until more or less 2050.

2.2 The followers of Hubbert.

The most famous follower of the Hubbert theory is Colin J. Campbell, who is the founder of ASPO Association for the study of peak oil, and whose most famous work on this argument is the article “The end of cheap oil” of 1998, written with the collaboration of Jean Laherrère and published by *Scientific American*.

In this article he develops Hubbert’s projections, and explains some problems for the correct prediction of the end of oil.

This analysis suggests that within the 21st century the supply of conventional oil will be unable to keep up with demand, going against the prediction that should born from the data of oil industry reports of that period, which suggested that crude oil could remain plentiful and cheap till 2040 more or less.

The difference between the two visions is given mostly by three errors on which the latter projection would be laid on: the distorted estimates of reserves, the hypothesis that production would remain constant, and the thought that the last bucket of oil can be pumped as quickly as the first one.

In the first part of the article Campbell explains the importance and the difficult to have real numbers referred to three vital numbers for oil projection, as the tally of how much oil has been extracted to date (cumulative production), the estimates of reserves, and a justified guess of how much of conventional oil remains to be discovered and exploited. When talks about reserves, Campbell talks about the amount of oil that companies can pump up out of known oil fields before having to abandon them.

There are a lot of publications of these numbers, but while there is not a big problem with those referred to cumulative production, with errors that can be easily solved, getting good estimates of reserves is rather hard, because it is an inexact science, where it is necessary to assign probability to the guess of the quantities of reserves. Doing that expert engineers cite quantities called P90 estimate if the quantity

considered has the 90% of probability to be right, P50 if it has the 50% of probability, and so on.
Most of countries and companies declare the quantities that fit them better, even if they have a low probability (often if they are P10 too) because exaggerated estimates can rise the price for an oil company's stock, and for it allows the members of OPEC to export a higher quantity of oil, because their exportations are related to the quantity of their reserves. During recent years some upward revision was warranted.
Another problem with the estimation of remaining reserves is the vagueness of the definition: indeed in the U.S. are called reserves proved just the ones that lie near a producing well, and if there is a certainty that this oil can be recovered profitably at current oil prices with existing technology, so they are near to a P90 estimate, but in most other countries it's impossible to find a particular definition of reserves.
Although using just P90 reserves is not right to understand the amount of proved oil in a region, it's not correct to use reserves with a so different value of probability, or with a too low one, the better way would be to sum up the average estimates of oil in each field (this is often called proved and probable reserve), so the P50 reserve, assuming prices remain constant within a limited range.
Campbell says that by his estimations world had, on 1996, 850 Gbo of conventional oil in P50 reserves.
The biggest problem is to know the size of ultimate recovery , so it's necessary to know if and how fast reserves are moving up and down; clearly reserves have grown during the last 20 years, but it would be an illusion the guess that they will continue growing like that: with a concentrated observation it's seen that most of oil used right now comes from fields discovered a long time ago, before 1973; these oilfields are depleting now, and because the consumption of oil from our growing population is growing as well, reserves are depleting too.
I have already presented the problem of the distortions that characterize the estimation of reserves; the right way of proceed it

would be to backdate each revision done by countries and oil companies to the year in which the oilfield was discovered, and then move on with forecasts based on these numbers. Doing that it’s possible to see that global discovery peaked in the first middle of 1960s, as Hubbert demonstrated, and then has fallen down.

Campbell with his projections has estimated that the oil industry will be able to recover just about 1000 billion barrels of conventional oil.

There is no possibility of changes due to an improvement of investments on exploration, because the finiteness of the presence of this resource, as shown by empirical data too, with the discovery rate in decline from 1980s.

In this article Campbell applying the Hubbert theory, predicts that the peak of oil production will occur on 2010 more or less, showing that neither a change of few hundred billion barrels higher or lower could change that situation.

Campbell does an overview of the aspects that are often treated as factors that could delay the peak, as the guess that deposits of oil could be present in corners of the world still unexplored, but he says it is so unlikely because most of the world has already been explored. Another point argued is the development of technology that should improve the recovery factor (the fraction of oil that can be recovered from fields in a basin), but this improvement is rather an artefact, and it’s to be considered that oil companies count on technological progress while doing their estimations of reserves; the third point is the importance of the presence of unconventional oil, but the development of techniques to use these sources would need a long time and big investments too, and even more, a big environmental price.

In the last part of his article Campbell concludes with the problem of the growing demand that oil companies have to face, and states that world is not going out of oil right now, but that it is going to face the end of the abundant, and so cheap, oil which our society depends on.

A different evaluation of reserves, firstly the ones of the Persian Gulf area, has led the EWG energy watch group to make the assumption that peak of oil production has already occurred in 2006.

These researchers base their report of the world oil supply on the Hubbert method, but with a different evaluation of reserves from the one of Hubbert, Campbell, and other scientists due to the problems of estimation presented before.

This is the reason of the different date of the peak, as can be seen in the appendix B of this elaborated.

Another so famous follower of the thesis of Hubbert is L.F.Ivanhoe, who is a geophysical and the founder of M.K.Hubbert centre for petroleum supply studies of the Colorado school of mines.

He is the author of a lot of works on technical subjects, and he deals with the estimation of reserves of oil in the world.

In one of his famous works based on Hubbert theory, “King Hubbert-Updated” he explains the model, and he focuses on the problem of the descending part of the Hubbert curve, explaining the importance of political events on the slope of this part of the curve, and, as Campbell, states that the peak of production will be around 2010, or maybe before, because of the unforeseeable situation of the equilibrium in Saudi Arabia or in the regions of Persian Gulf.

A lot of other researchers base their studies on the Hubbert method, predicting a peak of production compatible with the ones presented so far.

2.3 Criticism on Hubbert model.

King Hubbert not only has followers, but there are researchers, most of all economists, along with a few energy associations as USGS AND DOE too, who state that the worry about the peak of oil production is exaggerated and that there would be a big abundance of oil in the world.

Between these theses the one of Michael C. Lynch, chief energy economist of DRI-WEFA Inc., has more founded reasons than others.

In one of his more important articles he says that forecasts presented by Hubbert and Campbell have repeatedly proven to be incorrect, and bases his criticism firstly on the assumption of the fixity of recoverable oil resources. Instead he considers central in the possibility of recover resources the presence of dynamic variables as infrastructure, technology, and price, and not only the fixed geological factor of the quantity of oil.

In the article of Campbell "The end of cheap oil" he explains the central role of the estimation of URR (ultimate recoverable resources), and Lynch critics first the inaccessibility of the database on what Campbell has based his estimation, and then underlines the importance of improved recovery methods, better examination of seismic data, and so on, to increase the estimates of field size. He concludes that the size of recent fields has been underestimated compared to older fields, and so that the end is not so near, and the increase in recovery at existing fields are not artefacts as Campbell said.

Then he concentrates on the World Petroleum Assessment of USG for 2000 which, using the same database of Campbell, shows a projection of a substantial growth of reserves from existing fields, and on the announcement of IHS Energy, the firm owner of the database used by Campbell, that states that discoveries in 2000 have risen more or less of 10% from 1999, because the inclusion in this estimation of deepwater reserves and the discovery of two new super giant fields in Iran and Kazakhstan.

So he argues that the keeping of low discoveries in the last 30 years is due to the poor geology, and that these new discoveries give hope for a new cycle.

Lynch presents the difference between the estimations of reserve of Campbell and the ones given by revisions done by HIS Energy of the earlier discoveries.

So he states that the discovery curve presented by Campbell, following the one of Hubbert, is misleading, and that estimated recoverable resources have grown faster than consumption; so even if there is the necessity of thinking about the end of oil and the changes it would carry on, this is not a problem that the world has to face right now.

It’s necessary to say something about the points on which Lynch bases his suppositions. Heinberg (2004) analyzes these points in his work. Firstly the World Petroleum Assessment of USGS for 2000 is criticized from some of the experts of USGS as well.

The two authors, Schmoker and Klett, have declared that there is uncertainty about the growth of reserves outside U.S. because they have used the function of growth of reserves of continental United State for other states too.

Clearly this is a source of problems because of the different situations on which countries and their estimations of reserves are based (i.e. the consideration or not of changes of technology).

Hence it could lead to wrong conclusions about this astonishing growth.

Even more it’s noted that during the period between 2000 and 2030 there should be a growth of 40 million barrels per year, almost equal to the performance of the best period for discoveries in history (1957-1967), when there was a growth of 48 million barrels per year.

The evidence shows that from the 1990s the growth of reserves and new discoveries have been around 9 million barrels per year, so the projection of USGS seems rather optimistic, maybe too much.

The Energy Information Agency (EIA) shares this optimistic view.

Though it declares that these faithful projections derive from the adaptation of projection of oil supply to the projection of demand, because of politic pressure.

On the contrary the IEA - International Energy Agency has adopted a modified Hubbert method and has predicted the peak of oil production for the 2015, declaring that soon all the world will completely depend on Middle East countries.

Lynch declared that discoveries have grown a lot between the 1998 and 2000, but if it’s observed the best of these years (1999) it can be noted that new discoveries of oil represented just the 62% of the quantity of oil extracted and consumed that year, so the untenable situation is strongly shown.

It's quite sure that new discoveries in Middle East countries will come, but most of the biggest basins have already been discovered, and quite surely deepwater reserves won't be the solution of the problem, because their need of time and investments.

2.4 The Hotelling model for non-renewable resources.

The model most used to describe the economics, and the optimal consumption, of an exhaustible resource is the Hotelling model, developed by Harold Hotelling on 1931. A basic model has been developed, with several extensions.

The core of that model is the concept of "scarcity rent" (called Hotelling rent too) that represents the excess of the market price of the resource over the marginal extraction cost reflecting the scarcity of a non renewable resource, and it is related to another cost, the "user cost", that is the same of the opportunity cost of extraction, so it's the marginal benefit of conserving an exhaustible resource.

The basic Hotelling model assumes that the situation is characterized by zero extraction costs, the presence of a lot of producers (hence there is a competitive market), that there is a constant real risk free rate of interest on investments per year, r, and that the price of the resource at time t is P(t).

The resource owner can decide to extract the resource today and invest the profits earning r per cent per year, or to hold the resource and extract it in the future, expecting the price of the resource to grow more than r per cent.

In the presence of the competitive market, every owner will face the same situation, and will take the same decision, because if the price would rise slower than r every owner would sell off his stock of resource reducing the market price, otherwise if the price would rise faster every owner would keep his stock of resource increasing the market price; so the result is that the resource price will rise exactly at r per cent per year. This is the basic Hotelling rule.

So in equilibrium the price is rising over time, and meanwhile the quantity extracted is falling over time until the resource is exhausted, and finally the price will be so high that the demand will be totally eliminated, exactly in the point where the resource is completely exhausted; if not, if there is some owner that still have a quantity of resource when the price is so high to eliminate the demand, it would be useless, so the owner will start to sell off his stock of resource at a lower price before the price reaches the limit point, so the production trajectory, that is monotonically declining, will be extended in time, and the price still rises at r per cent, till the resource is depleted (T). the sum of extraction in all periods is equal to the resource endowment, and the timing of extraction has no consequences on the total amount that can be extracted.

The total value of the firm is:

$$\mathbf{V} = \sum_{(t=0)}^{T} p_t x_t (1+r)^{-t}$$

Where x_t is the extraction in time t. The firm only has a constraint that is that the quantity of the resource extracted in all periods cannot exceed the total endowment of the resource:

$$\sum_{t=0}^{T} x_t \leq R$$

The function that has to be maximized combining the two above is:

$$\mathrm{L} = \sum_{(t=0)}^{T} p_t x_t (1+r)^{-t} + \lambda\left(R - \sum_{t=0}^{T} x_t \right)$$

And the conditions (Kuhn-Tucker) that let solve this maximization problems are the following:

$$\frac{\partial L}{\partial x_t} \leq 0 \qquad x_t \geq 0 \qquad \text{and} \qquad x_t \frac{\partial L}{\partial x_t} = 0$$

Clearly extraction cannot be negative so the second constraint always happens, the third constraint only happens if x_t is equal to zero or if $\partial L / \partial x_t = 0$, so there is extraction just when $\partial L / \partial x_t = 0$.

It's possible to derivate the Hotelling rule, just assuming that extraction occurs in two different periods of time, so it would be:

$$(1+r)^{-t} p_t + \lambda = 0 \qquad (1+r)^{-(t+1)} p_{t+1} + \lambda = 0$$

so:

$$(1+r)^{-t} p_t + \lambda = (1+r)^{-(t+1)} p_{t+1} + \lambda$$

and then:

$$(1+r) p_t = p_{t+1}$$

that is the Hotelling rule as said.

So the price path and the quantity path are the following:

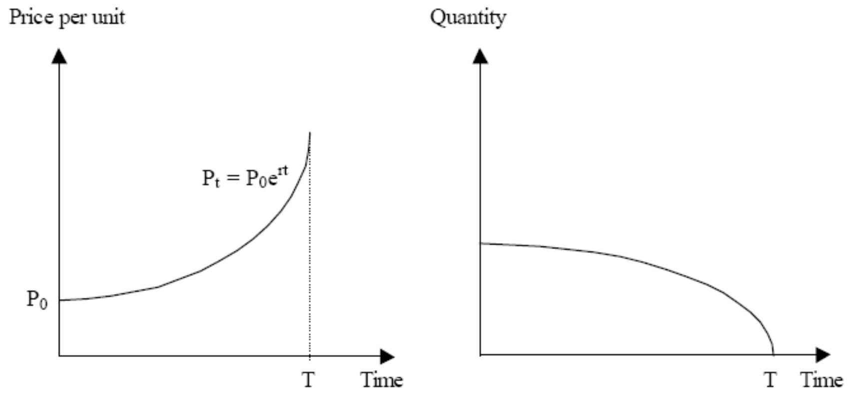

Figure 4 - Equilibrium Price and Quantity Trajectories for a Non-Renewable Resource. (Neha Khanna)

P_0 represents the initial price, and T is the point where the resource is completely depleted.

So the owner maximizes the present value of the flow of revenues through the exhaustion of the resource, and the production trajectory is Pareto optimal, because it maximizes the discounted sum of producers' and consumers' surplus.

There are different variations on the basic Hotelling rule, one of these is the one that includes extraction costs. If it is assumed that the marginal extraction cost doesn't depend on the stock of resource that has been already extracted, the result would be that the net price, so the price minus the marginal extraction cost, would rise at r per cent per year, following the Hotelling rule, but it's important to note that there is no reason for the market price to follow the same path of the net price. In fact it's know that the resource price is the combination of the opportunity cost of extraction and the marginal extraction cost: the former is growing over time, and the latter could decrease because maybe of technological progress, so one tend to raise the resource cost while the other one tend to reduce the price. As long as the scarcity rent outweighs the pressure of the falling extraction costs leads the market price to rise.

However in the long run the effect of the scarcity rent would dominate and so the price would rise; this could explain a U-shaped price path, and it's important to underline that in the long run resource price always increases.

Hence there could be a change for the equilibrium production trajectory that can change if it happens that the extraction cost decreases over time, so it could decline in the near term. Otherwise, if the marginal cost is rising over time, the equilibrium production trajectory is monotonically declining as well as the basic model.

Assuming that extraction costs are proportional to output, so that m_c is constant, it's possible to convert the simple equation of the Hotelling rule showed above, to that one:

$$(1+r)(p_t - mc) = p_{t+1} - mc$$

If it's assumed that there is perfect competition it's impossible to define the difference between the resource price and the marginal cost as a profit, but it should be seen as the opportunity cost of removing it. Defining q_t=p_t-m_c it's possible to write:

$$q_t = q_0 e^{rt}$$

seeing that is the opportunity cost defined that grows at the rate of interest, so the price grows more slowly than the rate of interest:

$$p_t = q_0 e^{rt} + mc$$

Another reason for the extraction costs to fall could be exploration; in fact while in the basic Hotelling model the resource stock is entirely known, in the reality it could change for new discoveries by exploration. It can lower the marginal cost, increasing the entire stock, the prices could fall in the near term, however in the long run they would rise again, because of the limited opportunities of exploration. So exploration forms expectations, and for that it should be added as a cost to the marginal extraction cost while taking decisions.

Then if it is assumed that extraction costs are dependent on the remaining resource stock, then the scarcity rent doesn't rise at the interest rate r, but at the interest rate less the percentage of increase in cost due to the reduction of the reserves.

Another particular case that has been studied is the presence of monopoly in the market. In this situation is possible to have a profit, so the difference between the marginal revenue and the extraction cost rises at r per cent per year.

If the monopolist faces a situation when there is a static demand curve and the price elasticity of demand decreases when the quantity extracted increases, he could slow the depletion rate, with an extraction path stretched out over time.

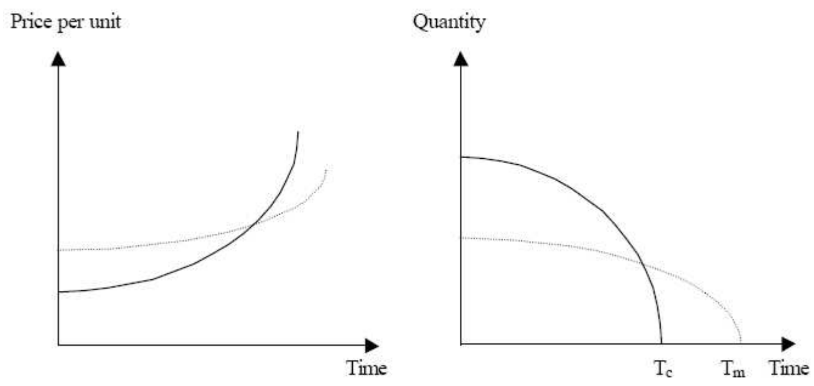

Figure 5 - Equilibrium Price and Quantity Trajectories. Solid lines indicate perfect competition, dashed lines indicate monopoly; Tc and Tm indicate exhaustion under competition and monopoly, respectively. (Neha Khanna)

The monopolist could decide to restrict the output at the earlier time when the elasticity is low, leading the price to rise, otherwise, if the elasticity is high the supply will be high initially. The monopolistic situation would be that one:

$$mr = p_t + p'_t\, x_t$$

represents the marginal revenue, where it can be seen that an increase in supply lowers the price, reducing total revenue, so the modified Hotelling rule is:

$$p_{t+1} + p'_{t+1}\, x_{t+1} = (1+r)(p_t + p'_t\, x_t)$$

If the monopolist faces a constant price elasticity demand, (isoelastic demand curve) so the total revenue is constant too, his equilibrium price path and extraction path are identical to those of the competitive owner; in all other cases he can choose different behaviours leading the market to a failure.

Another extension of the Hotelling model is the one that considers the presence of more sources for the non renewable resource, but with two different extraction costs, so if there was the perfect competitive market the production would start from the low cost source and the net price would rise at the interest rate r till it would be equal to the net price for the second source, then the former source would be completely depleted, and the latter would be the one to use for production, with an increase of the price at the interest rate as well, till this source would be completely depleted too; in this case there would be a succession of price trajectories, as shown by the figure below:

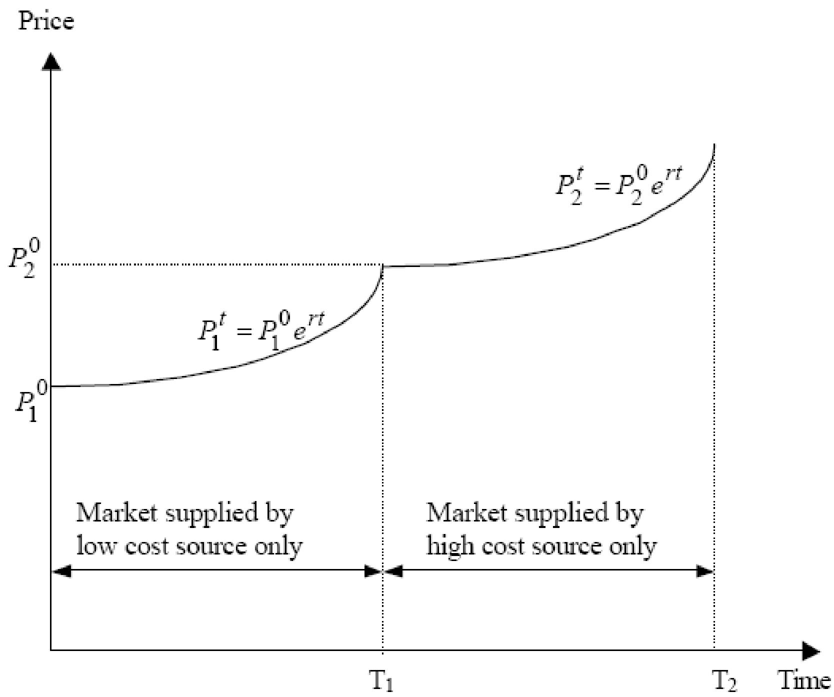

Figure 6 - Equilibrium Price Trajectory with Multiple Sources. (Neha Khanna)

If there would be a backstop resource (a perfect substitute of the non renewable resource) that is infinite over time, and its price would just cover the marginal extraction cost, or would rise lower than the price of the non renewable resource, the situation would be similar to the one with multiple sources, for the market would be entirely served by the backstop resource exactly when the price of the non renewable resource would be equal to the one of the backstop, so the price of the former would rise at the rate of interest r till this moment, that is the same one on which the resource would be completely depleted. In fact if there would be some stocks of the resource left, the owner would sell it at a lower price before it reaches the price of the backstop, so the net price would fall because of the increased supply, leading the price to reach the one of the backstop when there is the complete exhaustion of the resource. Meanwhile if there would be the exhaustion of the resource before its price reached the one of the backstop, the excess of demand would make the price higher, so the owners of the resource would hold some quantity of it to sell it later at a higher price, and then the production horizon would be extended.

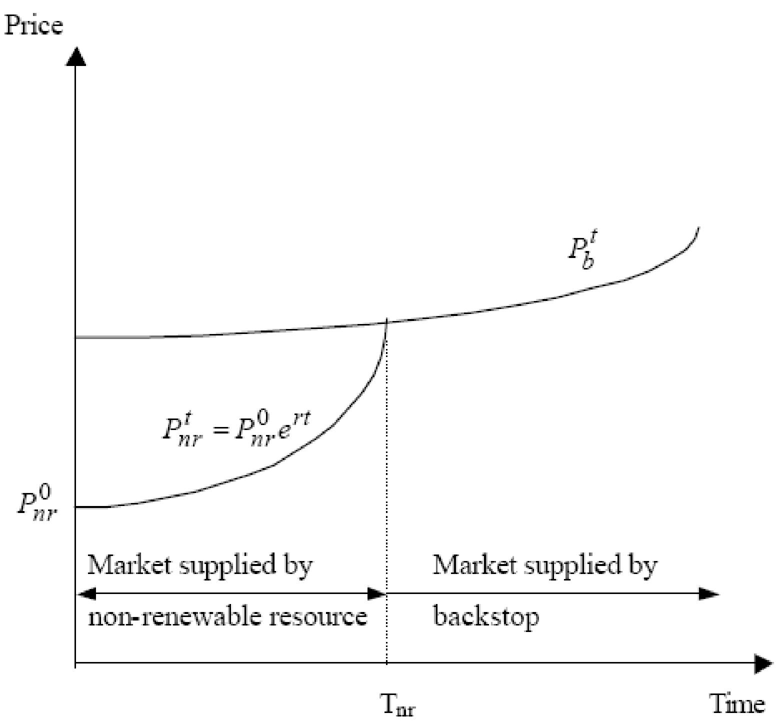

Figure 7 - Impact of Backstop Resource. (Neha Khanna)

In the basic Hotelling model resource consumption is supposed to be constant over time. As said in this type of the model the resource stock is considered to be fix and known, so when a quantity of the resource is extracted to become energy (E_t), the remaining deposit at time t (R_t) of the resource is R_{t+1}- $E_{t.}$ It's possible to say that if there is a price elasticity equal to one ($E_t^D=1/p_t$) the economy consumes a constant fraction (c_R) of the remaining resource in each period of time:

$$c_R = \frac{E_t}{R_t}$$

that could be developed to:

$$\frac{\overset{*}{R}}{R} = -c_R$$

where it's possible to see that the remaining resource stock will fall at a constant rate, so R(t) could be shown as an exponential function of time and the initial resource stock:

$$R(t) = R_0 e^{-c_R t}$$

so the dependence of resource extraction (E(t)) to the remaining deposit could be shown too:

$$E(t) = c_R R_0 e^{-c_R t}$$

and it falls at a constant rate too.

But if it is considered a growth on demand, as a consequence of the growth in population and in per capita income, with a rightward shift of the demand curve between two consequential periods of time, so the production trajectory should increase when there is a low user cost and the income of population is rising, and then decline to exhaustion when the user cost becomes higher and dominates.

