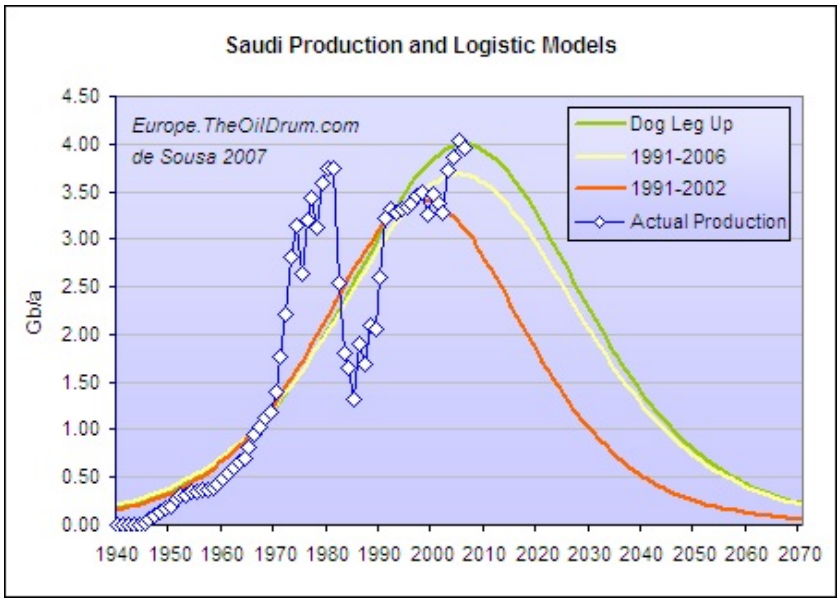
The Oil Drum: Europe
DISCUSSIONS ABOUT ENERGY AND OUR FUTURE

A few more thoughts on Saudi and HL

Posted by Luis de Sousa on October 22, 2007 - 8:50am in The Oil Drum: Europe
Topic: Geology/Exploration
Tags: hubbert linearization, reserves, saudi arabia, urr [list all tags]

There has been some discussion about how to apply the Hubbert Linearization (HL) to Saudi historical production in recent weeks at TOD. Trying not to fall into redundancy, let me have some loose thoughts on these models:



Three alternative Logistic models for Saudi production. Click for large version.

In The Beginning

While I was in Ireland for ASPO-6 it passed exactly two years on the day I registered at TOD. It was on September the 14th 2005, and I did it so I could leave a comment on this post. It was on this post that HL was introduced to TOD and interestingly the discussion about the applicability of the method started right there.

Two years later I can't say that we moved farther on that discussion, but I'm sure of one thing, most of the folks that commented on that post learned a lot since then (I for instance improved a lot on my Latin).

All over again today

Two weeks ago Euan put out two interesting posts about Saudi that once again stimulated the discussion on the country's remaining reserves. In the midst of the discussion

WebHubbleTelescope had this comment:

> I would tread very cautiously on this route. First of all, the logistic model on which HL is based is purely a heuristic with no first-principles derivation. The only process that matches logistic behavior is birth-death population dynamics, and we know that oil molecules don't mate and give birth.
> [...]
> So I see it that we have two routes to take:
> 1) Go for the trivial analysis as above (therefore undermining HL, which has proven to be a perfect example of a concocted and contrived analysis)
> 2) Go for a real model of oil discovery and depletion
> [...]

Go and check the discussion that emanated from there, it's worth it.

Why do we use HL?

Hubbert Linearization was a name coined by Stuart back in 2005 and is just another way of identifying a specific step of what prof. Deffeyes called in his books the Hubbert Method. It's a simple process to fit a Logistic curve to an historical time-series. Web's reserves towards the method are pertinent, but there are good reasons to use the method:

- Applicable with High School mathematics, easy to use for a first assessment of future production;
- It uses solely three parameters to fit a curve to the data, which makes it immune to seasonal or epoch trends (it is a good token of the "big picture");
- Oil and Population growth have been closely related (has Web stressed, Population Dynamics is the prime field for Logistic predictive modelling);
- The only information needed to apply the method is historical production data, which is usually freely accessible.

Ironically, all of these strengths can also be seen as weaknesses.

Don't get me wrong, Web is right in calling for the development of more advanced predictive methods, like his Shock Model, but that is to some extent out of reach for mere mortal engineers.

