

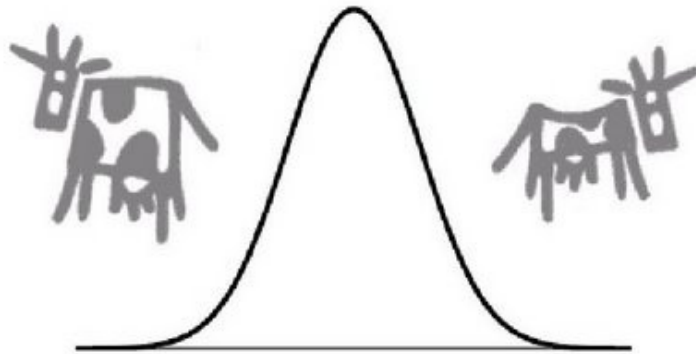


Mind-sized Hubbert

Posted by [Ugo Bardi](#) on September 21, 2009 - 3:46pm in [The Oil Drum: Europe](#)

Topic: [Environment/Sustainability](#)

Tags: [m. king hubbert](#), [peak everything](#), [peak oil](#) [[list all tags](#)]



The bell shaped Hubbert curve is commonly observed when a non renewable, or slowly renewable, resource is exploited in a free market. But what is the origin of the curve? Ugo Bardi and Alessandro Lavacchi have recently published a simple "mind sized" model of the Hubbert behavior in "[Energies](#)". Fat cows and lean cows are not included in the equations of the model, but come as a logical consequence of it.

(Note: I made the figure above using two cow images that I had downloaded from the internet long ago. If someone owns these images, please alert me or the editors. We'll be happy to give due credit or to remove the images if so requested.)

Have you ever tried to tell a politician about peak oil? If you did, you know what happens. Supposing that he/she pays any attention to you, you'll immediately face at least two typical objections: if there is still oil underground, what is the problem? If the price is high enough, why should production decline? It is not easy to answer these questions in the 30 seconds which are the typical attention span of a politician. Failing to do that will make you look like a representative of one of those millenarian sects eagerly waiting for the end of the world. And the problem is not just with politicians; try to explain peak oil to your mother or to an economist. It is not easy.

Possibly, peak oil will always be beyond the intellectual capabilities of the average politician, but it is also true that there are plenty of intelligent people out there who are perfectly able to understand the concept. The problem is how do we explain it to them. And, if we have to explain it, we must understand it first. What is, exactly, that causes production peaks for oil and for other non renewable resources?

If you look at the common explanations for the Hubbert curve, you'll see that it is often said to be due to the sum of many extraction curves for individual wells. (see, e.g., Roger Bentley's paper, [here](#)). There is something in this explanation: as you scratch the bottom of the wells, you produce less and less and that may generate some kind of curve that first goes up, then down (see [this](#)

[paper](#) by Dudley Stark). But this interpretation requires a number of *ad hoc* assumptions and I think it is not enough to explain how general these curves are. The bell shaped curve appears not just with crude oil, but with a number of resources which don't have the same behavior in terms of single production units. For instance, there are the cases of [coal](#), [whale oil](#), [caviar](#), [Carrara marble](#) and [many other cases of mineral resources](#). So, there must be some general explanation for why we have bell shaped curves so often and in so many different cases.

Hubbert himself never clearly explained what he thought was the origin of the bell shaped curve, but his model has been analyzed over the years using various versions of system dynamics and standard economics theory. There are many models which can explain bell shaped production cycles, including the well known "Limits to Growth" scenarios. The problem is that most of these models are not easy to understand for the non specialist. If you look at the scheme of the "world3" model used for "The Limits to Growth" scenarios, you'll see just a jumble of boxes and arrows. How does one make sense out of that? Yet, the bell shaped curve is not so complex, in itself. Can't there be a "mind sized" explanation for it?