2.5 The empirical evidence of the failure of the Hotelling model in the case of oil.

The data extracted from the real world for crude oil show with evidence the failure of the basic Hotelling model.

Following the Hotelling rule the price of that resource should rise exponentially, but observing the path of the price of crude oil it's possible to see that price was declining slowly between 1949 to the early 1970s, then, in the points of the two oil crisis, the price firstly, between 1973 and 1974, rose by more than 60 per cent, and then, after being on a plateau, almost tripled between 1978 and 1981, but then during 1980s and 1990s it declined again, to increase one more time between 1998 till present, showing the big volatility that characterizes oil prices since 1974.

It has to be underlined that since 1949 oil prices have not increased in real terms, reaching a lower value in 1998 than in 1949.

Although it is considered the fall of the interest rate (that can't be constant as the Hotelling model says), the oil prices should have grown at a slower rate, but they shouldn't have to fall.

Another important contrast between the Hotelling model and the real world is the consumption of crude oil, for it is known that for the model there should be a constant rate of consumption every year that should be proportional to the remaining stock resource, so the flow of consumption should fall over time.

Crude oil consumption instead increased by almost 50% in the period 1971-2000, and it is projected to increase again till 2030.

World Primary Energy Demand (Mtoe)

	1971	2000	2010	2030	Avg. annual growth 2000-2003 (%)
Oil	2,450	3,604	4,272	5,769	1,6

Table 1 – World primary energy demand for oil. (Tobias Kronenberg)

Adding to the basic Hotelling model the presence of constant extraction costs, the falling of the oil prices still cannot be explained, because they should still rise although at a lower rate than the interest rate, even more contradictory would be the presence of reserve depending extraction costs, because their increasing trend should lead to a faster growth than in the basic model.

With technological progress and exploration the price could fall for a period of time, but as said, in the long run it would rise again, because of the predominance assumed by the exhaustion effect in the case of new technologies, and because of the limited opportunities of exploration in the long run, involving a U-shaped price development.

Some researchers argue that there are institutional explanations to the failure of the Hotelling model, such as the one of the uncertainty of property rights, because the rights of the exploitation of oil are granted by corrupted and not democratic governments. In this situation there is always for the owner of the resource the expectation of the possibility to loose his right; so the expected present value of the resource is:

$$V = \sum_{t=0}^{T} p_t x_t \left[(1+r)\eta\right]^{-t}$$

defining η as the probability of retaining control of the resource during next period, having for the owner a lower value of the resource than the social value of it, because η is smaller than one.

The Hotelling rule now is:

$$(1+r)\eta p_t = p_{t+1}$$

so the price rises at a lower rate than the interest rate, and if η is small enough to be (1+r) η<1 the resource price could fall over time. In the case that the time path of resource extraction falls more quickly,

the Hotelling rule could be coherent with real data observed for prices, although it cannot still be explained the increase in consumption.
Another possible failure that influences the deviation from the Hotelling rule could be the strategic interaction between the supplier and the consumer of oil, in the presence of information asymmetry, and announcements of the presence of a higher stock of resource than the real one, or about the introduction, for example, of a backstop resource become so important. The importance of the overestimation of oil reserves, mentioned before, assumes a high value in explaining the failure of the rule too.

2.6 Forecasting oil production and the price path: another approach to oil management.

It has been shown that the Hotelling model doesn't apply well to the reality of crude oil, so different models of oil management have been developed, and the one that maybe comes most close to the reality is the one based on the reserves to production ratio, as shown by Ferdinand E. Banks.
In the next twenty years oil consumption is supposed to increase by 20% in the industrial world and by 40% in the developing countries, and it's sure that discovered reserves are not going to be enough to satisfy all the consumption.
Even with the discovery of new reserves, the world will have to face problems of extraction from these new fields, because their non ideal locations.
It's so important to make right forecasts of the price of oil, although it's known that irrational behaviours characterize markets, so forecasts can always be wrong.
To continue to satisfy the growing oil consumption, additional supply (ΔQ) is needed:

$$\Delta Q = \alpha Q_{t-1} + \beta Q_{t-1} - \lambda Q_{t-1} = \theta Q_{t-1}$$

(where $(\alpha Q_{t-1} + \beta Q_{t-1})$ represents the supply from existing and new sources, and λQ_{t-1} represents the decline in output from existing resources. θ is the percentage of the annual increase in demand).

It is well known that oil discoveries are falling from a long period of time, so even with the presence of new technologies, that also bring a reduction of costs of extraction, production cannot rise without new discoveries.

The current situation shows that the cost of looking for, finding, and producing oil right now is less expensive than ever. Hence the falling trend of production of a lot of countries as United States and Europe is clearly related to the poor reserves that are still present.

It's necessary to say that oil companies are actually looking for oil, and finding new quantities of it, but not enough to satisfy the demand.

Usually it is looked at the Reserves on production ratio to determine the lag of time the resource will be available at the actual situation.

Banks stresses one important issue related to this ratio.

It is assumed that there is a critical value established for the R/q ratio. That is most presented as ten (maybe because to optimize the value of a deposit the annual output is usually kept from falling below ten per cent of the remaining reserves), and production should keep the value of this ratio exactly, or just around, at the point of the critical value, otherwise there would be the temptation to overwork in the deposit. This would reduce the amount of oil that could actually be obtained, because of the accelerated production and the consequent physical depreciation of the deposit.

Considering the ratio measured at the end of the year in the Banks model, it should be:

$$10 \le \frac{R}{q_t} \le \frac{R_{t-1} - q_t}{q_t}$$

and then:

$$q_t \leq \frac{R_{t-1}}{11}$$

What is so important to notice is that the lower is the critical value of the ratio, the faster will be the decline in production, so it implies that the lower is the value the more intensive is the depreciation of the deposit.

Taking the example of United States production during the last few years, it's possible to see that the R/q ratio has fallen down till the value of nine, leading to the largest declines in U.S. oil output.

At the same time the ratio of the UK North Sea is almost close to five. This could be explained arguing about the necessity to pull production in order to cover so high costs of extraction of oil from the medium-deep water, and to remunerate the capital that was invested in the deposit.

A lot of researchers put their positive expectations on the power of rising oil prices; they should lead to the improvement of technologies, and to an increase of exploration. This point of view ignores that there is not certain that the efficiency price will take place in the oil market because of the presence of geological uncertainty, and, even more, it ignores the presence of the big constraint that cannot be found oil that doesn't exist.

The model presented here offers the construction of the plateau of production and the decline phase of an oil basin.

The R/q ratio plays an important role to manage and to forecast the production of oil, indeed if prices and profits were rising in a determined moment, and they would be supposed to continue to do so, it should be important to know the exact quantity that should be taken from the basin in order to have the largest physical amount of the resource.

The core concept is that pressure is the most important variable of a deposit, and when about half of oil has been extracted, the increase on investments to raise or maintain the production would be too expansive, hence extraction wouldn't occur.

One of the main things that reduces pressure in the deposit is a too rapid depletion. In fact there is the possibility for the basin to be damaged making the extraction of oil more expensive.

Hence by operating under the critical value of the R/q ratio the ultimate flow of oil is reduced. With a critical state of damage inside the basin, even with higher profits due to high prices of oil invested, extraction would not occur.

Hence when taking decisions about extraction it's important to consider the profits or consumers satisfaction that is given up by producing now instead that later.

The real marginal cost that has to be faced is the conventional one with the addiction of the user cost.

This model brings a correction to the Hubbert method. In fact in this case the addiction of large reserves is supposed to be reflected by corresponding increases in time lag to the new peak of production. Once forecasted the oil production path it's possible to forecast the price path too.

Banks considers the equilibrium in the sense of flow equilibrium and stock equilibrium.

He considers a situation where the demand for stocks (inventories) DI is equal to actual inventories, AI, so DI=AI. In the sense of flow equilibrium it's said that the flow of supply (s) has to be equal to the flow of demand (d). It's important to underline that there is the possibility to have a flow equilibrium without having a stock equilibrium, but without the possibility of having a full equilibrium.

Talking about the mechanics of price formation Banks considers the situation of the full equilibrium, so where DI=AI and s=d.

Then imagine that a lot of stock owners decide to sell off big quantities of their stock, maybe because of the expectation of a big fall in the price of oil: in this case there are three big consequences.

At first the demand for stocks falls so DI<AI, but AI can't drop in a moment because of geological reasons; then for AI to decrease, the

price must fall from the point of the flow equilibrium (s=d) and this leads to a raise of consumption, so when d>s, some of the existing stocks are consumed in current consumption; eventually the fall in the price can affect expectations, and the owners could continue to think the price to fall, so stocks would be consumed or sold as soon as possible.

After the forecast of the quantity path, Banks in his book "The political economy of oil" shows the formation of the price path in a stock-flow model. He firstly explains the Hotelling rule, and from that, changing the timing utilized, transforms it in a more coherent rule.

In fact the quantity produced at time t+1 (q_{t+1}) in the Hotelling model is sold at the price at which the stock is valued at the time t+1, while in the model developed by Banks it is sold at the price the stock is valued at time t, as it seems more reasonable. Defining p as the net price of the resource, K as the asset, and r as the highest rate, the simple Hotelling model purposes:

$$p_t K_t = \frac{p_{t+1} q_{t+1}}{1+r} + \frac{p_{t+1} K_{t+1}}{1+r}$$

as

$$K_{t+1} = K_t - q_{t+1}$$

So

$$p_t K_t = \frac{\left[(p_{t+1} q_{t+1}) + p_{t+1}(K_t - q_{t+1})\right]}{(1+r)} = \frac{(p_{t+1} K_t)}{(1+r)}$$

and then the well know relationship of the Hotelling rule

$$\frac{\Delta p}{p} = \frac{(p_{t+1} - p_t)}{p_t} = r$$

But assuming, as Banks does, that the quantity of the resource at the time t+1is sold at the price of the last estimation of the resource, so at pt, and calling this quantity qt he gets:

$$p_t K_t = \frac{(p_t q_t)}{(1+r)} + \frac{(p_{t+1} K_{t+1})}{(1+r)} = \frac{(p_t q_t)}{(1+r)} + \frac{[p_{t+1}(K_t - q_t)]}{(1+r)}$$

and the relationship will be

$$\frac{\Delta p}{p} = \frac{(p_{t+1} - p_t)}{p_t} = \frac{r}{\left[1 - \left(\frac{q_t}{K_t}\right)\right]}$$

In the last equation is clear the central role of the ratio $q_t/K_{t,}$ as said before, and surely when the production/reserve ratio raises the price of the resource should increase.

3. THE OIL MARKET

Considering the forecast of the end of oil, and a consequent oil shock could be important to show the consequences the previous oil shocks have had on macroeconomic variables characterizing countries.
To know who will be the key player on the game of price and production in the descending part of the Hubbert curve, it's important to investigate the market structure.
What appears most important in the actual market structure is the presence, and the role, of OPEC.

3.1 Oil and macroeconomy

3.1.1 Oil shocks, recession, inflation and other macroeconomic variables.

A lot of economists, in the United States as well as abroad, have usually believed the increases in the real price of oil to be the major cause of inflation and recession, as the imported oil is a third factor in the aggregate production function, after the labour input and the capital input.
In different works it is presented the possible influence that oil prices can have on output, prices and productivity, deriving a link between oil prices, recessions, inflation, and growth.
Looking at the ten recessions U.S. have been involved in since World War II, it's possible to see that nine of them were preceded by a spike up in oil prices.
There are different opinions about the role that oil plays in recessions.
Hamilton (2005) has tried to investigate if the relationship between the spike up in oil prices and U.S. recessions has been just a coincidence. He uses a statistical regression of real GDP growth rates quoted at a quarterly rate on lagged changes in GDP growth rates and lagged logarithmic changes in nominal oil prices. The regression shows that there is a dependence between the two factors. Hamilton also investigates the possibility that the relationship comes out from a

common dependence on a third factor, or more than one, that leads to an increase in the price of oil, and at the same time to a recession too.

This view is quite hard to sustain because of the lack of movements in other macro variables before oil price changes, at least in the early post war period.

The hypothesis Hamilton sustains is that oil shocks affect economy mainly through a disruption in spending by consumers and firms on other goods, and if it doesn't occur, the effects on the economy are due to the factor share argument.

Concentrating on the main exogenous events that are supposed by many economists to be the real causes of the changes in oil prices it's possible to see the changes that have occurred in world production and in the real GDP of United States.

Date	*Event*	*Drop in world production*	*Drop in U.S. real GDP*
Nov. 1956	Suez Crisis	10.1%	-2.5%
Nov. 1973	Arab-Israel War	7.8%	-3.2%
Nov. 1978	Iranian Revolution	8.9%	-0.6%
Oct. 1980	Iran-Iraq War	7.2%	-0.5%
Aug. 1990	Persian Gulf War	8.8%	-0.1%

Table 2-Exogenous disruptions in world petroleum supply. (Hamilton)

Hamilton in his work faces the argument with the following equations. Examining a production function of the output (Y) of a particular firm, depending on labour (N), capital (K), and energy (E), supposing that the nominal price of output is P dollars per unit, the nominal wage for labour is W and the nominal price of energy is Q, with a nominal rate r for capital, it's possible to see the effects of energy supply disruption as follows:

$$Y = F(N, K, E)$$

$$PY - WN - rK - QE$$

a price taking profit-maximizing firm is considered. To maximize its profits, given from the equation above, it purchases energy till the marginal product of energy is equal to its relative price:

$$F_E(N,K,E) = \frac{Q}{P}$$

Where F_E is the partial derivate of F in respect of E.
So it's possible to find:

$$\frac{\partial \ln F}{\partial \ln E} = \frac{QE}{PY}$$

Which shows that the elasticity of output with respect to a given change in energy is influenced by the dollar share of expenditures in energy in total output. But this share for the economy is quite small.
Hamilton treats the case of the oil shock as an exogenous change in the price of oil, and not as a decrease of the quantity supplied.
In fact a consumer can decide to maintain the same quantity of oil bought, reducing the quantity consumed of other goods. Behaving like that the value that the consumer looses is:

$$\frac{E\Delta Q}{PY} = \frac{QE}{PY} * \frac{\Delta Q}{Q}$$

So the economic downturns seem to be due to the movements induced by the oil shocks in other factors of production.
Other authors do not agree with the vision of a linkage between oil prices and recessions. As one of them Bohi (1990) states his doubt on the role of energy prices changes in inducing recessions, especially the one of 1970s in the United States.

One of his arguments is the lack of a rapid increase in economic growth after the decline of oil prices to almost half of their previous value, not growth in GNP nor in employment, as it should be according to the hypothesis that sees the economic fall due to oil prices increase.

Another reason is that energy consumption as a share of GNP remained almost equal after the increase in its price during the 1970s, while output and employment dropped immediately.

Bohi, focusing on the two oil price shocks of 1973-74 and 1979-1980, examines three reasons that are frequently used to explain the real importance that energy assumes in regulate the economy trends, in the place of the simple cost share reason, presented above by Hamilton's work.

The first one is rise in unemployment when wage rates are rigid, the second is the reduction in capital services due to increased obsolescence of the capital stock, and the last is that energy-induced shifts in the composition of aggregate demand aggravated the problems of adjusting to changes in relative factor prices when wages are sticky and factors are immobile.

He shows by a simple equation where P_K is the relative price of capital, P_L the one of labour, and P_E the one of energy

$$\frac{\partial \ln Y}{\partial \ln P_E} = \left[\frac{P_K K}{Y}\right]\frac{\partial \ln K}{\partial \ln P_E} + \left[\frac{P_L L}{Y}\right]\frac{\partial \ln L}{\partial \ln P_E} - \left[\frac{P_E E}{Y}\right]$$

That the effect of an energy price change is given by the cost shares of each factor of production and the substitution effect of the price of energy on the quantity of labour and capital used in production.

The third term shows the direct effect and the relationship with the cost share, the first two terms represent the indirect effect in substitution of energy and labour, and energy and capital.

Usually the first two terms are positive, but considering just the short run effect they could aggravate rather than offset the direct effect leading the economy to a worst damage than the one that would have occurred just because of the simple direct effect. The two causes taken into account are, first, the inefficient reaction of the labour market to the energy price shock. In the presence of rigid wages employment could be reduced, and hence output. The reason affecting the first term of the equation is the economical obsolescence of capital led by shock, reducing the flow capital services.

Bohi in the equation presented, considers the direct effect on energy as Hamilton did. It is supposed to be the product of the cost share of energy in GNP and the percentage change in the relative price of energy. Bohi shows by different estimations that, empirically, the direct effect is quite small considering both the aggregated product, and the disaggregated industry production in the United States.

One estimation that he presents is the one of Alterman (1985) that shows the aggregate cost share of energy in the United States was 4.5 percent in 1973 and 7.0 percent in 1979. During 1974, the index of all energy prices in the United States had increased by 97 percent, and during 1979-1980 by 75 percent, over the preceding annual levels.

Relative to the corresponding increases in the GNP deflator, the energy price increases amounted to 11.1 percent in 1974 and 8.3 percent in 1979-1980.

Bohi (1990) "These numbers suggest that higher energy prices could account for a decline in the growth of GNP by 0.72 percent in 1974 and 0.36 percent during 1979-80. Actual GNP declined from a growth rate of 4.5 percent during 1972-73 to -0.8 percent during 1974-75, and from 4.7 percent during 197678 to 0.9 percent during 1979-80. Thus, the estimated decline in GNP caused by a rise in energy prices would account for only 14 percent of the first actual decline in growth and only 9.5 percent of the second actual decline."[1]

Even examining the direct effect of the oil price shocks on manufacturing sectors of different countries, it is shown that there is not such direct relationship between oil prices and industry output, focusing again the attention on the indirect substitution effect.

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[1] Douglas R. Bohi-"On the macroeconomic effects of energy price shocks", *Resources for the Future*, 1990.

Talking about the lack of flexibility of wages as a cause of the fall in output, the theory would state that the wage should fall led by the fall in the marginal productivity due to the reduction of the quantity of energy inputs because of the shock, but the fixity of the wages leads to a fall in employment, reducing the level of output.

Conducting empirical tests on different countries Bohi shows that there is no relationship between energy intensity and employment, so changes in energy prices were not responsible for creating a wage gap, between actual real wages and the level necessary to maintain the level of employment.

The view of the capital obsolescence deals with the decline that could occur on services from the capital stock, because of a heavy increase in the price of energy.

There is no empirical evidence of that.

There could be a possible effect of an energy-induced shift in the composition of aggregate demand, with a need to reallocate resources in different productions.

First, the transfer of resources could take place, but the factor could have a lower productivity in expanding sectors rather than contracting them, deteriorating the indicators of aggregate economic performance. Second, the transfer could not take place because of rigidity.

The empirical literature treats this issue with different explanations. The main result should be that shifts in output and input mixes are not an important variable for the productivity slowdown in different industrial countries during the 1970s.

There is empirical evidence of correlations between energy intensity and percentage changes in inventories by manufacturing industry for some countries.

Barsky and Kilian (2004) also focus their attention on the possibility of the influence of oil prices on recessions, inflation, low productivity and economic growth. They study primarily the case of United States.

The first step is to take in analysis the linkage between political event in the Middle East and recessions in industrialized countries.

They show that there is an irregular pattern of cycles of oil price shocks and recessions that should be consequent to these shocks. Thus they states oil prices do not have a pivotal role in these recessions, but could contribute to them.

Talking about recession, Barsky and Kilian consider the theory of the cost share of oil on the production function, underlining again the small influence an oil price shock should have on gross output.

They consider also the presence of mark-up pricing, showing that an oil price increase lowers the factor demand because the mark-up is applied to all cost components, but this kind of effect is small too, at least for reasonable mark-up ratios.

They focus on the lack of empirical support for the obsolete capital hypothesis, taking in consideration also that in the presence of an obsolete capital there should be new energy savings equipment that should offset the effect of the shock.

The transfer of wealth that occurs by paying larger amounts of money, because the higher oil import prices, also do not seems to be large relative to GDP.

The reduction in aggregate demand occurs just because oil producers tend to buy less output of the industrial countries than domestic consumers.

Considering the transmission of the oil price shock in the markets of energy-using goods, is often presented the model of Hamilton (1988), that considers automobiles as an example of energy-using good.

He states the shock depresses the purchases, so there would be a reallocation of labour due to the shift on demand, and if the movement of labour is costly may occur large reductions in value added.

Taking in account the oil dates below

Business cycle peak	Events associated with subsequent major oil price increase
November 1973	October War and Oil Embargo October 1973–early 1974
January 1980	Iranian Revolution October 1978–February 1979
July 1981	Outbreak of Iran-Iraq War September 1980
July 1990	Invasion of Kuwait August 1990
March 2001	OPEC Meeting March 1999

Table 3- The Coincidence of Oil Dates and Recessions after 1972. (Barsky and Lutz Kilian)

there is no empirical evidence of a symmetric behaviour in the case of an oil price decrease, so this hypothesis does not seem to be realistic.

Moreover there is empirical evidence that it’s true that car sales fell after the shocks of 1974, 1979, and 1990, although they can be seen just as a continuation of something started before; there is no evidence of a change in car sales after 1980 and 1999, nor after 2001 and 2003; there is an increase in car sales just after the collapse of OPEC on 1986.

There is no evidence of a drop in consumer spending either. There was a stability of that spending after the 1973 and the 1979, and an increase after 1980, 1986, 1999, 2001 and 2003. The only case where there was a decline, although small, is after 1990.

It’s possible to find a similar result focusing on investment decisions of firms.

In short, it has been shown that there is no linkage between the growth of uncertainty and the fall in investments, consumer spending and energy-using good purchases, to contribute to recession.

One of the indirect effects that can be considered is the response of monetary policy to the oil price shocks.

Some authors sustain that the recession of 1974 in the United States could be due to the behaviour of the Federal Reserve with a tightening monetary policy, but it is important to note that this kind of policy started well before the oil price shock (Bohi and Bernanke 1989; Gertler and Watson,1997).

Another issue treated is the problem of the "wage-price spiral", when nominal wages are set in line with past price increases, while prices are set with past wage increases; this could propagate an oil shock effect. But this is not the case of the recessions considered (Barsky and Kilian, 2004).

As a result there is weak evidence that oil price causes recession.

Another important point to examine is how oil prices affect inflation.

There is strong evidence that oil prices shocks have as a consequence a sharp change in the cost of living index inflation rate although there is no evidence of their association with an increase in the GDP deflator.

So the GDP deflator could increase under certain conditions, but it doesn't always occur.

The problem of the consequences of oil price shocks on the economic growth has to consider that the cost of energy is a too small part of GDP to explain the fall of productivity, and the hypothesis already exposed of the obsolete capital has not empirical support as mentioned earlier.

Eventually it has not been found a solid correlation between the two events.

Another important macroeconomic variable that is often supposed to be influenced by the changes in oil prices is stagflation.

There are different opinions in considering the oil price shock as a pivotal event of the stagflation of the 1970s in the United States.

Stagflation is a situation where high unemployment occurs, accompanied by a rising inflation, or a high level of inflation.

There has never been a significant period of rising inflation along with excess unemployment in 1973-1974; stagflation in the data occurred in the form of periods of slow or negative economic growth with high levels of inflation.

So this hypothesis is weak too; none of the major oil prices increases since the 1980s have been associated with stagflation.

3.1.2 The origin of the oil shocks

So far I discussed about the consequences of a oil price shock on different macroeconomic variables, but another important issue to investigate is where oil shocks come from.

Barsky and Killian (2004) investigate as the main probable causes of an oil price shock the presence and the role of the cartel OPEC in the market, the political events in the Middle-East, the role of wars, the role of embargoes, and the one of the global macroeconomic conditions. Here are the main points of their study.

Taking a look of the role of cartels it has to be noted that logically low interest rates should lead to the formation of a cartel, while high interest rates should conduct to the break of it.

If the cartel does not have the possibility to control each producer's quota, as in the case of oil producers, a fall in prices could lead producers to sell all their output in the market.

So it can be said that periods of recession weaken the cartel, while periods of expansion strengthen it.

This could explain some periods of exceeding production of OPEC.

Another guideline of OPEC's price decisions has surely been the exchange rate of dollar versus other important currencies.

So the strong exchange rate of dollar leads OPEC producers to make prices higher to offset the loss in their purchasing power, while a weak exchange rate leads other countries to raise their demand of oil.

Another important factor influencing oil price shocks are political events in the Middle East.

This events leads to shifts on the supply curve.

History shows different reactions of the oil price to those exogenous events; indeed it's possible to observe spikes in oil prices after important political events as the invasion of Kuwait by Iraq in 1990. At the same time it's possible to observe relatively positive rates of change after some other events as the Iranian revolution of 1978-1979, or the OPEC meeting of 1999.

