Comments on the book: *Hubbert's peak: the impending world oil shortage*
K.S. Deffeyes, 2001 Princeton University Press
by Jean Laherrere jean.laherrere@wanadoo.fr
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This book is well written and interesting for reading by anyone from oil specialist to layman. It presents a good explanation on the origin of oil, its generation, its migration and its trapping. It is full of stories on the oil industry, as the author has witnessed most of the rise and the decline of the US production (but few abroad and lately far from exploration activity).

However in front of many strengths, there are some weaknesses. There is no definition of what is called oil (is it crude oil or liquids including or not refinery processing gains?) or what is called reserves (proved or proven + probable?) for the world. The sources of the data are not mentioned, and as they vary it is important to quote them.

For instance, Oil production in 1999 is reported by USDOE as:

1999	World Mb/d	World Gb/a	US Mb/d	US Gb/a
Crude Oil	65.9	24.0	5.88	2.15
Crude Oil, Natural Gas Plant Liquids, Other Liquids	72.7	26.5	8.11	2.96
Crude Oil, Natural Gas Plant Liquids, Other Liquids, and Refinery Processing Gain	74.2	27.1	8.99	3.28

The range is more than 13% for the world and 53% for the US. It is important to specify exactly which "oil" is concerned. Page 5 seems to be crude oil (in fact lease condensate is included in the US crude oil). But natural gas liquids are very important in the US and should not be omitted. In the same way, it is useful to have the break down between conventional and unconventional oil. For instance, page 4 the ultimate of Colin Campbell is given as 1.8 Tb without specifying that it is only for conventional with a very narrow definition (excluding heavy oil (<17°API), Arctic and deepwater oil).

In the past, we were told that a measure should be followed by its accuracy. Most of the times, accuracy is about 5% at best for population (in 1990 the UN estimated Nigeria at 122 millions when the census in 1991 gave 88, UN was wrong by 30%), 10% for production and 25% for reserves. Deffeyes is very quiet on accuracy and reliability of the data, which is the main problem as there are two types of data:
- "official", i.e. political or financial ones as reported by the media as Oil & Gas Journal (OGJ) World Oil (WO) BP Review, OPEC and called proved reserves even where they are not
- technical data, mainly confidential, on which development decisions are taken, available through very expensive files from "scout" companies.

Deffeyes displays some interesting presentations of the pattern of discoveries, but does not seem to know that the most efficient way to assess the potential of oil is the creaming curve (invented by Shell, but, I assume, after Deffeyes left Shell).

There is a factual error page 173 because Western Siberia discoveries are not limited to natural gas. They represent in percentage out of the total Russia 58 % for natural gas and 54% for oil.

But, in my view, the real weakness of the analysis is related to Hubbert curves. At first, I thought that Deffeyes does not use the web, but I found that he has an e-mail address and he should know sites as www.hubbertpeak.com or www.hubbert.mines.edu

The distributions of oilfields are described following lognormal law and Zipf's Law (1949), without mentionning first its application by Folinsbee (1977 "World's view; from Alph to Zipf" Geol.Soc Am.Bull. vol 88, July, p897-907) and later by the (linear) fractal distribution by Mandelbrot, now superseded by multifractal and parabolic fractal (Laherrere 1995). Deffeyes never mentions all the works done on Hubbert's peak for the last 20 years as for example L.F.Ivanhoe with his Hubbert Center at the Colorado School of Mines (with a quarterly newsletter since 1995), Albert Bartlett who correctly prefers Gaussian curves, Richard Duncan and Walter Youngquist, Richard Startzman and his students (Al-Jarri 1997 and Al-Fattah 1999) who plotted oil and gas production of every country with Hubbert curve and myself (Laherrère J.H. 2000 "Learn strengths, weaknesses to understand Hubbert curve" Oil and Gas Journal April 17, Laherrère J.H. 1999 "World oil supply -What goes up must come down: when will it peak?" Oil and Gas Journal Feb.1 p 57-64).

Explaining page 139 the symmetry of the bell-shaped Hubbert curve by Occam's razor (simplest curve) might be true but is more easily explained by The "Central Limit Theorem" In turn, the lack of randomness for example the influence of a parameter such as the business environment during a certain period (e.g. high prices and no constraints on production versus a period of low prices and constrained production, or the discovery of a new oil province) will be reflected by curves that are not anymore bell-shaped, but multi bell-shaped or others)

In that latter respect, it should be kept in mind that most of Hubbert followers treat the data as if there is only one cycle, when it is obvious for the US that there are at least three cycles of exploration and production which need to be treated separately: Lower 48, Alaska and the GOM US deepwater. I personally believe that this point is the main flaw of this book. Hubbert's peak is not unique and there are usually several peaks (minor and major), and often more to come. All modeling assuming only one peak are likely to give wrong results.

The chapter 8 with rate plots is interesting as it gives a way to estimate the ultimate, when assuming a logistic curve. The classic logistic curve was discovered by Verhulst in 1845 in connection with population studies. It assumes that population growth increases to a midpoint (tm) and then decreases to zero, giving what is known as an S-curve. In this application, where there is no negative growth, total population trends to be steady towards the asymptote (U). In the 1920s Pearl and Reed used the logistic curve to model the US population, but their forecast was that US population will not overpass 200 millions, showing that logistic modeling is not very good.

The logistic can also be used in modeling oil cumulative production under the general formula $CP = U/(1+EXP\ b(t-tm))$ and its derivative, $AP = 2Pm/(1+COSH\ b(t-tm))$ that can also be written as $AP/CP = 4Pm/U2\ (U-CP)$, where AP is the annual production, CP the cumulative production, Pm the peak at mid-point time tm, U the ultimate and b=4Pm/U. AP/CP is a linear function of CP and its extrapolation to zero gives U

In his graph of page 154, Deffeyes uses the same wording for the application to a logistic curve (S curve) used for population or cumulative production versus time, and to its derivative (bell-shaped curve) used for annual production versus time. Annual percent growth label is correct for population, but not for production.

There are two models versus time: one being the logistic curve (S curve page 152) for population and one being the derivative of the logistic curve for the oil production (bell-shape page 153). Only a box in the upper right displays the curve versus time, showing its pattern (S or bell).

Page 154 displays the different patterns for Gaussian, Logistic (it is the derivative) and Lorentzian (Cauchy). Why not to study other models as pertinent as Weibull or Gompertz? There are many models which look like a bell-shaped curve versus time, as a part of parabola or sine wave, mainly when looking at the upper part (the two-thirds)

Figure 1: comparison Hubert, Gauss, Cauchy and others
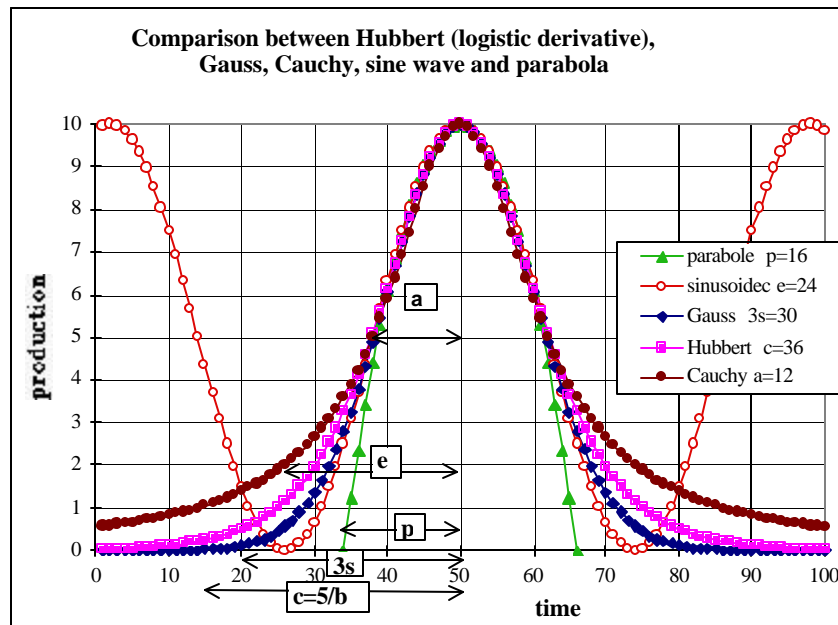
In fact in his famous 1956 paper, Hubbert did not give any equation and his bell-shaped curve is obviously drawn by hand (with templates), being fatter on the peak than any logistic derivative or Gauss. Deffeyes admits page 135 that he never dared to ask Hubbert (despite sharing more than 100 lunches with him) what equation he used in 1956. It is only in 1982 that Hubbert gave the equation of logistic derivative to describe his curve.