But there are rules to use HL, failing to observe them is a good recipe for disastrous results. Above all good knowledge of discovery is essential:

- How many discovery cycles were there in the past? If there were more than one, HL is not directly applicable and each cycle should be modelled independently with a Logistic curve (e.g. UK);

- Is discovery on its terminal phase? If not, it is probably too soon to apply HL. If so, to what URR is pointing the discovery cycle? HL should produce a similar result for URR;

- Finally it has to be considered that HL is not taking into account future cycles of discovery and ensuing production.

Can we apply HL to Saudi?

Technically yes, because the historical production data is publicly available; on the other hand the Saudi discovery cycle is not completely known and there are doubts about what the URR is.

Luckily for us, Khebab has been compiling a database on Saudi discovery, it is yet to be completed and it includes mostly giant fields, but gives us a good idea. Up to know he has data from Colin Campbell's book "Golden Century of Oil 1950-2050"; Rand, 1975; Matthew Simmons' "Twilight in the Desert" and Fredrik Robelius PhD Thesis. In the following days Khebab will publish a detailed version of this database with more data, so keep an eye on TOD's main page.

From this database I created two cases with the lowest and highest estimates for each field:

Table 1 - Lower and Higher estimates for Saudi's individual fields according to Colin Campbell's book "Golden Century of Oil 1950-2050", 1991, pages 296 & 341; Rand, 1975; Simmons, "Twilight in the Desert", 2005; Robelius, 2006.

Field	Discovery Year	Lower Estimate (Gb)	High Estimate (Gb)
Dammam	1938	0.325	1.05
Abu Hadriyah	1940	1.055	1.76
Abqaiq	1940	12.5	19
Qatif	1945	3.2	9
Ghawar	1948	66	150
Fadhili	1949	0.95	0.96
Safaniya-Khafji	1951	21	55
Khursaniyah	1956	2.3	4
Khurais	1957	8.5	19
Manifa	1957	11	23
Abu Safah	1963	6.15	7.81
Berri	1964	7.3	25
Zuluf	1965	8.5	20
Fereidoon-Marjan	1966	10	10
Marjan	1967	8	9.26

Janan	1967	0.5	0.5
Karan	1967	0.01	0.01
Shaybah	1968	5.71	19.82
Barqan	1969	0.5	0.5
Mazalij	1971	0.338	0.63
Harmaliyah	1972	1.025	1.81
Abu Jiffan	1973	0.279	0.5
Maharah	1973	0.5	1.1
Qirdi	1973	0.036	0.036
El Haba	1973	0.057	0.057
Rimthan	1974	1.3	1.3
Lawnah	1975	1.17	1.17
Dibdibah	1975	0.007	0.007
Hawtah Trend	1989	1.97	1.97
Totals		180.182	384.25

Plotting this data directly yields no useful information due to Ghawar that accounts for about 40% of the URR. Instead I plotted a low-passed version with a 5 year moving average:

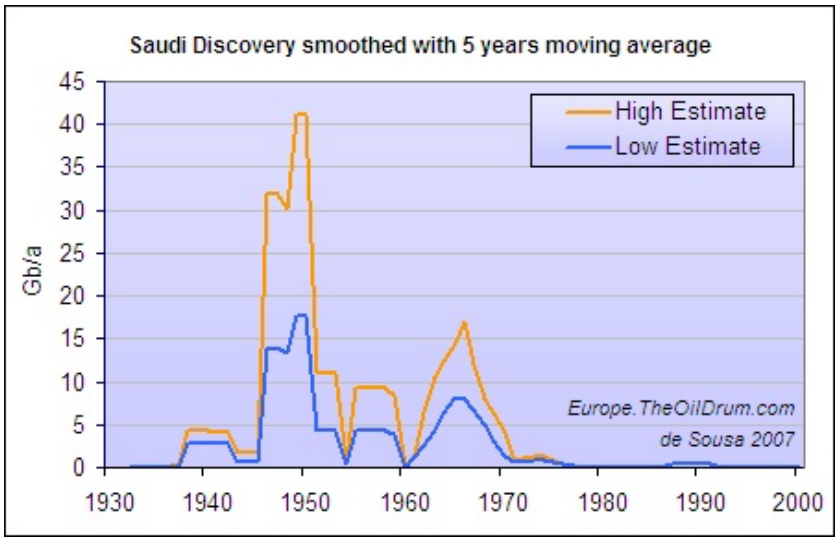


Figure 1 - Low and High estimates for Saudi Discovery smoothed with a 5 years moving average. Click for large version.

