The Loglet Analysis

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Topic: Supply/Production
Tags: logistic, loglets, m. king hubbert [list all tags]

Most peakoilers on this site have been introduced to the logistic curve through the famous prediction of King Hubbert on the Lower-48 production. Fewer maybe knows that curve fitting techniques have been extensively applied by people that we may qualify as cornucopians. Ironically, the logistic curve is also used as a prediction tool for market share and technology subsitution. For instance, a pioneer in logistic-based technological forecasting in the energy domain is Cesare Marchetti:

More recently, there is also the work of Jesse H. Ausubel and his team about the Loglet analysis:

> "Loglet analysis" refers to the decomposition of growth and diffusion into S-shaped logistic components, roughly analogous to wavelet analysis, popular for signal processing and compression. The term "loglet", coined at The Rockefeller University in 1994 joins "logistic" and "wavelet". Loglet analysis comprises two models: the first is the component logistic model, in which autonomous systems exhibit logistic growth. The second is the logistic substitution model, which models the effects of competitions within a market.

src: Perrin S. Meyer, Jason W. Yung and Jesse H. Ausubel, Logistic Growth and Substitution: The Mathematics of the Loglet Lab Software Package. Technological Forecasting and Social Change 61(3):247{271, 1999.

The Loglet analysis is interesting because it can potentially handle multi-peak production profiles which is a common challenge for curve fitting techniques. I won't go into too much details for the Loglet transform, all the mathematical details are well explained in the aforementioned reference (there is also a pdf version here). The Loglet decomposition is an elegant mathematical framework which consists in fitting a sum of logistic curves. The decomposition is performed using successive Fischer-Pry decompositions (*J.C. Fisher and R.H. Pry. A simple substitution model of technological change. Technological Forecasting and Social Change, 3:75-88, 1971.*) which consists in plotting the log of the cumulative production as a fraction of reserves versus time:

$$\log(Q(t) / (1 - Q(t) / URR))= -K(t - t\_half)$$

An example of a Fischer-Pry representation is given on Fig. 1. The notations used for the logistic parameters differ from the notations usually encountered on TOD:

- *N(t)* is the cumulative production (i.e. *Q(t)*)
- *t_m* is the peak date (i.e. t_half)
- *Dt* is related to the logistic growth (*K= log(81)/Dt*) and corresponds to the time necessary to deplete between 10% and 90% of the total resource.