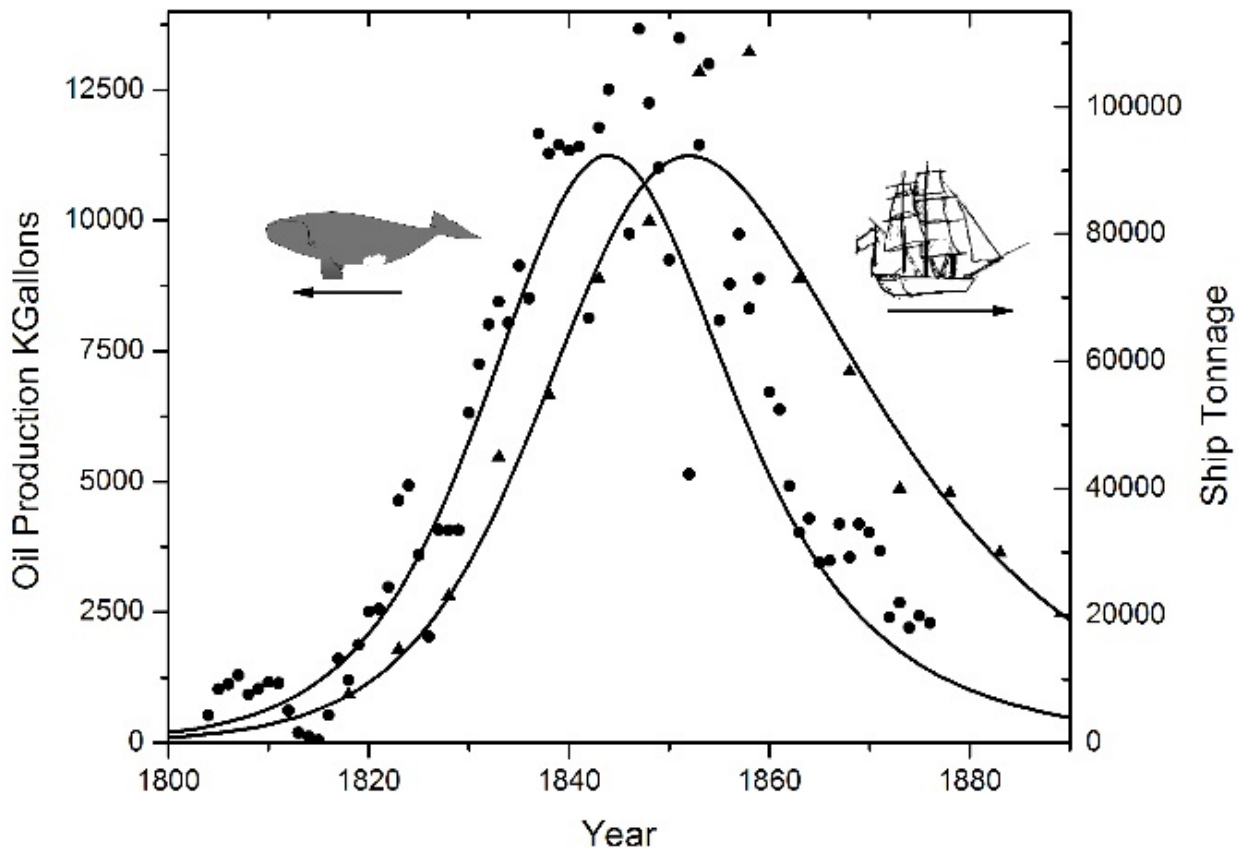
"Mind sized" is a term invented by Seymour Papert, the creator of the "logo" programming language. He said that complex problems can always be broken into mind-sized blocks, and so can be grasped by the human mind. Indeed, most of us (including politicians) tend to take decisions based on the way we understand what's going on and our understanding can't be but mind sized. In addition, we tend to ignore what we don't understand. That may be one of the reasons why peak oil is so commonly ignored by politicians and decision makers.

While trying to understand the Hubbert curve a few years ago, I started studying the history of whaling, which turned out to be a perfect example of a the Hubbert cycle. Even though whales are, theoretically, a renewable resource, they were exterminated so fast that they didn't have time to reproduce. So, I found very clear, bell shaped curves for the production of whale oil. It was while I was working on whales that there came to my mind the Lotka-Volterra model. After all, Volterra had developed his model studying Mediterranean fishing, so could the model be used to describe whaling?

