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Peak Oil and "The Limits to Growth": two parallel stories

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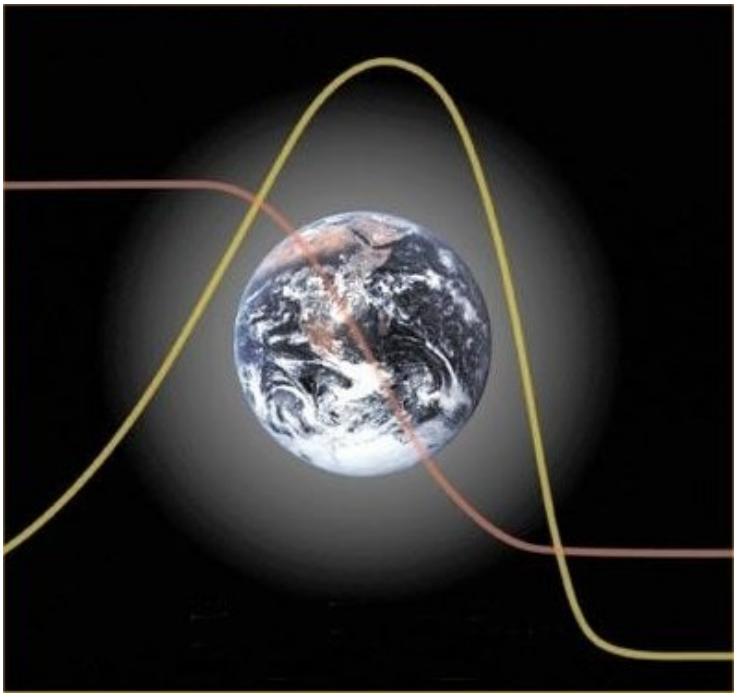

The figure above is taken from the 2004 edition of "The Limits to Growth". It shows the typical curves that the models of the study produce. These curves are similar to those of oil depletion studies based on the "Hubbert model". The similarity is not casual, the theory and the method behind the two approaches have a lot in common.

It is safe to say that, in the 1950s, Marion King Hubbert and Jay Wright Forrester didn't know of each other's existence. Yet, working independently, they were setting the basis for a new science. They were not the first to study the limits of the world's resources. But they were the first to do that using mathematical models that could be extrapolated into the future.

Marion King Hubbert, a geologist working at Shell Oil in Houston, was using an empirical approach for studying crude oil production. In 1956, he published his, now famous forecast that oil production in the US 48 lower states would peak around 1970 and then decline. It did. In the same paper, Hubbert applied his method to the whole world, arriving to the conclusion that oil production worldwide would peak around the year 2000. This long term forecast might turn out to have been approximately correct as the world peak ("peak oil") is still expected for the first decade of the 21st century.

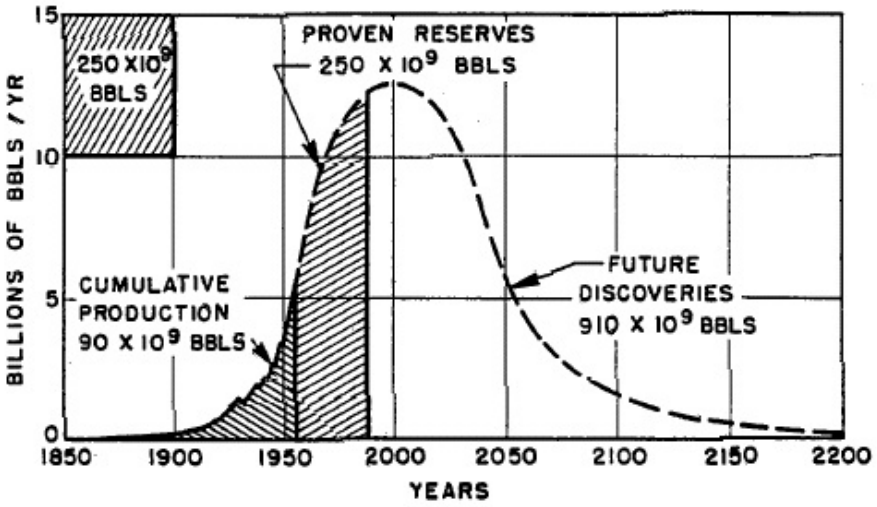

Fig. 1 Hubbert's forecast for the world's oil production, from his 1956 paper

Jay Wright Forrester, professor at the Massachusetts Institute of Technology, had a background in engineering and his goals were more ambitious than those of Hubbert. In the 1950s Forrester had developed a new approach to modeling that he had called "system dynamics". The idea was to use the digital computers, newly developed at the time, to solve a set of differential equations that described the system under study.