Plotting the percentage of annual production over cumulative production (AP/CP %) versus the cumulative production (CP) is interesting (called thereafter as "Deffeyes plot") as it is a linear plot for the logistic derivative (as shown above). Deffeyes display page 154 is as follows:

Figure 2: Deffeyes plot page 154
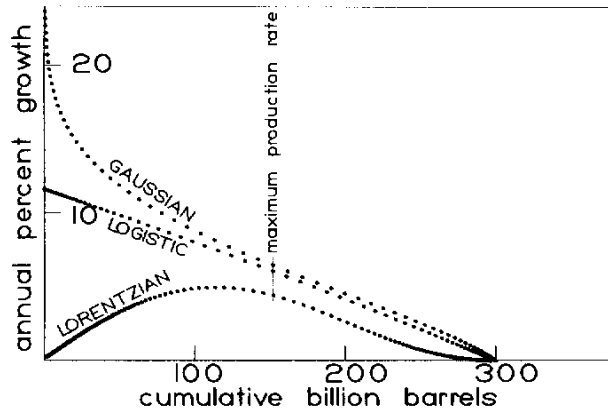
On a growth rate versus cumulative graph, a Gaussian curve lies reasonably close
to the straight logistic line through the latter part of its history. However, on the
left the Gaussian curve is well above the logistic. The U.S. and the world oil pro-

The annual percent growth is indicated to be displayed versus cumulative production, in fact it
is the percentage of the annual production over the cumulative production (AP/CP %). But it
is interesting to notice that the normal (Gauss) model trends fairly quickly (when cumulative
production is over a quarter of the ultimate) converges to the logistic derivative model (let's
forget Lorentz). However there is a problem of accuracy: In my article on weaknesses of the
Hubbert model (2000), I mention that modeling a rising curve before it passes the inflection
point (where annual production stops to grow) is very inaccurate.

Figure 3: Hubbert, Gauss and derivatives
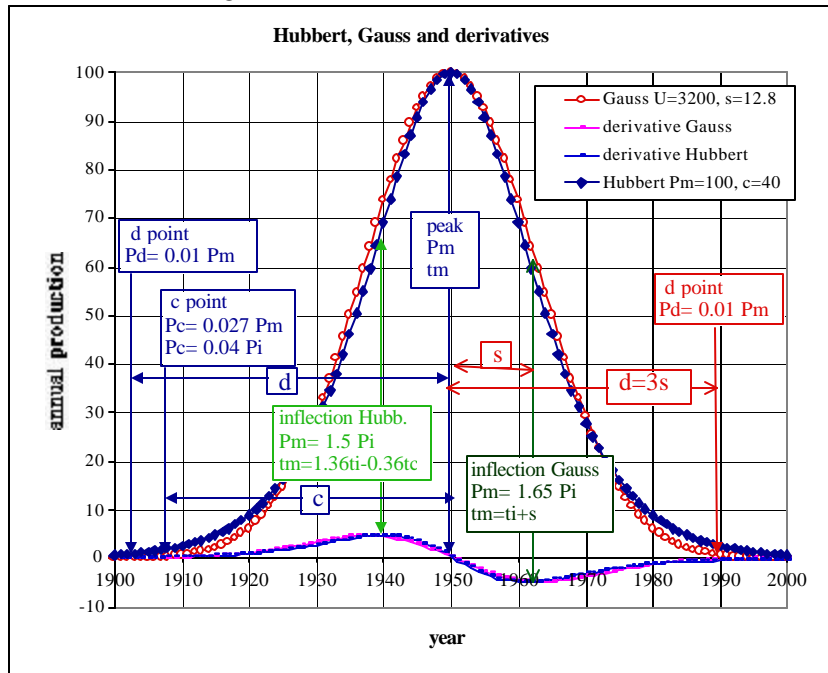
In the population plot (wildly spaced data) page 152, the annual growth in percent peaks around 3% for 3.5 billions. Searching for a more detailed set, I found on the web that US Bureau of census is the only source, that most publications are based on their data, and the peak for annual growth in % is at 2.2 % in 1963 for 3.2 billions. Deffeyes mentions the religious crusade in China in 1860, but he forgets to show the famine in 1960 in China also, giving a very sharp valley in the growth.

Figure 4: Deffeyes plot for world population:

World population; annual growth (%) versus population from US Bureau of Census 1998 for 1950-2050
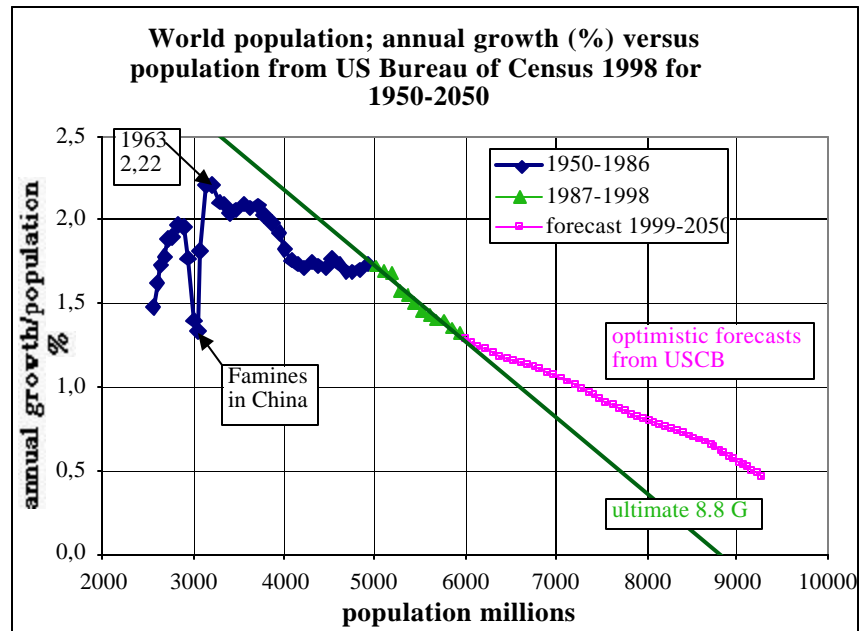
As Deffeyes shows, a logistic curve gives a straight plot on this kind of display. The plot is erratic from 1950 to 1986, but straight from 1987 to 1998, with an extrapolation to 8.8 billions as the asymptote of the logistic curve. The USCB forecast is similar but with a larger asymptotic value. Both are probably wrong because the hypothesis of a logistic model is too optimistic. It assumes that the rate of growth declines to zero (fertility rate converging towards a replacement ratio), but this is really unrealistic. In Nature what goes up must comes down and civilizations appear and disappear. With a fertility rate of less than replacement (2.1 child per woman) the developed countries are going towards a die-off (if no immigration). Japan is a good example (as Russia).

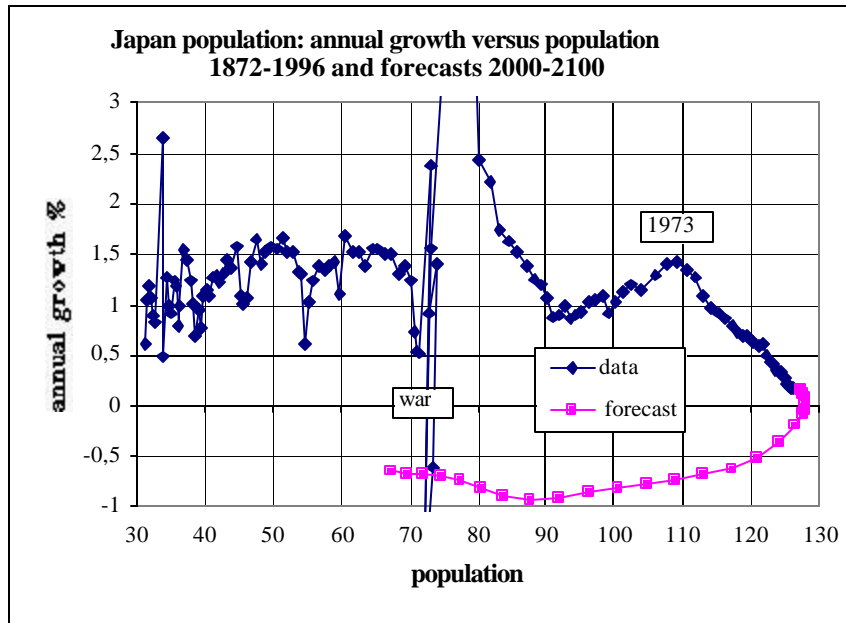Figure 5: Japan population
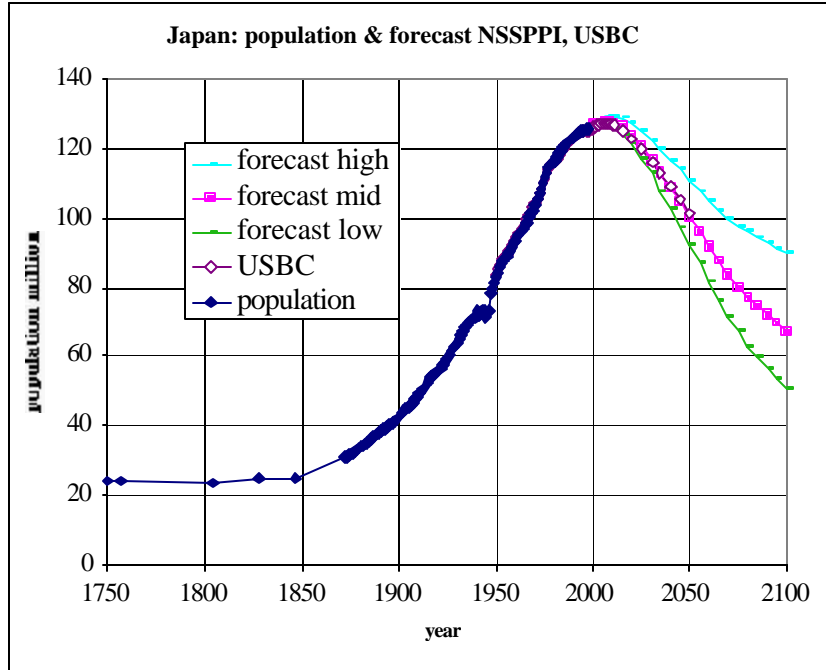
Figure 6: Deffeyes plot for Japan population is far from a straight line

It is obvious on this example that the extrapolation of the straight line from 1973 to 1998 data would give a wrong value of the assumed future steady population of Japan.