So the argument that menaces of wars, or wars, in the Middle East lead to an interruption of production and hence high prices of oil is difficult to sustain.

It’s much more plausible to think that the fear of those events leads to a rise in the precautionary demand of oil, carrying up oil prices.

It’s not necessarily that wars lead shift in the supply curve of oil, they could result indeed in shifts in the demand curve.

This point of view is difficult to demonstrate because it depends on an unobserved shift in expectations. However observing the data, it’s clear that there have been cuts in supply after those events, but with different reactions in the oil price for each event. Even with the same magnitude.

The different time lags of reactions in the sense of an increase in oil price, when occurred, support the view that there is not a real important correlation between the supply cut and these variations.

A possible explanation of an increase in price in these situations may be the anxiety brought by uncertainty about supply, as previously mentioned.

The effect of a supply cut depends mostly on other producers reactions to it, and on demand conditions.

Another endogenous event that can affect oil prices is the oil embargo, because of the political considerations that brings to it.

The experience shows the increase in oil prices in the period of 1973-1974, after the Arab OPEC countries’ embargo.

Global macroeconomic conditions, as monetary expansions, are directly involved in oil price shocks. Indeed they shift the demand for oil, and involve all the possible causes named before.

3.2 Oil and microeconomy

3.2.1 Oil market structure.

The current oil market is characterized by the presence of a cartel which has more power than other oil producers, and other extractors that have importance in determining the behaviour in the market, impeding the full exercise of the monopoly power.

The cartel is represented by The Organization of Oil Exporting Countries (OPEC) which is an international organization composed by eleven developing countries with oil based economies.

The original thought of OPEC included two different goals, hardly reachable at the same time, as OPEC has just a single tool, output quotas.

OPEC has always operated to reach the minimization of the volatility of the market, accompanied by the development of the members; the former a microeconomic goal, the latter macroeconomic.

OPEC meets twice a year at least, and during these meetings it analyzes the situation of the market, and tries to move it by its quotas.

The decisions taken between the two goals can reflect themselves on the international market structure.

OPEC produces the 40% of the whole oil production.

Looking at the market a lot of independent firms are present.

They sell oil at the same price, taking as given the sales path of the others.

As presented by Salant (1976) this kind of market could be considered as a Cournot non-cooperative game.

Each firm owns an extraction plant if doesn't join the cartel, and each plant has the same cost function and the same oil stock.

The cartel is supposed to own more plants, so a larger oil stock.

Because of the upward sloping cost function of each plant, it can extract at the same rate of another firm that operates alone, but at a smaller cost.

Hence the market structure is composed by one firm which dominates the others, and a fringe of small firms that behave like perfectly competitive firms because of their size, hence they take the price that is given by the dominant firm. It is the so called dominant firm model.

The cartel chooses the price path taking as given the sales path of the competitor (the small firms); on the other side the competitor takes as given the price path choosing a sales path.

Assuming that marginal costs are zero, the cartel has to deduce its sales path to maximize its profits, knowing the stationary consumer demand curve, the sales path of the competitors, and its own stock of reserves.

In the competitive fringe can be included speculators who begin with nothing and purchase and resell quantities of oil.

The cartel has to value the marginal revenue (M) of selling a more unit today, or keep it and sell it in the future.

So it will be:

$$M = P(Q^m + \overline{Q}^c) - Q^m a(P)$$

Where Q^m are the sales of the cartel, $\overline{Q}^c$ the ones of the competitive fringe, P the market price, $a(P)$ the absolute value of the slope of the demand curve as a function of price.

The optimal strategy for the cartel implies that it has to sell all of its inventories, and it has to generate marginal revenues of the same discounted value in all periods, and when it stops selling the discounted marginal revenue doesn't ever exceed the one of any period of sales, or there would be the possibility of extra profits.

The price path the cartel faces could have regions where the price rises more than the rate of interest, and regions where it falls absolutely, because the excess demand curve it faces depends on the arbitrary decisions of the competitive fringe.

An important issue is the way the competitive fringe reacts.

Its sales could be negative in some periods because of speculators.

The competitors will send all their stock as well as the cartel.

If the price rises at the rate of interest, there is no difference on the discounted value in the way of selling oil. If the price rises by more between two periods, there will be speculators entering the market in the first period, buying stocks of oil, and then reselling it at a higher price.

The optimal behaviour of the competitive fringe in the case that the price rises by less than the rate of interest is to sell all its inventories before that region.

In equilibrium, price can never rise by more than the rate of interest, and it rises at the rate of interest as long as competitors hold stocks.

Then it can rise at the same rate or at a smaller one.

If the cartel makes positive sales the marginal revenue rises at the rate of interest. The cartel will conserve stock to continue selling after the competitor fringe drops out.

In fact when the cartel sells, its marginal revenue is less than the price because the loss that occurs for not keeping a unit. If the cartel has zero sales, the marginal revenue would be equal to the price because it has not the loss. Price is growing at the rate of interest hence the marginal revenue would rise by more, giving the cartel an incentive to change its strategy.

Competitors cannot sell after the cartel drops out in equilibrium.

The competitive fringe drops out the market when a limit price P* is reached; before that point the price grows at the rate of interest as well as the marginal revenue, and the cartel and the competitors operate together.

Calling u the measure of time, u moments before the price P* is reached, the price and the marginal revenue are:

$$P(u, P^*) = P^* e^{-ru}$$

$$M(u, P^*) = MR(P^*) e^{-ru}$$

And they depend on the two quantities sold by the cartel and the competitive fringe:

$$P(u,P^*) = P\left[Q^m(u,P^*) + Q^c(u,P^*)\right]$$

$$M(u,P^*) = P\left[Q^m(u,P^*) + Q^c(u,P^*)\right] - Q^m(u,P^*)a\left[P(u,P^*)\right]$$

Then it is obtained:

$$P^* e^{-ru} = P\left[Q^m(u,P^*) + Q^c(u,P^*)\right]$$

$$MR(P^*)e^{-ru} = P^* e^{-ru} - Q^m(u,P^*)a(P * e^{-ru})$$

To determinate the sales of each sector in this moment:

$$P^* : Q^c(u,P^*)$$

$$Q^m(u,P^*)$$

After the competitive fringe leaves the market, the cartel’s marginal revenue must continue to grow at the rate of interest, until demand is eliminated at the established price of F.

So the marginal revenue starts at MR(P*) and grows until it reaches F.

It’s possible to determine the duration of the first phase and the price P*:

$$\int_0^S Q^c(u,P^*)du = \overline{I}^c$$

$$\int_0^S Q^m(u,P^*)du + \Delta(P^*) = \overline{I}^m$$

Defining $\Delta(P^*)$ as the sales of the cartel in the second phase.

To fulfil this situation the consumer demand curve just has to have a point of unit elasticity, and the elasticity has to grow strictly with price.

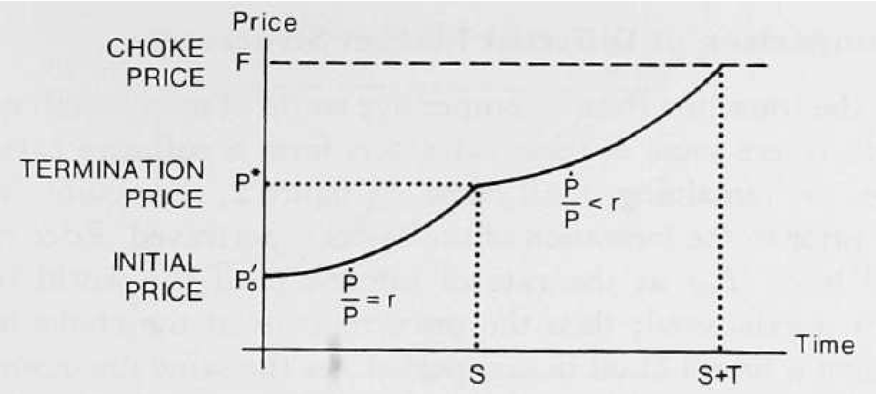

Figure 8-The equilibrium price path in the dominant extractor model. (Salant)

The price grows at the rate of interest during the first period, and then grows more slowly.

During the first phase price and marginal revenue remains at the same point, due to the constant elasticity of the excess demand in each point chosen by the cartel.

A comparison with the market structure of perfect competition (A) and monopoly (C) is show below:

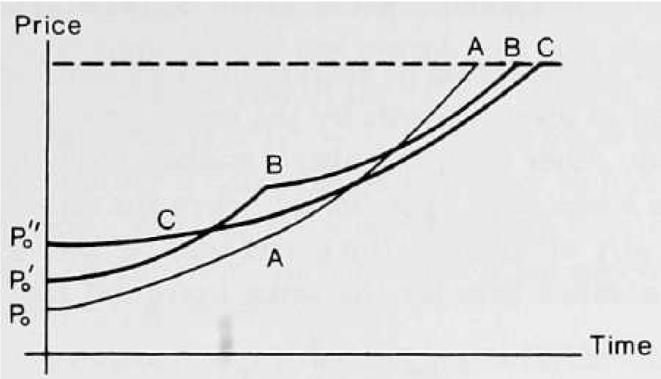

Figure 9-Comparison of price paths under different market structures. (Salant)

It's possible to see that the beginning price in the case of the presence of a cartel is higher than the one in perfect competition, so the cartel rises the profits of all the competitors, even though rises more the profit of the competitive fringe.

In fact the competitive fringe doesn't have to contain its sales to have the higher price, but it just benefits of it.

The cartel, on the other side, has to sell some of its stocks in the second phase at a lower discounted value.

For one of the firms enjoying the cartel there is no incentive to chisel, because this behaviour could have two different consequences. On one side if the firm is the only one to break the agreement it could earn more, selling all its stocks during the first phase ate the price of P_0'.

On the other side, if its behaviour leads to a break of the cartel by all the firms, they will have to sell the entire stock at P_0, with a loss for everyone.

So it has been shown that the market structure of oil lays between the pure monopoly and the pure competition, as said by Hotelling first, with an intermediate price between the two, and an intermediate time of exhausting the resource.

The situation doesn't change in a significant way in the presence of increasing marginal costs.

I have already said that OPEC has two important goals to reach. The one presented above is the mechanism that regulates the microeconomic one. Looking at the macroeconomic one some considerations have to be made.

There could be developing countries which are more concerned with production stability than higher profits, so it could happen that their governments decide not to join the cartel.

These governments focus their attention firstly on the volatility that can be brought in national income, and in the macroeconomic environment, by the output volatility.

Another reason that can lead to the decision between the two goals is the imperfect access, for the developing country, to international capital market.

This could be because the country has weak financial institutions or because of political business cycle problems.

In these cases it may happen that the equilibrium situation can only be reached with consumption that follows output, underling the importance of stability.

The importance in output, and so the certainty for producers, can help the development of other sectors too. Indeed oil suppliers have the possibility to invest in other sectors, and develop areas in which the country could have a comparative advantage.

Output stability also involves employment stability, because of the lay off of workers when there is an adjustment of output. This situation creates new jobs too, hence the possibility of loosing them, due to a possible break of the stability.

So a government which cares both for profits and output stability will have an objective function that will depend on the time preference, the firm’s profit, the loss in production due to instability, and its instability aversion.

A positive demand shock leads to an increase in output production, by both the cartel and the competitive fringe. The volatility in production decreases as the time preference parameter and the instability aversion parameter increase.

So it can be said that countries with a heavy preference for current profits will join the cartel, abandoning the idea of a rich long term economic performance and per capita output growth.

For countries that care about output instability it is better to enjoy the cartel prices, but have a low output variance too.

It’s important to underline that if there is a low volatility of the oil market all the oil exporting countries would join the cartel.

3.2.2 The real structure of OPEC.

The real structure that OPEC assumes has been inquired by a lot of economists.

The principal question is if OPEC is really a cartel which faces a competitive fringe.

The main hypothesis about its real structure have been tested by Griffin, for the period 1971-1983. The different explanations of the market are:

1. the cartel model;
2. the competitive model;
3. the target revenue model;
4. the property rights explanation.

Already investigated the hypothesis of the dominant firm, here is shown the one of the market-sharing cartel model that allows the change of market shares over time.

The simplest point of view is the one considering constant market shares.

This market share (Q^0) is supposed to depend on a derived demand that depends on the world demand (Q^W), which derives from price (P) and economic activities (A), and the non-OPEC supply (Q^{NO}), which depends again on price and on exogenous supply variables (Z).

$$Q^O = Q^W(P, A) - Q^{NO}(P, Z)$$

Each country produces:

$$Q_t = \alpha'_i \, Q_i^{OO} \qquad\qquad i = 1, \ldots, n$$

Where α_i represent the fraction of total OPEC production, and α'_i is

$$\alpha'_i = \frac{\alpha_i^*}{(1 - \alpha_i^*)}$$

Which is supposed to be a function of price.

Three different types of the market sharing model are tested: constant market sharing, market sharing, and partial market sharing.

Another possible explanation given to the real structure of OPEC is the one presented by MacAvoy. It explains oil prices by the simple rule of supply and demand.
The competitive model sees the current production as a function of price (P), user cost (U), and current extraction cost (M).

$$Q_{it} = S_i(P_t, U_{it}, M_{it}) \qquad \text{with} \qquad i = 1,\ldots,n; \qquad t = 1,\ldots T$$

Conducting the test user costs cannot be estimated, so there is a lack in it.
The target revenue model instead states that the internal investments needs determine oil revenue needs.
Once the necessity of investment is satisfied there is no need to produce more oil.
Clearly it involves the absence of foreign investments, the long run of the internal investments, and the role of unique source of revenues of oil.
It will be:

$$I_{it}^{*} = P_t Q_{it}$$

Increases in investment needs lead to an increase in oil production (Q), and a price (P) increase leads to a fall in output.
The property rights explanation looks to the period of 1970s as a period when there was the transfer of ownership to the producing countries of oil, leaving the international oil companies.
The host countries tend to apply much lower discount rates, leading to an increase of prices and to production cutbacks, because of the passage from a high real discount rate to a low real discount rate, following Hotelling.
So the control operated by governments influences production: the more the government controls it the bigger are the cutbacks.
Conducting the tests, Griffin reaches this result:

Models	A. OPEC Countries		B. Non-OPEC Countries	
	Do Not Reject	Reject	Do Not Reject	Reject
1. Cartel				
Constant Market Sharing	1	10	0	11
Market Sharing	5	6	2	9
Partial Market Sharing	11	0	8	3
2. Competitive	6	5	10	1
3. Target Revenue				
Strict Variant	0	10		
Partial Variant	9	1		
4. Property Rights	6	5		

Table 4-Summary of Hypothesis tests. (Griffin)

It can be seen that there is an important support to the cartel model for OPEC countries, with partial market sharing.

It has to be underlined that partial market sharing represents a looser cartel model because market sharing considerations partially affect production decisions, but the cutbacks do not need to be proportional.

Non-OPEC producers on the other hand, respect the position of a competitive model.

3.3 A market affected by oil shocks: The exchange rate market.

Paul Krugman (1980) traced a theoretical model to estimate the effects of an oil price increase on the exchange rate of two different currencies.

The original model was developed considering Dollar and Mark as currencies. It can be easily adapted to an analysis of the exchange rate of Dollar and Euro.

Considering the two different effects, the short run and the long run, it has been shown that they can go in opposite direction.

Indeed it's important to consider the direct effect on the balance of payments of a higher price, but the indirect benefit too, deriving from OPEC's spending and investments.

In the short run what has to be considered is the financial implication, so investments of OPEC, while in the long run the attention has to be focused on real factors, as the oil dependence of the country, and the OPEC's income spent on country's goods.

The model developed explicates the effects on U.S. dollar, and is a partial–equilibrium portfolio model.

World is considered composed by three countries, U.S., U.E., and OPEC. OPEC is supposed to export just oil, and its price is assumed to be fixed exogenously in dollars.

U.S. and U.E. are supposed to produce manufactured goods and to sell them to OPEC and between the two countries.

The real price level and the real income one of the industrial countries are given.

U.E.'s trade balance (T) measured in dollars is:

$$T = T(V)$$

Where V is the euro price of the dollar.

Volumes of oil imported by the two countries are exogenously fixed:

$$O_A = \overline{O}_A$$

$$O_E = \overline{O}_E$$

$$\overline{O} = \overline{O}_A + \overline{O}_E$$

$\overline{\mathrm{O}}$ is the total oil export of OPEC, A stays for America and E stays for Europe.

OPEC dollars expenditure (X) on U.E. and U.S. goods is:

$$X_E = \gamma(V)X$$

$$X_A = [1 - \gamma(V)]X$$

Where X is the total expenditure of OPEC.

It's important for the issue examined to note how OPEC imports answer to OPEC export earnings, and the lag in the adjustment.

OPEC's dollar spending depends on income, and it adjusts gradually to the level of dollar export earnings:

$$\overset{*}{X} = \lambda(P_O \overline{O} - X)$$

Looking to the asset markets there are just two assets, dollar (D) and euro (E), and all the three countries held both.
Industrial countries hold a fixed amount of the foreign currency:

$$\frac{E_A}{V} = H_A$$

$$D_E V = H_E$$

With E_A that is American euro holdings and H_A, H_E as constant terms.
Total wealth of OPEC (W_O) is:

$$W_O = D_O + \frac{E_O}{V}$$

A fraction (α) of the wealth is held in Euro and a fraction (1-α) in dollars as:

$$\frac{E_O}{V} = \alpha W_O$$

$$D_O = (1-\alpha) W_O$$

The European current account in dollars, the American current account and the OPEC current account are:

$$B_E = T(V) + \gamma(V) X - P_O \overline{O}_E$$

$$B_A = -T(V) + [1-\gamma(V)] X - P_O \overline{O}_A$$

$$B_O = P_O \overline{O} - X$$

With

$$\frac{\partial B_E}{\partial V} > 0 \qquad \text{and} \qquad \frac{\partial B_A}{\partial V} < 0$$

The rate of change in OPEC wealth takes into account gains and losses on its European currency:

$$\Delta W_O = B_O - \alpha W_O \left(\frac{\Delta V}{V} \right)$$

For continuous changes there is a flow of capital into Europe, that is:

$$K_E = \frac{\overset{*}{E}_A}{V} + \frac{\overset{*}{E}_O}{V} - \overset{*}{D}_E$$

And the balance of payments for Europe is:

$$B_E + K_E = 0$$

An increase in OPEC expenditure improves the current account of each country, and for that there has to be an appreciation of the dollar in the case of America, and a depreciation in the case of Europe, to restore the equilibrium.

If OPEC expenditure has to rise from its long run it improves the current account of Europe, for the spending part of it on European goods. On the contrary OPEC would be facing a current account deficit, that has to offset by liquidating its holdings on Euro, and this would worsen the European capital account.

Hence the effects of an oil price increase depend on the share of Euro in OPEC's portfolio (α), the share of European goods in OPEC's imports (γ), and the European share in world oil imports ($\sigma = O_E/\overline{O}$).

The short run effect depends on the comparison of the value of σ and α, while the long run effect depends on the one between γ and σ.

Firstly an oil price increase worsens the situation of America and Europe because of the rise of their import bills. There is also an improvement of OPEC investments in Dollars and Euro.
The net effect for the dollar depends on if the value of OPEC's investment in dollars is more than America's current account deficit. In the long run OPEC stops investing abroad and what is important is just the goods market.
The directions of the long run effect and the short run one can be opposite as said.
It can be said that an oil price increase can lead firstly to a dollar appreciation, and later to an even greater depreciation.
Putting on the model two complications, as the effect of oil prices in oil consumption, and the effect of market anticipation of exchange rate changes some changes are observed.
Imagine two demand curves for oil imports with maybe different elasticities, but surely less than one:

$$O_A = O_A(P_O)$$
$$O_E = O_E(P_O * V)$$

This changes both of the effects, because of the change in the share of the marginal burden of an oil price increase.
The share variable becomes:

$$\sigma = \frac{[O_E(1-\varepsilon_E)]}{[O_E(1-\varepsilon_E) + O_A(1-\varepsilon_A)]}$$

Considering market expectations the long run effect and the short run one don't have a big distinction as before. So real factors can dominate both effects.
In fact if V is initially expected to fall, the rate's path will have an initial discrete devaluation of the dollar, followed by a greater depreciation.

If V it’s expected to rise, the rate’s path will rise then fall, even with different values in respect of the case considered before.

Eventually it’s possible to conclude that the effect of an oil price increase depends on if the negative effect on the balance of payments of the industrial countries is offset by the improvement of OPEC’s imports and investments. In the long run what matters are the real factors, for the falling of the importance of OPEC’s investments.

4. OIL AND THE MIDDLE EAST

Most of the oil producing countries are located in the Middle East region. Although they are rich of a fundamental resource they experienced a lower growth than resource poor countries.
As these countries have completely oil based economies they are starting to move toward new sources of growth for the evidence of the coming oil depletion.

4.2 The resource curse.

Stijns has developed an analysis on the economies of oil rich countries to show the fundamental characteristics present on these economies. It shows that oil rich countries present better education, more market oriented economic policies, and more favourable investment-saving characteristic than other developing countries.
He investigates different explications of this evidence. He argues that it may be that resource rents allow the country to have better education and all the positive effects mentioned before. On the contrary it could be that countries with a higher human level have facilitation on discovering and exploiting their natural resources.
This is one side of the coin.
Many researchers sustain the thesis that natural resource abundance has adverse consequences on economic growth. Looking at the evidence indeed, since the 1960s, countries with less endowment of natural resources have outperformed the ones with an abundance of them.
This phenomenon has been named the resource curse.
Different models investigate the relationship between abundance and growth for oil rich countries.

4.2.1 The Dutch disease view

One possible explanation given to the evidence of the low growth of oil rich countries is the one that considers the possibility that oil extraction crowds out manufacturing activities, leading to violent and inefficient political behaviours. This hypothesis is called the “Dutch disease”.

Firstly Sachs and Warner dealt with Dutch disease as the explanation of the curse. They empirically demonstrated the evidence of an inverse statistical relationship between natural resource based exports and growth rate, during the period of 1970-1990.

To sustain their hypothesis they start observing the casual fact that there is no coincidence between countries with large natural resource endowments and high levels of GDP. Even more, countries with the highest endowment, as the ones of the Persian Gulf, don’t have sustained rapid economic growth.

The regression shows the trade off that occurs between high resource intensity and low growth. The result keeps the same, even adding a lot of different variables.

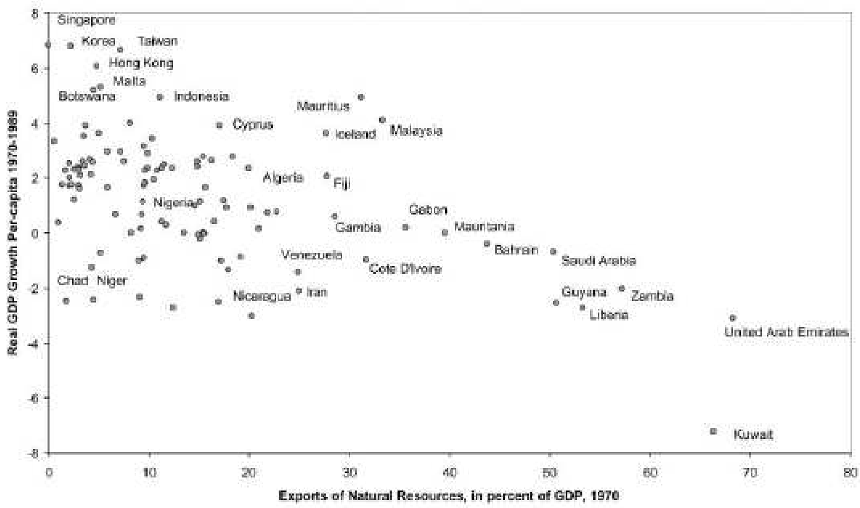

Figure 10-Growth and natural resource abundance 1970-1989. (Sachs-Warner)

With the exceptions of Mauritius, Malaysia, and Iceland, the resource poorer countries are the ones that have developed most.

To improve their analysis Sachs and Warner have considered the presence of another variable, constant during time, that could affect growth, for example the country's geography.

The outcome of the analysis is that there is no correlation between geography and the endowment of resources. The central idea of the analysis is that through time countries with favourable geographic conditions will grow for a while reaching a high income. Hence the share of natural resources in the economy will appear to be modest, because the rest of the economy has grown. The countries with no favourable geographic conditions instead will appear to have a bigger share of the resource, because their economies have not grown. Hence they will appear to be rich resource countries. Measuring growth and natural resources as a share of GDP, we would find a negative relationship between the two variables. But this could be due to the presence of the geographic variable not considered.

To investigate this Sachs and Warner present two different ways.