Forrester started using his method with physical systems. Then he moved to simple economic and social systems. From there, an obvious step was to model the whole world, something that had to take into account, among other factors, the limits to Earth's resources. Forrester developed his first world models in the late 1960s and published his results in 1971 in a book titled "World Dynamics". But the real impact of Forrester's ideas arrived as a study performed by a group of young scientists at the MIT who used Forrester's approach to develop more detailed models of the world's economy.

Dennis Meadows, Donella Meadows, Jorgen Randers, and William Behrens III published their work in 1972 with the title of "The Limits to Growth." The book developed a series of scenarios according to various hypothesis on the availability of resources and on world policies that could be developed and implemented in the future. All the scenarios, except for some special cases, generated the collapse of the world's industrial and agricultural systems at some date within the 21st century. Forrester had arrived to similar results in his 1971 book.

A typical result of the 1972 LTG study is shown in the following figure for what the authors had called the "base case" model. In this model, the resources in input correspond to the best available data and it is assumed that the current policies and economic trends remain unchanged over the period considered.

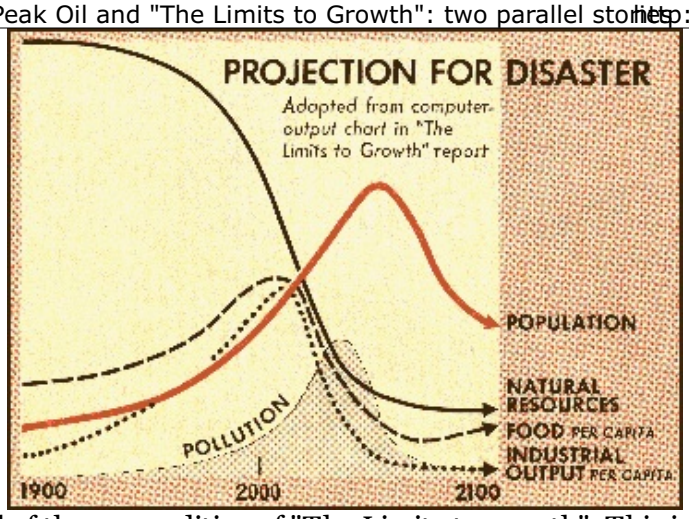

Fig. 2 Base case model of the 1972 edition of "The Limits to growth". This image was published by the Time Magazine in 1972. From http://www.holmestead.ca/reserved/popexplo/popexplo.html

The work of the LTG team had a huge impact, with millions of copies of the book sold. Hubbert's work also had a considerable impact, although mostly within the world of specialists in crude oil. However, as years passed, both studies were strongly criticized. The period of apparent abundance of the 1990s seemed to cause the total obsolescence of all ideas and theories that predicted bad times ahead. "The Limits to Growth", went through a phase of active demonization that pictured it as having been "wrong" in its predictions. Even though the collapse envisioned in the scenarios was to take place only in 21st century, still today for most people the LTG study is an example of flawed predictions. Hubbert's work, ion the other hand, was simply forgotten.

But the models and the ideas that were behind these studies were not abandoned. "The Limits to Growth" study was updated and the latest version was published in 2004. It is, at present, again generating considerable interest. Hubbert's ideas and methods were revived in the late 1990s by Colin Campbell and Jean Laherrere who started what we call today the "peak oil movement."

The results of the models that we are discussing have not changed much if we compare the early work with the recent updates. Here are some results of the 2004 version of "The Limits to Growth". This is, again, the base case model. As you can see, the collapse of the world's industrial and agricultural system is still generated for this case for approximately the same date as in the 1972 version.

