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Energy Prices and Resource Depletion: Lessons from the Case of Whaling in the Nineteenth Century

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Abstract *The Hubbert model assumes that the worldwide production of crude oil will follow a bell-shaped curve. Oil prices are expected to increase, or even to spike up, at or after the production peak. However, the Hubbert model provides no description of price trends. We also lack historical data that can be used as a guide, since so far there have been no cases of a complete, worldwide depletion of a mineral resource. Nevertheless, historical examples of worldwide Hubbert-like behavior can be found with biological resources. The present paper examines the cycle of whaling in the nineteenth century, showing that for both whale bone and whale oil the smoothed price curve shows a gradual increase that starts well before the peak. A strong increase in the amplitude of price oscillations is also observed after the peak. If the same trends will be observed for crude oil, the production peak may not be such an epochal change as it has been sometimes described.*

Keywords crude oil, energy prices, Hubbert, whale oil

1. Introduction

The Hubbert model (Hubbert, 1962) describes how the production of a mineral resource (specifically, crude oil) varies as a function of progressive depletion. According to the model, the production curve is "bell shaped" and approximately symmetric. Hubbert himself successfully applied the model to the production of crude oil from the lower 48 states in the U.S., and a Hubbert behavior has been observed for several local cases of mineral production, such as for U.S. oil production (Deffeyes, 2001, 2004; Campbell, 2004).

It is often assumed that the worldwide production of crude oil will behave according to the Hubbert model and, therefore, will follow a bell-shaped curve. Much of the present debate focuses on when the global production peak is expected to occur. Some estimates place it within the first decade of the 21st century (Campbell and Laherrere, 1998; Deffeyes, 2001; Duncan, 2001; Bentley, 2002; Campbell, 2004), while others postpone it a few decades longer (Wood and Long, 2000).

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The interest in the peak date stems from the belief that it will represent an epochal change in the world economy: something that has been defined as “the big rollover” (Magoon, 2000). It is often argued that the dominance of the sellers on the market will cause a steep rise in prices at or immediately after the peak. Indeed, the rapid rise in crude oil prices in 2004 and 2005 has been often interpreted as an indication that the peak is close in time.

However, the Hubbert model does not provide information on prices, and no models appear to exist that can simulate the behavior of prices for a system that follows the Hubbert curve. The examination of the historical behavior of crude oil prices or of other mineral resources is of no help. The known cases of complete or nearly complete Hubbert cycles are all local (e.g., the U.S. crude oil production); however, since the crude oil market is global, the decline in production of a limited area can be offset with resources from another area. Therefore, local peaking does not affect world prices as strongly as global peaking is expected to do.

However, a resource does not need to be a mineral one to show a Hubbert curve. A biological resource that is “extracted” much faster than it is replaced should follow the same production dynamics. A case relatively close to our times is that of American whaling in the nineteenth century, where the curves for the production of whale oil and whale bone show the typical bell-shaped behavior predicted by the Hubbert model. Since no replacement for whale oil was developed until well after the production peak, and since all the whaling fleets of the world operated on the same oceanic range, the cycle of whaling in the nineteenth century in the U.S. is similar to that of global crude oil of the twentieth century.

The present note has the main objective of determining how prices varied over the whaling cycle in the nineteenth century and compare the results with the present price trends of crude oil. The results show that prices started to increase well before the production peak. If the data reported here can be seen as general validity for all systems following the Hubbert model, it appears that crude oil prices may not show a discontinuous jump upwards at the global Hubbert peak, but rather only a gradual rise with strong superimposed oscillations.

2. Results

The data used in the present study are all taken from Starbuck’s 1878 book, which reports price and production data for the American whale fisheries from 1807 to 1876. Further data from different contemporary sources can be found in the book by Davis et al. (1997), but Starbuck’s data present a consistent picture sufficient for the purposes of the present analysis.