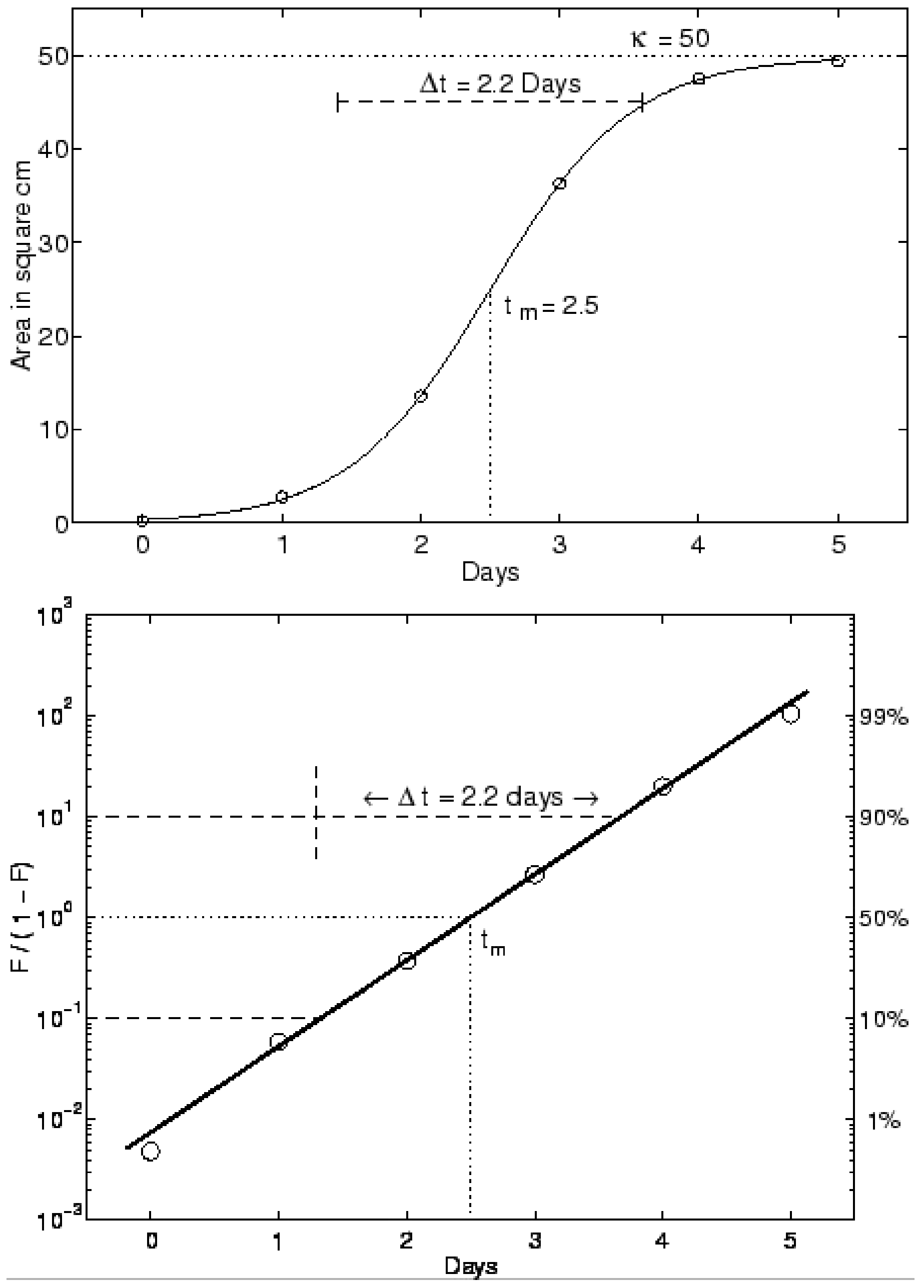


Fig. 1- The logistic growth of a bacteria colony plotted using the Fisher-Pry transform (bottom) that renders the logistic linear (from Meyer et al.). Click To Enlarge.

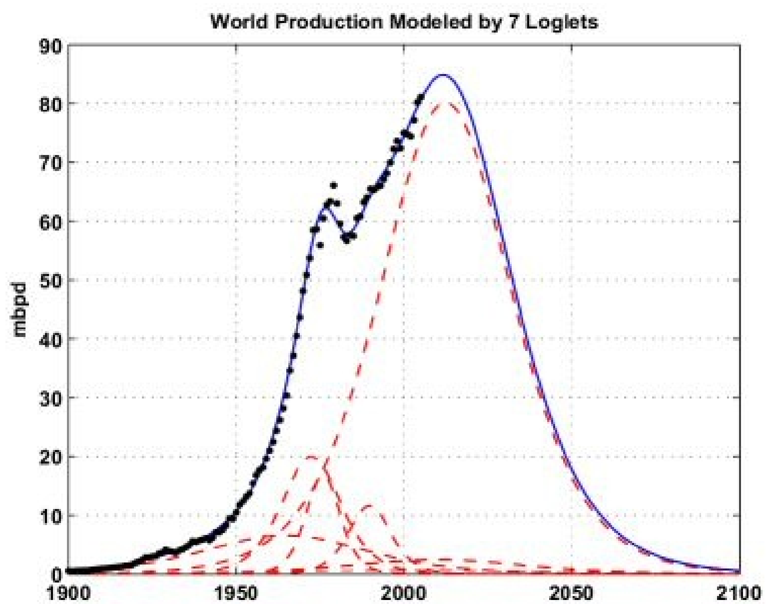
Fortunately, an open source software (in Java) is freely available called Loglet Lab. The software is fairly simple to use and well documented (there is a tutorial here). I tried to apply different

Loglet analysis on the world production with an increasing number of curves.

Number of Loglets	URR (Gb)	Peak date	Peak Production (mbpd)	RMS (Gb)
1	1408	1990	71.3	61.1
2	1470	2002	63.8	104.5
3	1995	2005	75.0	20.8
4	2020	2007	78.2	20.0
5	2018	2011	78.0	15.8
6	2094	2011	83.1	13.3
7	2119	2012	84.8	11.4
8	2125	2012	83.9	12.4

Table I. Results on the world oil production (all liquids excluding refinery gains) for different number of loglets. The RMS (Root Mean Square Error) measures the quality of the fit.

The best fit was reached for a number of loglets equals to 7, the corresponding production profile is given on the figure below. Note how the different Loglets are concentrated around the different oil shocks.



