PRICE TRENDS OVER A COMPLETE HUBBERT CYCLE: THE CASE OF THE AMERICAN WHALING INDUSTRY IN 19th CENTURY.

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Abstract

The Hubbert model (Hubbert 1962) predicts that the worldwide production of crude oil will follow a bell shaped curve. It is often assumed that the production peak will coincide with a steep rise in prices. However, the Hubbert model in itself does not provide information on prices. The present paper examines the price trends for a historical case of a non-recyclable resource which went through a complete Hubbert cycle: whales in 19th century. The results show that the main trend that takes place after the peak is a strong increase in the amplitude of price oscillations. The smoothed price curve shows a gradual increase that starts well before the peak. The average price increase can be fitted with an exponential function.

1. Introduction

The "bell shaped" production curve of a non recyclable mineral resource was described first by M. King Hubbert (1962) for the case of crude oil production in the United States. Experimental evidence of Hubbert curves has been observed in several local cases of mineral production (see, e.g., Deffeys 2001, Campbell 2004) and it is reasonable to suppose that the worldwide production of crude oil will also follow a bell shaped curve. Much of the present debate on this subject focus on when exactly the global production peak is expected to occur. Most estimates place the peak within the first decade of the 21st century (See, e.g. Campbell and Laherrere 1998, Deffeys 2001, Duncan 2001, Bentley 2002, Campbell 2004), even though others postpone it of a few decades in the future (Wood and Long, 2000).

The interest on the determination of the peak date stems from the belief that it will represent an epochal change in the world economy, something that has been termed "The big rollover" (Magoon 2000). The expected change is attributed to the transition from a "buyer's market" to a "seller's market" and 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 that took place in the summer of 2004 has been interpreted by many analysts as an indication that the production peak may be near.

However, the Hubbert model in itself does not provide information on prices and no models appear to exist which can simulate the behavior of prices for a system that follows the Hubbert curve. The examination of the historical behavior of crude oil prices is, also, of no help. The known cases of Hubbert cycles for crude oil are all local (e.g. the US 48 lower states); but since the crude oil market is global, the decline in production of a limited area does not necessarily affect world prices.

In order to obtain historical evidence relevant for the future behavior of crude oil prices, one would need to examine a case where a non-recyclable resource was completely depleted within an economically closed region. There are no such examples for mineral resources, so far; crude oil may turn out to be the first case.

However, a resource does not need to be a mineral one to show a Hubbert curve. A biological resource which is produced (or "extracted") much faster than it is replaced follows the same production dynamics. Historically, there have been several cases of terminal depletion of biological resources. A case relatively close to our times is that of whale oil in 19th century. The similarity of the whale oil cycle and the crude oil one has been already noted and an extensive comparative study has been reported by Coleman (1995). The present note examines whaling in 19th century with the objective of determining price trends over the whole cycle and in particular on the effect of the production peak.

The examination of the data show a strong increase in the amplitude of the price oscillations after the peak. However, the smoothed price curve shows only a gradual increase that starts well before the peak and continues for approximately a decade afterwards. If these data can be used as a guide for the future, it appears that no major discontinuity in oil prices will be observed at or immediately after the global Hubbert peak. However, the strong oscillations and the robust trend of rising prices may still negatively affect the world economy.

2. Data analysis

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. Starbuck's data are for the American market only, but the range of the American whaling fleet was global. Therefore, when whale depletion set in, the effect on prices could not be offset by shifting production to other areas or importing oil from elsewhere. This condition is similar to the present global crude oil market.

In 19th century, two species of whale were hunted: the "sperm whale" and the "right whale", both mainly for the oil obtainable from their fat which was 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 in the early years of 19th century when deep sea fishing replaced shore fishing. The production of whale oil peaked about mid-century and waned with the end of the century. In 20th century, whale hunting resumed, but with different technologies and for different species of whales. Therefore, the hunting of sperm and right whales represents a complete cycle of a resource that was nearly completely depleted. This conclusion has been reached also by Coleman (1995) and it is supported by data relative to the actual abundance of whales (as opposed to catch data) (Baker and Clapham, 2004).