In the nineteenth century, at least five species of whale were hunted by American whalers (Davis et al., 1997). The data examined here are relative to the two main species hunted: the sperm whale and the right whale. Both species were sources of whale oil, obtained from their fat and then used as fuel for lamps. Whales were also hunted for whale bone or baleen, which was used as a stiffening material for clothing. The production of whale oil and whale bone started to increase rapidly early in the nineteenth century when deep sea fishing replaced shore fishing. Production reached a maximum about mid-century and waned with the end of the century. In the twentieth century, whaling resumed on a larger scale but with different technologies, for different whale species, and with different purposes. Therefore, the production of whale oil and whale bone from right and sperm whales represents a complete cycle of resource exploitation.

In Figure 1, the main results obtainable from Starbuck's data are reported. Here, whale oil production is defined as the sum of the production of right and sperm whale oil. It has been demonstrated (Bardi, 2005) that the modeling of resource depletion in the case of a finite economical system leads to curves that can be approximated as Gaussian functions. Accordingly, this function has been used to fit the data of Figure 1. In this approximation, the date of the production peak turns out to be approximately 1846, which also corresponds to the year when the largest U.S. whaling fleet was assembled (Starbuck, 1878). The prices reported in Figure 1 are the production weighted average of the two types of oil (sperm and right whale). These prices have been corrected for inflation and translated into 2003 values according to the data reported by Sahr (2004), based on an estimation of the consumer price index (CPI). The data for whale bone are shown in Figure 2. Also in this case, prices have been corrected for inflation according to Sahr (2004) and the production data fitted with a Gaussian function. The production peak for whale bone occurs for 1849.

A comparison of smoothed price data for whale bone and whale oil is shown in Figure 3. Whereas the raw data show considerable oscillations, the smoothed price curve for both whale products show a rising trend that starts well before the production peak and levels off only about a decade afterwards. The rising sections of both price curves can be fitted with an exponential function. These price trends appear to be similar to that of old-growth timber (Livernois et al., 2003).

Figure 4 shows a comparison of production and price data for crude oil.

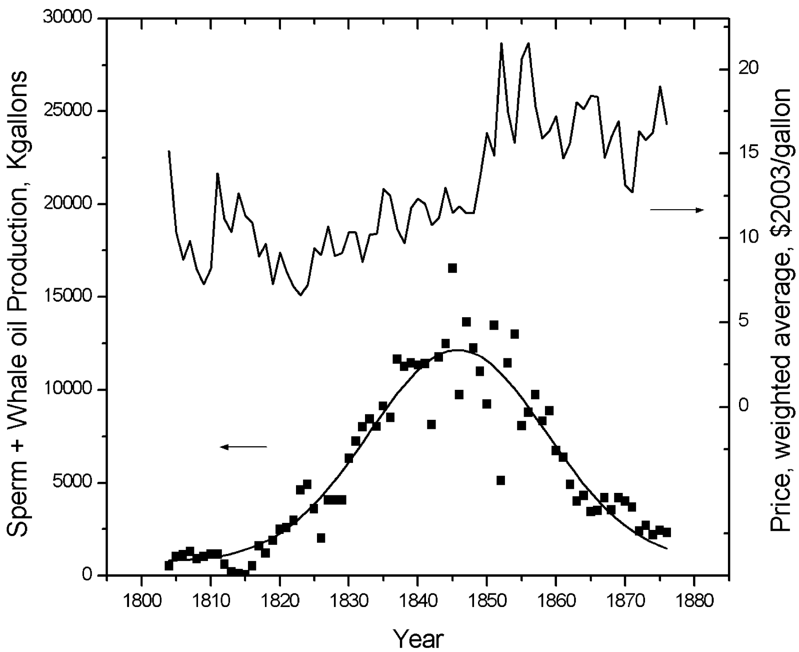

Figure 1. Sum of the production of sperm and right whale oil and production weighted average of prices (Starbuck, 1878). The production data have been fitted with a Gaussian curve (Bardi, 2005). Prices have been corrected for inflation and translated into 2003 prices according to the data reported by Sahr (2004).