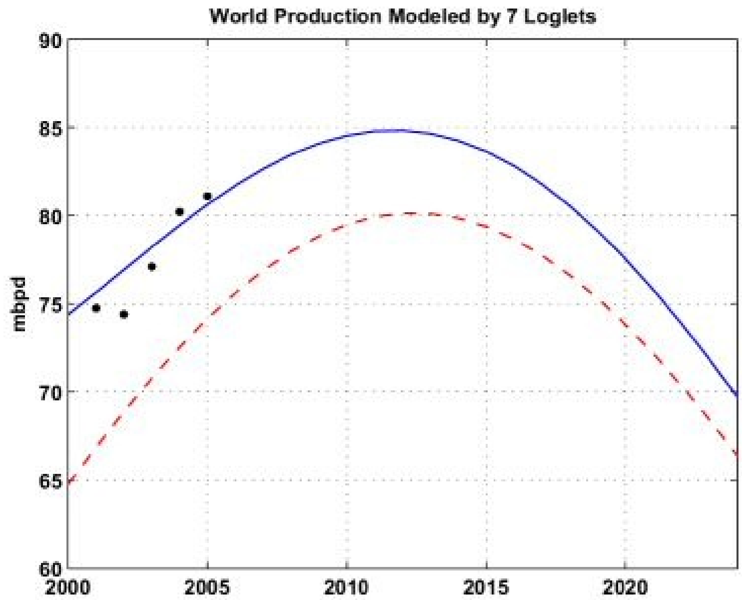


Fig. 2- Results of the Loglet analysis for 7 loglets applied to the world production (all liquids excluding refinery gains). The different loglets are the dotted red lines. Click To Enlarge.

The table below gives the parameter values of the different Loglets (the dataset is also available on EditGrid):

URR (Gb)	1541.7	172.5	156.5	83.8	72.1	62	30.3
% of total URR	72.8	8.1	7.4	4	3.4	2.9	1.4
Dt (years)	57.9	26	71.8	15	18.7	77.2	141.9
K (%)	7.6	16.9	6.1	29.3	23.5	5.7	3.1
Peak date	2012.4	1972.3	1964.7	1975.9	1989.8	2010	2001.1

One Loglet dominates the production and contains nearly 73% of the total URR and is due to peak in 2012 (see Fig. 3). The rest of the contributions come from 6 Loglets and has peaked in 1975. I wonder if this component represents the early "easy oil" from the super-giant fields.