In figure 1, the main results obtainable from Starbuck's data are reported. In the figure, whale oil production is defined as the sum of the production of right and sperm whale oil. The production curve is fitted with a Gaussian function. Other functions may also be used for the fitting, but in all cases the date of the 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 fig. 1 are the production weighted average of the two types of oil (sperm and right whale). 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) of the time.

The data for whale bone are shown in fig. 2. Also in this case, prices have been corrected for inflation according to Sahr (2004) and the production curve fitted with a Gaussian. The production peak for whale bone occurs for 1849.

A comparison of smoothed price data for whale bone and whale oil is shown in fig. 3 During the period of increasing prices, the price curve can be well fitted with an exponentially growing function. Fig. 4 shows the results for whale bone prices; similar results are obtained for whale oil.

3. Discussion

As already reported by Coleman (1995), the production of whale oil and whale bone in 19th century followed a bell-shaped curve, in agreement with Hubbert's theory. The American whaling industry of this period may be the only known case of a complete "resource depletion cycle" for which we have a complete set of data, both about production and market prices.

The case of whale oil is especially interesting since we also have good data about the resources which replaced it. "Rock oil" (or "coal 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. The electric light bulb wasn't invented until 1874. Therefore, the peaking and the initial phase of decline of whale oil production were not caused by the availability of a better technology, but by the physical depletion of the resource.

The price data, corrected for inflation, show how expensive was whale oil in comparison with the resource that was to replace it. Even at its lowest historical prices, in the 1820s, the least expensive type of oil (right whale oil) was priced at the equivalent of more than 200 (2003) dollars per barrel (crude oil barrel, or 42 gallons). At its highest price level (1855) sperm oil sold at almost 1500 (2003) dollars per barrel. It appears, nevertheless, that whale oil was not more expensive than agricultural vegetable oils at the time (Lee 2004). These data should tell us something about how difficult it may turn out be to substitute fossil fuels with "biofuels" (bio-ethanol, bio-diesel, or other). 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 cost in 19th century, that is at least about ten times as much as crude oil derived fuels.

The data also show us what an incredible bonanza crude oil has been. In the initial years of commercialization, the 1860s, crude oil went for some 90 (2003) dollars per barrel (www.wtrg.com, 2004). In the 1870-80s it had already gone down to values of the order of 20 (2003) dollars per barrel, comparable to what was considered the "normal" crude price until ca.1999. If hydrogen were to substitute gasoline today at the same price differential, it would have to cost no more than a few cents for the equivalent of a gallon and it should be as easy to store and transport as gasoline is. Needless to say, these conditions are not satisfied yet.

The visual examination of the price data for whale oil and for whale bone shows that the curves are similar in shape and can be roughly subdivided in three principal domains: i) Constant or diminishing prices from the early phases of production to, approximately, the first inflection point of the production curve, ii) rising and oscillating prices approximately from the first inflection point of the curve (before the peak) to the second inflection point (after the peak), iii) Oscillating, but constant on the average, prices after the second inflection point.

It is possible to fit the growing section of the price curve with an exponential function (fig. 4). The occurrence of the production peak does not cause major discontinuities in the price trend. However, the peak does seem to have an important effect in the amplitude of the price oscillations, which show a considerable increase starting approximately five

years after the peak. These oscillations have been already noted by Coleman (1995) and attributed to market cycles. Strong price oscillations have been also observed to be superimposed to the later phase of an exponentially rising price curve for the case of old-growth timber (Livernois, Thille, and Zhang, 2003)

The exponentially growing curve for whale products may be related to the Hotelling rule (Hotelling 1931) which stipulates that the real price of a non renewable resource should rise exponentially with time. However, the acceptable fit of the experimental data with an exponential function should not be taken as proof that Hotelling's rule is valid in this case. Indeed, there are several assumptions in Hotelling's model which do not appear to be satisfied for the case under study here. In particular, the assumption that agents have complete knowledge of the amount of remaining resources (obviously not valid for whalers) as well as that production should decline monotonically with time, something that obviously does not take place in this case. Further study will be needed to assess the validity of Hotelling's model for whale oil and whale bone production. For the time being the exponential growth of the smoothed prices can be considered as an empirical result, useful for its predictive value.