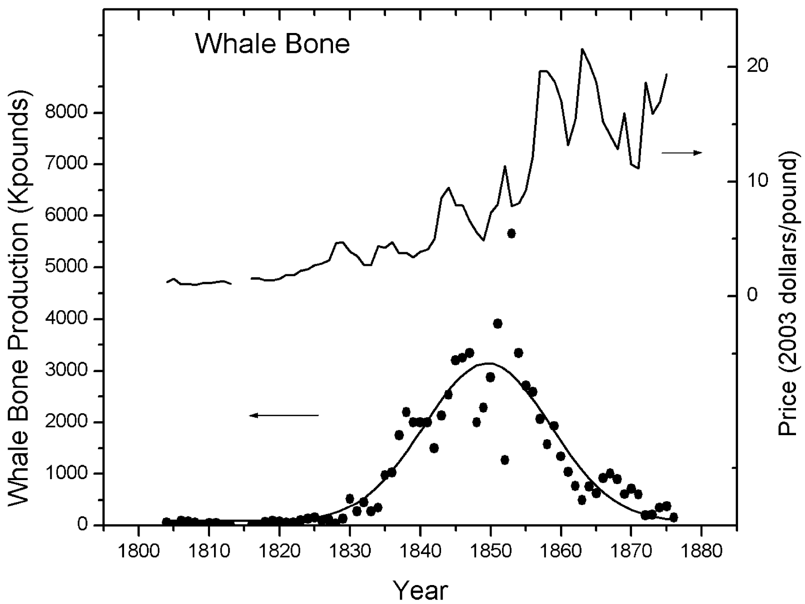

Figure 2. Production and prices of whale bone (Starbuck, 1878). Prices have been corrected for inflation according to the data reported by Sahr (2004).

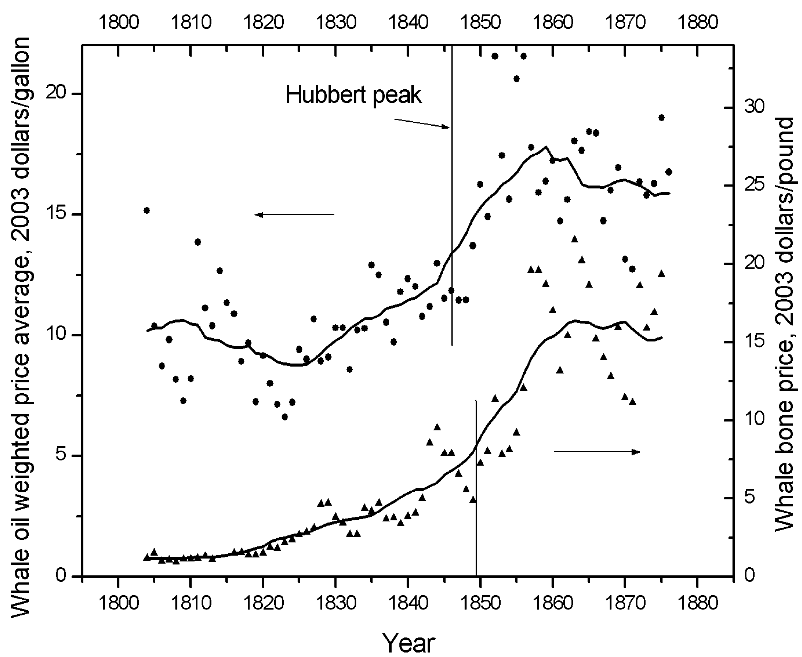

Figure 3. Smoothed and inflation corrected (Sahr, 2004) prices of whale oil (weighted average of sperm and right whale) and of whale bone. The date of the respective Hubbert peak of production is also shown.