Figure 7: World population: UN forecasts and Bourgois-Pichat (head of the French Institut des Etudes Demographiques) model (1998) based on the addition of different bell-shaped cycles for developed countries and developing countries.
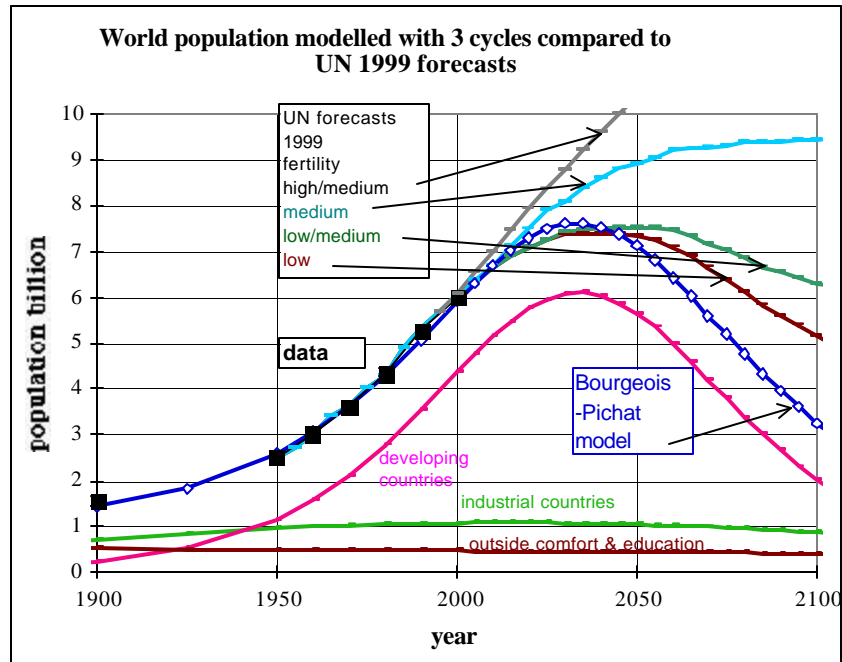

Deffeyes gives the oil plot for the whole US page 143 & 155, for the production and also the discoveries, being current remaining proved reserves plus cumulative production. In many of my papers I have shown that the US proved reserves are a very poor estimate, as more than 90% of the annual additions for the last 20 years come from revisions of past discoveries. I prefer to forget such so-called discoveries and stay only with production data. The plot from API and USDOE crude oil production data is as follows for the annual production versus time.

Figure 8: US crude oil production versus time
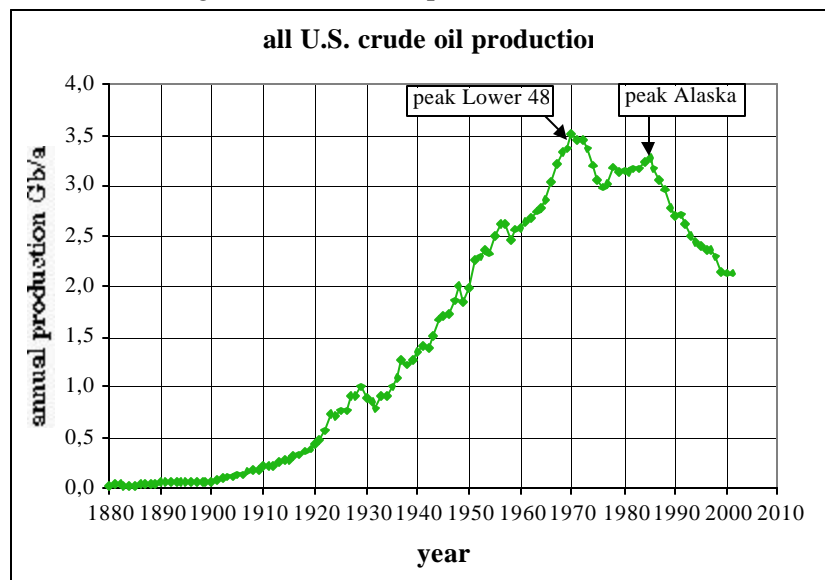
The plot of these production values as percentage of annual production over cumulative production versus cumulative production displays an erratic cloud from 1860 to 1939 but a almost straight line from 1940 to 2000 extrapolating towards 220 Gb. But such display hides completely the different cycles of Lower 48, Alaska and GOM deepwater.

Figure 9: Deffeyes plot for US crude oil production
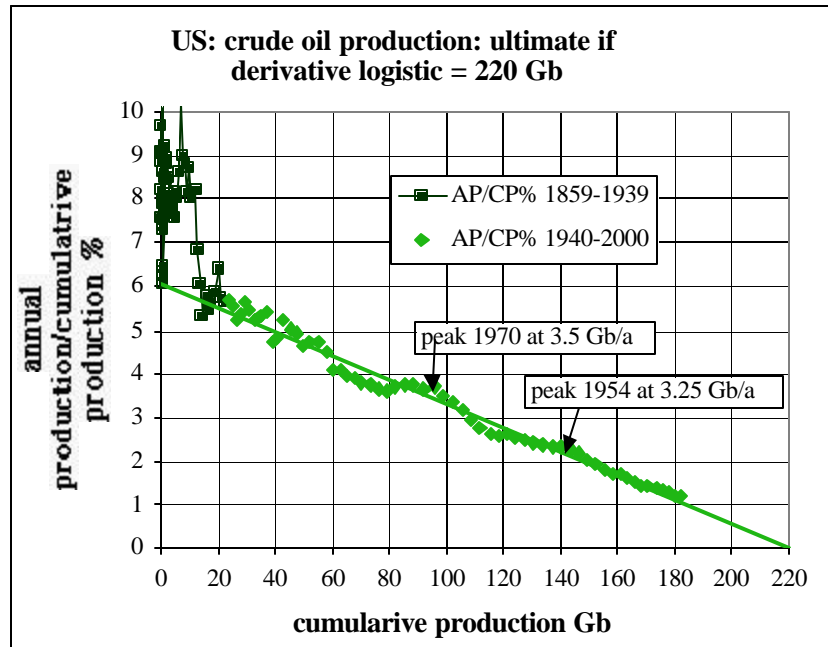
This display is identical to that of page 155 because data are the same for production. But the following graph for discoveries is completely different because the retained value of each annual discovery is the mean value (expected or ultimate recovery) backdated to the year of discovery when Deffeyes uses the proved current value. However the result is about the same with an ultimate recovery about 220 Gb.

Figure 10: Deffeyes plot for US backdated mean oil discovery
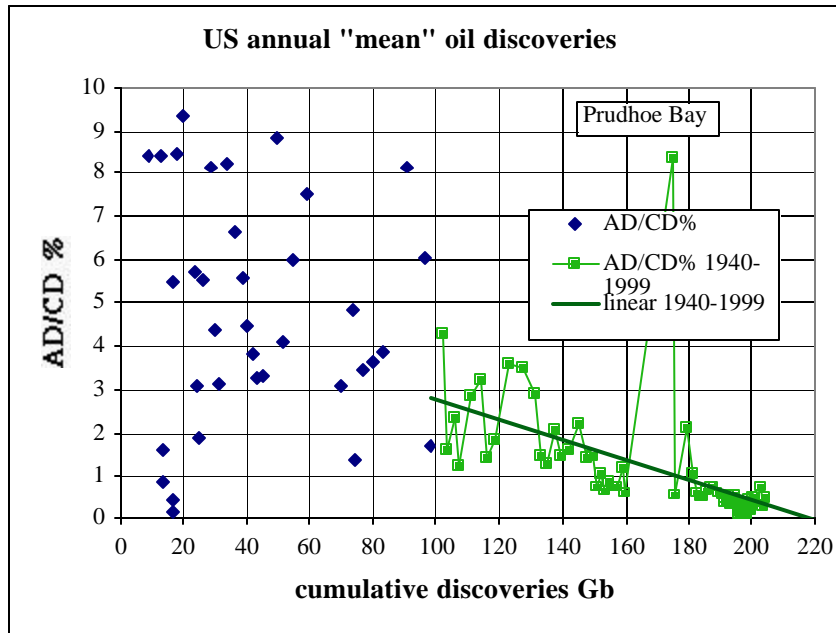
For the two above graphs, Deffeyes plot seems to give fairly good results, but this can be improved if one were to use the "creaming curves" which display the cumulative discovery versus the cumulative number of New Field Wildcats (NFW).

Figure 11: US creaming curves
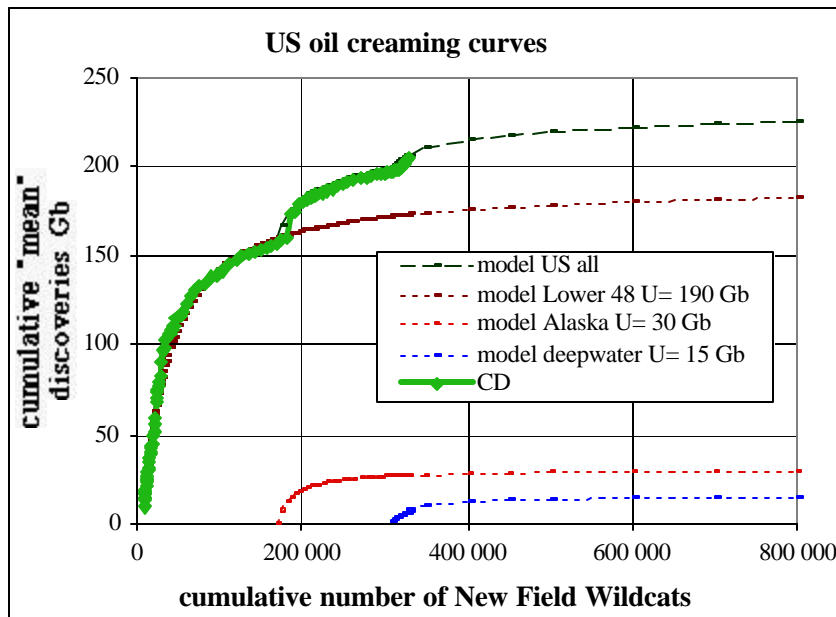
Each of the three cycles (Lower 48, Alaska and deepwater) can be easily modeled with a simple hyperbola and the ultimate recovery for doubling the present number of NFW (320 000) will be around 225 Gb.