The interruption of the growing trend of whale oil and whale bone prices approximately 15 years after the production peak is somewhat surprising, since one might have expected that prices would continue to grow as production shrank. This trend may be explained as due to the competition with crude oil which started, indeed, approximately at the time of the start of the flat region of the price curve. Still, the price of whale oil remained always considerably higher than that of crude oil so that the constant price trend cannot be explained in terms of pure market competition. Furthermore, there was no equivalent of crude oil to compete with whale bone. Tentatively, therefore, the constant prices may be interpreted also asan intrinsic effect of the production cycle, possibly due to the shrinking size of the whaling fleet which permitted to reduce the investments on equipment.

We may at this point compare the data for whale oil with those of modern crude oil production (fig 5). Crude oil prices show a more complex behavior than whale oil and whale bone prices. Nevertheless, we can recognize an initial phase (up to 1971) of nearly constant prices, similar to that of whale oil until ca. 1825. Even though it is impossible to fit the crude oil data after 1971 with a simple exponential curve, it is evident that the average tendency after 1971 has been one of increase and that, after the great "oil crisis" of the 1970s, prices never went back to the pre-1971 values. This phase may correspond to the period from 1825 to ca. 1845 for whale bone and whale oil. If this interpretation is correct, further price oscillations will be observed in the future, superimposed to an increasing average price.

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 expect strong price oscillations, a trend which may have already started with the oil crisis of the 1970s. In analogy with the case for whale oil and whale bone prices, we may expect the crude oil market to become even more unstable in the future. The trend which started in 1999 may be therefore the result of a new cycle of increasing prices in progress, but it is not in itself an indication that the Hubbert peak is close (although it doesn't rule this out, either). We may also expect that the price oscillations will be superimposed to a gradually rising exponential growth of the average prices. At present, this exponential growth is not clearly discernable in the available price data, but it may become apparent in the coming years.

The historical case of the whaling industry tells us that the occurrence of 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 prices may still have a disruptive effect on the economy.

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References

A. Starbuck, 1878 History of the American whale fishery, Seacaucus, N.J. 1878, reprinted 1989

H. Hotelling, 1931, J. Polit. Econom. 39, pp. 137–175

Hubbert M.K. 1962, Nat. Res. Council publ. 1000-D Washington DC, p. 54

C.Coleman, 1995, Non Renewable Resources, Oxford university press, 4, p. 273

Campbell, C.J., Laherrere, J.H., 1998, Scientific American, March,60 –65.

Magoon L.B. 2000, U.S. Geological Survey Open-File Report 00-320, http://geopubs.wr.usgs.gov/open-file/of00-320/of00-320.pdf

Deffeyes, K. S. 2001, "Hubbert's Peak, the impending world oil shortage", Princeton 2001

R. Duncan, 2001 Population and Environment, May-June 2001, v. 22, n. 5.

Wood J., Long G., 2000, *Long Term World Oil Supply: A Resource Base/Production Path Analysis*, http://www.eia.doe.gov/pub/oil_gas/petroleum/presentations/2000/long_term_supply/index.htm

Bentley R.W. 2002 Energy Policy **30** 189 –205;

Livernois j., Thille, H., Zhang H., 2003, Working Paper http://www.economics.uoguelph.ca/econ/faculty/research/dispage.asp

C. Campbell, 2004 “The essence of oil and gas depletion” Multi Science Publishing Company Ltd,

Scott Baker, C. and Clapham, P.J., 2004 Trends in Ecology and Evolution Vol.19 No.7, p.1

Sahr R. 2004, http://oregonstate.edu/dept/pol_sci/fac/sahr/sahr.htm www.wrtg.com, accessed in 2004

Gelbert, D (accessed in 2004): http://oh.essortment.com/whaleoil_redd.htm

Lee, K.D. (accessed in 2004) http://www.che.utexas.edu/~kenneth/petrol/

Figure Captions

Fig. 1 Sum of the production of Sperm and Right Whale oil and production weighted average of prices (from Starbuck, 1878). The production data have been fitted with a Gaussian curve. Prices have been corrected for inflation and translated into 2003 prices according to the data reported by Sahr (2004)

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

Fig. 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.

Fig. 4 Fitting of whale bone prices with an exponential function. The results of a 15 points smoothing are also shown for comparison.