On one hand it can be seen that the discovery cycle has already ceased, but on the other hand there's no divisible logistic. This is where problems start with Saudi Arabia; the giant fields are so giant that the discovery signal is in practice chaotic.

Still we get the URR from each estimate, 180 Gb for the Low Estimate and 380 Gb for High Estimate. Adding to that information there's the official number of 720 Gb for the OOIP. So we are looking at a recovery rates between 25% and 52% of the OOIP. That's a large swath of

spectrum to cover.

So let's get our hands dirty and plot the P/Q vs Q chart:

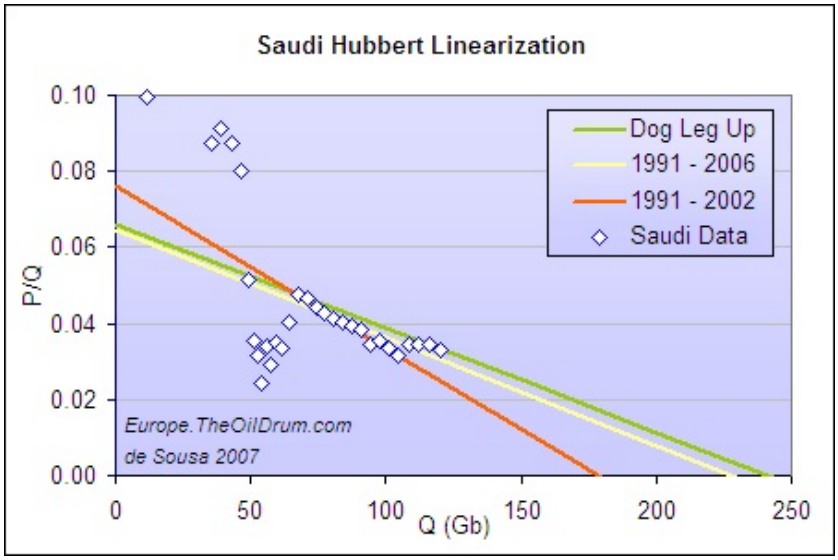


Figure 2 - Three alternative Logistic fits for Saudi production using HL. Click for large version.

The chart portraits 3 alternative fits, that have been the base of much of the discussion around Saudi on TOD lately:

- 1991 – 2002 : the fit that's the basis for ace's forecast – which regards the years from 2003 to 2006 as outliers;
- 1991 – 2006 : the fit by Khebab;
- The Dod Leg Up : the fit by Euan - which takes on the alignment of the data respective to the years 1991, 1992, 2005 and 2006 (more on that later);

The parameters and points of interest of each of these fits are resumed on the following table:

Table 2 - Parameters and results of the three Logistic fits considered.

	1991 – 2002	**1991 – 2006**	**Dod Leg Up**
URR (Gb)	178	227	241
Peak year	1998	2005	2006
Pmax (Gb/a)	3.40	3.68	4.00
b (slope)	0.076	0.065	0.066
Recovery	24.7%	31.5%	33.5%

So, which one do you choose? A hard decision? Look at the familiar Production vs Time chart:

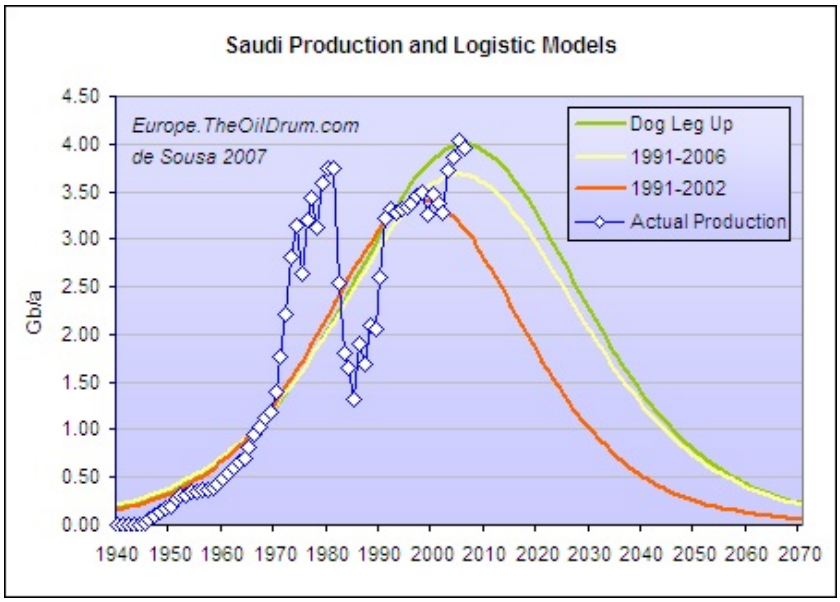


Figure 3 - The three alternative Logistic ploted on the familiar Production versus Time chart. Click for large version.

Still undecided? Try the Cumulative Production vs Time chart:

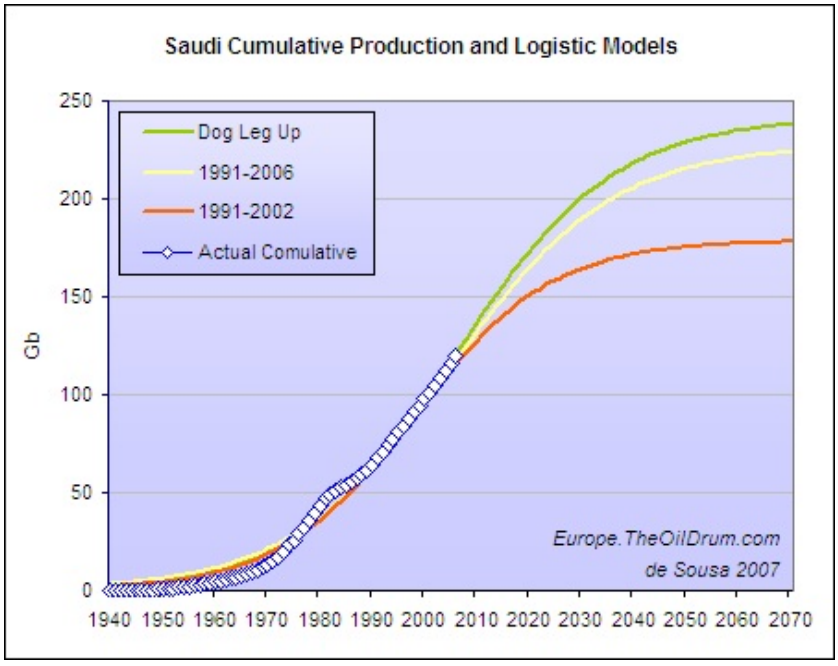


Figure 4 - The three alternative Logistic ploted on the Cumulative Production versus Time chart. Click for large version.

Again, which model do you pick?

Why do I care?

Why am I, here stuck at this *finisterra*, concerned with this kind of stuff? Because like you, I want to know when will the lights of this oil party start to fade away. Do any of these models help on that? If you're still undecided between these models you are probably on the right track.

The main problem with the discussions going around at TOD about Saudi and HL is that they have been concentrated on estimating a value for URR. This value is just a secondary result of HL and a number of which foreknowledge is advisable to check the method's efficacy. The main object of the method is to model future production and enlighten a possible epoch for the peak.

As the last charts show, none of these models seem to be doing a good job on the production profile modelling chapter. When applied to the Saudi case HL is fitting very closely the recent Cumulative profile but doing terribly on the Production profile.

Maybe we should just throw all of these models overboard.

But not so fast, let's thought about it a bit more.

That Dog Leg Up

This is a funny name Euan coined some time back when he started looking into Saudi's HL. It characterizes a phenomenon where after a period along a certain logistic fit, production jumps up to another path. The Dog Leg Up fit uses solely four points, but there are good reasons to consider such model.