For the world crude oil (USDOE data), the annual production versus time shows a peak in 1979 at 22.9 Gb/a due not because of a shortage in the supply but of a shortage of the demand It took more than 15 years (1996) to reach again such level. Using OGJ estimates for 2001 shows 2000 as a new peak for the moment.

Figure 12: World crude oil production versus time

World crude oil production
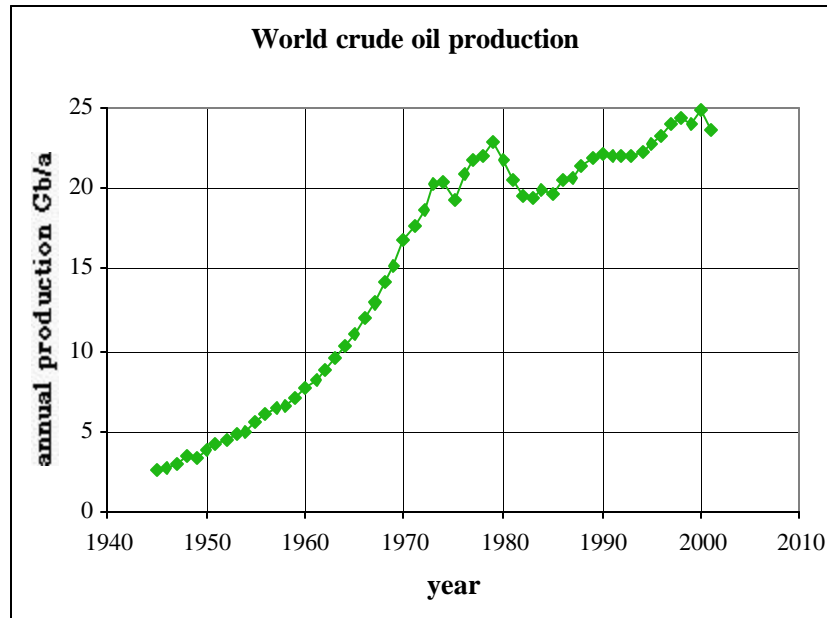
It is obvious that world oil production is not a simple bell curve and that the Deffeyes graph (following) will not be a straight line. In fact after a sharp rise (1945-1970) and a sharp decline (1971-1986), the annual/cumulative percent is straight from 1987 to 2000 but it does not mean that it will be the same in the future. The extrapolation trends towards 1.8 Tb, which is the ultimate value of Colin Campbell (for conventional excluding Arctic, deepwater and heavy oil (>17°API)), whereas the annual production is plain crude oil including Arctic, deepwater and heavy oils. I personally believe that in future the plot will change from this straight line (lower decline).

Figure 13: Deffeyes plot for world oil production

**World crude oil production 1945-2001: ultimate if derivative logistic = 1800 Gb**
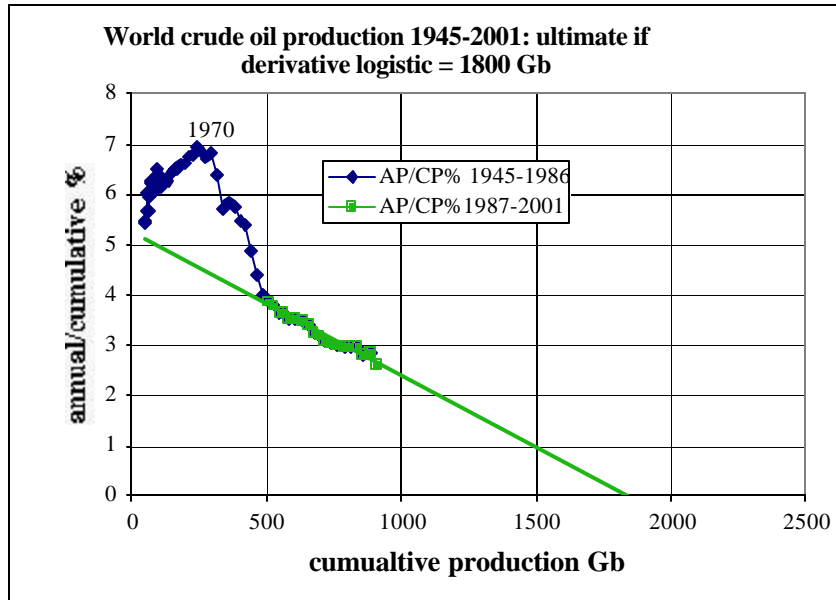
It is interesting to plot the same graph for world offshore crude oil production from 1969 to 2000. A very sharp decline (1969-1987) and a straight line extrapolating towards 600 Gb (one third of the global ultimate, meaning that the onshore represents twice the offshore)

Figure 14: Deffeyes plot for world offshore oil production

World offshore oil production 1969-2000
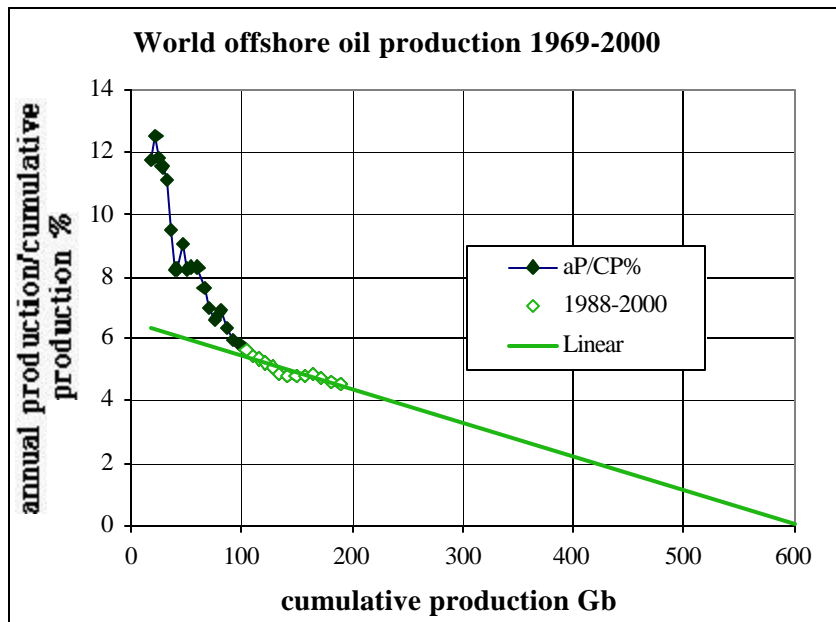
I prefer to display the annual production fitted with the annual mean discoveries shifted by 30 years. The fit is not very good as most of discovery are from large fields and the discovery curve (despite a +/- 3 years smoothing) shows up and down. But it is obvious that the offshore discovery has peaked (one large peak around 1995-30 = 1965 and a smaller peak around 2005-30 = 1975). The shift shows that offshore production will peak around 2010 and will decline sharply after.
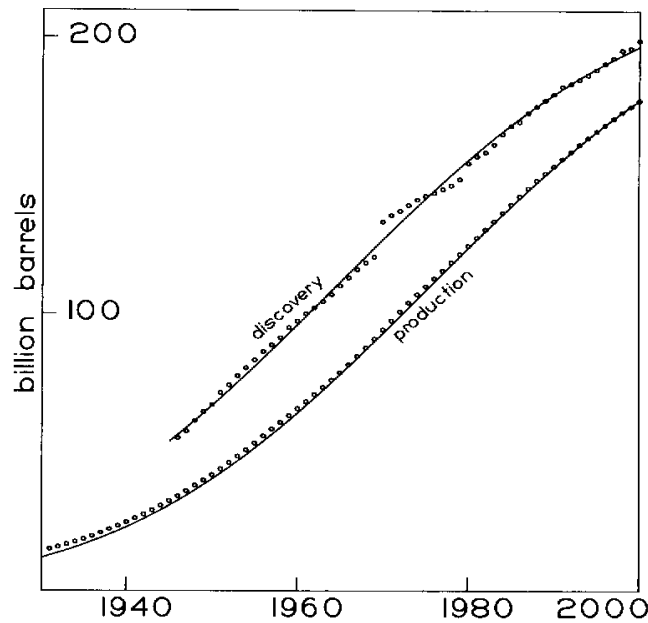
Figure 15: World offshore oil: annual production and shifted discovery
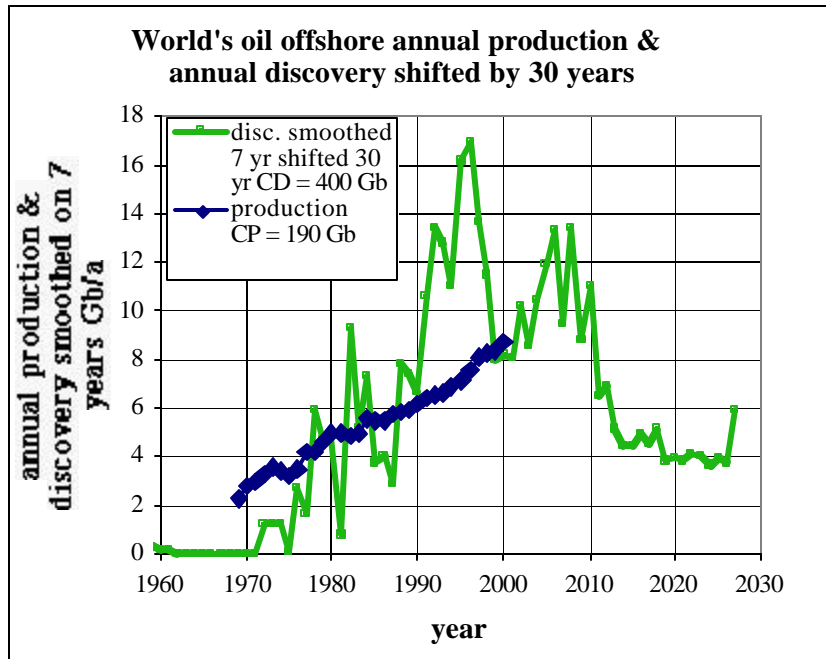
Deffeyes displays an interesting graph where cumulative discoveries are compared to cumulative productions over time. For the US, the display page 145 as shown below says that "the best fit occurs with discoveries leading production by 11 years". But this result is in complete disagreement with the graph page 138 where it is written that "more oil was found in the decade from 1930 to 1940 than in any decade before or since ". If the peak of discovery is around 1935 (as says Deffeyes: where the price was very low 1$/b; but without the proration imposed by the Texas Railroad Commission it would have been 0.1 $/b) and the production peak in 1970 the shift is about 35 years and not 11 years. The graph on page 138 is the one with mean backdated values for oilfields over 100 Mb, when the graph on page 145 is the one based on the total discovered reserves, being current remaining proved reserves plus cumulative production.