In the first method previous growth is used as a proxy for the geographic variable, if there is not the possibility of measuring it directly.

Then it's important to note if the natural resource variable still stays in the regression.

The second method controls the variable directly in the regression.

Using the two tests Sachs and Warner have demonstrated that the result stays the same, the evidence of the resource curse keeps present in the regression.

One explanation of the curse given by the two authors is that natural resources crowd out an important activity that should has drown growth, as traded-manufacturing activity, actually harming growth.

They sustain that a positive wealth shock in the natural resource sector creates an excess of demand of non-traded goods, that drives up the non-traded goods prices (i.e. wages).

But these non-traded goods are used as inputs in the manufacturing sector that still sells its goods at fixed international prices.

Hence this mechanism leads to a decline in the manufacturing sector that harms growth.

To test this hypothesis the authors checked the real presence of higher non-traded prices in resource abundant countries.

The instrument is the general price level, which should be higher in resource abundant countries. It would depend on the higher non-traded prices in resource abundant countries and the constant traded prices across countries.

The national price level is usually positively associated with levels of income across countries. In the regression Sachs and Warne have used the ratio of the country's purchasing power parity exchange rate to its nominal exchange rate, and the result that follows is that there indeed is the presence of higher price levels for resource abundant countries.

Hence other sectors in these economies front the problem of competitiveness.

This could lead to impede exports growth. Resource rich countries show a scarce contribution from export growth of manufactures. It could depend on the promotion activity too. Hence there is not export-led growth in these countries.

Another activity that should be a part of the explanation of the curse could be education, as investigated by Gylfason (2000). The model presented by Sachs and Warner stands in this particular case, and for other activities too, instead of the manufacturing sector.

4.2.2 The role of institutions: rent-seeking and political competition

Another factor considered by authors are the institutions. In fact the evidence shows that the curse doesn't occur for all the resource abundant countries, so the explanation could be different from the one proposed above. Countries as Australia, Canada, New Zealand, the U.S., Iceland and the Scandinavian countries have experienced a resource-led growth.

Hence the different performance can be explained by political and institutional differences.

There are three different visions of the interaction between economic growth, resource abundance, and institutional quality.

The first one is the one from Sachs and Warner presented above. It sees institutions as an intermediate casual link between resources and economic performance. The main explanation used by the sustainers of this view is that oil dependency tends to hinder democracy. By more, resource booms can lead politicians to dismantle institutions in order to obtain private gains from the extraction.

Although the observation of evidence agrees with the presence of these kinds of problems in institutions, there still is the doubt of the grade of the curse.

Another hypothesis considers institutions having a neutral role on the curse.

The last one is the one that sees institutions and resources co-operating in generating the curse.

The model developed by Mehlum, Moene and Torvik (2006) takes into account the relationship between production and rent seeking.

If the most effective rent seeking is outside the productivity part of the economy, the two activities are competing. They are complementary activities instead when there are producer friendly institutions.

In the first case the presence of rent seeking in the hands of “grabber-friendly” institutions leads to corruption, crimes, frauds, extortions, warlordism, and so on.

So there is a disadvantage from being producers in the competition for natural resource rents.

When institutions are “producer friendly” it’s necessary to be a producer for being a rent seeker.

The consequences of a good quality of institutions are low corruption, high bureaucratic quality, and so on.

In the presence of grabber-friendly institutions entrepreneurs find higher gains going into unproductive activities. Assuming that there is a defined number of entrepreneurs, that can choose to be producers or rent-grabbers, they move in the two directions until the return in both activities is equal. Grabbers are better off when they are a low number because they take advantages from the higher number of producers. Producers instead have higher returns the higher their number, because the return for a producer depends on the total income of the economy.

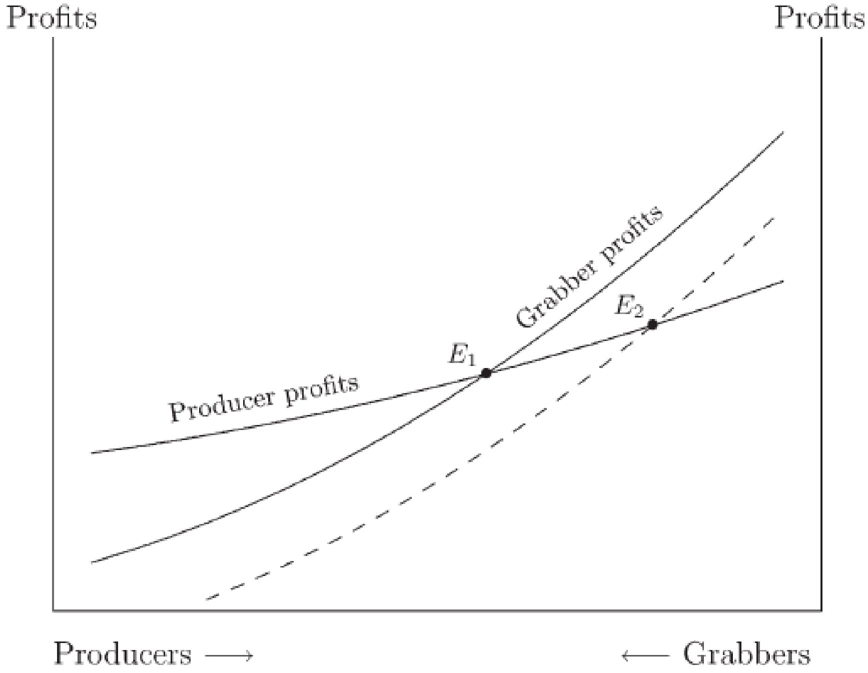

Figure 11- The Allocation of Entrepreneurs. (*Mehlum, Moene, Torvik)*

Another advantage for producers of their high number is that having a fixed number of entrepreneurs the presence of grabbers is low.

The grabbers' profit curve is steeper than the one of producers, because an increase of the number of the formers is more damaging themselves than producers. It is due to the lower number of the latter that would be present and to the higher competitiveness.

Point E_1 is a stable equilibrium, as there is no incentive for any entrepreneur to move from his position.

The dashed line in the figure indicates a movement towards more producer friendly institutions that make less profitable being a grabber.

The new equilibrium shown has got higher profits for both parts of the game.

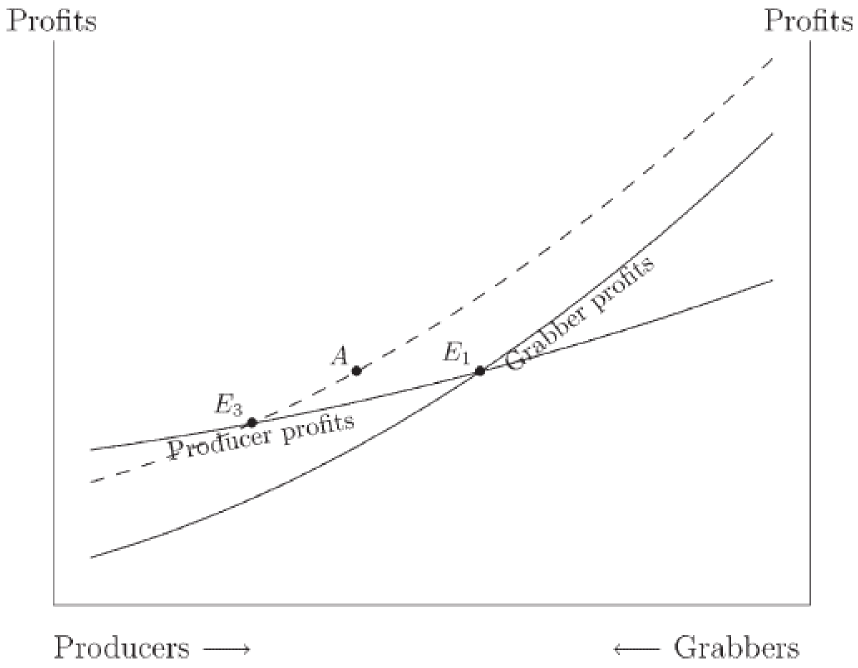

Figure 12- Resource Rents with Grabber-friendly Institutions. (*Mehlum, Moene, Torvik)*

In the presence of grabber friendly institutions instead resource is a new source of income for grabbers, and their profit curve shifts up.

The new equilibrium has got lower returns for all the actors.

Here it comes the resource curse, where higher resource income reduces the total one.

There is a reduction of the opportunity cost of grabbing; entrepreneurs move to grabbing and producers' income lowers, pushing more producers to move into grabbing.

Hence there is the evidence that grabbers generate negative externalities, and producers positive externalities.

In the presence of completely producer friendly institutions instead, natural resources are an additional source of income for producers, so that their profit curve shifts up.

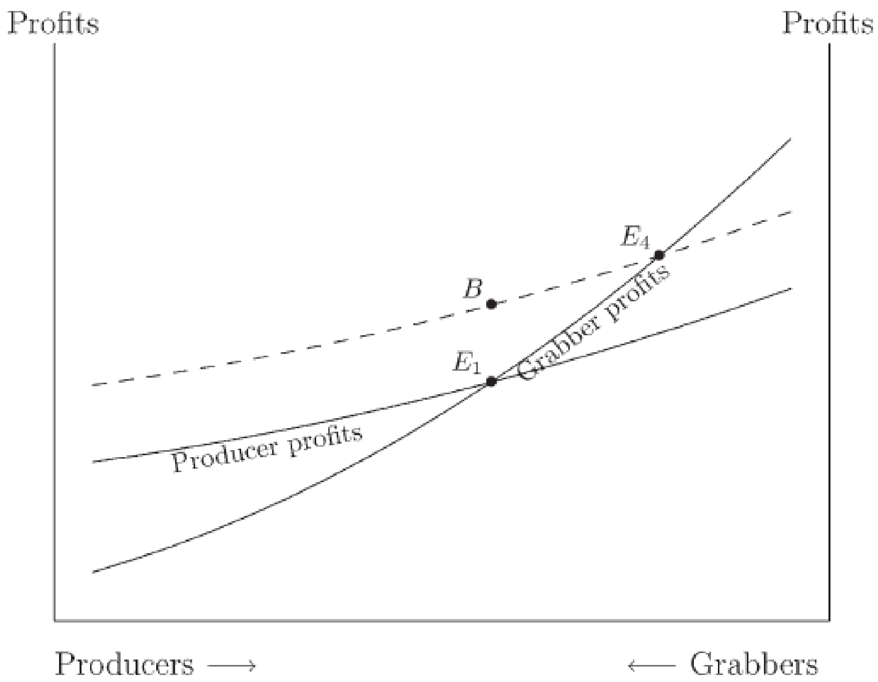

Figure 13-Resource Rents with Producer-friendly Institutions. (*Mehlum, Moene, Torvik)*

Here it's possible to see the beneficial effect of the resource, as the total income is higher than the one of the resource.

In both cases the authors show that the resource income has got an amplified effect on the total income.

An institutional quality index has been added to data used by Sachs and Warner. Rule of law, bureaucratic quality, corruption in government, risk of expropriation, and risk of government repudiation of contracts are the indices involved in the creation of the quality index.

The index runs from zero (low quality of institutions) to one (high quality of institutions).

The growth impact of an increase in resources results negative for more countries, and even more, the magnitude of the effect depends on the quality of institutions.

This result is stronger in the case of mineral dependent economies.

In the sample of 87 countries taken by Mehlum, Moene and Torvik just 33 countries show a sufficient institutional quality to avoid the curse.

A detailed examination of the political foundation of the resource curse is given by Robinson, Torvik, and Verdier (2006).

They developed the model especially for resources of which rents accrue to the public sector, as oil.

The model considers two politicians, one is the incumbent, and one is the competitor. Clearly both want to be elected.

There are two periods, with the election occurring at the end of the first one.

The incumbent has to take the decision of how much of the resource extract in the first period, and how much in the second one.

He can decide if consume the income of the resource or distribute it to influence the election, in the form of offering public employment.

This kind of offer is credible because employment can be given in advance and is costly to reverse.

The model leads to four main results that are: first, politicians care about the future stock of resources just if they will be still in power, so they tend to over-extract them relative to the efficient extraction path. Their evaluation of future stocks is lead by the probability of being in power later. Second, permanent resource booms improve the efficiency of the extraction path, because the value of being in power later is higher. Third, permanent resource booms increase the misallocation of resources in the rest of the economy too; politicians indeed tend to improve public employment to stay in power, leading the sector to a higher inefficiency.

Fourth, resource booms can lead to a beneficial state or a negative one due to the kind of institutions.

In a voting model the politician takes in consideration his own utility and the one of his own group. The intertemporal price path of the resource is given.

The decision for the incumbent is whether consume himself the resource rents, transfer them to citizens, or employ people in the public sector. He also can put tax on incomes.

Voters of each group have linear preferences in their income, where Z^i_t is the income of the member. The utility of the politician V^i_t is given by the income of himself (X^i_t) and the weight of the concern for the members of his own group (α).

$$V_t^{\,i} = X_t^{\,i} + \alpha \int Z_t^{\,i} di$$

With α that varies between zero and one.
Per period income of the voters is given by

$$Z_t^{\,i} = \omega_t^{\,i} + T_t^{\,i} - \tau_t^{\,i}$$

Where ω^i_t is the wage income, T^i_t is the transfer to the voter, and τ^i_t is the lump sum taxes paid.
Productivity is higher in the private sector, and it’s assumed that the difference, considering productivity equal to zero in the public sector, between the productivity in the two sectors is H, that also represents the private productivity.
W_t is the wage in the public sector, and δ is the maximum tax that can be paid by the agent. Ha can indeed hide all income from taxation at his cost.
G_t is the number of workers in the public sector, and 1- G_t are the ones employed in the private one.
F is the cost for the citizen to be fired.
For calculating the probability of a re-election for the incumbent the model considers also the ideological inclination (σ^i, with density s>0) in favour of the incumbent named A.
The competitor is named B.
The voter would support incumbent just if

$$Z_t^{\,i}(A) + \sigma^i + \theta > Z_t^{\,i}(B)$$

Where θ is a popularity shock in favour of the incumbent. After winning the elections there is the possibility of the renegotiation of the wages of the employers of the first period, and the possibility of firing too.

Analyzing the behaviour of politicians it's possible to predict which policies could be credible. A promise of lower taxes is not, because the politician would set taxes in order to maximize his revenues.

A promise of transfer is not credible too, because of the higher evaluation of his income by the politician. Because of the higher importance of his income there won't be hiring in the public sector after the election, because this sector is inefficient, and there is not enough production.

There are two different kinds of wage renegotiations: the one with a member of his own group, and the one with a member of the other group.

The first case is

$$\max_{W}\left[(-W+\alpha W)-\alpha(-F+H)\right]\left[W-(-F+H)\right]$$

(-W+αW) is the utility for the politician of hiring the member of his own group at a wage W, α(-F +H) is the utility of firing the same member, and W-(-F +H) is the surplus relative to the second period of employment for the member. This kind of renegotiation would take place if F>H.

The negotiations with the member of another group would be

$$\max_{W}\left[-W\right]\left[W-(-F+H)\right]$$

It's simply to say that the negotiation between the politician and the member of this group would never take place, because firing is always better for the politician.

Members of the group B already know that they will be fired after the elections if the incumbent wins, and they will be not if the competitor wins. There is not hiring of members of group B because of the knowledge of this situation of the incumbent.

The model shows that the re-election probability for the incumbent depends on the number of public and private employers of group A that support him, and on the share of voters of group B that support the incumbent.

Deriving the re-election probability equation, the authors show that hiring public sector workers from people of incumbent's group increases the probability of staying in power.

Hence clientelism has a good consequence on his probability of re-election.

This model reaches the conclusion that the optimal number of public employees after the election equals the number of before.

The authors have developed a similar model in the case of a dictatorship. In fact the dictator would have to face a similar probability, adding as variables the loss in popularity due to be a dictator, the size of the group necessary to support him, and the heterogeneity in ideals of the population.

The socially optimal extraction of the resource in the first of the two periods considered is:

$$\max_{e} p_1 e + p_2 R(e)$$

So

$$p_1 + p_2 R'(e^e) = 0$$

Where e is the physical quantity of resource extracted in the first period, R(e) is the quantity left to the second one, and p_1 and p_2 are the prices at the different periods.

In the situation described resources are over extracted inefficiently, such that $e > e^e$, as the politician discounts the future stock of the resource by the probability of his re-election, and as it is lower than zero, the incumbent will over-extract the resource in the current period.

Developing this kind of model Robinson, Torvik and Verdier reach the conclusions that a permanent resource boom reduces resource extraction, leading the extraction path closer to the efficient one. Through history it's clear that the rate of oil is extraction tends to rise when oil prices are lower, and vice versa. It could be due to the OPEC's behaviour, to push oil price up, but this happens also in countries that are not part of OPEC, and in such a small countries that cannot influence oil price in the market too.

This happens in the presence of an anticipated future resource boom. When the resource boom is temporary instead resource extraction increases moving away from the efficient path.

Another consequence of a permanent resource boom, or an anticipated future resource boom, is the increase of the public sector employment, and so the decrease of the private sector one.

It happens because the incumbent has a higher incentive to remain in power, for the perspective of having higher rents.

So there is the contemporary presence of a beneficial effect that is the efficiency of the extraction path, and a negative one, that is the decrease in the efficiency of the economy due to the misallocation of labour.

When the boom is temporary instead, the incumbent has not so a high incentive to stay in power later, so he doesn't employs more citizens in the public sector.

The effects that can have all three types of booms over the all economy are ambiguous. In fact, for example in the case of a permanent boom, the three effects of a boom, the direct increase in income, the indirect one by the extraction path, and the indirect decrease by the misallocation of labour, can have different magnitudes, and so lead to different outcomes over the total economy. A similar reasoning can be done in the case of other booms.

One consideration that can be made is that income is more likely to go down the higher is the power of the incumbent on influencing the probability of his re-election, so a resource curse occurs.

Hence with the presence of meritocratic institutions resource curse could be avoided.

The problem of the misallocation of resource rents due to public wages and salaries is reflected by the analysis of Hamilton (1998) about the level of genuine saving rates on a wide range of countries.

Genuine saving represents the net saving rate extended to include technological changes, human resources, exhaustible resource exports, resource discoveries and critical natural capital. Measuring negative rates of genuine saving implies non-sustainability of the path, so the decline of the per capita welfare, and the one of GDP too. Genuine savings rates are calculated as the net saving rate minus the value of resource depletion. Hamilton shows that a lot of Middle East countries are continually characterized by negative saving rates.

His analysis shows that resource rich countries that present high government consumption too, have on average lower economic growth, so current government expenditure, and its misallocation of rents, could be an explanation for the curse.

The quality of institutions is also involved again to explain the efficiency or not of savings and investments. In fact a good quality of them would grant a transformation of the liquidation of resource wealth into additional genuine saving, although high quality leads resource abundant countries greater savings and investments at a declining rate.

4.2.3 Rent-seeking in Iran: a particular case

Rent seeking has been shown as a source of the resource curse. When it occurs in fractionalized countries there are three main consequences: the competition for rents wastes resources, there is less private investments due to the lack of intellectual property rights, there is a distortion in the allocation of investment founds due to imbalances in the distribution of political power between different factions.

Models of rent seeking state that increased dominance of a faction improve efficiency, lowering competition on rent seeking.

It’s not always like that. In fact in the presence of high subsidies on capital or other factors of production, the low efficiency of the investment can over-perform the reduction in costs due to the lower competition. This is the case of Iran.

Oil revenues in Iran are about 34% of GDP and about 60% of all government revenues. Earnings of oil export are more that the 80% of the country’s earnings with foreign exchanges.

Iran is characterized by four factions fighting for power and rents, so it is highly fractionalized.

The market of savings and investment is controlled by State banks, although there is the presence of few private banks that are heavily regulated by government.

Interest rates are set politically and Iran faces a negative real interest rate.

Even more the concession of credit is done by political reasons, so it is often not efficient.

Another inefficiency is that Iranian industry operates a waste of energy, and wrong energy management. Even more oil price in the domestic market is lower than the one on international markets, so there is an implicit subsidy of about 10% of GDP.

Iranian income is realized from productive activities too, but the lack of property rights on income leads to lower investments, because firms know that a part of their income will be taxed by extortion.

Bjorvatn and Selvik (2005) developed a model showing that “the qualitative effect of changes in the relative political influence between groups on overall economic efficiency depends on the level of subsidies on factors of production like credit and energy. With substantial subsidies, as in Iran today, a bias in the allocation of capital between the groups is the dominating source of inefficiency in the economy, and aggregate welfare is at its highest when groups are equally strong. When subsidies are relatively less important, rent-seeking is the most serious source of inefficiency, and a more imbalanced distribution of political power between the groups is likely to improve aggregate welfare”.[2]

The authors assume that there are two different groups a,b. They have commercial interest and take firstly a decision of investment, then take the decision of the amount of rent seeking.

Investment creates income that is redistributed between firms because of the low definition of property rights.

Taxation reduces the profitability of investment, and efficiency is lead down by the use of resources for grabbing.

So the contest of rent seeking is the one that follows:

$$p_i = \frac{q_i}{q_a + q_b}$$

Where p_i is the share of the total income for the group i, q_i is the rent seeking effort by the group i. R(k) is the size of rent in the economy, due to the total investments in the economy ($k=k_a+k_b$). The influence of the groups is $\alpha_a+\alpha_b=1$.

The objective function guiding the rent seeking effort is:

$$v_i = \alpha_i p_i R(k) - q_i$$

The total rent seeking effort is:

$$q_a + q_b = \alpha_a \alpha_b R(K)$$

That is the highest when $\alpha_a=\alpha_b=0.5$.

The model investigates investment decisions considering the production function. International price of capital is higher or equal to the price of capital in the country.

[2] Destructive competition: Factionalism and rent-seeking in Iran. (Bjorvatn, Selvik)

The optimal investment of the firm increases with an increase of the technology parameter (β), decreases by the cost of capital r, and increases with political influence.
Considering welfare a function of the political influence of the groups for different levels of subsidies:

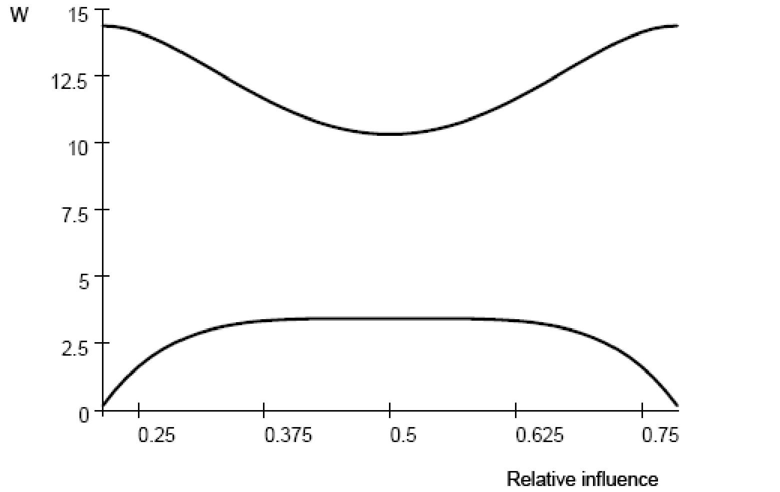

Figure 14-Relative influence and welfare. (Bjorvatn, Selvik)

With low subsidies welfare is at its minimum when α_i=0.5, but with high levels of subsidies the same point represents the maximum welfare, because of investment efficiency.
Because of the high presence of subsidies in factors of production in Iran, as said, a political shift to the favour of one group will lower the whole efficiency in the economy.

4.2 Middle East countries beyond oil

4.2.1 The rate of openness of Middle East countries.

During the last decade of the previous century Middle East countries have attempted at diversifying their economies, to reduce their dependence on oil.

In fact by 1998 the share of manufactured exports in total merchandise exports more than doubled in the entire region.
But this is not enough to grant growth. There is the need of substantial change on the commercial policies applied, and the need of an increase of FDI from foreign, in order to develop new sectors.

4.2.1.1 The role of protection.

Integration is a basic issue for all developing countries, concerning with welfare, growth and job creation.
As seen in the previous part, Middle East countries oil exporters don’t have a developed manufacturing sector most of all due to the resource curse.
As Sachs and Warner demonstrated the presence of the resource make other markets non-competitive they can develop in the internal form neither.
Oil countries use the revenues of their exports to buy almost all their needs for consumption, intermediate and capital goods, and labour services.
In the lack of growth of these sectors of production in the countries also trade barriers are involved. For that these countries are trying to diversify their structure of trade.
It’s interesting to note that they were more opened than other developing countries years ago, through 1960s, 1970s and 1980s.
In 1975 the trade share of oil exporting countries of this area was about 90%.
These countries’ share has fallen from the mid-1970s to the mid-1980s, and then again in the 1990s.