You have probably heard of the Lotka-Volterra model that goes also under the name of "predator-prey" or "foxes and rabbits" model. You find it typically in biology textbooks, but it is not so often used in biology because it doesn't catch the complexity of a complete ecosystem. Nevertheless, the Lotka-Volterra model is a good "mind sized" model that tells you how populations grow and tend to overshoot their resource base. Think of an island inhabited by rabbits and foxes. Initially, foxes reproduce rapidly with plenty of rabbits: it is positive feedback. But, with many foxes around, the number of rabbits goes down and foxes starve and die, too. That's negative feedback. Then, without foxes, it is the surviving rabbits who have an easy life, they reproduce and grow. At this point, foxes start having plenty of food again, and the cycle restarts.

So, I spent a few Saturday afternoons developing a simple fitting program for the whaling data based on the Lotka-Volterra model and, bingo! It worked right away! The model could reproduce very well the production of whale oil (the prey) and the predator activity, taken as proportional to the tonnage of the fishing fleet. I could also simplify the model assuming that whales were just like crude oil: a non renewable resource. Here are the results in a graph that I made a few years ago (there is another, more refined version of this fitting in the paper in "Energies").

Whaling in 19th century



A nice result, but I think that anyone who has just a whiff of an economist's soul inside would find it appalling. How come that you can describe an economic system without taking prices into account? And how come that you don't take into account technological progress, which was there even in 19th century? Yet, the model catches the basic long term behavior of the system. Evidently, the system is dominated by internal feedbacks rather than by technological changes or external market factors, which appear as variable prices.

So, there is this very complex system with whales, whalers, whaling vessels, the whale oil market and all that, and the way it has evolved in time is - basically - mind sized. Whalers have been catching as many whales as they could, reinvesting their profit in more whaling vessels. It was positive feedback. But, with whale numbers dwindling, catching them became more difficult and expensive. Profits went down so that, after a while, whalers had to reduce their activity. It was negative feedback taking over. Eventually, they had to stop whaling altogether, at least for those species of whales hunted in 19th century. That was helped by the appearance of crude oil in the market but, surely, depletion was the main factor. It has been estimated that at the end of this whaling cycle there remained only fifty females of "right whale" (the main species hunted) alive in all the oceans.

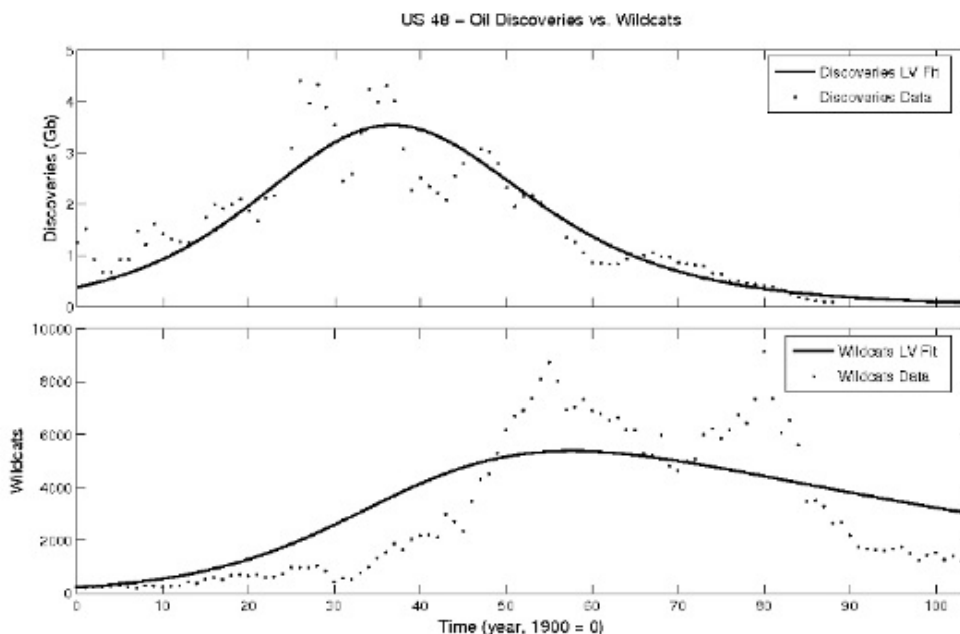
Now, I think there are not many cases of a quantitative fitting of the Lotka Volterra model to a real life situation; so this is a very interesting result. And, when you discover something interesting, you feel excited and elated. But you have to see whether you have something that has general validity or if it is just a quirk of the particular system that you are studying. In my case, I needed to show that the model applies to other resources, including crude oil. That took quite a bit of head scratching.