Fig. 5. Worldwide Production and price data for crude oil (from ASPO, 2004)

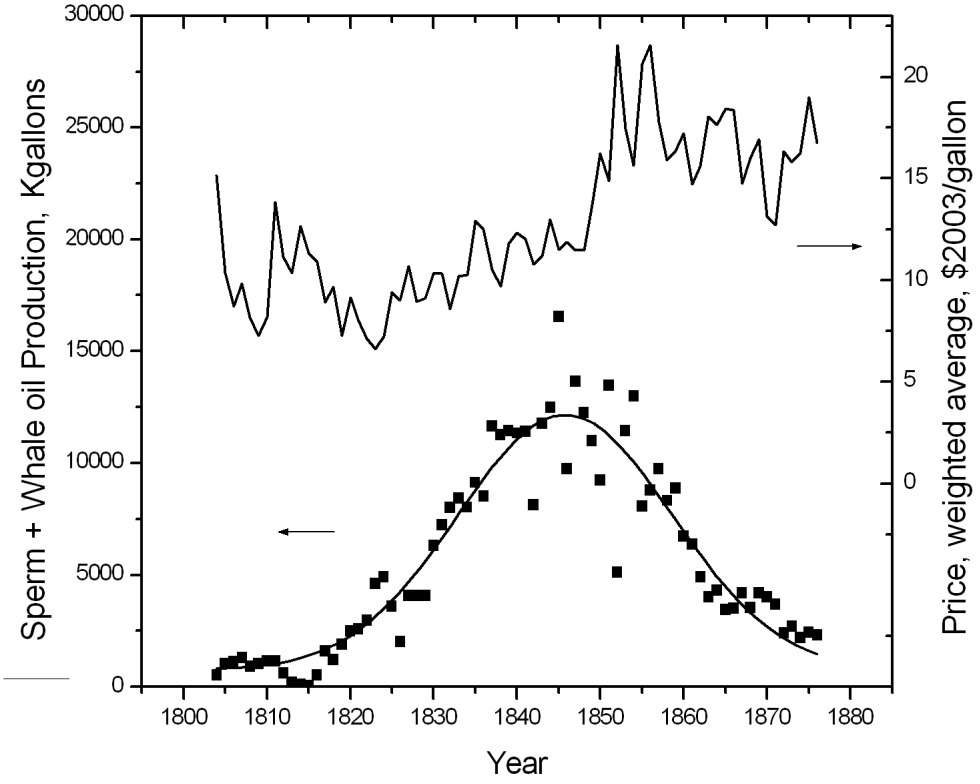
Sperm + Whale oil Production, Kgallons
Price, weighted average, $2003/gallon
Year
30000
25000
20000
15000
10000
5000
0
20
15
10
5
0
1800
1810
1820
1830
1840
1850
1860
1870
1880

Figure 1

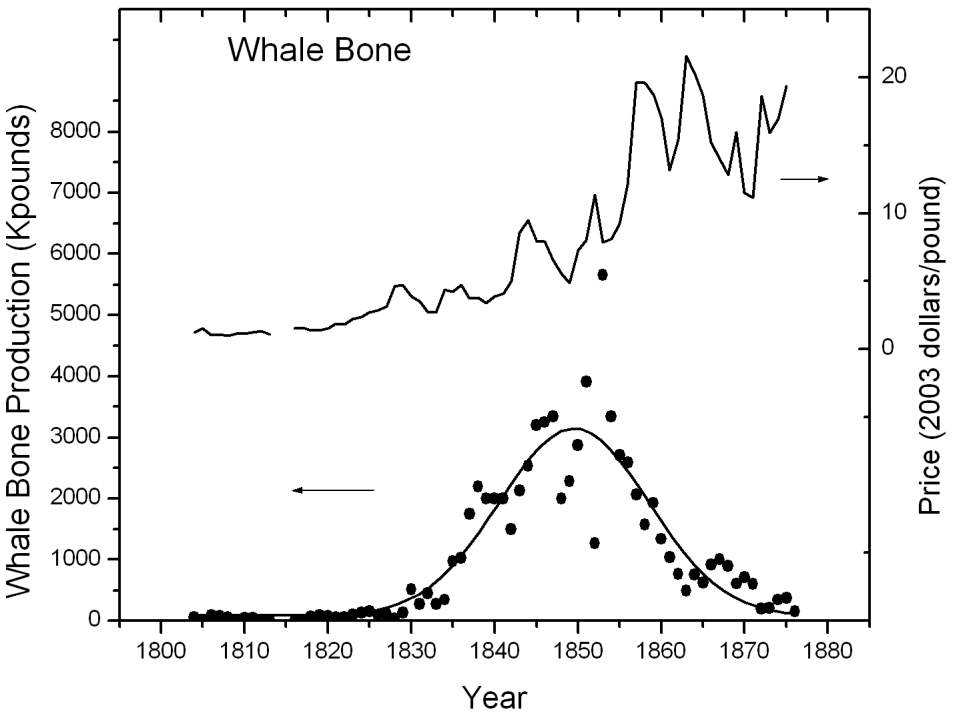
Whale Bone
Whale Bone Production (Kpounds)
Price (2003 dollars/pound)
Year
0
1000
2000
3000
4000
5000
6000
7000
8000
0
10
20
1800
1810
1820
1830
1840
1850
1860
1870
1880