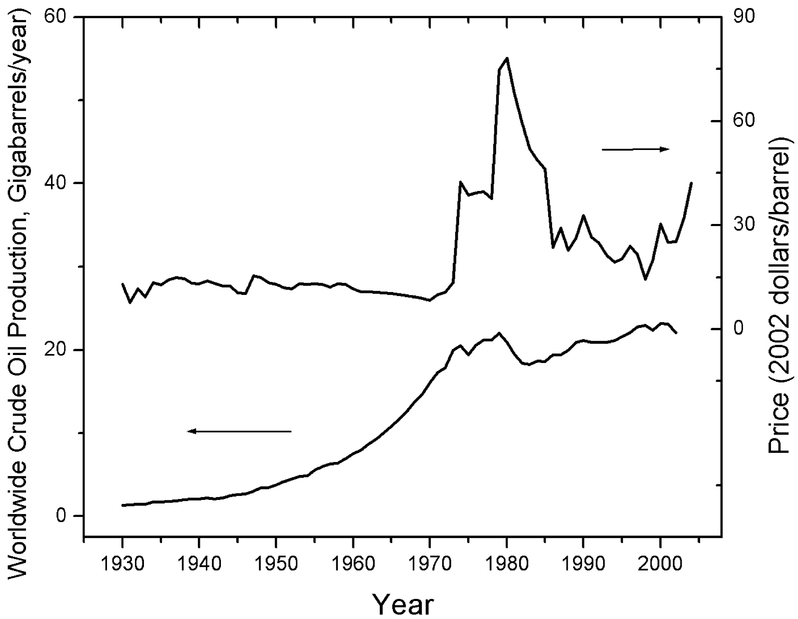

Figure 4. Worldwide production and price data for crude oil (Campbell, 2004).

3. Discussion

The exploitation of a biological resource is often described as an "open-access" situation, where the resource is available to everyone who is able to exploit it. This condition often leads to over-exploitation of the resource according to a mechanism described by Garrett Hardin as the "Tragedy of the Commons" (Hardin, 1968). Modeling such systems is often accomplished by means of coupled differential equations (Reuveny and Decker, 2000; Clay and Wright, 2003; Conrad, 2003), in turn based on the well known predator/prey models developed by Lotka (1925) and Volterra (1926).

Open-access models are not normally applied to mineral resources. Nevertheless, the difference between crude oil and the pastures described by Hardin is mainly one of replacement rate: grass can regrow in a few years, whereas crude oil needs hundreds of thousands of years, at least, to reform by natural processes. If, in the Lotka-Volterra model, the reproduction rate of the preys is assumed to be zero, the result is a single "production curve" which is bell shaped and approximately symmetric. This curve is equivalent to the bell-shaped "Hubbert curve" (Hubbert, 1962). Indeed, the Lotka-Volterra model and the Hubbert one are based on the same mechanism and the decline in production is caused by the gradual depletion of the resource (be it rabbits or oil) (Bardi, 2005).

Accordingly, the good fit of the production data for whaling with a Hubbert-like production curve (in this case approximated as a Gaussian) indicates that the decline of whaling in the second half of the nineteenth century could be attributed to the depletion of the resource (i.e., to overfishing). In 1878, Starbuck had noted that the scarcity of whales was one of the causes of the decline of whaling. This interpretation was reproposed by Coleman in 1995.

Davis et al. (1997) claimed, instead, on the basis of their estimations of whale populations, that overfishing did not occur for whaling in the nineteenth century. However, the recent study by Baker and Clapham (2004) clearly shows a considerable reduction of the whale population during the nineteenth century hunting cycle. A sharp drop in both right and sperm whale populations is actually observed in correspondence of the production peak of whale products. A detailed discussion of the merits and limits of the estimations of whale populations in the nineteenth century is beyond the purposes of the present paper, but it may suffice to note that for whales, just as for crude oil, depletion does not mean the complete disappearance of a resource. An oil well, for instance, is considered depleted, on the average, when around 35% of the oil is extracted. For whales in the nineteenth century, it is obvious that effect of whaling on whale populations was important, especially for right whales (Baker and Clapham, 2004), even though whales did not disappear. Evidently, the reductions in whale populations were sufficient to make whaling progressively more expensive and difficult, given the technology of whaling at that time. We can conclude that the American whaling industry in the nineteenth century followed a complete Hubbert-type production cycle as a result of the physical depletion of the resource.

The set of data for whaling is especially interesting for a comparison with the case of crude oil. Currently, crude oil is traded in a global market; in the nineteenth century, whale oil and whale bone were also a case of a "global" commodity. Even though the data reported by Starbuck are for the U.S. market, the range of the world whaling fleets covered all the oceans and all faced the same depletion problems. A further element of similarity is the lack of cheap substitutes able to offset depletion. "Rock oil" derived from crude oil as a lamp fuel appeared on the market only in the 1860s, at least 15 years after the production peak of whale oil. For whale bone, the only possible replacement as a stiffener for clothing was steel, but steel was not generally available worldwide until 1870–1880 (Stevenson and Cook, 1983), again, at least two decades after the whaling peak. Therefore, the prices of whale oil and whale bone were directly affected by depletion, just as it may happen for crude oil prices in the near future. Accordingly, the general trends may be expected to be similar.