Think of crude oil, the "prey" is oil itself, but what is the "predator"? Evidently, it is all those things that are used to find and extract oil: people, machines, rigs, trucks, etc. All this can be described with a single term "capital", as it was done, for instance, when modeling similar situations in "The Limits to Growth". The problem is how to quantify capital.

There are plenty of historical data available in terms of the extraction of crude oil and of other mineral resources. But data on what I called "capital" are not easy to find. And, then, what should be used as capital for crude oil? The budget of the oil industry? The number of workers? The number of active rigs? When I could find data for these parameters, I tried to fit them to the model, but nothing worked. That was good, incidentally, because, at least, it told me that the model is not a "fit-all" model.

Since this work was done mainly overnight and with no financial support, it took me a lot of time, years, to reach a conclusion. (There is a general rule in scientific research that says, "No research that is relevant is ever financed".) Initially, I enlisted the help of Leigh Yaxley, petroleum engineer based in Jakarta, and we published a [preliminary version of this study](#) in the proceedings of ASPO-5 in 2006. Unfortunately, Leigh had to stop working on this subject because of other engagements. So, I asked Alessandro Lavacchi, a former PhD student of mine, to give me a hand. Both Leigh and Alessandro are much better than I am at data processing and curve fitting and, with their help, eventually, we found the key to the story.

Let's go back to whaling in 19th century; at that time the main problem related to killing whales was finding one. Once it was found, killing it and making whale oil out of it was a relatively quick process. In the case of crude oil, instead, the length of delay between discovering a field and getting oil out of it often amounts to several years. But, the main point is discovery: once a field is discovered, it will be put into production at some point--that's almost automatic. So, prospecting for oil is the main "predation" activity, and also the most expensive one. So, the production parameter in the model is the amount of oil *found*, not the produced oil. At that point, you can think that a measure of the effort (the capital) placed into prospection is the number of wildcats drilled. Once we found this idea, it was bingo again. The relationship of predator to prey was there, although it was not as good as for whaling. Here are the results for the US 48 lower states (the case studied by Hubbert).

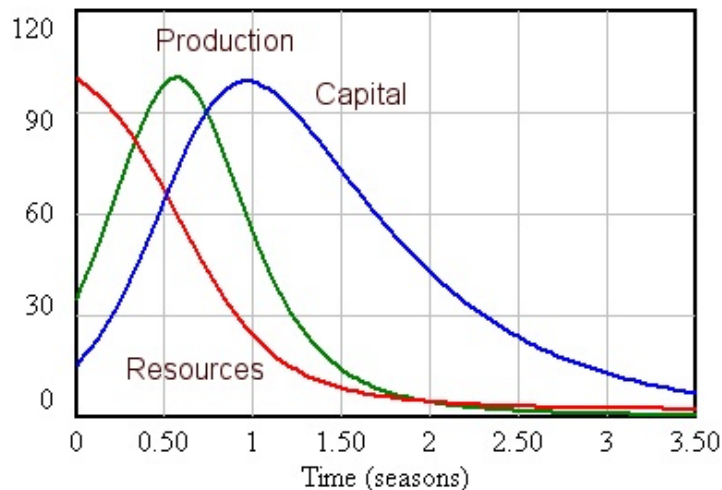


In our paper in "Energies" you'll find also the case of Norwegian oil and two cases of gold mining, including California gold in 19th century (the forty-niners, my darling Clementine and all that). I