Fig. 2

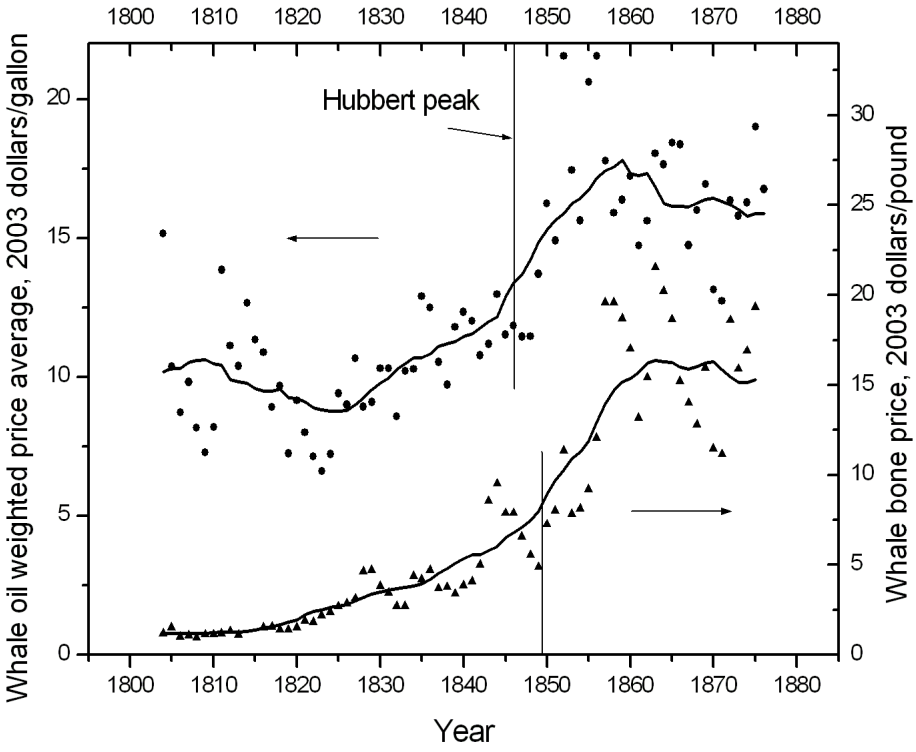
Hubbert peak
Whale oil weighted price average, 2003 dollars/gallon
Whale bone price, 2003 dollars/pound
Year
1800
1810
1820
1830
1840
1850
1860
1870
1880
0
5
10
15
20
25
30