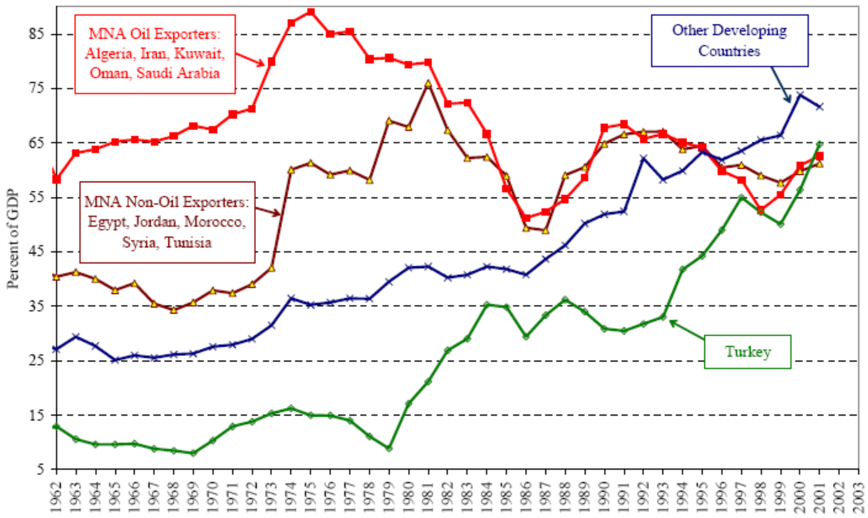

Figure 15- Imports plus Exports as Share of GDP: MNA vs. the Rest of the Developing World (GDP-Weighted Averages). (Salehi Esfahan, Squire)

The drop of the oil prices during the 1990s made resource revenues diminishing, so that oil producing countries were not able to expand their imports as before.

Trade barriers have been used mainly as a second best policy, because of the market failures present in these countries, most of all the failures of credit and insurance market.

I've already explained resource rents are not managed in the correct way. So it was easier for institutions to follow a second best policy, in order to maintain interests of government in rents.

In order to measure the actual integration into the world economy of the oil producer countries, it's considered their openness of trade, regarding to the importance that barriers (tariff or non tariff) assume in these economies.

It is well know that the use of tariffs and import quotas reduces trade as well as standard of living.

In all the region of Middle East trade volumes are low, as trade related services, there is a lack of trade information, the existence of tariffs and non-trade barriers, and the trade structures present do not serve well for trade development.

One indicator to measure the grade of integration of countries is the share of countries' merchandise export in their GDP.

Clearly oil producers have a big share of export on their GDP, about 39,8% with a peak of 44,6% during recent years.

But this not exactly indicates that they are real open economies.

It is also important to note the structure and direction of actual trade of these countries. In fact if one economy sells or buy most of the products to few countries, such an economy could be instable because of what may happen in its partner countries.

Although with some differences, most of oil producer countries export around 50% of their merchandise to their three main customers, so they are highly depending on them. The big exception is Bahrain that has got a percentage of 9,8% of export to the three main customers.

On the side of imports there is more differentiation, with a range of percentage of goods imported from the three main partners, going from 24,6% of UAE, to 51,7% of Oman.[3]

There would be relevant consequences on oil producers if their three main customers would decide to stop buying for any reason.

It would lead to less capacity of import, and to higher pressure on consumers' consumption, because of the reduction of their income.

Considering the issue of trade barriers and analyzing the level of tariffs, oil producers countries seem to have quite high protection for primary goods, and less for manufacturing goods. Only Iran and Saudi Arabia have lower tariffs on primary goods than on manufacturing.

Oman has got a tariff for primary goods of 31,6%. This level of tariffs on primary goods could reflect the importance of agriculture in this country due to the lack of development of manufacturing sectors.

Comparing these tariffs with the ones imposed by U.S., Europe, and Japan, it's possible to see that oil producing countries are rather far from their grade of integration, and it is noticed that only Iran has got a level of tariff lower than 5% for both kinds of goods.

Hence trade liberalisation seems to be a difficult issue to manage. In fact the high level of tariffs imposes an important effort to correctly determine the way to offset budget losses of governments due to their

[3] Data of 2002. SESRTCIC (2005)

elimination. A movement toward a change, in the direction of lowering tariffs, has been led by the raise of oil prices during recent years.

What impedes the complete integration of these countries is not only the presence of trade barriers. An even more important issue in this region is the presence of inefficiencies related to non-trade barriers. Improvements to trade facilitation would lower destination price of the goods.

In many of these countries customs procedure are troublesome because of the requirements of several documents, the need for approval from different agencies for an authorization, and a subjective application of the procedures.

There are also indirect trading costs due to the corruption of public sector, the product standards and certifications, the regulation, and the impossibility for some business visitor to enter these countries, because of visa problems.

Also the transportation system is inefficient and adds costs and delay to the trading environment.

A signal of the consciousness by oil producing countries of the need to go forward a larger integration into the world economy is that almost all of them are members of WTO (not Iran and Iraq).

The accession to WTO imposes these countries to change in a significant way their policies, reducing tariffs and non-tariffs barrier.

Although WTO regulation imposes to the countries joining the organization to behave in the same way with all other countries participating, Middle Eastern members also participate to regional trade agreements (RTAs).

This is considered as an exception to the non-discrimination principle of WTO, considering regional agreements complementary to multilateral agreements, in order to promote the integration of national economies at a regional level.

The Greater Arab Free Trade Agreement (GAFTA) is one of the most important RTAs of all the Middle East and North Africa region.

It involves Iran, Iraq, Bahrain, Oman, Qatar, Saudi Arabia and UAE with other Middle Eastern and North African countries, and it was signed on 1997.

Its main goal is the full implementation of a free trade area: the dead line was 2005 for the higher income Arab countries, and 2010 for the less developed members. It requires a minimum value added to goods by the countries participating of at least 40%.

GAFTA hosts other free trade regional agreements, one of these is the Gulf Co-operation Council (GCC).

GCC was created on 1981 by Bahrain, Kuwait, Oman, Qatar, Saudi Arabia and UAE, and by 1983 had been created a free trade area for agricultural and non-agricultural goods.

Goods had to possess a value added of at least 40% by the council countries, and the producing plant has to be owned at least for the 51% by GCC nationals.

GCC became a custom union on 2003, with an external tariff of 5%, and the goal of a common currency expected for 2010.

Some agreement with other big free trade areas, or custom unions, as EU would lead an increase in welfare and GDP of the countries enjoying, although it wouldn’t be so heavy for all of Middle Eastern countries.

It would be essential for the ones which already have a bigger trade expansion with the custom union.

The expansion of trade and the consequent higher increase on welfare would lead to a higher employment and higher wages too, firstly for unskilled workers, that represent the largest part of workers of oil producing countries.

4.2.1.2 FDI and economic growth.

Another fundamental aspect to encourage the growth of oil producing countries is the development of FDI.

The central role of FDI in developing economies has been shown by evidence.

They can have direct and indirect effects on economic growth. The direct effect is the one concerning the higher capital formation, a fundamental aspect for the evolution of sectors. Many people think that FDI could have the effect of crowding out domestic investments, but this is not a necessary condition, both kinds of investments can take place together, and in the case that FDI supports activities that wouldn't develop otherwise, the effect is clearly positive.

The indirect effect of FDI is characterized by the efficiency gains.

These are correlated mostly with technology transfer, that positively affects total factor productivity, and competition created; indeed what is needed most for the development of new sectors of production is an improvement of technologies, as global economy seems to be technology-driven.

FDI can generate technology spillovers by labour turnover from multinational firms to domestic ones, by technical assistance and by the consequences on management environment they have.

The spillovers of technology transfers are highest the more is the gap between technology equipment of domestic and foreign firms.

The capacity of absorbing new technologies has an important role, accompanied by the structure of trade, that should be export orientated.

Hence it is important to analyze the flow of FDI that interest oil exporters in order to complete the idea about their integration.

During the 1990s while a huge movement of capital flows has occurred toward developing countries, the most from the private sector, all Middle East countries have experienced little flows of foreign investment.

The lack of FDI to these countries has prevented them to live the rapid growth of other developing countries as the ones of Latin America and East Asia.

Observing the evidence until 2000 it's clear that the link between capital flows and the real economy of Middle East countries is weak.

To attract more FDI a substantial issue is the composition of the host countries policies, institutions, and the general economic environment. As said before the actual situation of economic environment in Middle East countries still has many problems, in fact it doesn't supports the improvement of trade and investments.

Generally the most FDI to developing countries are efficiency seeking and vertical. The oil countries are not often involved in the chain of production of the major direct investors mainly because of the composition of their labour force. In fact labour is not cheap here, and not high skilled, because of the low grade of education.

Now traditional patterns of FDI flow are changing.

They have increased a lot in oil producing countries in the last few years. In fact after the bad performance of the 1990s and the first years of 2000s, between 2004 and 2006 some of these producers have seen a big push on their investments. The region has reported a 25.5 per cent increase in FDI during 2006, with a flow of $43.3 billion.

The countries that have attracted more are Saudi Arabia, Bahrain, United Arab Emirates, and in part Qatar, while Oman and Iran have had a medium grade of increase. United Arab Emirates have seen FDI inflows drop by around 24%, from 10.9$ billions on 2005 to 8,3$ billion of 2006. Despite the fall, the UAE still ranks as one of the top recipients of FDI inflows and sources of FDI outflows, ranking third and second respectively out of the 14 economies in West Asia.

The big push in FDI to the Gulf region is due to the huge liquidity in the Gulf due to strong oil prices that attracts foreign investors. In fact although oil prices are supposed to drop again, it is clear from the actual situation that they won't reach again the low levels of the previous years.

Saudi Arabia figures as the second largest FDI target with a 51% growth in FDI over 2005 to $18 billion. The Saudi Arabian General Investment Authority (Sagia) stated that the most FDI were directed to energy-related industries and its derivatives.

The growth on investments in Saudi Arabia comes from an increase by the three main investors (U.S., EU; and Japan), but also to a higher interest demonstrated from other countries.

Clearly the access to WTO has lead countries like Saudi Arabia toward a liberalization of the financial sector, allowing more foreign investments.

In fact the access to WTO would allow economies like Saudi Arabia to exploit new growth path. Mainly small and medium enterprises (SMEs) should closely interact with the WTO through their chambers of commerce and industry to know how they can benefit.

What Saudi economy needs most is more market access to realise its full potential.

Although the Kingdom is the world's major exporter and importer, the business sector hasn’t a real complete participation to the whole world trade yet.

The kingdom is still largely restricted to Saudi and Gulf residents and institutions. So far foreign access to the Tadawul, the only stock exchange in Saudi Arabia, has been limited to a few Saudi mutual funds.

But this is changing. The Saudi stock market regulator announced that a launch of exchange traded funds that will be accessible to external investors, in order to eliminate the Saudi lack of institutional investors.

According to a survey of UNCTAD the surge in FDI in the region doesn’t affect only the oil sector; there is the interest of investors in participating to the booming domestic market of these countries.

The service sector is the one that has attracted the greatest volume of investment. Hence it seems that the efforts of the Gulf countries to diversify their production mainly toward banking and real estate are an important tool to attract investments into the region.

Although FDI are not supposed to continue this trend, this is an important signal, and a push for the development of new sectors beyond oil.

On the side of the banking sector there have been impressive new investment players, such as Dubai newcomer Noor Islamic Bank, that keeps the aim to create the world's largest Islamic bank within five years, spending between $500m and $1bn on individual acquisitions in countries as far apart as Indonesia, Egypt and the UK. But this is not the only case.

Doha Bank will open offices in the United Arab Emirates (UAE), Kuwait, China and elsewhere. The expectation is a significant proportion of Doha Bank's expansion to revolve around the Sukuk (Islamic bond) market, which is growing at about 200% a year.

The big example of the new idea of business of the Gulf is the UAE economy.

It grew 7.4 per cent in 2007 on the expansion of the manufacturing and construction sectors, as well as oil and gas, and non-oil sectors accounted for 65 per cent of the gross domestic product (GDP).

The effort of UAE to diversify its economy away from a dependence on energy exports passes by pouring windfall oil revenues into real estate, financial services and infrastructure.

The share of manufacturing sector to economic growth rose to 13 per cent in 2007 from 12.2 per cent in 2006, and the building and construction sector's share rose to 8 per cent from 7.5 per cent, while Crude oil production accounted for 35 per cent of the GDP, down from 37.3 per cent in 2006.

4.2.2 The Masdar Project: the state of the art.

The importance of going beyond oil for Middle East countries is clearly shown by a giant step of innovation in the use of renewable sources: the Masdar project.

This project implies the construction of the first city of the world with zero carbon emissions, and zero waste.

It is a green community in the heart of Abu Dhabi, UAE, which will recycle all of its waste into usable products or energy.

The city will be totally car free, with a maximum distance of 200m to the nearest transport link and amenities. This will create a walker friendly environment and will be complemented by a personalized rapid transport system. The city will be entirely self-sustaining exploiting wind, photovoltaic farms, research fields and plantations, and solar-powered cooling systems.

This project should demonstrate that combining the latest technologies with the optimum use of local natural resources will provide for sustainable development.

The central role to eliminate carbon emissions will be played by Carbon capture and storage (CCS) method.

CCS is an approach that captures carbon dioxide (CO_2) from large point sources such as fossil fuel power plants and stores it instead of releasing it into the atmosphere. By this method carbon dioxide would be injected directly into oil fields, or other underground geological formations.

The physical and geochemical characteristics of the formations would prevent the CO_2 from escaping to the surface.

The injection into the oil fields could be useful to increase oil recovery, maintaining pressure although plans producing by that mechanism produce less efficient energy. Hence that loss has to be offset by policy makers, in order to be an attractive for investors.

Long-term liability is, however, a significant issue.

In fact the long term storage and its security have not been tested yet, as no large scale power plant have operated so far a full carbon capture and storage system.

This way of operate needs an appropriate regulatory regime in the Middle East, as has been done in other countries as UK.

The main issues are if it’s legal or not to inject carbon dioxide into geological structures, if it is profitable, and the analysis of the long term problem.

Not only the use of CCS, but also the implementation of the other energies applied in Masdar requires a huge amount of capital, as the development of solar energy plants.

Hence a big effort to canalize investments from the capital market has to be operated to reach the goal of the development of this city.

Large-scale demonstrations of renewable technology will play a significant role in encouraging investment and increasing cost-efficiency.

5. THE PRICE OF OIL REACHES 100$: THE CALL ON OPEC, AND THE HOPE ON SAUDI ARABIA

5.1 One of the main causes of the high price of January 2008: the "Theoretical limits of OPEC Members' oil production" report.

OPEC provides by itself to the 40% of world oil supply. Saudi Arabia behaves as a swing producer within the OPEC.

The oil price has reached the 100$ at the beginning of 2008, and OPEC president Chakib Khelil said he expected oil prices to keep rising during the first quarter of this year before stabilising in the following quarter.

One of the main reasons for that raise has been the forecast of the impossibility for OPEC to respect its quota of production for the year 2024.

This thought hangs on Ayoub Kazim's report of December 2007.

Global oil demand is supposed to increase at an annual rate of 1% or 2% up to 2020. In this model the production rate of each member is based on its share in OPEC in the past 25 years.

The author investigates the limit of supply that OPEC could have in three different scenarios.

The first one considers an OPEC's average annual growth rate of 2,7% in the past 25 years; the second one an annual growth rate of 5%, that seems to be more realistic because of the big increase expected in oil demand.

The last one considers an individual growth rate for each member, based on its oil production in the past 25 years.

The model presented by Kazim is developed as follows:

$$E = E_O \exp[\alpha(t - 2004)]$$

E Represents the estimation of OPEC's oil production. E_o is the initial OPEC's oil production. The estimation is an exponential function of time (t), and the annual growth rate (α).

The share of production of each member (S) is:

$$S = \frac{P}{\sum_{n=1}^{n=11} P_n} (\%)$$

Where P represents the contribution to the overall production of OPEC by each member, n represents the oil producers, and the denominator is the whole OPEC production, such that:

$$\sum_{n=1}^{n=11} S_n = 100\%$$

Each year each member sees its reserves (R) reduced by the amount of oil produced in the previous year:

$$R_t = R_{t-1} - P_{t-1}$$

Every year this process is repeated. Once that a member has depleted its reserves, the others will have the responsibility to produce their own shares of production, more the share of the member that fails to produce, until all the members will have completely depleted their reserves.

So the adjusted share for each member would be:

$$S_a = \frac{P_e}{\sum_{m=1}^{m} P_m}$$

Where P_e is the expected oil production of the member, and the denominator represents the total expected production of members excluding the one that has failed to produce. The number of the members still producing is represented by m.
The oil production of each member is:

$$P = P_e + \frac{P_e}{\sum_{m=1}^{m} P_m}(S_{ex}E) = P_e + S_a(S_{ex}E)$$

So it is a function of its expected oil production plus the expected oil production of an OPEC member which failed to produce its share.
In the third scenario the estimation of oil production depends on an annual growth rate (β) of oil production different for each member:

$$P = P_O \exp[\beta(t - 2003)]$$

The following part of the model is the same presented above.
The results on production for the first scenario show what follows:

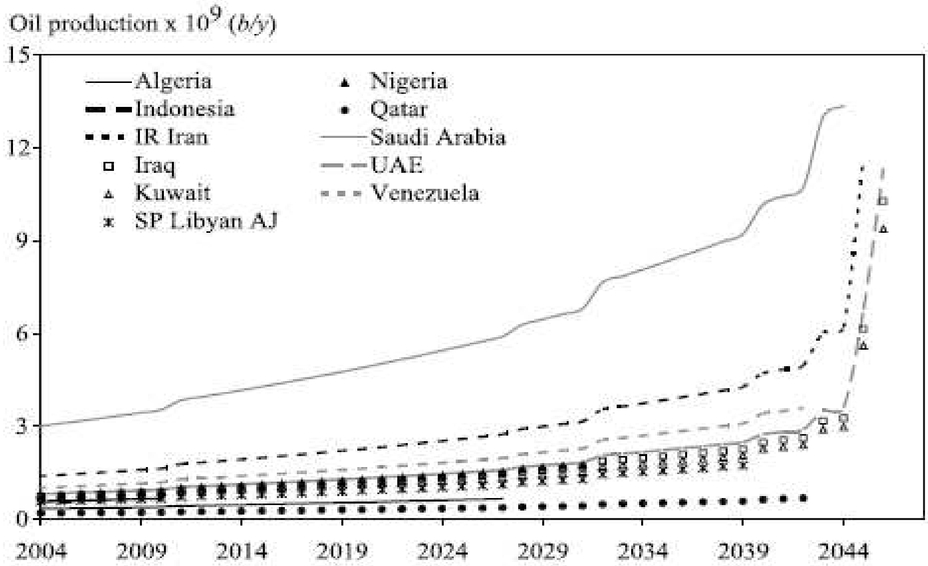

Figure 16- Future production of OPEC Members at OPEC's average annual growth rate. (Kazim)

The complete depletion of oil reserves is supposed to occur in 2048, and Iraq and Kuwait are supposed to be the last two producers.

In the second scenario the rate of failure is greater, and the global production would fail in 2037. Again the two last producers are Iraq and Kuwait.

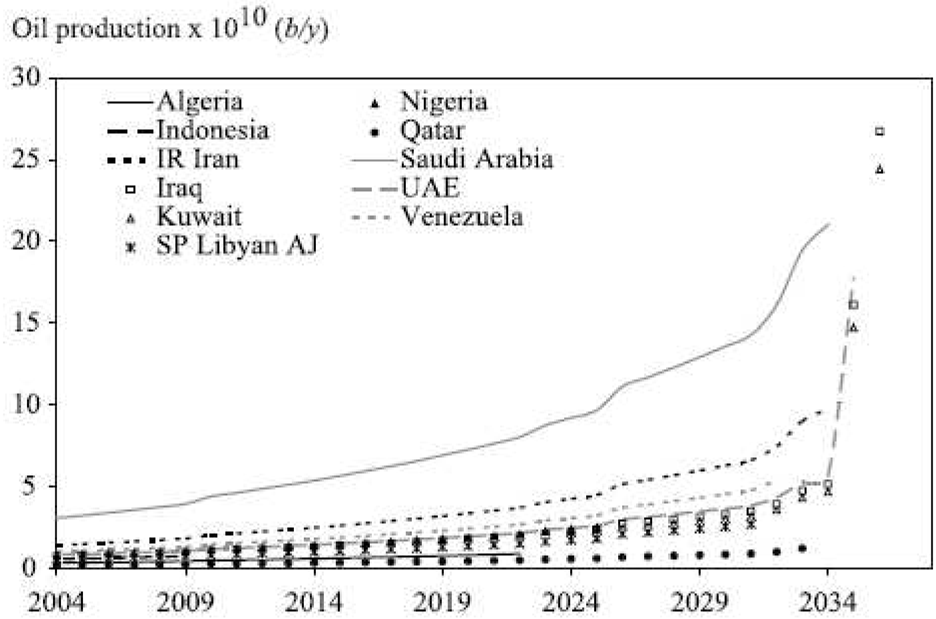

Figure 17- Future production of OPEC Members at annual growth rate of five per cent. (Kazim)

In the third scenario instead, global oil production would fail in 2024, with Saudi Arabia, Iran, Iraq and UAE as last producers.

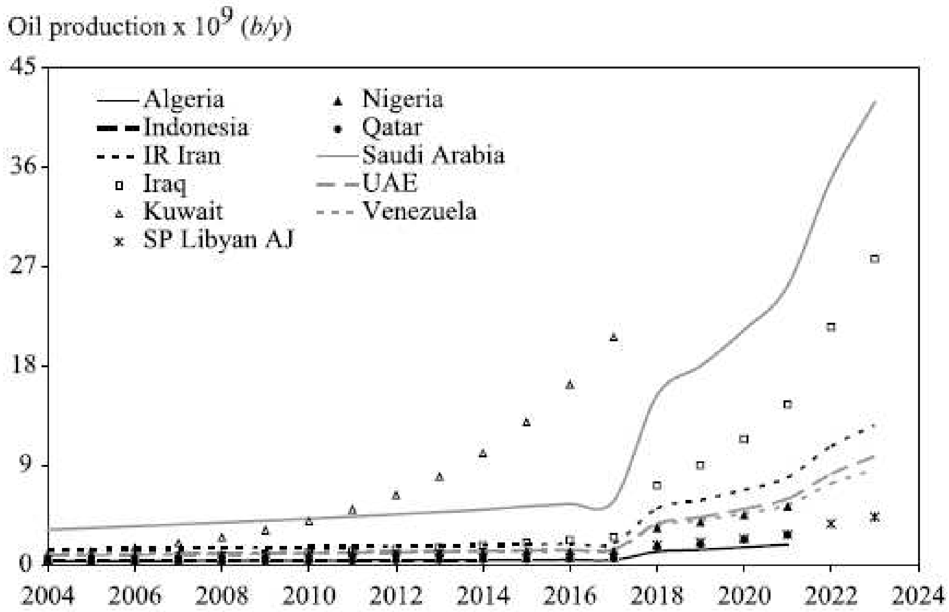

Figure 18- Future production of OPEC Members at individual annual growth rates. (Kazim)

It is the idea presented in this last scenario that has driven the big push in oil prices.

5.2 The general asking for an increase of oil production: the role of Saudi Arabia.

As said the oil price at the beginning of 2008 reached the "limit" value of 100$.

On November 2007 there had been the first signals of the incoming situation, generating fear for consumption, and putting on movement discussions about the need of an increase in oil supply.

In that occasion OPEC didn't seem to want to increase production, talking about their long-term strategies, and their belief in a better situation of the oil price.

Seen the actual situation of oil prices, the most have started asking for an increase in OPEC production, in order to lower prices, although most OPEC members are currently producing at full capacity, so they wouldn't be able to increase their production capacity anyway.

OPEC had an extraordinary meeting on the first of February of this year, and the decision the members made out was not to increase oil production, due to the general idea of the members that oil prices will reach a new equilibrium in the second quarter.

The share of production of all the Middle-East countries has dropped since 1970s, because the growth of other suppliers all over the world as Russia.

But Middle East oil production is supposed to rise again, mainly because of the presence of their high reserves.

About a third of the increase in global production by 2010 that is assumed in the EIA's reference case forecast is supposed to come from Saudi Arabia.

Saudi Arabia possesses the world’s largest onshore oilfield, Ghawar, and the world’s largest offshore oilfield, Safaniya.

Ghawar is the world’s largest and most important oilfield. It was founded on 1948, with a declared quantity of 100 million barrels of oil, and its production is of about 4,5 million barrels per day.

This country declares to possess the world’s highest oil reserves, about 262,300 billion barrels on 2007.