don't know if that can be considered sufficient to prove the generality of our assumptions but, surely, there is something there. [In the paper that I wrote with Leigh Yaxley](#), we also show a correlation between the world's GDP (the predator) and the energy produced (the prey). We didn't show this result in the paper in "Energies" because we are not really sure about this interpretation but, again, I do believe that there is something there. As I said, this is not a "fit-all" model; so, when you find that two parameters are related according to the model, you may strongly suspect a prey/predator relationship.

Indeed, once you start thinking in these terms, you'll see that the "predator/prey" relationship is a very useful concept that can help you understand a lot of things. For instance, you may go back to the jumble of boxes and arrows that is the "world3" model, and now you'll see that you can cut it down to a number of "mind sized" subsystem that are often based on negative/positive feedbacks similar to those of the Lotka-Volterra model.

It may be difficult to find sufficient data for a quantitative fitting but, qualitatively, the Lotka-Volterra model can be applied to many cases. Here you can see it, without experimental points - mind sized.



We can see it in terms of a "results" curve (the central curve, labeled "production") and an "efforts" curve (on the right, labeled "capital"). Think about that: haven't you noticed many times that there is this kind of temporal shift in so many human endeavors? You start with something that works well, so you increase your efforts and it goes even better, but at some point you see that no matter how much you increase your efforts, you can't increase the results any longer. You have run out of resources, you get discouraged and your efforts dwindle, too. It is a bell shaped curve.

Maybe I am seeing ghosts created by my own mind, but I tend to see many things that I have done in my life in these terms. I see it even with the research grants for my lab, at the university of Florence. Despite having stepped up our efforts, we are getting less and less money to run the lab. "Peak grants" has taken place a few years ago and my lab is being destroyed by the same mechanism that, long ago, [brought down the Roman Empire](#).

But we had started with the idea of explaining the Hubbert curve to a politician; so, let me summarize the main assumptions of this "mind sized" model. It may still be too much for a politician, but at least it gives you a fighting chance.

1. There exists a non renewable or slowly renewable resource which is limited in amount and "graded" in costs of extraction/production.
2. People will extract/produce first the low cost resource and will re-invest an approximately constant fraction of their profits in more facilities for extraction/production. This is the positive

feedback that generates the rapid initial growth of the curve

3. As the resource is consumed, increasing costs of production reduce profits and - as a consequence - investments in extraction/production. This is the negative feedback that generates the decline.

When these three assumptions are described by two coupled equations, they generate a nearly symmetrical, bell shaped, curve. Political, technological and market factors may modify the behavior of the system. However, since the curve has been often observed in historical cases, we can conclude that these three assumptions are sufficient at least for accounting for the main tendency of this kind of system.

In the end, don't take the Lotka-Volterra model as the universal explanation of everything. But it is mind sized model that can help you describe what the peak is (including fat cows and lean cows) next time you discuss with a politician.

Acknowledgement

Besides my coauthor, Alessandro Lavacchi, I would like to thank the people who have helped me in various ways in this work: Leigh Yaxley, Colin Campbell, Jean Laherrere and Juergen Mueller. I would also like to thank the friendly and supportive staff of the "Energies" journal at [MDPI](#)

References

The paper that we published in "[Energies](#)" in 2009. It is written in what (I believe) is a readable style, so that you can download the paper and understand it. Here is the full reference:

Ugo Bardi and Alessandro Lavacchi, "A Simple Interpretation of Hubbert's Model of Resource Exploitation" *Energies* 2009, 2(3), 646-661; doi:10.3390/en20300646

The early paper on the LV model applied to the Hubbert cycle written with Leigh Yaxley is at <http://www.aspoitalia.it/images/stories/asp05presentations/Bardi-ASPO5.pdf>

You can find one of my papers on whaling at <http://www.energybulletin.net/node/3338>



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