Fig. 3

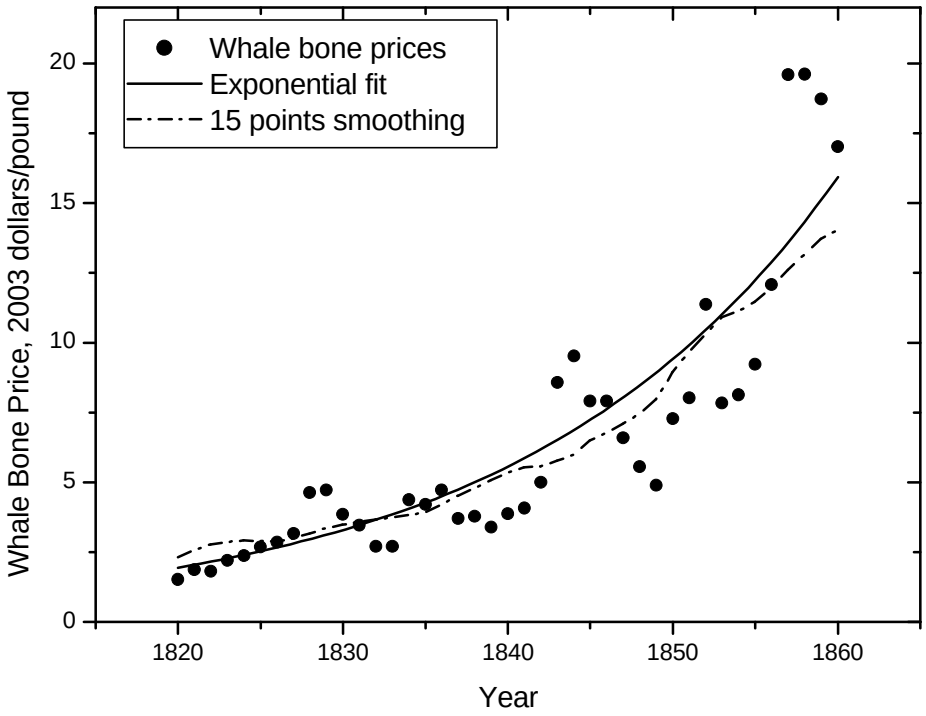
Whale bone prices
Exponential fit
15 points smoothing
Whale Bone Price, 2003 dollars/pound
0
5
10
15
20
1820
1830
1840
1850
1860
Year

Fig 4

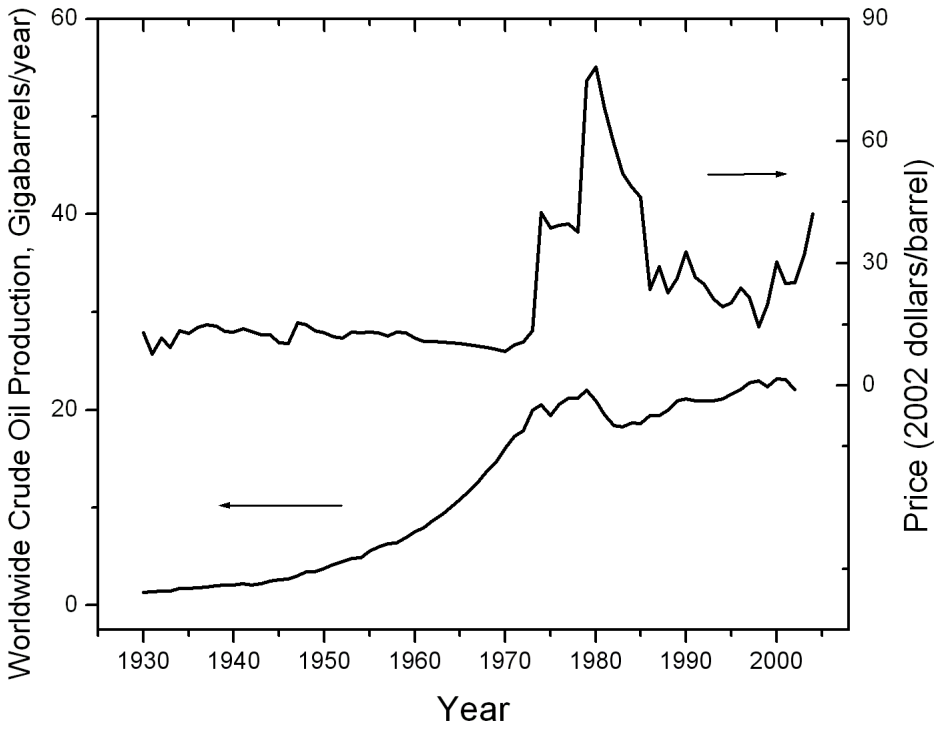
Worldwide Crude Oil Production, Gigabarrels/year)
Price (2002 dollars/barrel)
Year
0
20
40
60
0
30
60
90
1930
1940
1950
1960
1970
1980
1990
2000

Fig. 5