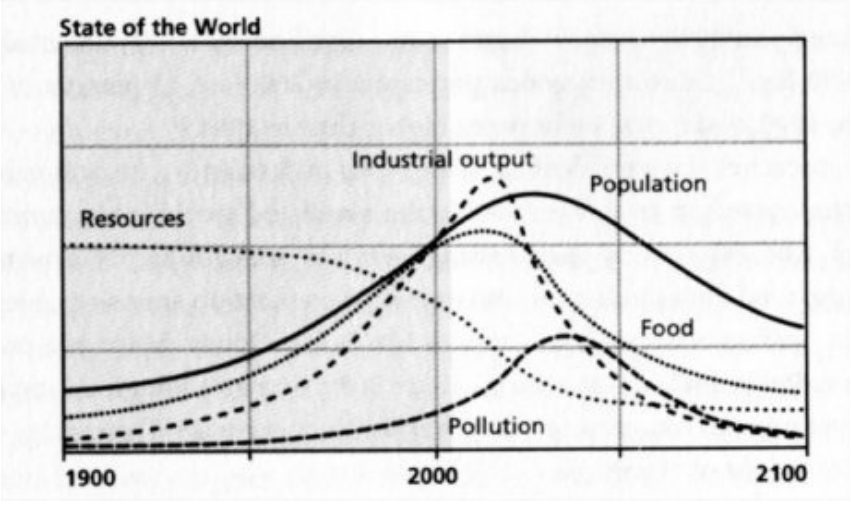

Fig. 3 Base case model of the 2004 edition of "The Limits to growth".

Here is, instead, an example of recent results obtained by Jean Laherrere who uses a Hubbert-

like approach for describing the production of the main categories of fossil fuels. The date for peak oil is shifted by some years forward with respect to the early predictions by Hubbert, but the bell shaped curve remains about the same.

Fig. 4 From Jean Laherrere, 2006. http://www.oilcrisis.com/laherrere/groningen.pdf

These results indicate that, in the coming decades (or even years), we may see the reversal of some of the growth trends that we came to see as the natural order of things. Peaking and decline is expected not just for fossil fuels, as shown before by Laherrere, but also for most mineral commodities (see a recent study by Bardi and Pagani). These are just subsystems of a vaster system that may collapse in the coming years according to the LTG models.

So, "Hubbert modeling" and "world modeling" have a lot in common but, of course, they are also very different. Let's now examine more in detail how the two methods are related and what are the specific differences.

The Hubbert model is purely empirical. It postulates that the production of crude oil and of other mineral resources will follow a "bell shaped" curve, often taken as the derivative of a logistic function. Modeling production means to fit two parameters to the bell shaped curve: past production and the available reserves. Good data obtained from geological estimates are, therefore, a crucial element of the model, which is considered to be a tool for forecasting future production. The model is robust, in the sense that it depends on just a few parameters, and it has turned out to produce reasonably reliable predictions. Of course, it is rare that the model generates the amazing precision of Hubbert's 1956 forecast for the US oil production. But, on the whole, the model is able to detect an impending production peak, as it has happened for cases such as the North Sea oil production, that peaked around the turn of the century. The Hubbert model, in itself, says nothing about what could be the consequences of the global peaking of oil production, even though "peak oilers" tend to see it as an important turning point for mankind.

World modeling studies based on system dynamics start with a detailed description of the main features of the system under study. Obviously, that implies drastic simplifications in describing the world's economy. Nevertheless, world models are much more complex and detailed than the simple Hubbert one. In addition to quantitative data on the available resources, these models include such factors as market, technology, government policies, regulations and others. Because of the large number of parameters and the inherent uncertainty in the data, the results of the models may vary considerably depending on the parameters in input. For this reason, these models are not considered as predictive tools, as Hubbert-style models are, but, rather, as *descriptive* tools. The idea is that, if the model can describe the system under study, it can be used for understanding how one can control it. In the case of world modeling, the authors of the LTG studies always emphasized that their models were not "predictions" but rather scenarios and that their purpose was understanding what policies should be implemented for avoiding collapse.

Let's go a little more in depth on how system dynamics is used in order to simulate the whole world. In the LTG studies, it is done by aggregating the elements of the system into a relatively small number of variables: 1) natural resources, 2) agriculture, 3) population, 4) capital, 5) pollution. Here are the main elements of the model in graphical form according to Magne Myrtveit.