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The circles labeled "production" are the cumulative U.S. oil production (including Alaskan and offshore oil) added up from 1860 to a given year. The "discov-

Figure 17: The discoveries are those listed in the US-DOE/EIA report 90-534 plus, for the 1990 decade those listed in the annual US-DOE revisions. These discoveries are "grown" to their expected value and compared, on a cumulative basis, with the cumulative production. The cumulative mean US discoveries have a good fit with cumulative production after a shift of 30 years.
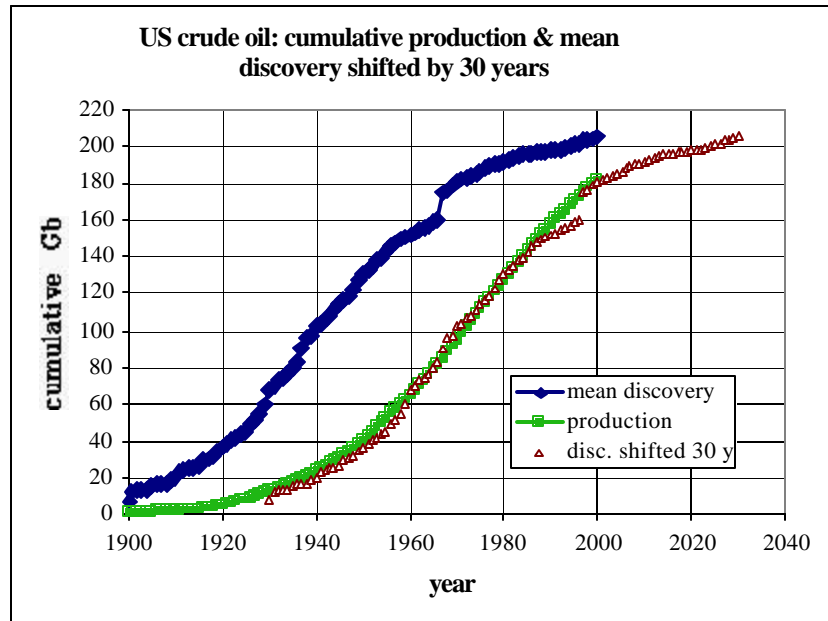
For the world oil production Deffeyes graph on page 148, it is written "discoveries lead production by 21 years". Again discoveries are current proved values and the fit is poor.

Figure 18: Deffeyes world cumulative production & proved current discovery showing a poor fit with a shift of 21 years
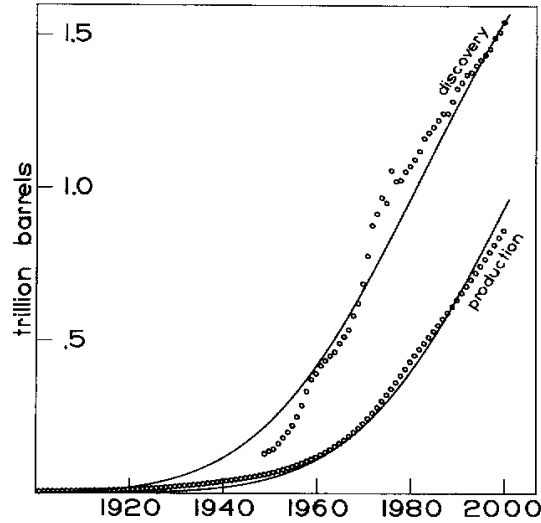
Cumulative world oil production and cumulative production plus reserves (discoveries) are compared with the best-fitting cumulative Gaussian curves. The two solid curves are constrained to have exactly the same shape but are dis

Figure 19: The plot with the backdated technical data for oil and gas displays a fairly good fit between cumulative discoveries and productions with a 35 years shift for both oil and gas

World: cumulative discovery and production of conventional oil + condensate and natural gas
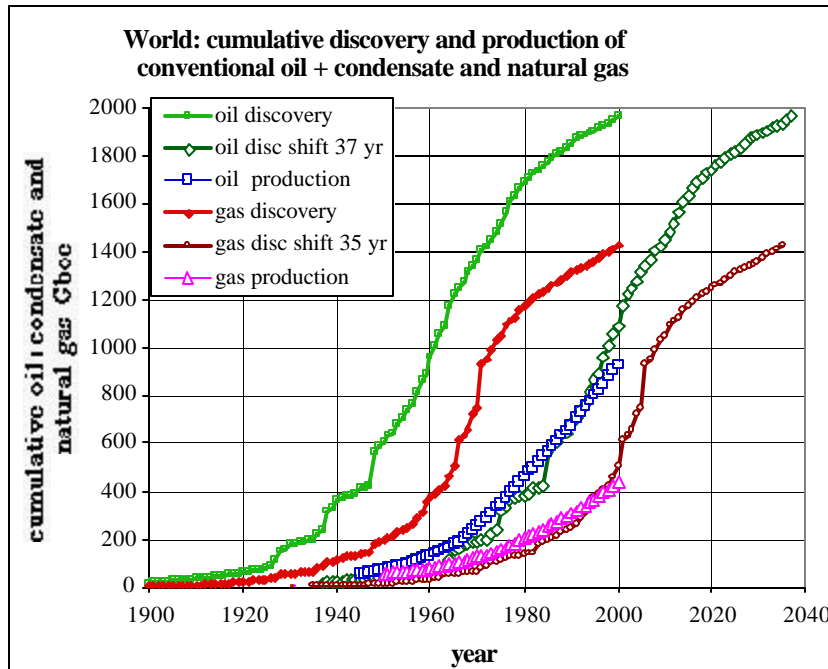
There are other interesting applications on important subjects as US natural gas supply; where one cycle is a poor model.