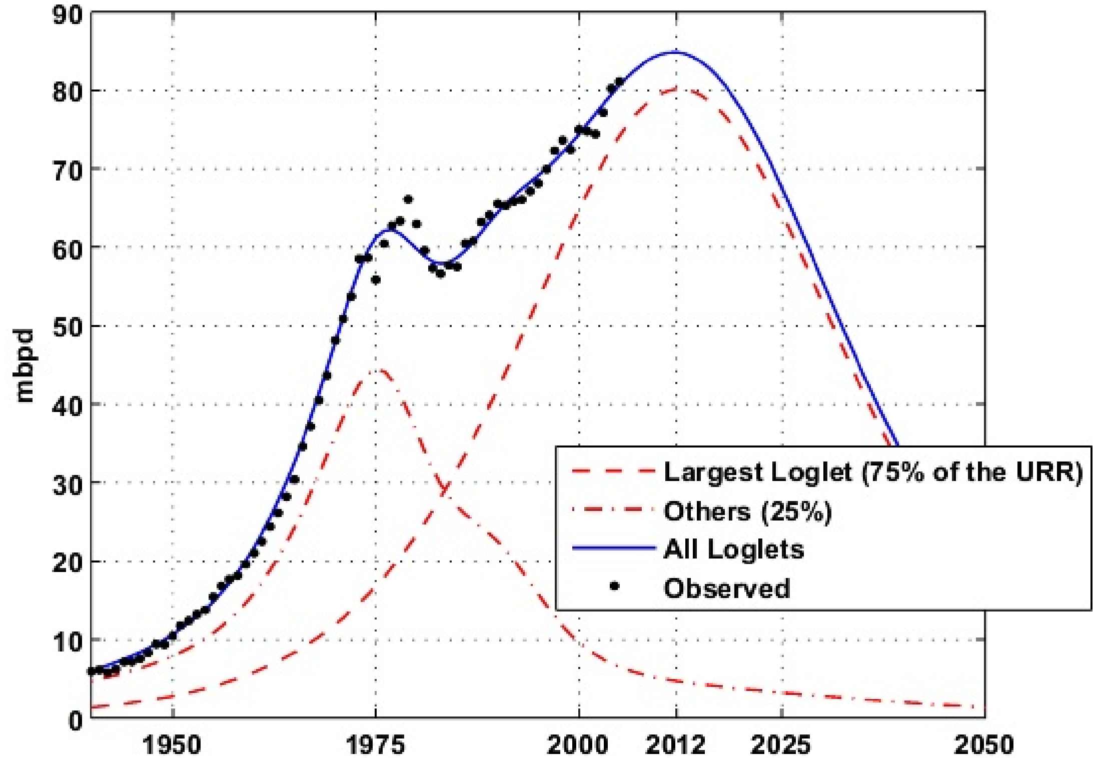


Fig. 3- Same as Fig. 2 but only the Largest loglet is shown and the 6 others are merged in one contribution (~25% of the URR) . Click To Enlarge.

Compared to other curve fitting results (Fig. 4 below), the Loglets give a better result on the left side but is much more pessimistic on the production decline.

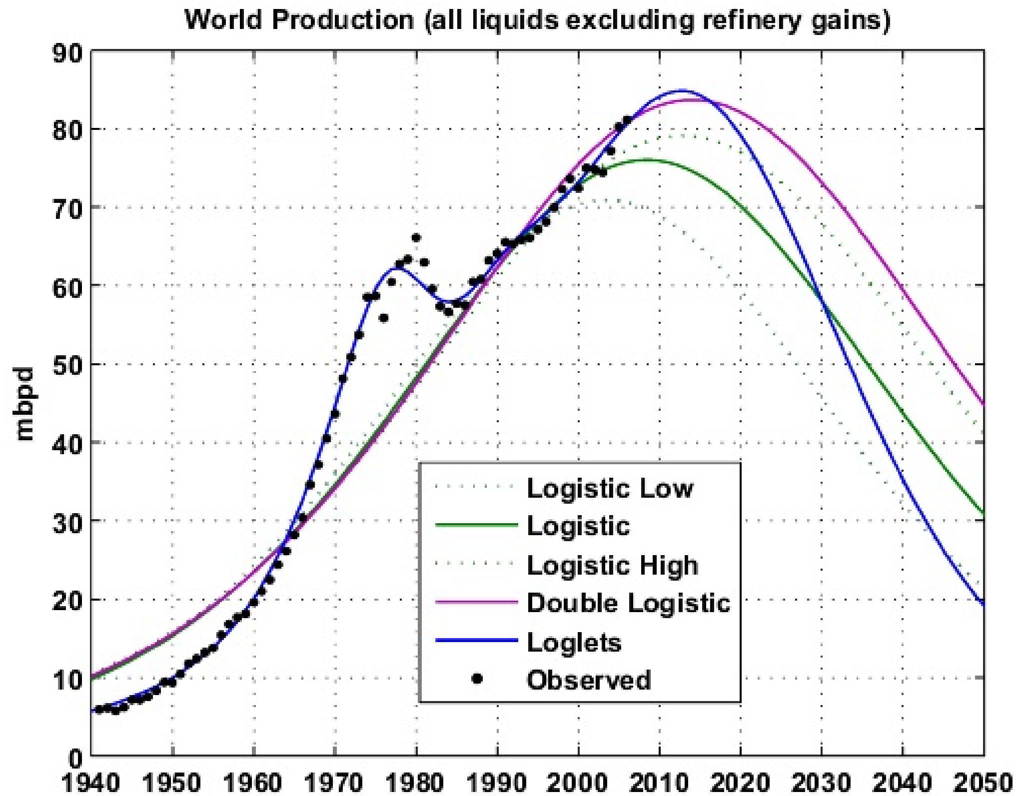


Fig. 4- Different logistic-based predictions: Stuart staniford (in green), Double Hubbert Linearization (in magenta) and Loglets (in blue). The spreadsheet is available here Click To Enlarge.

In summary, the Loglet analysis gives promising results and could be applied on other difficult cases (e.g. Russia). With this approach, the oil shocks and the different production regimes are well modeled. The Hubbert Linearization technique could be used instead of the Fisher-Pry transform which I don't find very practical. The Loglet Lab software could also be used to model energy substitution scenarios (i.e. conventional oil replaced by synfuels, biofuels, etc.). I have noticed a few limitations in the software:

- The Levenberg-Marquardt algorithm is used to perform the Loglet analysis and is dependent on the initialization.
- There is no display of the resulting production curve, only the Loglets and the cumulative production are given.
- Some statistics on the quality of the resulting fit are missing (e.g. RMS error).