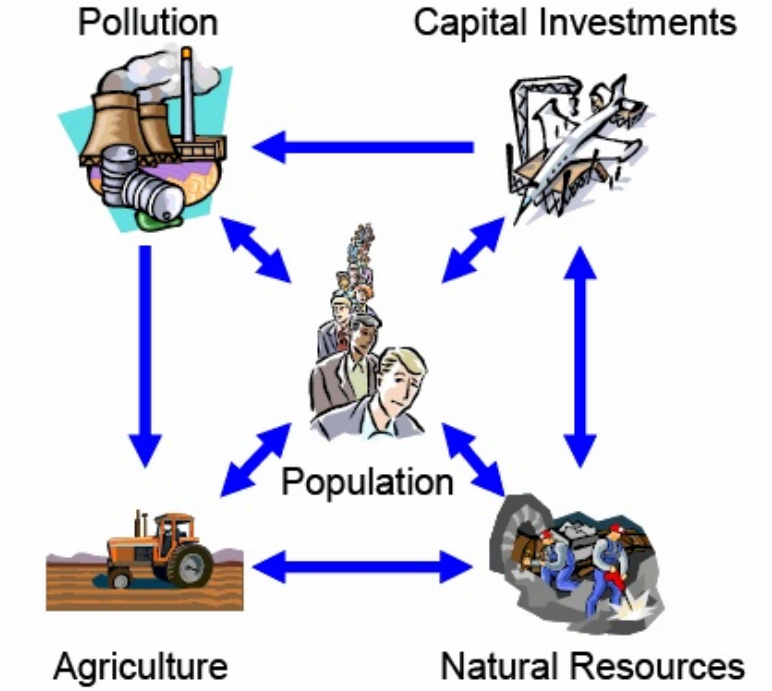

Fig. 5 - the main elements of the world model, according to Magne Myrtveit (https://bora.uib.no/bitstream/1956/1974/1/WPSD1.05WorldControversy.pdf)

As you see, the model takes into account mineral resources, but just as one element of a more complex system. However, it is perfectly possible to use system dynamics for modeling specific sectors of the economy, for instance for the extraction of a mineral resource. One of the first models of this kind was made in 1974 by Roger Naill who worked in close contact with the LTG team and used the same software to model natural gas production in the United States.

You can find a detailed description of Naill's model at http://www.albany.edu/cpr/sds//DL-IntroSysDyn/ch6_f.htm. The model is complex, involving such parameters as prices, technology, market responses and others. Nevertheless, the fundamental concepts of the model are simple: the resource is supposed to be finite; extraction is assumed to be driven by market factors and ultimately slowed down by the rising costs caused by depletion. The final result is a bell shaped curve similar to the typical Hubbert curve. Here is what we can call the "base case" model of this study, taken from "Towards Global Equilibrium" (1974)

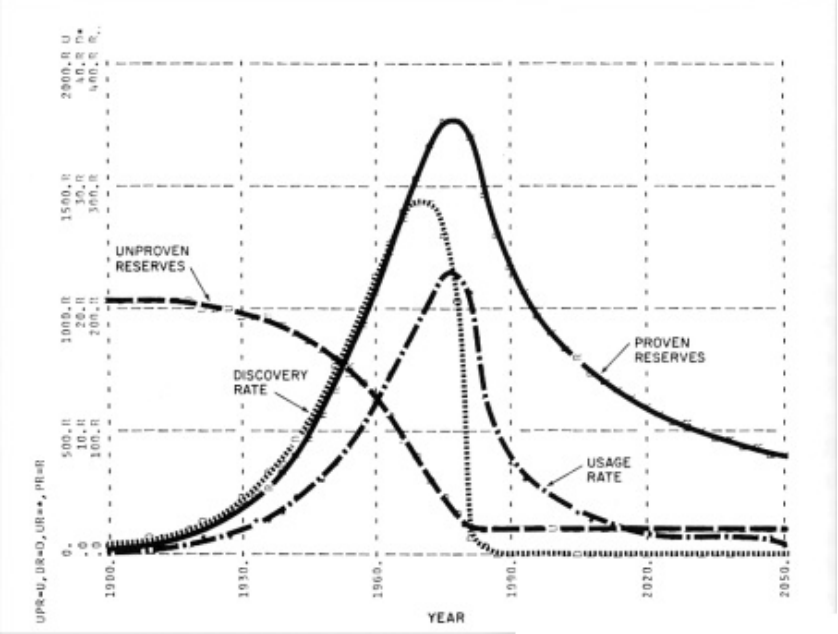

Fig. 6 - Natural gas production in the 48 US lower states as modeled by Roger Naill in "Towards Global Equilibrium" 1974. "Usage rate" is what is normally called "production". The peak of the usage rate curve occurs for about 1975 in this scenario.