Saudi Arabia is the swing producer within OPEC, with its 30% of the total production of the Organization.

It produces more than the 10% of global oil production, and almost a quarter of the oil globally available for export.

Although Saudi Arabia presents vulnerability in the Kazim’s report, it has been supposed by the most to be the only country that could really be able to increase oil supply in the short-medium term, because of its high declared reserves.

In the first two scenarios presented by Kazim however, it fails to produce right before the complete failure of production of OPEC.

It is due to its high rate of production, such that the time lag derived from its reserves-to-production ratio becomes lower than the ones of other countries.

This country has always played a significant role in the control of short-term spikes, increasing or decreasing oil supply.

Its cost of oil production is one of the lowest in the world: indeed it costs to Saudi Arabia 1,5$ per barrel, while to the rest of the world, oil production costs about 5$ per barrel.

Even more the cost of current production, and of the development of it, is probably one of the lowest in the world.

It has always had “a card” in the game no other country has: spare capacity. This spare capacity has had different interpretation from researchers: the most sustain it keeps a quantity of reserves that has to be exploited as a last resort in the presence of a crisis in the oil market. Others simply justify the presence of this spare capacity as the result of miscalculations about future demand by Saudis mainly between the end of 1970s and 1980s.

The history of Saudi Arabia behaviour shows it has always played in the direction of maintaining stable reasonable oil prices. In fact, it is one of the OPEC countries that are more concerned with long-term strategies in order to maximize oil revenues and maintain its share of production. Given its huge production it has always guided OPEC production and pricing policies.

Also in recent years Saudi Arabia has worked to maintain stability in oil prices. Since 2003 it’s pumping more than 9 million barrels per day in order to offset cuts in production of Venezuela and U.S., and for the lower supply due to the Iraq war, as it did in the case of the Gulf war of 1991.

Hence it is possible to say that in the situation of the oil price at 100 $ there has been a call on Saudi Arabia more than on OPEC.

Mr. Ali Al-Naimi, the Saudi oil minister declared “We live in one world whose geographical and economic blocks are interrelated and affect each other. Excessively high prices could have a negative impact on the world economy, which in turn weakens demand in the long run and causes producing countries to lose their credibility.”[4]

But now the answer of Saudis to those who are asking them for a substantial increase in production, is that they are not inclined to

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[4]Bahgat G. (2003), “The New Geopolitics of Oil: The United States, Saudi Arabia, and Russia”, Orbis, Vol. 47, 3, pp. 447-461.

rapidly exhaust their resource, so they won't pull production in order to contain prices.

Actually Saudi Arabia's production declined 8% in 2006.

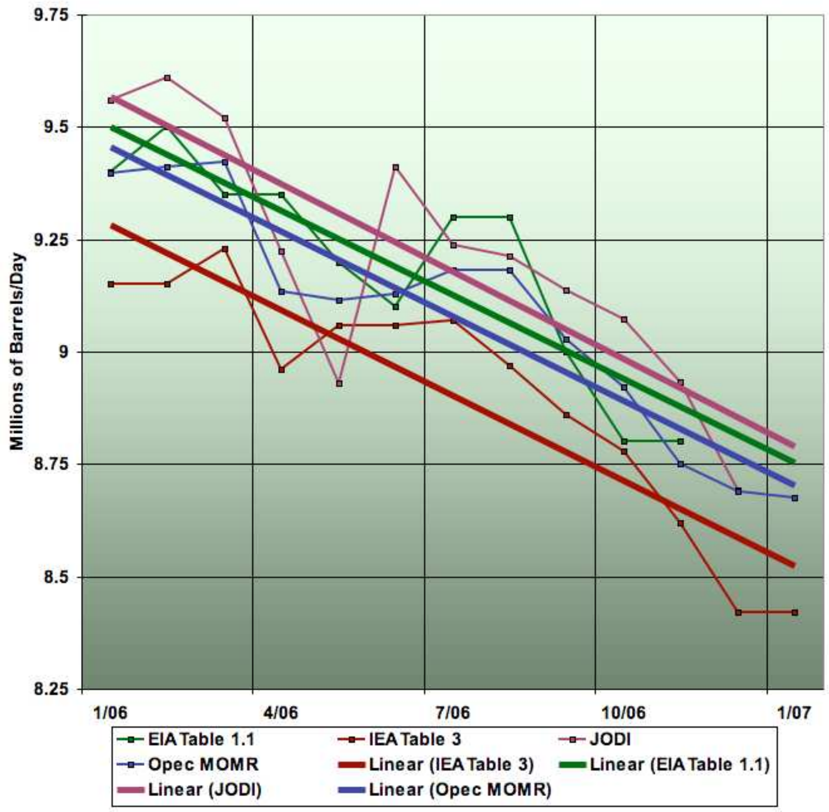

Figure 19- Saudi Arabian oil production, Jan 2006-Jan 2007, from four different sources. Linear trends fitted to each series. Graph is not zero-scaled to better show changes. Click to enlarge. Source: US EIA International Petroleum Monthly Table 1.1, IEA Oil Market Report Table 3, Joint Oil Data Initiative, OPEC Monthly Oil Market Report, Table 17 (or similar) on OPEC Supply. (Staniford)

Saudi data about real reserves and real production of oil are not available, so there are different estimations about them.

Although there are differences on the absolute level of production, due to the different sources utilized, it is rather clear that during the year going from January of 2006 to January of 2007 there has been an important decline in production.

But Saudi Arabia is not the only OPEC member that has operated production cuts.

In fact on October 2006 and on December 2006 there were two announcement of OPEC for production cuts.

These were the projections of the announcements:

Country	Oct announced	Dec announced	Total announced	Actual decline
Algeria	59	25	84	30
Indonesia	39	16	55	10
Iran	176	73	249	50
Kuwait	100	42	142	130
Libya	72	30	102	20
Nigeria	100	42	142	130
Qatar	35	15	50	60
Saudi	380	158	538	200
U.A.E.	101	42	143	100
Venezuela	138	57	195	50
Total	**1200**	**500**	**1700**	**780**

Table 5- Cuts in production ceiling determined by OPEC on October 20 and December 14, and actual cumulative production decline between October 2006 and April 2007, in thousand barrels per day. (Hamilton)

From those declarations Saudi Arabia was supposed to cut its production of about five hundreds thousand barrels per day, but reality has seen Saudi Arabia cutting its production of about one million barrels per day. So it has almost doubled its cuts.

This has had different interpretations: some researchers sustain that Saudi Arabia is actually not able to increase its production, not really having so high reserves, with its oilfield, mainly Ghawar, already in decline.

Others state that Saudi Arabia doesn't want to increase production, for several reasons.

A first taught is that production cuts are due to the lack of willingness of Saudis. Indeed they would still be able to pump more oil than they actually do, but they put more value on maintain their spare capacity to assure future production than produce at full capacity now to satisfy world high demand; this would enforce their powerful negotiation position, and they would gain extra profit in the future.

5.2.1 The physical depreciation of Saudi oil.

Another point of view still not purposed of this situation could be the one that considers natural consequences of the model of Banks.

In fact, as Banks shows, the ratio linking reserves and production should be kept around a particular value, and pump more oil than the efficient level, would damage the oil basin, leading to a physical depreciation of it, having actually less oil to extract.

So it wouldn't be in the interest of Saudis to increase actual production, as their reserves have declined in recent periods.

Following the model of Banks, it's impossible to keep the same level of production on a plateau over time, because of the evident decrease of reserves.

This is actually what Saudi Arabia has done.

Not only Saudis kept the same level of production, they have also increased production in order to satisfy a higher level of demand, due to global growth, and to internal growth from seven million to more than ten million people since 1980s.

This performance has been impossible for each giant oilfield in all other countries.

So it leads to the though that Saudis have already over-exploited their fields, maybe in order to keep their position within OPEC, and a stability in OPEC oil production, and now they try not to depreciate even more their sources.

There is also the evidence of a bad management of the resource in the internal market.

In fact some oil producing countries, also Saudi Arabia, have suffered an energy use growth rate far more than economic growth. It seems due to implicit generous subsidies for energy, as the price of the resource in the domestic market is lower than the global one.

Saudi Arabian growth is more dependent on energy than the one of other oil producing countries.

The direction of the influence between energy and GDP goes from the first to the second, in the short-run as well as the long-run.

It is a big difference with other oil exporting countries, as Iran and Kuwait, that see their direction going on the other way.

In these countries is the growth of GDP which affects positively energy consumption. On the contrary in the case of Saudi Arabia it's energy consumption affecting positively GDP growth, such that the elimination of subsidies could cause a fall in the GDP.

So this could be part of the causes of the overexploitation of oilfields by Saudi Arabia so far, causing the physical depreciation of the basins.

Big oil producers countries have energy consumption almost equal to the consumption of developed countries, which have a so higher GDP.

So Saudi Arabia with its production has faced the growth of the global demand and the internal one without adding relevant reserves.

Saudi Arabia hasn't experimented relevant new discoveries in recent years indeed. Actually big investments have made for research and exploration in other parts of the world, as in Africa or Asia.

Hence the substantial quantity of oil reserves present in the country is related to oilfield discovered a long time ago.

Even more, Saudis have started to involve in production an oil field (Manifa oilfield) that was discovered in the 1950s but wasn't exploited so far, because of the lower quality of the oil present.

With a lack of new discoveries, another instrument that affects reserves is the oil price.

In fact estimations of reserves are often revisited, and the price of oil in the moment of the estimation plays an important role. As reserves do not represent the whole quantity of oil present in the basin, but the quantity that is economically feasible to recover with the current technology, the changes in oil prices affect the technology, which could be developed, and so the feasible quantity of oil. Hence could be argued that high oil prices that characterize the market at the moment could lead to a major quantity of oil recoverable, with the possibility to produce at a higher rate, without damaging the basin. By the way it has to be considered that big steps in improvement of technology have already been done, so it rather difficult that there will be a big difference in the recovery factor from now. Even more there is the evidence of a trend of low expenditures on scientific research and technological development in the entire Arab region, as underlined by a United Nations report of the beginning of 2000s, mainly probably depending on politics problems, as said before.

The change in oil quality could be a sign of the physical depreciation of oil in Saudi fields.

There is the evidence of a lowering in the quality of Saudi oil. As Hamilton writes in one of his articles “China contracted to buy 500,000 bpd of Saudi crude in 2006, but cut that back by 10 percent in the second quarter after refiners ill-equipped to handle the kingdom's mainly heavy-sour oil were forced to slow production after running the grades…”.[5]

The oil actually extracted presents itself so heavy, almost in a solid form, and with a high concentration of sulphur.

Because of their lower quality Saudis operate discounts on the sale of these barrels.

Most of the spare capacity of Saudi Arabia is composed by lower-quality oil with high sulphur content, which can be processed just by few refineries in the world.

Most investments of Saudi Aramco, Saudi Arabia’s main oil producer, have been made to develop new refineries in order to be able to process the low-quality oil. It seems to be a signal of the predominant presence of this kind of oil.

The only high-quality oil that Saudi Arabia still possesses is the one extracted from Saybah oilfield, which was discovered on 1968 but that

[5] “Saudi oil production cuts”, available from http://www.econbrowser.com/archives/2007/02/saudi_oil_produ_1.html. (Hamilton)

has been started to be exploited just 30 years later, with the technological advances that permit oil rigs to pump horizontally.

The Simmons and Company International, a private investments bank specialized in middle-eastern energy, states that the geological formations Saudi Arabia owns, are not able to answer to a so high continuative production keeping high quality.

The main problem caused by over-extraction is the decline it causes to reservoir pressure.

Saudi Arabia faced this problem in its oilfields, mainly in Ghawar.

Using the technique of water injection Saudi Arabia has stimulated production, and reduced the cost of extraction. This way of extraction would guarantee a constant rate of production for a longer time than with traditional technologies.

The global recovery factor average keeps around 29%, but Saudi Arabia declared it owns a recovery factor of 51%.

However the improvement of new technologies from Saudis seems to be so difficult to reach a higher recovery factor in their basins in the short term. So the only possibility would be to install more oil rigs in order to pump more without expanding reserves.

This could be the reason of the difficulty of this country on answering to the ask for a higher production.

The installation of a major number of oil rigs without expanding reserves could be the wrong answer to the problem as said.

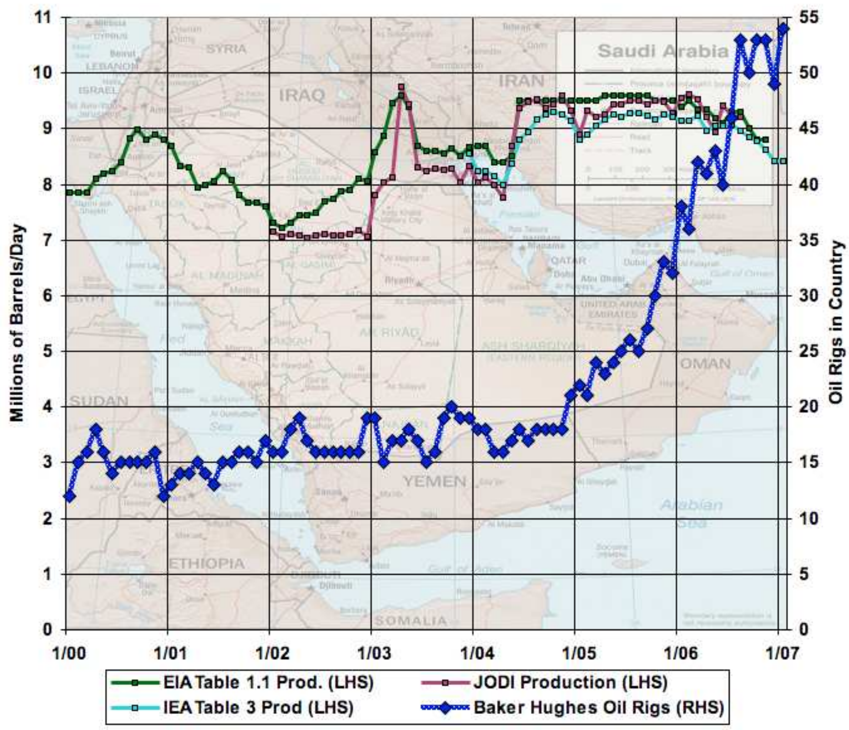

Figure 20- Saudi Arabian oil production (left scale) and oil rigs in country (right scale), Jan 2000-Jan 2007. Source: US EIA International Petroleum Monthly Table 1.1, IEA Oil Market Report Table 3, and Joint Oil Data Initiative for oil supply. Baker Hughes for rig counts. (Staniford)

From that figure it's easy to see that the year in which there have been the most oil rigs installed on the Saudi Basins is the one when Saudi production has declined the most.

It shows exactly the consequences forecasted by the Banks' model.

Concluding, maybe would be incorrect to say that Saudi Arabia is not able to increase its oil supply right now because of the steady depletion of its oilfield.

Clearly a sort of depletion has occurred, and probably most of the oilfields are in decline.

What has to be underlined is that Saudi Arabia is still not as other OPEC member producing at full capacity, so unable to produce more.

Probably the change on behaviour of this country hangs on the consciousness of the consequences a push up in production could have in the future.

Saudis know that they have already overexploited their basins, due to different reasons, as internal and global growth, maybe laying on the thought of new technologies, actually undiscovered, in order to increase their reserves.

At the actual evidence they face an inter-temporal choice: to produce now, or to produce later.

Facts have shown Saudis that is improbable they'll find new technologies to expand their reserves, and their recovery factor with actual technologies has already reached a so high value that doesn't give the hope for an even greater improvement.

Maybe their bad management of oilfields so far is also due to wrong expectations of new findings of oil, as can be argued by their effort to look for oil also abroad.

Following Banks' model, Saudi Arabian bad management of their precious resource has led to a physical depreciation of the basins, forcing Saudis to look out of their habitual sources in order to keep production.

Saudi Arabia has tried to do something that no basin has could done so far: keep, and even increase, production quotas over time without expanding reserves.

The decrease of Saudi production during the year 2006, which is also the period the biggest number of oil rigs has been installed, shows coherence with Banks' model. Probably the R/q ratio of Saudi basins has reached a heavy low value, as the lowest is the value of the ratio, the faster is the decline in production.

Hence Saudis' strategy should be not to push up production, in order to maintain the possibility of producing oil as longer as possible, without lower the final oil flow available in their oilfields.

They have to manage their resource in a more conscientious way than they have done so far, also considering that their growth on GDP depends even more than other oil producing countries on oil consumption, so the need of maintaining a long term production takes heavy importance not only considering the export side, but also the internal side of demand.

Hence a push up in Saudi production wouldn’t be favourable for the entire world, as an even higher rate of production would be destructive as I have said.

6. CONCLUSIONS.

6.1 The development of an hydrogen economy with the help of nuclear and renewable energy.

As said the world is going to face a moment of change in the energy field. Hence it’s important to know which are the perspectives of energy sources.

A lot of alternative energy sources have been developed some way, but the most important competitor to oil as energy supplier seems to be hydrogen, as it is one of the elements most present in nature, although it is not properly a source of energy but a carrier.

It is not often available in its proper natural condition, but it is present mainly in water, fossils, and all living organisms.

Although most of the hydrogen produced so far has been derived by a process of steam reforming from natural gas, thinking about future the most interesting method of production seems to be electrolysis.

Two electrodes are introduced in water and through the continuous passing of electricity, the molecule of water is split, and hydrogen and oxygen are separated.

As it’s shown by an analysis driven by Leven, Mann, Margolis, Milbrandt (2007), the main component of the production cost of hydrogen is the cost of electricity derived by electrolysis. This cost includes capital, operating, and maintenance costs.

The three different primary energy supply systems that can be used to the hydrogen production are fossil fuels, nuclear reactors, and renewable sources first of all solar energy.

Although sources as solar energy, or wind energy are supposed to reduce their costs of production, the main source of energy for the electricity needed it’s supposed to be nuclear energy.

In fact the cost of photovoltaic (PV) to convert the sunlight to electricity is still is too high to be competitive, although is important to underline that from the 1960s so far the cost of PV has declined of about 95%, and is supposed to decline even more, due to technological advantages and economies of scale. Also the costs of wind energy have declined heavily since the 1980s.

In the point of view of competitiveness of costs nuclear energy plays a central role as it is possible to use the small low cost reserves of hi grade uranium.

The main problem of both, solar (or generally renewable resources) and nuclear energy, is that they are characterized by high capital costs, and low operating costs. Hence the minimization of the consumer's cost derives from the full capacity production of these energy systems.

But there is high oscillation of consumers' energy demand. The incongruence between energy production and energy demand can be solved by the storage of hydrogen in underground facilities, that allows for weekly and seasonal storage, in order to meet demand.

The only low cost method of storage is using the same technology of natural gas, as hydrogen is stored as compressed gas. The main constraints that have been observed are the need of very large capacity facilities, and the importance of the site. In fact hydrogen produced in nuclear plants sited near a geological formation that allows the storage, permits lower costs of production because the lack of transport costs.

The cost of nuclear energy is independent of location, while renewable resources are highly dependent on it.

Nuclear power plays an important role also as a competitor of oil by itself.

It plays direct and indirect competition: in the power generation for the first, and in the end use markets.

Although searches (Toth and Rogner, 2006) show there is no relationship between the share of nuclear energy in power generation and the share of electricity in final energy in different countries.

Hence the actual market structure seems to indicate that nuclear energy is not going to undermine the position of oil sales for power generation by itself, putting again attention on hydrogen as future energy supplier.

6.2 Concluding remarks.

Following the projection of many researchers, as firstly predicted by M. King Hubbert, the world is running out of oil.

This is not happening in the literary sense, as when production of oil will end the resource will be still present in the ground, but it won’t be economically convenient to extract.

In fact although there are economists and energy agencies that state the contrary, it seems that their bases of criticism are not supported by reality and data.

King Hubbert had a precise projection of the peak of oil production in the U.S. of 1970.

Now he and other researchers have developed the same model used for U.S. adapting it to the entire world. Hubbert developed a logistic curve showing the relationship between annual production and the quantity of oil that remains to be produced.

As world discovery curve peaked in 1962, and considering the effects on production of the two Arab embargoes, researchers have fixed the peak of oil production between 2006-2012.

Facing this projections the correct management of the resources left becomes a fundamental activity. The model usually used to describe economics, production and consumption of all non renewable resources, is the Hotelling model, developed by himself in 1931.

The fundamental concepts presented are the “scarcity rent”, that is the excess of market price over the marginal extraction cost, and the “user cost”, which represents the opportunity cost of extraction.

This model serves well the most of non renewable resources, but not for oil, as it implies the price of the resource should grow over time, and consumption should remain constant.

Empirical evidence instead demonstrates that price hasn’t grown over time, but the path has been characterize by periods of rise and periods of fall, and in real terms the fall on price has overtaken the rise for a long time.

Hence, here I have presented another approach concerning oil management, the Banks model.

This model takes into account the importance of the Reserves-to-Production ratio, showing its influence on the price path, starting from the Hotelling rule, and stressing the importance of this ratio in the resource management.

In fact Banks states that this ratio should be kept around a critical value, which is often set at ten, avoiding the physical depreciation of the basin that would occur for overworking it.

The overexploitation of the oilfield would lower the flow finally available, because of the impossibility of extracting it with current technologies, and the damage of the basin could be such heavy that could lead to the impossibility of extracting the whole quantity of oil present.

As oil is the third factor of the aggregate production function of developed countries, with labour and capital, the fluctuations on its prices have been often considered causes of recessions, and of the movement of other economic variables. Analyzing this relationship instead spikes in oil prices seems to have a central role only on inflation.

The volatility of oil market prices are one of the two main goals of OPEC. The oil market is represented by a dominant firm model, with the presence of OPEC as a cartel, and a fringe of other producers taking price as given.

The game takes place in two parts: in the first one the cartel and the fringe operate together enjoying a higher price than the one that could take place in a perfect competitive market, growing at the rate of interest.

In the second part the cartel is the only producer, and the price here grows more slowly than the rate of interest.

The second goal for these developing countries is the development of their economies due to output stability. In the case of a country more concerned in this goal, the government would decide not to join the cartel, preferring stability in output, and consequently also in employment.

Spikes in the price of oil affect the exchange rate market. The consequence on a currency in the short run and in the long run can be opposite.

In fact in the short run the increase of investments of OPEC could offset the loss in the current account of the country, leading an appreciation of the currency.

In the long run instead, the real factors, as the manufacturing goods market, take power. Hence there could be an appreciation of the currency first, followed by an even greater depreciation of it.

The world region most involved in this process of oil depletion is clearly Middle East.

Middle East oil producers have completely oil based economies, and the new scenario could have even greater consequences on them than on the rest of the world.

Although they are exporters of a so important resource Middle East countries haven't shown high rates of growth. This phenomenon is called resource curse, and it is explained by different views.

The first one is the Dutch disease view, which assumes that oil rich countries do not grow because of crowding out a sector (i.e. manufacturing) that would be the one to lead growth. The second point of view is the one treating of rent seeking, where institutions have a central role. It's shown that with grabber friendly institution the general welfare of the country worsens. Generally the increasing dominance of a faction in a fractionalized country where rent seeking takes place leads to an increase in efficiency, lowering the competition. This is not always true, such that in countries with high subsidies on factors of production, as the case of Iran, the highest welfare takes place when groups are equally strong.

The political inefficiency in Middle East countries takes place mostly on the too high salaries of public employers. This is due to the willingness of the incumbent to be elected again, "purchasing" power with public employment, such that the public sector is inefficient.

With the lack of growth so far, and with the approach of the end of oil era, Middle East countries are trying to update their economies in order to develop.

They are moving toward a higher integration in trade, with the abolition of trade and non-trade barriers, and participating to WTO, and to other regional agreements.

A big push to their economies cold surely derive from the push on FDI coming from foreign countries. Not only the oil sector is interested by that flow of FDI, but a lot of countries are interested in the growing manufacturing sector of the region, and even more to the service sector.

Within the Middle East area and the OPEC countries, Saudi Arabia is the one which has been addressed to when the oil price reached 100$ on January 2008.

Saudi Arabia has always played a central role on containing the volatility of this market increasing its output. Hence the world has asked Saudi Arabia to increase its production in order to lower the price, but the answer was negative.

There are different positions explaining this behaviour. What I have proposed it’s an explanation derived from the Banks model mentioned before.

In fact, probably, Saudi Arabia would be able to increase its supply at the moment, but as the decline on its production so far and the use of old oilfields with lower oil quality seem to indicate, maybe their production management so far has damaged the basins.

In fact Saudi Arabia has not experimented a significant expansion of its reserves, but has kept its production for a long time, and has also increased it in order to cover other countries’ decline in production.

This is impossible as the model of Banks says.