Figure 20: The display of cumulative mean discoveries and productions for conventional natural gas for the US + Canada + Mexico shows a good fit for a 20 years shift
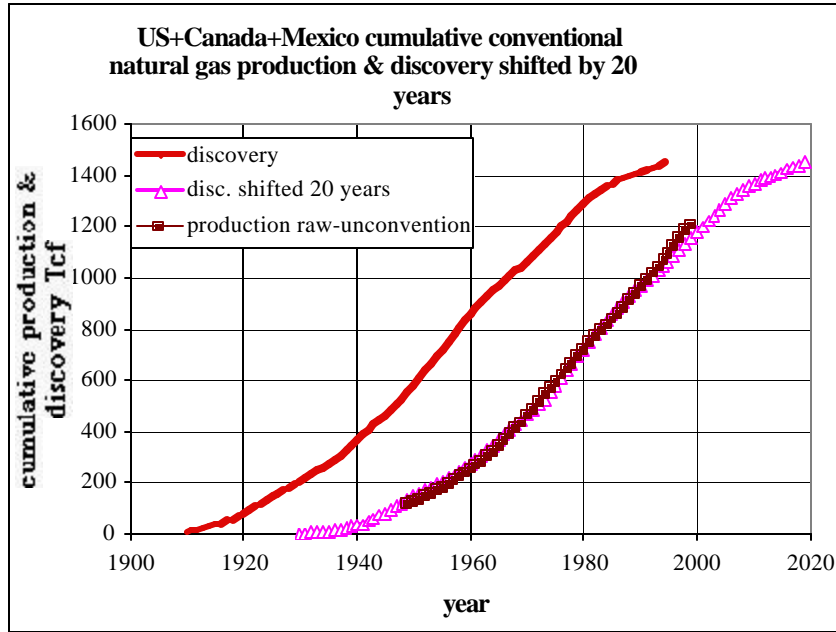
Figure 21: It is more appealing to compare the derivative of the cumulative values of the former graph, i.e. annual productions and shifted discoveries (the shift of 20 years has been chosen because it provides the best apparent fit between the two series) because it is a good indication for forecasting future production, with an obvious decline to be expected.
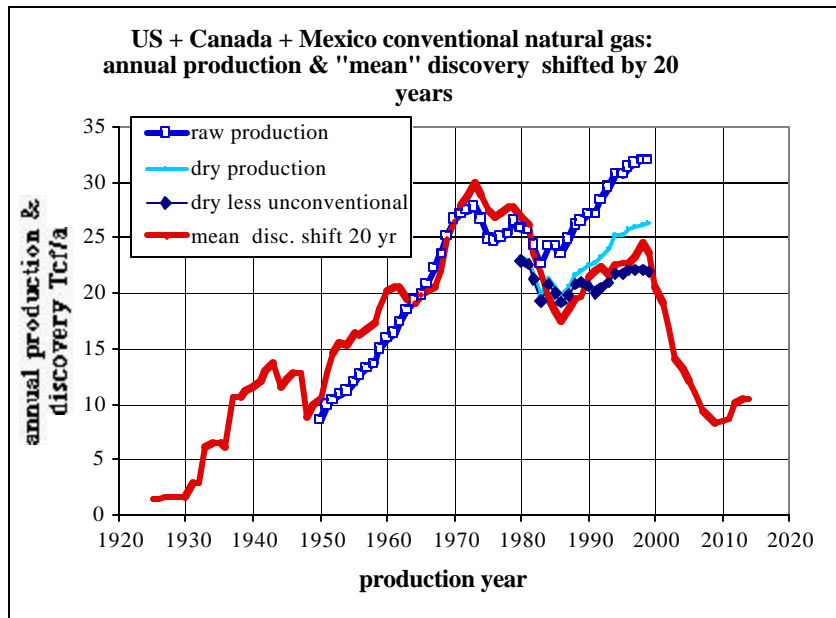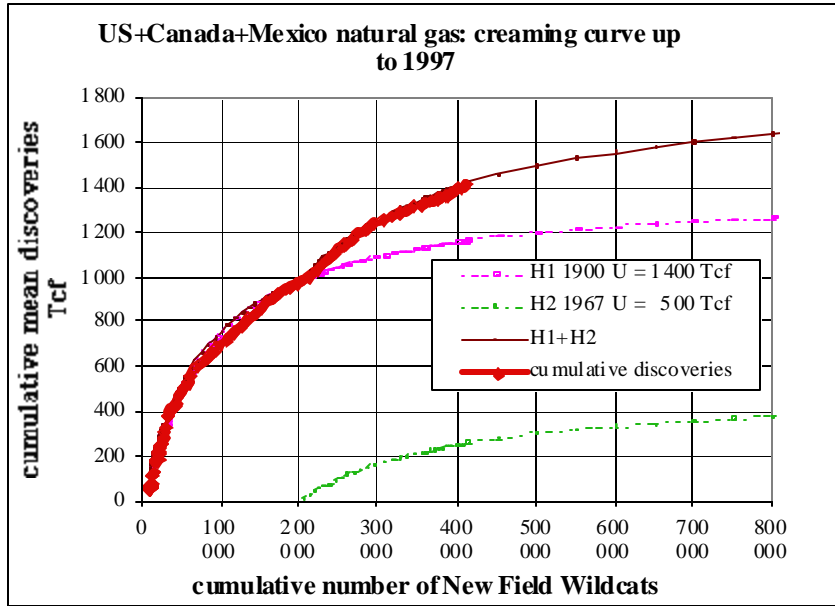
Figure 22: As shown by the creaming curve, the US + Canada + Mexico cumulative dis-
coveries and productions smooth the ups and downs and converge towards ultimate reserves

This gas creaming curve exhibits two cycles one from 1900 to 1967 and a second one from
1967-2000. Without a third cycle, the ultimate with doubling the present NFW number (over
400 000 NFW) to 800 000 would reach about 1650 Tcf.

But there are better examples of two separate cycles as the United Kingdom, France, or
Netherlands. For the UK, published data in the US as remaining proved reserves (The
Department of Trade & Industry releases much better data, but they are converted to the poor
US practice) show a chaotic variation (see Oil & Gas Journal and World Oil values) whereas
the technical mean data shows a much higher value declining since 1977.

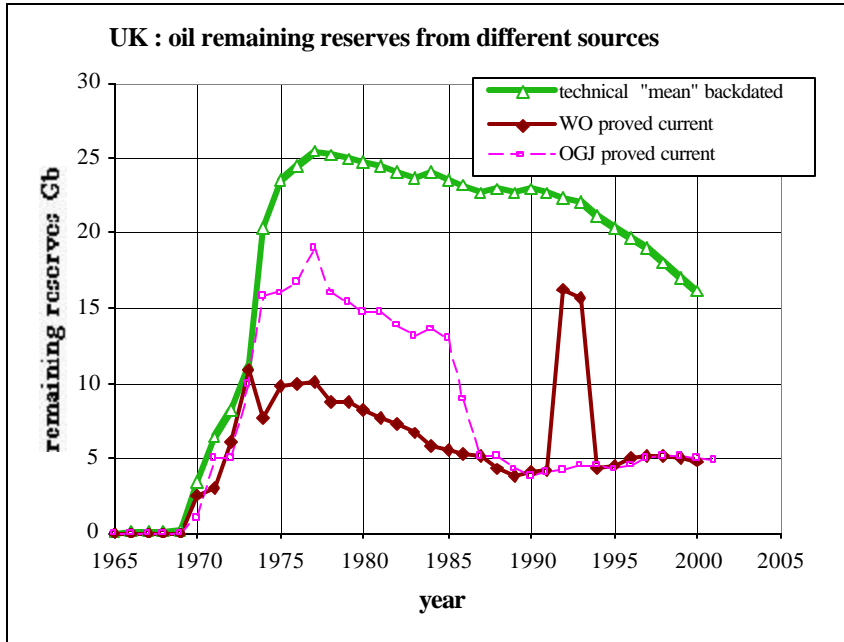Figure 23: UK remaining oil reserves from different sources

Figure 24: UK cumulative mean discoveries have a very poor fit with cumulative productions
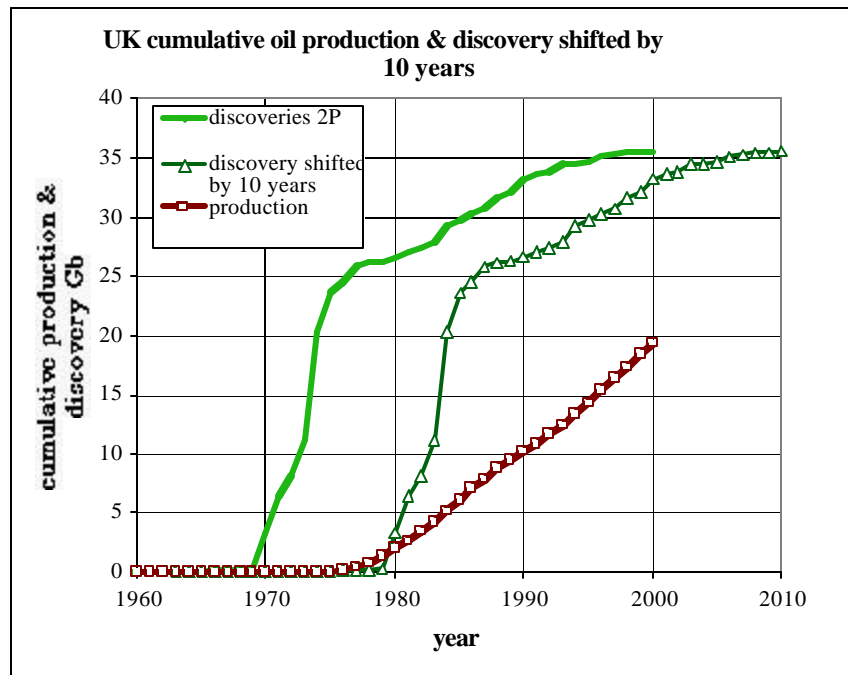

UK cumulative oil production & discovery shifted by 10 years

Figure 25: The UK Deffeyes plot for oil productions & discoveries is very hard to extrapolate towards an ultimate value
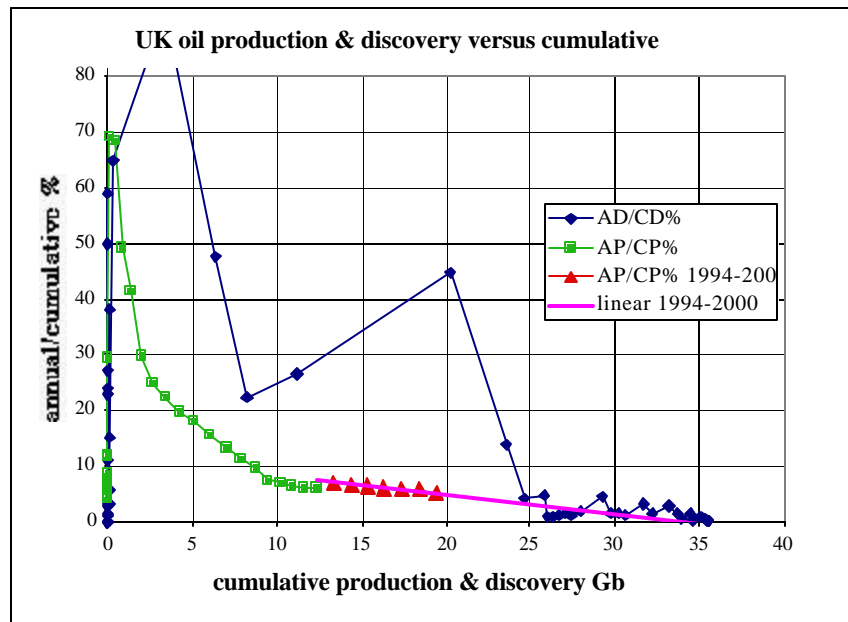