We can now compare Naill's results with those that Hubbert had proposed in 1956 for natural gas production in the United States

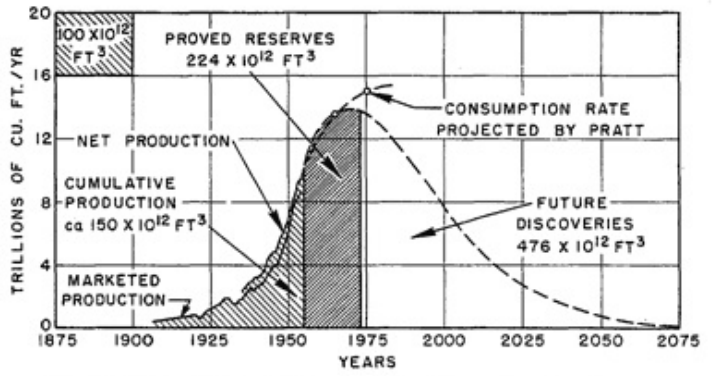

Figure 22 – Ultimate United States production of natural gas based upon initial reserves of 850 trillion cubic feet (~~after~~ Pratt, 1956).

Fig. 7 - Natural gas production in the US as modeled by Marion King Hubbert in 1956

One difference that is immediately apparent in these models is that Hubbert's curve is normally symmetric or slightly skewed backwards, as in this case. Naill's curve, instead, is skewed forward; as it seems to be the case for most system dynamics studies of this kind. The reason for the forward slanting curve lies in the built-in tendency of the market of compensating for depletion by increasing the effort of extraction. This strategy succeeds in retarding the production peak. However, since the extractable amount is finite anyway, postponing the peak must be paid with a more rapid decline. Apart from this point, the two models produce similar curves and, in this case, indicate approximately the same date for peaking.

Several decades after that these models were proposed, we can say that neither one provided an exact description of reality. Natural gas production in the US did peak in the early 1970s, as Hubbert had predicted and as Naill's models tended to indicate. But, after about 10 years of decline, production stopped following a bell shaped curve. It picked up again and peaked a second

time approximately in 2000, without having reached again the level the first peak. This behavior may be explained in various ways (see a recent reassessment by Luis de Souza), but that is not the point here; models are always approximate anyway. The point is that when modeling the production of a single mineral resource, the Hubbert approach and system dynamics generate very similar curves.

That doesn't mean, of course, that world modeling is the same thing as Hubbert modeling. World models take into account many more elements than resource depletion models. In particular, as early as in the first LTG study, one of the elements of the model was called "pollution;" something that, today, we see as mainly related to global warming. Depending on the input parameters chosen, the collapse that the LTG world models generate may be caused mainly by resource depletion or by a runaway climate change.

If global warming hits us first, our worries about resource depletion are of little importance and the reverse is also true. At present, we can't say which problem is the more immediate one. What we can say is that fossil fuels (and crude oil in particular) are the crucial resource of the world's economy. In the hypothesis that resource depletion is a more pressing concern than global warming, the vision of impending "peak oil" and "peak fossils" is equivalent to that of the "base case" model of the LTG studies. In both cases, we see the collapse of the industrial society due to resource depletion.

So, it may be that peak oil and "peak civilization" will coincide as an event taking place in the first decades of 21st century. Of course, we are not there yet, but the world's economic system is letting out ominous creaking noises. Are these signs of impending collapse? We won't have to wait for many years to know.

There would be much more to say on the subject of peak oil and world modeling. One is how the results of the first LTG study have been so effectively demonized and marginalized; a fate that peak oil studies have avoided - although they received a fair share of political criticism as well. That will be the subject of another post.

I wish to thank Dennis Meadows, Jorgen Randers, Magne Myrtveit and several others who introduced me to the fascinating world of system dynamics

References

Matthew Simmons was one of the first of those involved in peak oil studies to re-examine the story of the Limits to Growth. His 2000 essay on this subject can be found at http://www.simmonsco-intl.com/files/172.pdf

A detailed reappraisal of the world model controversy can be found in Magne Myrtveit's 2005 paper at https://bora.uib.no/bitstream/1956/1974/1/WPSD1.05WorldControversy.pdf

Jean Laherrere has also re-examined the LTG study in this paper, pubshed in the ASPO-Ireland site
http://www.aspo-ireland.org/index.cfm?page=speakerArticles&rbId=9

Another recent positive reassessment of the LTG study by "Big Gav" can be found at http://anz.theoildrum.com/node/3572

A description of how Roger Naill generated the Hubbert model from system dynamics assumptions can be found at http://www.albany.edu/cpr/sds//DL-IntroSysDyn/energy.htm. His model was published for the first time in "Toward Global Equilibrium, Collected Papers". D.L. Meadows and D.H. Meadows (eds), Cambridge, MA, 1974, pp 213-256.

The original 1956 article by Marion King Hubbert can be found at

http://www.energybulletin.net/13630.html