Hence the general scenario presented shows that the resource on which world has based its way of living is depleting now.

As evidence seems to agree with the models presented here, what is important to concentrate on is the correct management of the quantity of resource still feasible.

Thinking only in terms of the short run could make things worsen, leading to a situation as the one Saudi Arabia probably already is in.

Analyzing the Middle East countries behaviour, it is possible to see two opposite directions.
In the previous period they were more concerned with reducing price volatility. Most of OPEC producers have used output quotas in order to regulate oil prices, giving a sort of stability in a so volatile market.
Some of them have overworked their basins in order to regulate the market, and to maintain their position within the cartel.
Their behaviour was founded maybe mainly on the thought of the possibility of new discoveries. What they seem not to have considered a lot is the development of technologies.
In fact this should be an area interested by huge investments in research, as the economies of these countries are completely oil based.
But reality shows that this area has always been characterized by a low grade of research in new technologies.
Hence these countries seem to have operated without thinking about the future, maybe laying on irrational thoughts and hopes.
Right now instead, with the actual situation, their behaviour seems to be rather rational.
In fact as said with the high price of oil of January 2008 the world has started asking OPEC an increase in production.
The oil producing countries have maybe reached a major awareness of what their previous behaviour has led to the present.
They are facing a heavy depletion of their basins that is in part due to their behaviour of extraction.
The high price of oil of the actual period has numerous consequences on oil producing countries.
If a resource boom is supposed to last over time, leads to an extraction path nearer to the efficient one, hence the lack of willingness to overwork oil basins from OPEC could also indicate that thought. But following this view, also high prices of recent years should have led to a more efficient extraction path. So far instead it hasn’t occurred.

On the other side, the permanent resource boom also leads to an even higher inefficiency in the public sector, due to the higher value for the actual political class to remain in power in order to gain from higher rents.

Meanwhile the development of better institutions is a critical point to improve, to facilitate the formation of a favourable environment for trade development.

With the actual high price of oil Middle East countries could reach a higher quantity of feasible oil in the basins, although this improvement seems not to have the possibility of being so heavy, not to shift the point of peak of production in a significant way.

What is even more important for the development of the oil producers’ economies is that this level of price allows them to have huge liquidity, which is the main reason of the recent flow of FDI toward this region.

Then their refuse of the suggestion of an increase of oil production allows them not to damage their basins overworking them, reducing the total oil available, and even more, allows them to keep one of the most interesting characteristics of the area for the most of countries abroad.

As they have completely oil based economies they have reached the consciousness of the need of other sectors improvements as show the trends of banking and real estate sector.

To do that what is more convenient for them is to have the resource available as longer as possible in order to perceive resource rents, that with this price are even higher contributing to their development.

The willingness of attraction of FDI is also shown by the participation to WTO of almost all oil producing countries of Middle East.

This is important in order to improve their rate of openness and to create a more favourable environment for the development of trade, attracting FDI.

The actual production behaviour of Middle East countries seems rational also regarding the global scene. In fact as said before a push in production would lead to a decrease of the total quantity available of oil. Hence with an increase in production there would be a reduction of price right now, but it wouldn't be useful in the long run, as with the decrease of the quantity available price would rise again, and even more there would be a shorter production path.

As previously said the high oil price of January 2008 has been attributed to the projection that OPEC could be unable to cover its output quota on 2024 due to oil depletion.

As fear seems to be the first driver of this jump in the price of the resource the facts occurred consequently could increase fear, and lead to distorted behaviours.

As OPEC declares it won't push up production in order to decrease price, whit the awareness of the increasing consumption of the resource, due also to the development of developing countries, and looking at previous moments, where OPEC has always increased production when needed, the general thinking is that actually OPEC could have problems for covering its quota, adding fear for a lack of supply.

The negative answer of OPEC with regard to the increase in production, could lead to an even higher fear for the future scenario of its supply, with the consequence of irrational behaviours on the demand side. There could be a shift on demand as mentioned before, that could lead to an even higher increase in oil prices propagating the effects of the actual spike in oil prices.

Hence to avoid heavy consequences on macroeconomic variables, as inflation, countries should implement a monetary policy in order to avoid the propagating of the oil shock.

In fact as spikes in oil prices strongly affect inflation, countries could be led to adopt a monetary policy in order to contain that inflation. But if this monetary policy results exaggerated some way, not carefully calibrated, it can lead the country to recession. Hence likely an interventionist monetary policy would be necessary, also thinking that probably the oil price is destined to rise again, but it has to be properly calculated not to damage the country more than help it.

I have already treated the problem of the impossibility of maintaining the same quantity of oil production for long periods of time.
After the first oil embargo of 1973 there has been the acquisition of a better management of the resource in the entire world. But the improvement reached is not enough.
As said in oil producing countries this resource suffers of high grades of waste, as these countries have rates of consumption equal or even higher of some developed country.
In order to adopt the correct management of the resource is important to eliminate the implicit subsidies present in the internal markets of the oil producing countries.
As said for Iran, the resource is sold at a lower price in the internal market, and this creates different behaviours of consumption, generating waste.
The elimination of the subsidies would finally bring a higher welfare to the countries.
The low price that oil has in the internal markets of Middle East countries allows this behaviour, carrying heavy consequences for the global scene.

What seems to may occur with this scenario in the descending part of the Hubbert curve is the redistribution of power in the world areas.
As Middle East region is the one which owns the majority of oil quantity, in the last part of the production path its power will increase over time.
Developed countries, and the entire world, have completely based their economies and their way of living on oil, hence the necessity of the resource is clear.
At the beginning of the 2008, with the request of the increase in production and the negative answer of OPEC, the situation that is going to come has appeared evident.
The world is becoming more depending on Middle East countries day by day.

Managing the extraction of their resource, they can influence economies and behaviours of all countries all over the world.

Even more oil producing countries are developing the internal consumption in a significant way, reducing the quantity of oil available for the rest of the world. As they are trying to develop their economies, it’s rather possible they will firstly extract quantities necessary for the correct path of their development, leaving the rest of the quantity available to foreign. With the constraint of the reserves-to-production ratio, this quantity available is always less.

The redistribution of power has strong importance in a political sense, as the fight for the oil consumption could lead to wars and other political destabilizing events.

This is a critical issue for forecasting the timing of the end of oil utilization. As said indeed, the descending part of the Hubbert curve strongly depends on political events, and an instable global scenario could lead to a reduction of the production path.

Another aspect that can bring even more power to the region or to some country of the region is the quality of oil left.

Taking into account the case of Saudi Arabia, as said before the quality of oil has changed.

Now the majority of the quantity available has got a lower quality than before, and in some cases such low that becomes impossible for some nations to refine it.

Saudi Arabia is investing in new refineries in order to easily utilize this kind of oil.

This is another big tool of power. In fact there is the necessity of huge investments for developing new refineries to work the new low-quality oil. For that it is not convenient for all countries to make this investments to refine a resource they don’t own, and which quantity is limited. In this case could be important to operate FDI to the countries with the development of these new refineries, in order to be able to work oil.

Hence a country like Saudi Arabia can become not only the main owner of a depleting resource, but also the only one that can refine it.

This gives Saudi Arabia an incredible power over all oil depending countries.

What seems to take even more importance in this emerging situation is the presence, in the oil producing countries, of institutions that are able to guide the country with its new kind of power.

In fact badly managing this situation not only damage foreign countries, but also the oil producing country involved, impeding its development and welfare.

The increase in the oil price should have positive effects on the possibility to recover more oil from the basins, developing new technologies.

Nevertheless investments in new technologies to increase the feasible oil don't take place right now, and probably they won't take place later.

Also with the improvement in technology what seems more convenient to the Middle East area is to maintain a low rate of production. As said before, the new technologies could not be able to increase reserves in a huge way, and probably the reserves-to-production ratio of these oil producing countries has fallen so lower the critical value.

By that, with the increase in reserves derived by the new technologies applied, and containing production, they could re-place the reserves-to-production ratio near the correct value, having the possibility of exploiting the resource as longer as possible, maintaining the high prices, and reaching always more liquidity to invest.

With the high rents deriving from oil what can also be increased is the rate of savings of these countries.

This can happen only with the change in institutions. The creation of the new capital markets that seems to take place in a lot of these countries is important to correctly canalize savings to investments, in order to develop other sectors, and hence the whole economy.

This is a fundamental aspect, as well as the development of instruction. Almost all Middle East countries seems oriented to a heavy effort on improving instruction. The possibility of having high investments and a high grade of instruction plays a central role for the development of these economies in all aspects, and in new sectors, as seems to have been for other developing countries, as the High Performing Asian Economies.

Another aspect that is influenced from the length of the production path is the development of new sources of energy economically competitive. The possibility of using oil for a longer time could be important to let the costs of production of energy as hydrogen lower, reaching an easier point of exchange between the two different sources.

What should make easier the management of the oil left during the last period of production could be the use of new resources in some field starting from now.

In fact there are sectors, as the one of transportation, that could be able to utilize new resources as hydrogen. Developing the use of renewable resources right now in these sectors, would clearly lead to a lower necessity of oil. This would help to maintain the correct production in order not to decrease the reserves-to-production ratio, not damaging the basins, and letting the sectors where new resources can't be applied yet the time for develop a new use of energy.

This would be useful also for reducing the strategic power of the Middle East area, so the political tensions too, although maybe only in a little sense.

What seems fundamental now is to invest in these new resources, in order to play a significant role in this market. In fact being a pivotal player in the market of the new energy resources would surely be very important for the economy of all the countries.

The Middle East area seems again to have this consciousness more than other developed countries. As mentioned before UAE are implementing one of the most important projects in the field of renewable resources. Also Iran is developing nuclear energy in order to face the moment of the end of oil.

This leads to an even higher problem in the political scene.

In fact as said before the more economically convenient competitor of oil, and the most probable substitute to the resource, in serving the world scenario in the future is Hydrogen.

The most economic way of producing hydrogen is by electrolysis driven by nuclear energy.

Hence nuclear energy plays an important role both with the figure of alone competitor, and as the tool for producing hydrogen.

The proliferation of nuclear energy can be a dangerous activity, for the whole world security. Even more it creates problems in political relationship as in the case of Iran.

Hence maybe there would be the need of a control of the production of nuclear energy, but in this case wouldn't be easy to establish who would be the controller, creating probably confusions and corruption.

Maybe there would be the need of the creation of an international organization including all countries, with the ability of controlling this kind of production.

APPENDIX A: A TEST OF HUBBERT METHOD

Because of the different positions about the Hubbert method here it's purposed a test of three of his assumptions developed by Adam R. Brandt of the University of California Berkley, on the base of a large and publicly database.

The first assumption tested is that oil production follows a bell-shaped curve, the second one is that production over time in a region tends to be symmetric, and lastly that production is more bell-shaped in larger regions than in smaller regions.

These assumptions are tested using data from 139 regions that produce oil, and the regions are sub-national, national, and multi-national.

Alternative models of oil depletion are presented, first the one based on the ratio R/P, so the quantity of current reserves on current production, but it is considered to not be able to face the problem that neither reserves, neither production are constant over time, so it couldn't produce a real forecast.

Have been developed modified versions of Hubbert method too, as the one of Hallock, where the curve peaks at 60%, and not at 50% as the one of Hubbert, drawing an asymmetric curve.

Exponential models are so used too, one was used by Hubbert himself on 1956.

On the models of oil depletion projection there are problems about the uncertainty and poorness of data, first of all the uncertainty about the remaining oil that still has to be found; a problem of uncertainty involves terminology and methodologies too, mostly because of the unclearness of quantities predicted, and about the importance of the quantity to predict itself.

It's known that the Hubbert model is based on a logistic curve, although sometimes a Gaussian curve it's proposed.

It presents the methodological difficult of the use of the Central Limit Theorem.

CLT creates a bell-shaped distribution when there is the sum of distributions that are independent one another.

Hence there is no possibility for the application of CLT to the sum of individual production curves, as they are not independent. In fact production in different regions is affected by the decisions of producers, which are pressed by common stimuli.

Hence there is no expectation that the Gaussian profile fit all cases.

In the work presented data are collected for United States state-level, United States regional-level, national-level, and multi-national-level. Data for smaller regions have been aggregated creating geologic regions, to have a smoother spectrum of regional sizes.

By this method six different models are presented, three symmetric of three parameters (the Hubbert model, the linear one, and the exponential one), and three asymmetric with four parameters (the asymmetric Hubbert model, asymmetric linear, and asymmetric exponential).

Model	**Number of parameters**	**Parameters fit by software**
Hubbert	3	Maximum production, year of maximum production, standard deviation of production curve
Linear	3	Year of first production, year of maximum production, slope of increase and decrease
Exponential	3	Year of first production, year of maximum production, rate of increase and decrease
Asymmetrical Hubbert	4	Maximum production, year of maximum production, standard deviation of increasing side of production curve, standard deviation of decreasing side of production curve
Asymmetrical linear	4	Year of first production, year of maximum production, slope of increase, slope of decrease
Asymmetrical exponential	4	Year of first production, year of maximum production, rate of increase, and rate of decrease

Table 6- Six studied models and their features. (Adam R. Brandt)

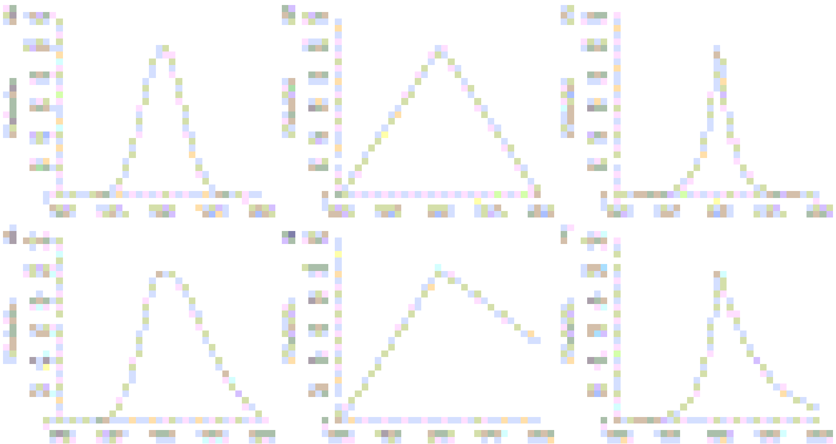

Figure 21 – Schematic illustrations of the six tested models: (a) Gaussian Hubbert production curve, (b) linear production curve, (c) exponential production curve, (d) asymmetric Hubbert production curve, (e) asymmetric linear production curve, and (f) asymmetric exponential production curve. (Adam R. Brandt)

There is no a precise method to determine which model fits well, but it has been compared the non-linear fitting algorithm, that determine the best values of the model parameters. Not all the regions are studied because there are few that are not conform to one of the basic assumption of the models tested, mostly the ones that present a so chaotic production, so 16 of the 139 regions are disqualified from the three models comparison as well as the six models comparison.

Six other regions have been considered borderline.

For the three model comparison firstly have been analyzed the total amount of error of overall points between the best fitting curve of each model and the data by SSE and the root mean square error – RMSE, although they are not properly the best for the numbers of parameters in the models.

To compare models that are not nested and that have different complexity, in that work has been used the Akaike’s Information Criterion (AIC); the AIC score corrected (to account for errors that can occur with AIC when the number of datapoints is small) is given as follows:

$$AIC_c = N \ln\left(\frac{SSE}{N}\right) + 2K + \frac{2K(K+1)}{N-K-1}$$

AIC_c is the corrected AIC score, N is the number of data points in data series, SSE the sum of squared errors, and K the number of the model parameters.

The model that presents the smallest AIC_c score should be the best fitting one, and comparing the difference between the AIC_c scores it's possible to say how much better is one model in respect to another one, lastly it's possible to determine the probability that one model is correct when compared to another one, using the following equation:

$$\Pr obability = \frac{e^{-0.5\Delta AIC}}{1+e^{-0.5\Delta AIC}}$$

ΔAIC is the (AIC_c of best fitting model)-(AIC_c of second best fitting model).

When observed if the best fitting model didn't have a strong evidence (>99% probability to be correct) residuals have been compared, intending as a residual for each data point the difference between what the best fitting model predicts and the actual value; residuals have to be smaller in magnitude, more evenly spread around zero, and have fewer trends.

When there wasn't strong evidence for a model, and neither residuals could tell more, the best fitting model of these regions has been declared undetermined. These are the results of this comparison:

	Regions which AIC_c favors	**Regions which AIC_c favors with strong evidence**	**Regions in which model is best fitting**
Hubbert	63	48	59
Linear	36	23	26
Exponential	24	18	26
Undetermined	–	–	12
Nonconforming	16	–	16
Total	139	89	139

Table 7–Results of three-models comparison. (Adam R. Brandt)

Here it is possible to see that Hubbert model fits production curves more than other models, although it doesn't seem to be dominant.

In the six models comparison 49 regions in total have not been included for the missing of data relative to the rate of decline of the production curve. The results are the ones below:

	Regions which *AIC$_c$* favors	**Regions which *AIC$_c$* favors with strong evidence**	**Regions in which model is best fitting**
Hubbert	2	0	5
Linear	4	0	6
Exponential	7	1	7
Asymmetric Hubbert	16	11	14
Asymmetric linear	15	6	10
Asymmetric exponential	30	24	25
Undetermined	–	–	7
Nonconforming	16	16	16
Disqualified because of lack of post-peak data	49	49	49

Table 8 – results of six-models comparison. (Adam R. Brandt)

It's clearly showed that no model dominates in the six-model comparison.

To test the assumption of Hubbert that oil production would be symmetric have been considered the 74 regions included in the six-models comparison; firstly has been considered the distribution of best fitting rates of exponential increase and decrease in the asymmetric exponential model r_{inc} and $r_{dec,}$ secondly has been studied the distribution of the rate difference, the difference between the best fitting rates of exponential increase and decrease of each region:

$$\Delta R_{\exp onential} = r_{inc} - r_{dec}$$

By that has been noted that the rate differences are highly concentrated above zero, so the typical rate of increase is higher in each reason than the rate of decrease in that region.

Lastly it has been tested the quality of the Hubbert fit across regions of different sizes, so the smoothing behaviour of the curve, and the test have been developed considering two different definitions of size: the squared Kilometres of the area, and the total production to date, expressed on cumulative bbl.

To compare the different areas has been used a normalized RMSE, so the RMSE of each region has been divided by the mean production of that region.

By that it's possible to conclude that neither regions with greater cumulative production are really better described by Hubbert model than the ones with a lower cumulative production, nor the ones with a larger area.

To end it seems important to underline that in this work has been shown the superiority of asymmetric models respect to the symmetric ones in most cases, leading the conclusion of the guess of an asymmetry of production, also because of the evidence of the rate difference.

APPENDIX B: THE CRUDE OIL SUPPLY OUTLOOK OF THE ENERGY WATCH GROUP.

The Energy Watch Group is a group of independent scientist and experts who investigate sustainable concepts for global energy supply.
In the report of October 2007 they project the future availability of crude oil up to 2030. They derivate the possible scenario by aggregating projections for ten world regions defined as the regions considered by the International Energy Agency (IEA) in its World Energy Outlook.
The regions are:

• OECD North America, including Canada, Mexico and the USA.
• OECD Europe, including Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Luxembourg, The Netherlands, Norway, Poland, Slovak Republic, Spain, Sweden, Switzerland, Turkey and the UK.
• OECD Pacific, including
– OECD Oceania with Australia and New Zealand,
– OECD Asia with Japan and Korea.
• Transition Economies, including Albania, Armenia, Azerbaijan, Belarus, Bosnia-Herzegovina, Bulgaria, Croatia, Estonia, Yugoslavia, Macedonia, Georgia, Kazakhstan, Kyrgyzstan, Latvia, Lithuania, Moldova, Romania, Russia, Slovenia, Tajikistan, Turkmenistan, Ukraine, Uzbekistan, Cyprus and Malta.
• China, including China and Hong Kong.
• East Asia, including Afghanistan, Bhutan, Brunei, Chinese Taipei, Fiji, Polynesia, Indonesia, Kiribati, The Democratic Republic of Korea, Malaysia, Maldives, Myanmar, New Caledonia, Papua New Guinea, Philippines, Samoa, Singapore, Solomon Island, Thailand, Vietnam and Vanuatu.
• South Asia, including Bangladesh, India, Nepal, Pakistan and Sri Lanka.

• Latin America, including Antigua and Barbuda, Argentina, Bahamas, Barbados, Belize, Bermuda, Bolivia, Brazil, Chile, Colombia, Costa Rica, Cuba, Dominic.Republic, Ecuador, El Salvador, French Guyana, Grenada, Guadeloupe, Guatemala, Guyana, Haiti, Honduras, Jamaica, Martinique, Netherlands Antilles, Nicaragua, Panama, Paraguay, Peru, St. Kitts-Nevis-Antigua, Saint Lucia, St. Vincent Grenadines and Suriname, Trinidad and Tobago, Uruguay and Venezuela.
• Middle East, including Bahrain, Iran, Iraq, Israel, Jordan, Kuwait, Lebanon, Oman, Qatar, Saudi Arabia, Syria, the United Arab Emirates, Yemen, and the neutral zone between Saudi Arabia and Iraq.
• Africa, including Algeria, Angola, Benin, Botswana, Burkina Faso, Burundi, Cameroon, Cape Verde, the Central African Republic, Chad, Congo, the Democratic Republic of Congo, Côte d'Ivoire, Djibouti, Egypt, Equatorial Guinea, Eritrea, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Lesotho, Liberia, Libya, Madagascar, Malawi, Mali, Mauritania, Mauritius, Morocco, Mozambique, Niger, Nigeria, Rwanda, Sao Tome and Principe, Senegal, Seychelles, Sierra Leone, Somalia, South Africa, Sudan, Swaziland, the United Republic of Tanzania, Togo, Tunisia, Uganda, Zambia and Zimbabwe.

The paper doesn't base its analysis on the reserves data, because of the difficult already explained to find correct and coherent data, as shown primarily on the work of Campbell.
The analysis is based on production data and historical discoveries.
It has been used an industry database for past production data and partly for reserve data too, used for certain regions. Because of the uncertainty of the reserves data the authors have made their own reserves estimates based on various sources in some cases.
In the Industry database (HIS 2006) remaining oil reserves are supposed to be about 1,255 Gb, but operating some corrections for the projections about some key countries or regions as the Middle East, remaining reserves should be projected to 854 Gb.

Region	Remaining reserves		Production 2005		Consumption 2005 [Gb/yr]
	EWG [Gb]	IHS [Gb]	onshore [Gb/yr]	offshore [Gb/yr]	
OECD North America	84	67.6	3.20	1.71	9.13
Canada	17	15.3	0.89	0.12	0.82
USA	41	31.9	1.93	0.59	7.59
Mexico	26	20.4	0.36	1.00	0.72
OECD Europe	25.5	23.5	0.1	1.94	5.72
Norway	11	11.6	0	1.13	0.08
UK	8	7.8	0.01	0.70	0.65
OECD Pacific	2.5	5.1	0.025	0.18	3.18
Australia	2.4	4.8	0.02	0.17	0.31
Transition Economies	154	190.6	4.1	0.18	2.02
Russian Federation	105	128	3.4	0.13	1.00
Azerbaijan	9.2	14	0.01	0.15	0.04
Kazakhstan	33	39	0.47	0	0.08
China	27	25.5	1.1	0.22	2.55
South Asia	5.5	5.9	0.11	0.16	0.96
East Asia	16.5	24.1	0.3	0.65	1.75
Indonesia	6.8	8.6	0.27	0.11	0.43
Latin America	52.5	129	2.0	0.61	1.74
Brazil	13.2	24	0.075	0.55	0.75
Venezuela	21.9	89	1.17	0	0.20
Middle East	362	678.5	6.97	1.97	2.09
Kuwait	35	51	0.96	0	0.11
Iran	43.5	134	1.19	0.24	0.59
Iraq	41	99	0.67	0	
Saudi Arabia	181	286	2.85	0.86	0.69
UAE	39	57	0.46	0.45	0.14
Africa	125	104.9	2,03	1,53	1.01
Algeria	14	13.5	0.72	0	0.09
Angola	19	14.5	0.01	0.45	
Libya	33	27	0.61	0.02	
Nigeria	42	36	0.39	0.52	
World	**854**	**1,255**	**19.94**	**9.15**	**30.3**

Tabele 9-Oil reserves and annual oil production in different regions and key countries. (EWG)

In every region the largest fields are developed before the smaller ones.

The most of the largest fields that have been already discovered show declining production rates. Developing the smaller ones it is observed that they reach the peak much faster contributing to increase the production decline as a whole.