UK oil production & discovery versus cumulative

Figure 26: The UK oil creaming curve has a much better look. In spite of the continuous increase of the number of wells (new fields are still discovered with the same success ratio but their size is shrinking sharply), the volume of cumulative discoveries trends towards 40 Gb for oil + condensate.
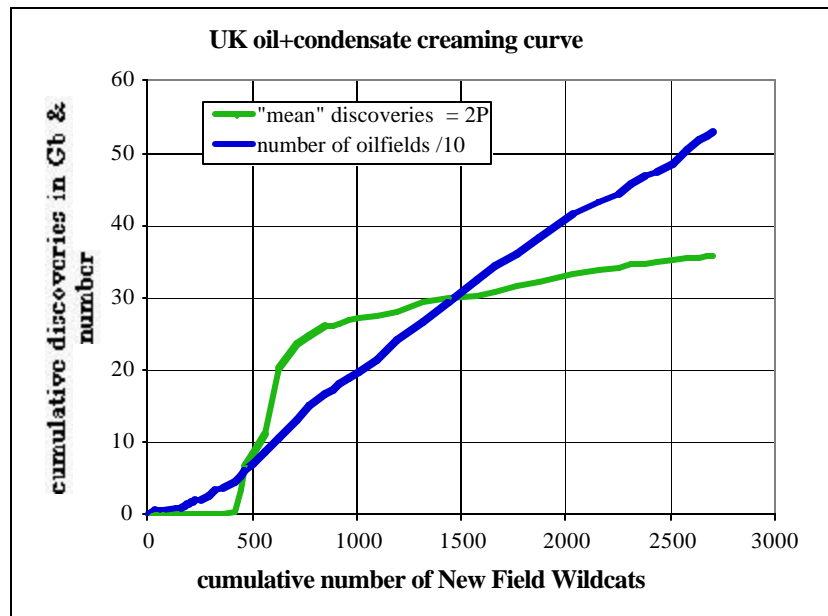

Figure 27: The UK annual productions and shifted (10 years) annual discoveries do not fit well in terms of quantities but there is a good correlation between peaks and troughs. Two cycles are well identified and provide an indication of a decline of the future production
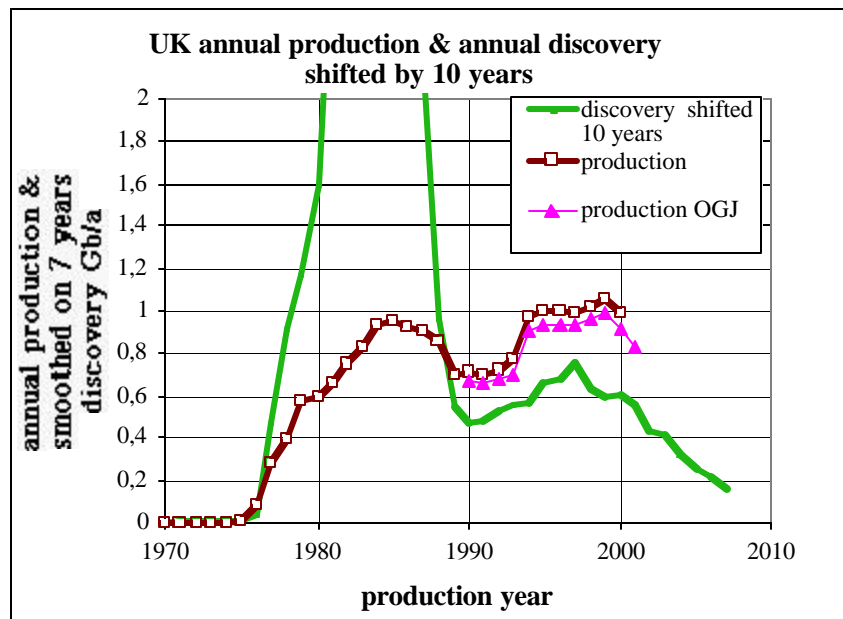
Figure 28: French production displays two cycles with an amazing symmetrical shape. The fit with discoveries is good for a 7 years shift but would be better with 10 years for the first cycle and 5 years for the second (onshore discoveries easy to produce)
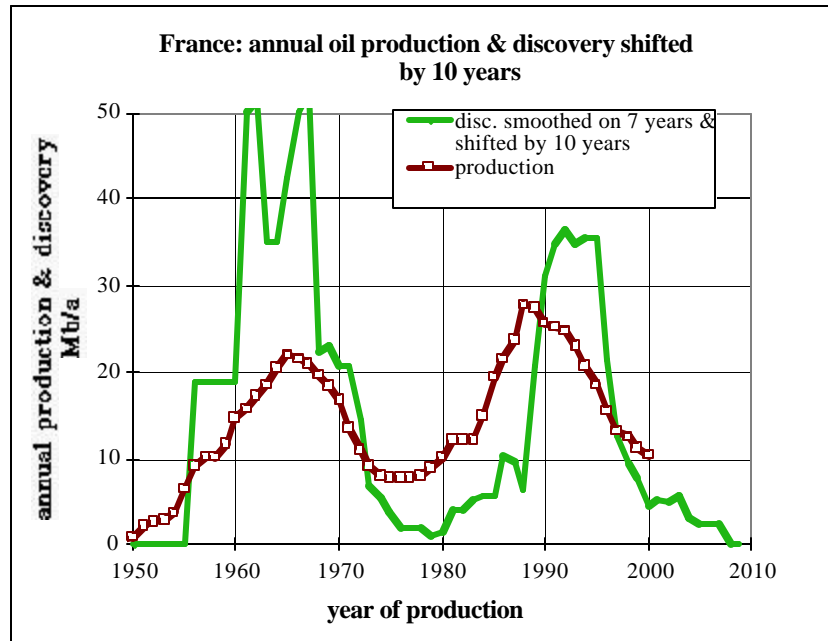

France: annual oil production & discovery shifted by 10 years

Figure 29: Because of the two cycles and the small number of fields the correlation between cumulative oil productions and discoveries is not good.

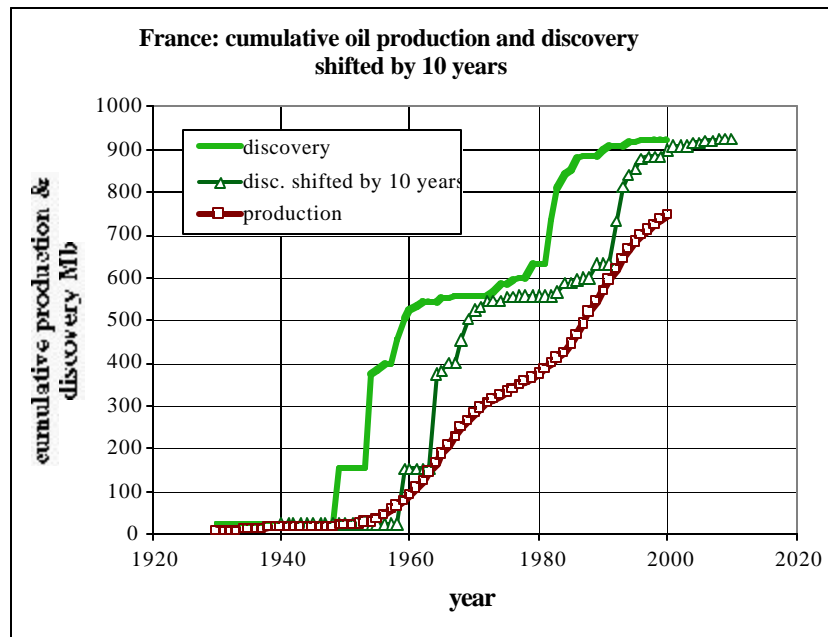**France: cumulative oil production and discovery shifted by 10 years**

Figure 30: The Deffeyes plot is quite unclear for the discoveries and far from a straight line for the annual productions. Extrapolation does not suggest the possible coming of a third cycle, which is unlikely even in the Iroise Sea

France oil production & discovery versus cumulative production & discovery
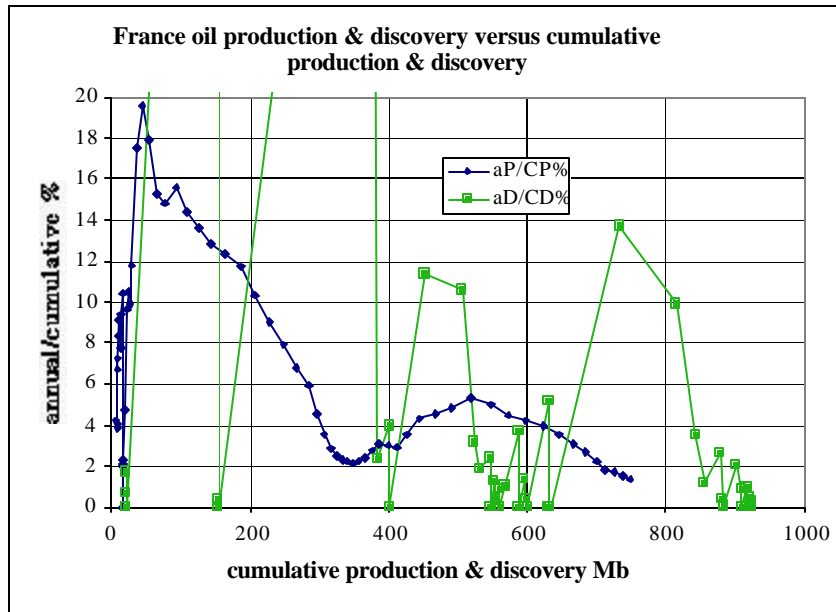
Modeling is possible when discoveries and productions follow a natural course. Conversely, as shown by the example of Saudi Arabia, when production is constrained by political decision, modeling is impossible.