In the price data of Figures 1 and 2, we observe a considerable upward spike for whale oil prices a few years after the Hubbert peak. A less clear spiking upwards is detectable in the data for whale bone. In both cases, we observe a considerable increase in the price oscillations after the peak. However, we also observe that prices started to increase for both whale products well before the production peak, as shown by the averaged curves for the two prices (Figure 3).

Hotelling proposed in 1931 the first theoretical model for the price behavior of a mineral commodity. According to the model, prices should rise exponentially as the resource is gradually depleted. However, Hotelling's assumptions cannot be applied to the case of whaling. For instance, whalers (or agents in the whale products market) had no direct perception of the extent of the remaining stock of whales, as instead Hotelling's model would require. Besides, Hotelling's model implies that production should gradually decline as the resource is produced, which is evidently not the case for whales (nor for crude oil).

Barnett and Chandler (1963) were perhaps the first to note that price increases may positively affect the production of a mineral resource by making it profitable to exploit more diluted resources or using more sophisticated technologies of production. This interpretation may be applied to whale products where we note that, after an initial phase of low prices, production and prices start to increase together. We may suppose that higher prices of the products made it possible (and profitable) for whalers to offset depletion by using more expensive whaling methods. Indeed, Starbuck notes how longer voyages, longer cruise times, and more expensive ship outfitting had become the norm in his time.

However, the capability of the market to absorb higher prices is finite, as was the whale stock when compared with the whaling rates. Apparently, the costs associated to offsetting depletion can rise faster than prices without becoming too high for the market to bear. The eventual result is the peaking and subsequent decline in production. These considerations are applicable to the whale data reported here.

The last part of the price curve for whale products, with the average prices leveling off about a decade after the peak, may be tentatively attributed to the arrival on the market of suitable backstop products which, as discussed earlier, were crude oil and steel.

These considerations remain qualitative for the time being but are consistent with all the data available for whaling. If the same mechanisms operate for the present market of crude oil, we should see a trend of rising prices starting well before the production peak. In this case (Figure 4), the long-term price trends are masked by the large spike corresponding to the oil crisis of the 1970s. However, it is clear that after 1973, oil prices never returned to the pre-crisis levels. Accordingly, the strong price increases observed from about 2001 may not be a sign that the production peak is near (although they do not rule it out, either), but rather part of a general trend of oscillations superimposed to a rising average.

As a final note, we can compare the inflation-corrected prices of crude oil and whale oil. Even at its lowest historical prices in the 1820s, the least expensive type of whale oil (right whale oil) was priced at the equivalent of more than $200 (2003) per barrel (crude oil barrel, 42 gallons or 159 liters). At its highest price level (1855), sperm oil sold at almost $1,500 (2003) per barrel. It appears, nevertheless, that whale oil was not more expensive than vegetable oils at the time (Lee, 2004). In comparison, in the 1870s–1880s, crude oil prices had already decreased to values of about $20 (2003) per barrel (WTRG, 2004), comparable to what was considered the "normal" crude price until about 1999. These data are useful, among other things, as a reminder of how difficult it may be to substitute fossil fuels with "biofuels" (bio-ethanol, biodiesel, etc.). Without the support of fertilizers, pesticides, irrigation, transportation, and agricultural machinery (all depending on fossil fuels) biofuels would probably cost as much today as whale oil did in the nineteenth century, i.e., at least ten times as much as crude oil derived fuels.

4. Conclusion

If we can rely on the historical case of whale fisheries as a guide for the future, we can draw some conclusions for what we should expect for crude oil prices in the coming years. First of all, we may see strong price oscillations, a trend that may have already started with the oil crisis of the 1970s and may lead to further instabilities. We may also expect that the price oscillations will be superimposed to a rising growth of the average prices. The data presented here imply that the Hubbert peak may not be such a drastic "rollover" as it is sometimes described. However, strong oscillations and a robust and long-lasting rising trend of the average oil prices are still an effect of depletion and indicate the need of substituting oil with renewable resources as soon as possible.

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