It also has to be observed that the evidence of the oil depletion problem is given also by the fact that the oil companies haven't been able to increase their production in the last ten years, despite the big rise in oil prices. Prices started to rise in 2000, and it was attributed to different reasons. Five years ago an oil price above 60 $ per barrel was unthinkable, now a price below that limit is considered cheap, as it has been reached the price of 100 $ per barrel today.

The pricing behaviour of OPEC has changed too from 2000. In fact it had been established a price corridor of 22-28 $ per barrel before, but when prices have moved over 40 $ per barrel OPEC not say anything about the corridor anymore. This is an indication of the lack of capacity for OPEC to control the maximum price by increasing its production.

In the supply projections of EWG are considered conventional oil, natural gas liquids and oil produced from tar sands.

In this study crude oil is considered as consisting of conventional oil and non-conventional oil.

Conventional oil includes oil > 10°API, deep-sea oil, polar oil and condensate as well as NGL. Synthetic crude oil (SCO) and bitumen from tar sands are treated explicitly as "non-conventional oil". Oil shales are not considered.

There are some differences between the scope and methodology used by EWG and other studies as the ones by ASPO, Robelius and IEA.

ASPO has got a time horizon that extends to 2100, and considers quite different kinds of oil. It bases the scenario on Hubbert curves, and has got own databases derived from various open and disclosed sources.

The analysis of Robelius is based on reserves and production of giant fields.

The IEA has got a time horizon that extends to 2030, and they project the future oil demand based on an economic model, and then supply is supposed to equal demand. The estimation of the reserves is given by USGS, and the supply scenarios are the ones of EIA.

The situation of maturity of production of different regions changes from a region to another, and it's possible to see that the total

production of the countries outside the former Soviet Union and OPEC has increased till 200, and then has started to decline.
The major responsible for this decline is the peak of production of the North Sea area, which occurred on 2000.
The decline of the onshore production that started on the mid 1990s has been replaced by the growth on production of the offshore fields, but now this is not possible anymore.
The gap of these countries should be balanced by the growth on production of OPEC and FSU, but the chances of that are marginal.
Another problem related to the pass of the peak is that in the regions where that has already occurred it's possible to notice the degradation of the quality of oil, pushing up the price of the good oil still present.
One of the big questions is if Saudi Arabia is in decline or not.
Now there is a current decline in production in this area, what is important to establish is whether it is voluntary.
One interpretation is that Ghawar, the world's largest field, is now in terminal decline, so it would lead Saudi Arabia and OPEC as a whole to not still be a swing producer.
But Saudi Arabia declared that they would be able to raise production in the next years to 12 Mb/d and even to 15Mb/d if it is necessary; although it does not seem realistic, it is quite lower than the prediction of US EIA and IEA that both project a production of 20 Mb/d in 2030.
The projection of EWG is that Saudi Arabia won't be able to increase its production significantly for any meaningful period of time.
Today it's well known that three of the four biggest fields of the globe are in decline, and perhaps the biggest one of Saudi Arabia too, as said before.
In the EWG report then it's possible to find an overview of the different scenarios of future oil supply for each region studied, till at the end arrive at the scenario of future oil supply of the world as a whole.
Starting by the Middle East region it's important to say that although it is the main oil producer, oil production here is expected to decline in

the near future. The main problem to foresee that production in reality is the real reserves present in this region.

The only country in this region that is supposed to increase its production is Saudi Arabia, but there are a lot of doubts in this possibility, also because the giant fields have already peaked or are near to peak. The projection for the decline rate of Saudi Arabia is of 2% per year.

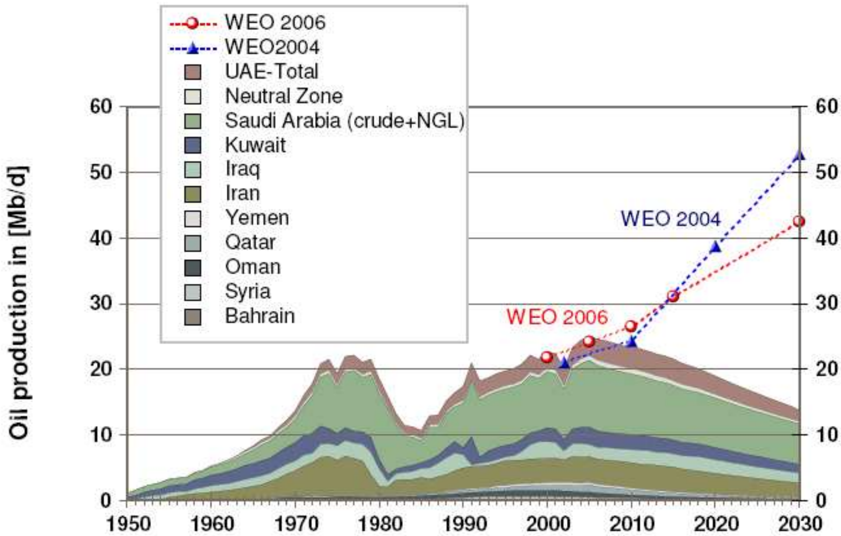

Figure 22 - Oil production in the Middle East. (EWG)

In the region of OECD North America oil production peaked in 1984, and the conventional oil production is supposed to decline by 80% up to 2030. If it is included the production of non conventional oil, as the one deriving from tar sands in Canada, the decline rate is supposed to be of about 50%.

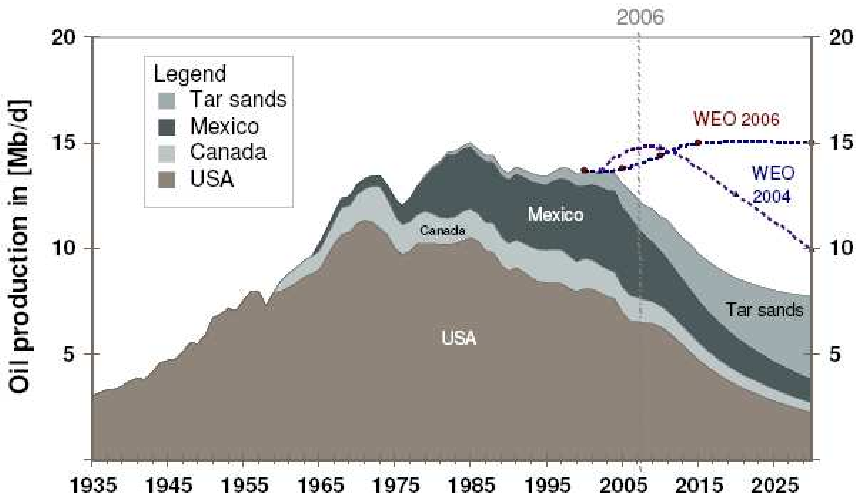

Figure 23 - Oil production in OECD North America. (EWG)

In the USA the conventional oil production is in decline since 1970, and offshore oil from the continental shelf turned into decline in 1995. Deep water areas of the Gulf of Mexico have been developed in the late 1990s and early 2000, but they've peaked in 2001. This is a problematic region, because of its hurricanes, and so it is characterized by high costs; the production of that region is supposed to decline at the latest around 2010.

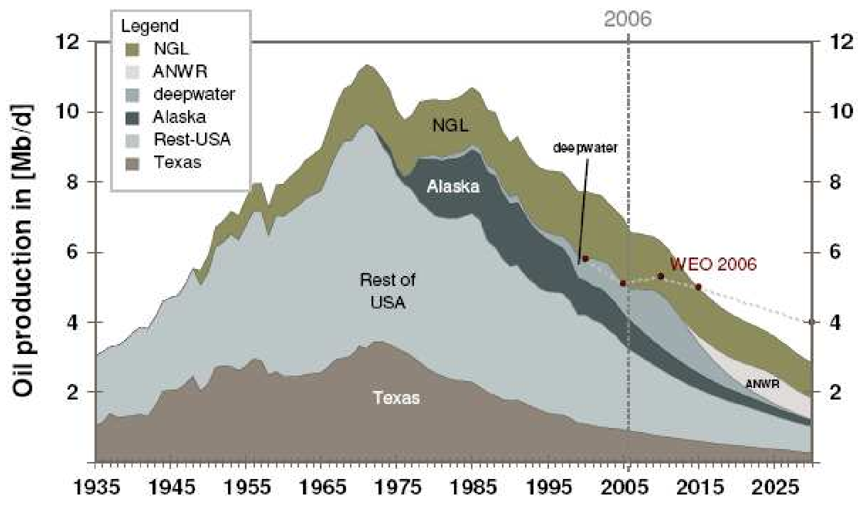

Figure 24 - Oil production in the USA. (EWG)

In Canada conventional oil production peaked in 1973; then this region developed the offshore production that could compensate the decline of conventional oil production till 2003.

Now offshore production is in decline too. Since 1967 Canada has developed the production of oil from tar sands and the production of synthetic crude oil and bitumen, and these kinds of production are supposed to become the first resource for Canada up to 2030.

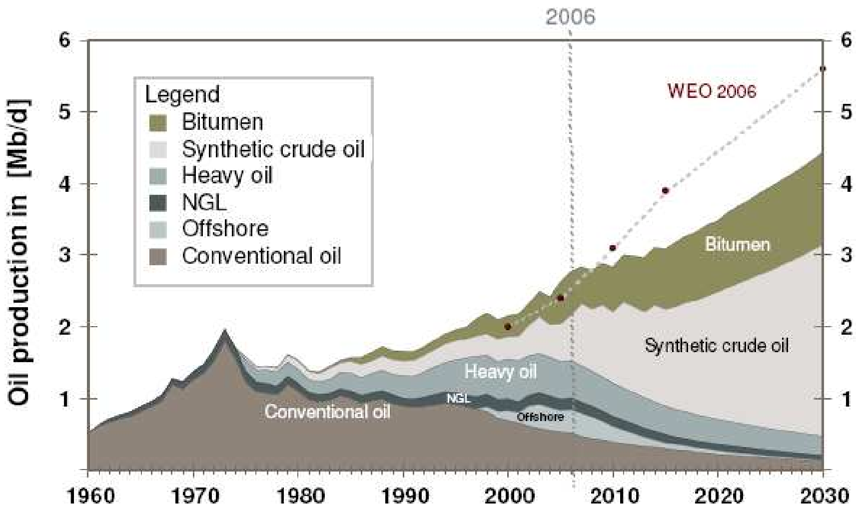

Figure 25 - Oil production in Canada. (EWG)

Transition economies are among the important oil producing and exporting countries, firstly Russia and especially Siberia.

At the end of 1980s production declined by 40% within five years, and because the small opportunities left, a second peak of production is projected around 2010.

Another oil region of the Former Soviet Union is Azerbaijan, that is the oldest industrial oil region in the world, but now it's possible to expect a growth just on offshore production in this region.

Another region of FSU is Kazakhstan that was considered as a "new Saudi Arabia" during some years, but now it's known that this was an exaggerated expectation; in fact only about 45 Gb of oil are likely to be recoverable in that region.

One problem of that region is that it is characterized by high costs and difficult geological conditions.

In the best case Kazakhstan and Azerbaijan will increase their production up to 2015 from 1,3 Mb/d to about 2,5 Mb/d.

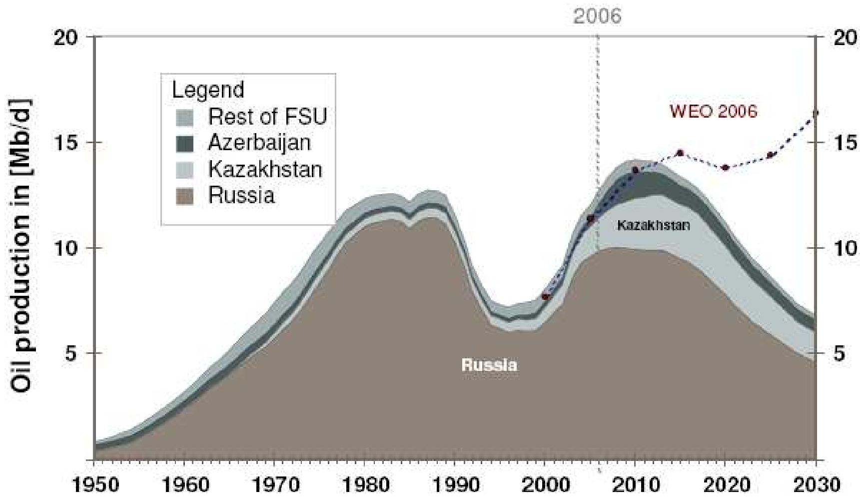

Figure 26-Oil production in Transition Economies. (EWG)

Oil production can increase in some regions of Africa, but it is expected to decline in the whole between 2010 and 2015.

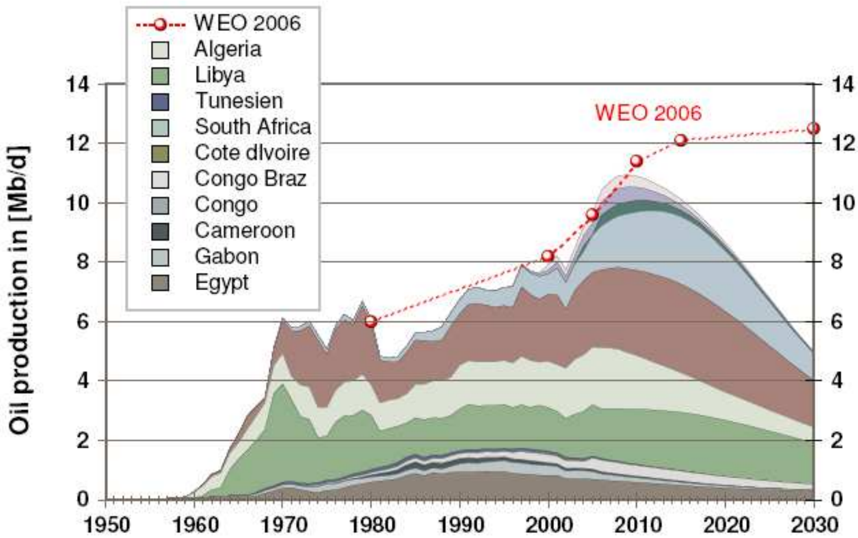

Figure 27–Oil production in Africa. (EWG)

Venezuela is the main oil producer of Latin America, and it has reached a peak in 1970, then again in the mid 1980s, and then again in 2000. However Venezuela won’t be able to maintain its present production rate.

Brazil is the second oil supplier of Latin America, and has increased its oil production , and the peak of production is expected to be reached by the end of this decade.

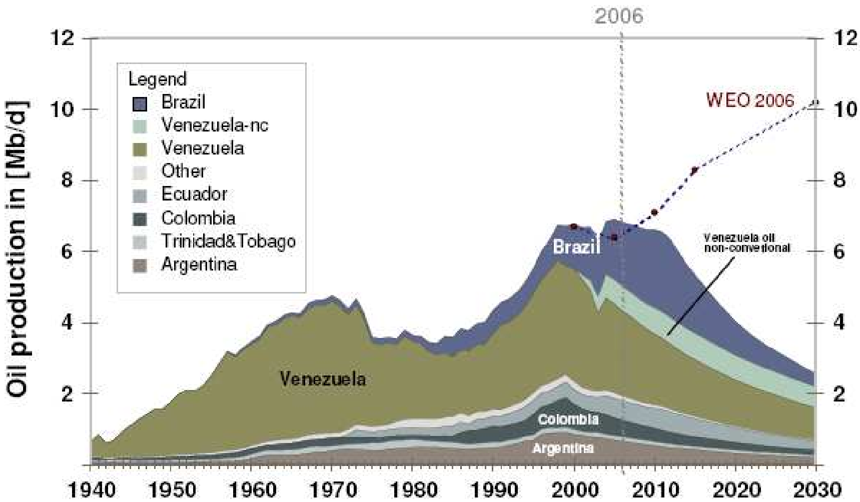

Figure 1-Oil production in Latin America. (EWG)

Oil production in OECD Europe has peaked around 2000, and probably production in 2015 will be down by about 50% compared to 2005 production.

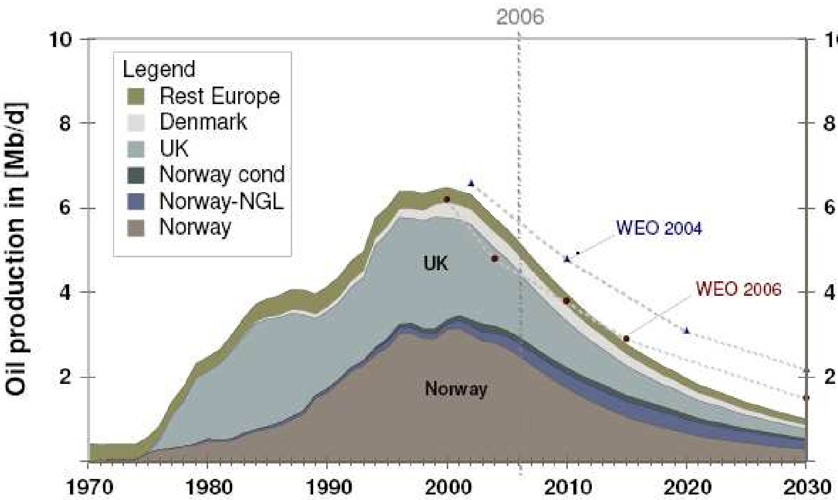

Figure 29-Oil production in OECD Europe. (EWG)

The largest oil field in China is already in decline. Oil production in this region is expected to peak before 2010 and the decline rate is supposed to be about 5 % per year until 2030.

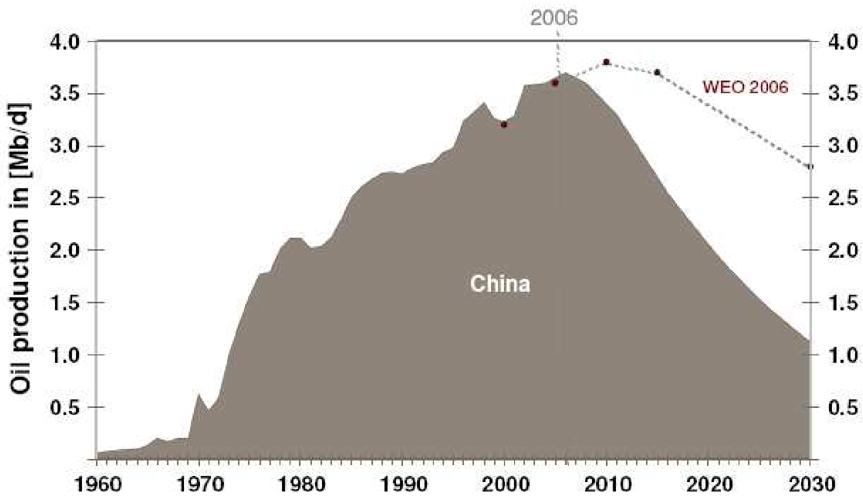

Figure 2-Oil production in China. (EWG)

In East Asia oil production is expected to peak before 2010. Indonesia is the largest producer of this area, and it has been declining since 1990 by around 30%.

Malaysia is the second largest producer of this area, and it is close to peak too. Oil production in Malaysia, Vietnam, and Thailand is expected to peak before 2010, and a sharp fall is projected until 2030.

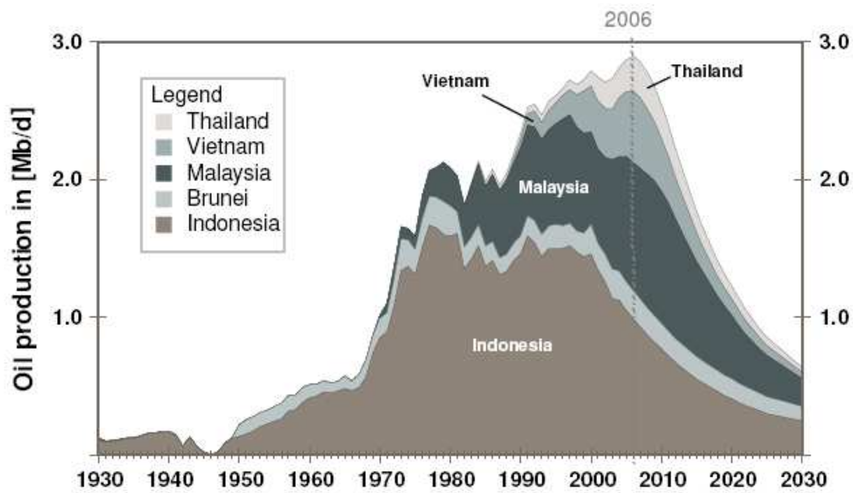

Figure 3-Oil production in East Asia. (EWG)

India is the only oil producing in South Asia, and it reached a peak in 2006, followed by a steep decline.

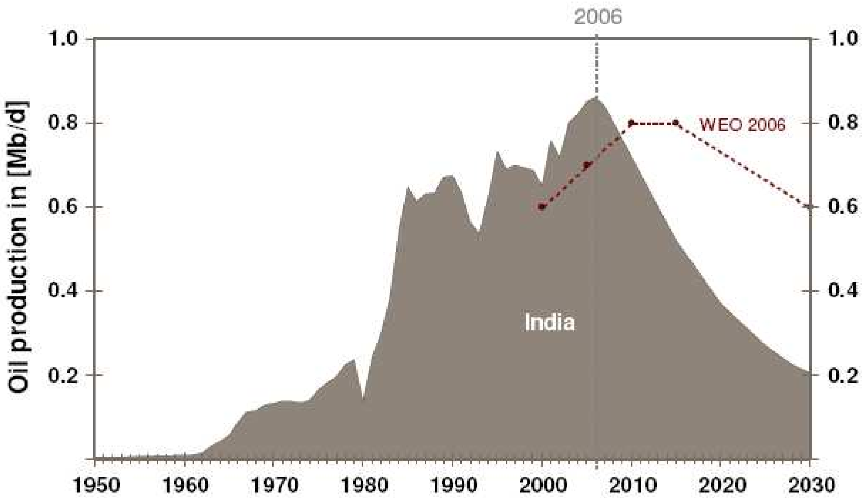

Figure 4-Oil production in South Asia. (EWG)

In the region of OECD Pacific the main oil producer is Australia, and it has already reached the peak in 2000, with a decline rate of 10% per year.

It is characterized by a steep decline because of the aggressive modern extraction methods used in this region.

It's possible to see that every region's production is expected to decline in the near future, or has already started to decline.

So for the world scenario it has been said that peak oil occurred in 2006 with a peak production of 81 Mb/d.

This scenario includes natural gas liquids and tar sands too.

Oil production is expected to decline by about 50% up to 2030, so with a rate of 3% per year. This is a moderate projection because of the big presence of offshore production, and the very aggressive modern extraction methods utilized for it, that could lead to decline rate after peak of 10% per year or even more.

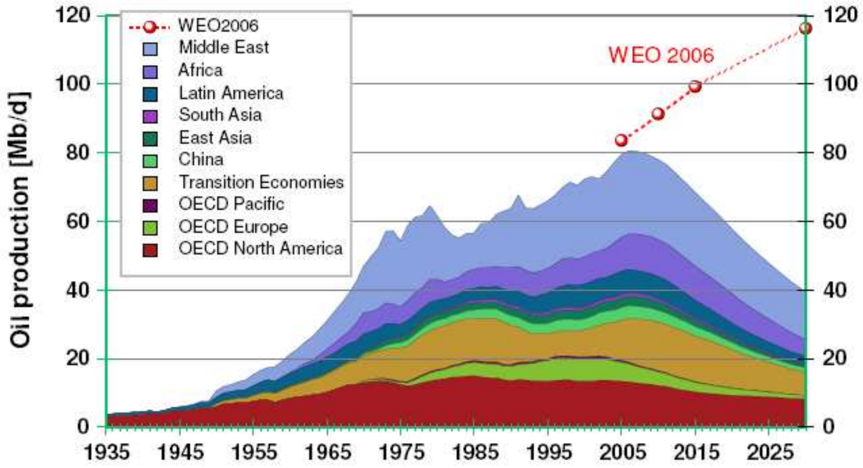

Figure 33-Oil production world summary. (EWG)

The conclusions of the EWG report are quite different from others such as the one of IEA.

Starting from the point of 2006, the differences in the two projections are the follows:

2020	EWG 58 Mb/d	IEA 105 Mb/d
2030	EWG 39 Mb/d	IEA 116 Mb/d

The IEA doesn't foresee a peak of oil production up to 2030 in its report World Energy Outlook of 2006.

The scenario presented by EWG differs from the one presented by ASPO too.

ASPO foresees a peak for the year 2011 at about 90 Mb/d, and the future projections differ as follow:

2020	EWG 58 Mb/d	ASPO 75 Mb/d
2030	EWG 39 Mb/d	ASPO 65 Mb/dò

So the main result of the EWG report is that global oil production peaked in 2006, and from that point, a big gap of oil supply is growing day by day.

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