Figure 31: The published data of remaining reserves of Saudi Arabia (OPEC, OGJ and WO) are different from (much lower than) the technical mean data
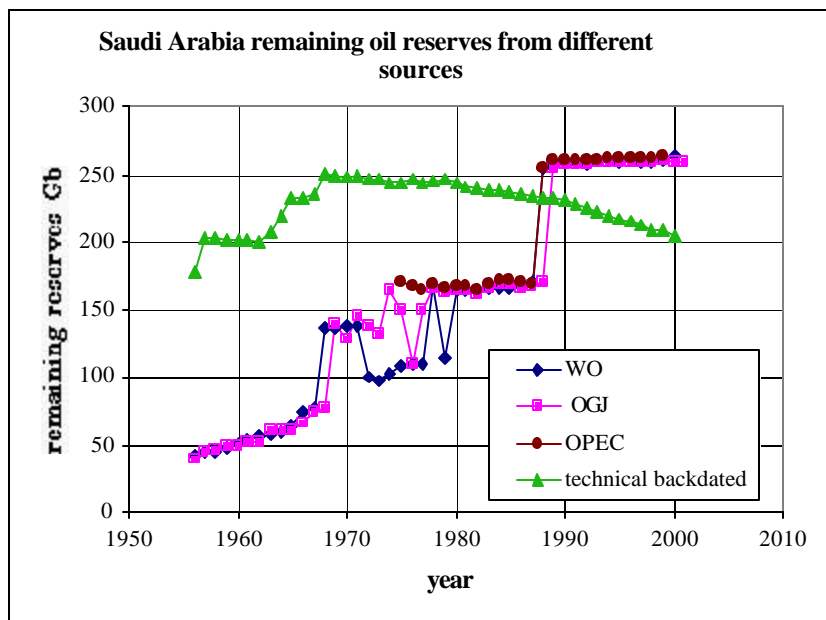

Saudi Arabia remaining oil reserves from different sources

Figure 32: Saudi Arabia cumulative mean discoveries do not fit with cumulative productions
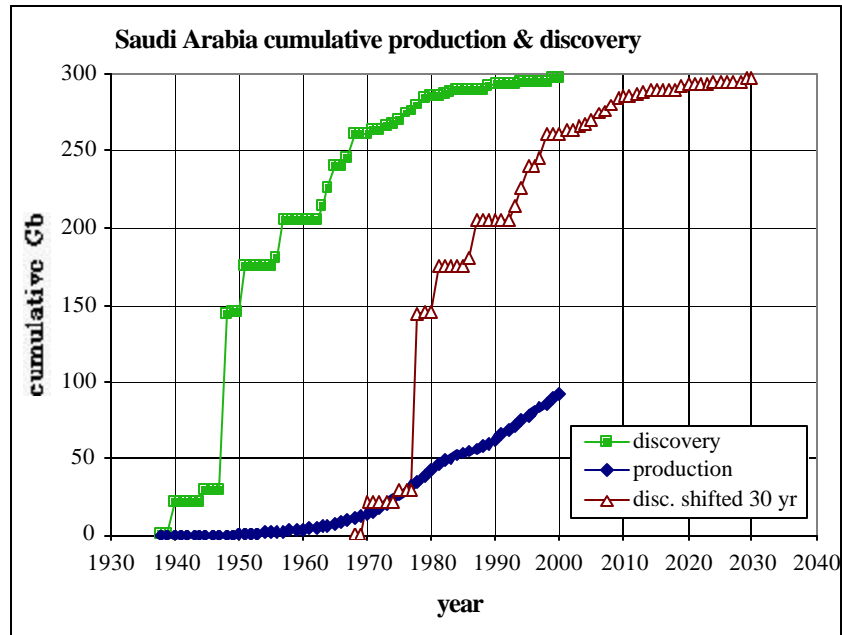

Saudi Arabia cumulative production & discovery

Figure 33: The creaming curve of Saudi Arabian oil is good and does not suggest the possibility of a second cycle.
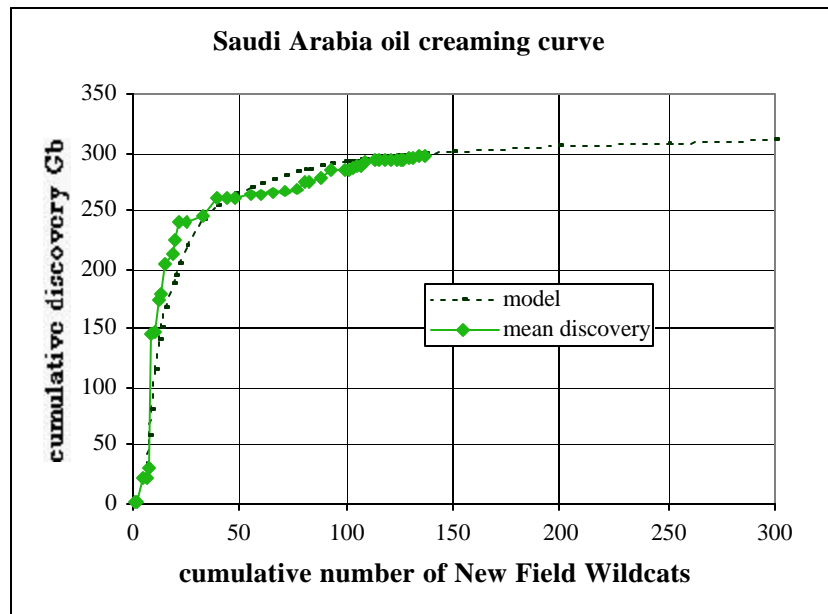
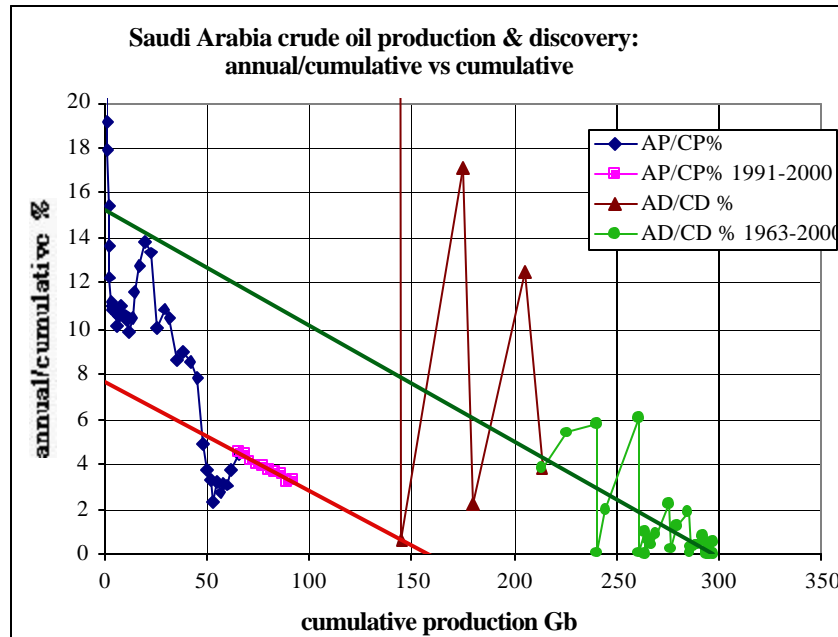

Saudi Arabia oil creaming curve

Figure 34: The Deffeyes plot for Saudi Arabia is meaningless and displays different trends for discoveries and productions

I agree with Deffeyes when he says that the large reserve estimates of the latest USGS (2000) report are implausible. Oil (conventional?) production is forecasted by Deffeyes to peak in 2004 (2003-2009 range) but if the present US recession stays for years and extends to the world the demand will be constrained for several years. The world oil production will flatten and the peak could be a bumpy plateau, around 2000.

In conclusion, Deffeyes's book is a good way to know about the history of the oil exploration and production. The title Hubbert's peak is misleading, as there are several cycles (and peaks) in most of oil or gas production. Hubbert and Deffeyes fail when they try to model the world and countries with a single cycle. Another weakness is that Hubbert and Deffeyes deal with conventional oil (or gas). Hence an ambiguity of definition: does "oil" include condensates, NGL processing gains…? And a miss: that of unconventional oil (e.g. Orinoco belt or Athabasca sands) or gas (e.g. coal-bed methane).

The best contribution of Hubbert was to emphasize that oil has to be found before it is produced and you have to look at discoveries (mean or expected value) before looking at productions. The problem for University geologists is that they do not have access to the technical data. They cannot deal properly with "mean" discoveries.