The Dog Leg Up is the signature on the P/Q vs Q plot of a constrained production profile. Let's consider a theoretic Logistic cycle and its counterpart restrained at 70% of maximum production:

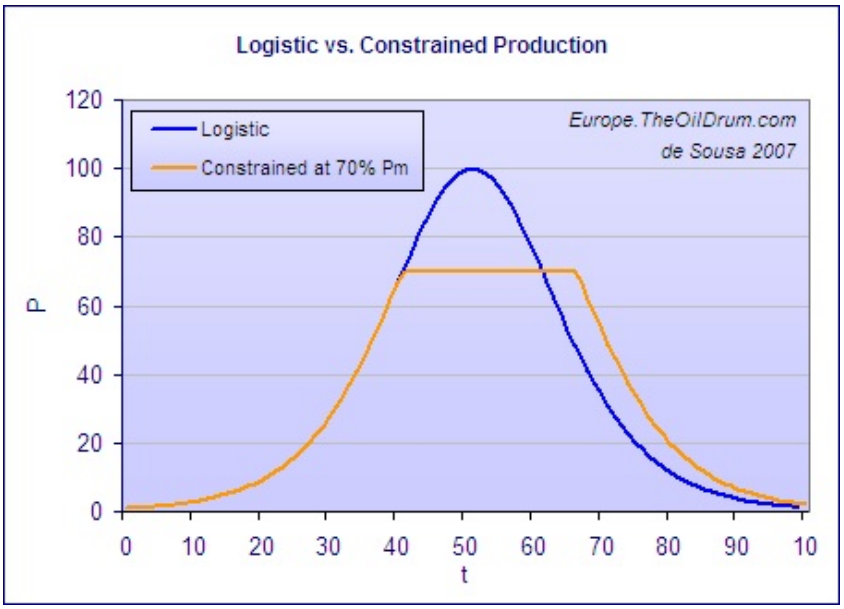


Figure 5 - A Logistic cycle and its counterpart constrained at 70% of maximum. Click for large version.

These two cycles look like this on the HL plot:

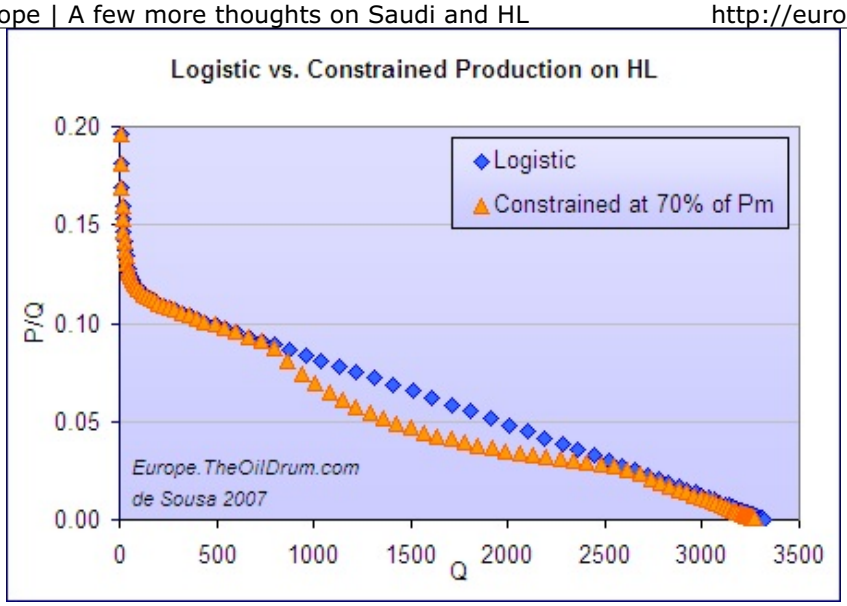


Figure 6 - The same Logistic cycle and its constrained counterpart plotted on the P/Q vs Q chart. Click for large version.

Fitting a logistic curve directly on, say half, of the constrained data series would produce a very different curve, and of course a lower URR estimate.

Look again at the Production vs Time chart for Saudi, don't the periods 1974 – 1981 and 1991 – 2002 look like constant production periods? And what about 1982 – 1990? Moreover, it is well known the role of "swing producer" that Saudi underwent especially after 1981.

If I had to salvage one of the three previous models from the seas of oblivion it would be the Dog Leg Up.

What to expect from Saudi?

The Dog Leg Up model forecasts Saudi production above 3.5 Gb/a for ten years more, but nothing assures us that our dog won't stretch its leg a bit more. Also, it looks plausible that by constraining production again to the range of 3.2 – 3.5 Gb/a Saudi can keep up with constant production even longer and possibly avoid the terminal decline for two decades or more.

No worries then? At least not for tomorrow. But let me tell you that I'll keep watching Saudi production regularly and recheck all these models every time another year stacks up to the time series.

Just in case.

Luís de Sousa
The Oil Drum : Europe