

Research in Irreversible Depletion Model Based on the Blood of Industry

Xuejun Wu¹, and Jun Lu²

¹ College of Science, Zhejiang University of Technology, Hangzhou, Zhejiang, China
Email: wuxj1959@126.com

² College of Zhijiang, Zhejiang University of Technology, Hangzhou, Zhejiang, China
Email: lujunhz@163.com

Abstract—Few people would deny that the world runs on oil. Oil, regarded as the blood of industry, may cause economic crises, and even lead to conflicts and wars. Three applicable models and several feasible policies are presented to settle the problem. We devise the Irreversible Depletion Model, and use global statistics data in logistic regressions to predict the total ultimate oil recovery. Relying on the estimated cumulative production, we make a prediction of the remaining ultimate recovery, and finally obtain the estimate of depletion year. We conclude that the prediction of the total ultimate Recovery equals 3.402Tb1 and the depletion year is in 2080. As a result, our model is robust.

Index Terms—depletion model, logistic regression

I. INTRODUCTION

As we know, oil is nonrenewable energy sources. Oil is demanded in many countries. They are rapidly being used up. More and more consumptions and less and less discoveries warn us that an oil crisis looms in the nearly future. There are many factors will influence the reserve of the oil [1][2].

Up-to-date, oil is not only the blood of industry, but also closely related with the political strategy of a country. In this paper, we first need to select a vital nonrenewable or exhaustible resource and find appropriate world-wide historic data on its endowment, discovery, annual consumption, and price. Then our task is to develop a model of the commodity over a long horizon by using the data properly. We choose annual data of six continents to analyze. And it is enough to represent the situation of the whole world.

According to the result we obtain, we need to offer some useful advice on the oil policy, including harvesting/management, security policy and policies controlling "environmental effects".

Finally, we should compare oil with any other alternatives, consider about new science or technologies to mitigate the use and potential exhaustion and develop a research policy to advance these new areas.

Model the depletion or degradation of the commodity over a long horizon using resource modeling principles. Adjust the model to account for future economic, demographic, political and environmental factors [3][4].

II. THE IRREVERSIBLE DEPLETION MODEL

Based on collected data and information, one could walk through the process of analysis and derive a set of high probability conclusions. By contrast, it was very difficult to find trustworthy oil reserve data. Published statistics are unreliable and subject to broad interpretation. One of the more technically complex methods is to calculate how much oil is recoverable using F5, Mean and F95 odds. At this point, however, we need to define our objective. Although there may be plenty of oil in the ground, only a fraction of this oil is recoverable, available for production, and economically viable as an energy resource. We seriously analyze the relations among the variables to make the estimate.

This paper ignores the influences of future economic, demographic, political and environmental factors. the Known reservoir varies according to the Logistic model [5][6].

So-called Known reservoir that referred to the total known storage (inventory) of oil is the sum of Cumulative production and Proved reserves satisfied the Eq. (1)

$$R_k(t) = C_p(t) + P_1(t) \quad (1)$$

Cumulative production automatically satisfied the form:

$$C_p(t) = \sum_t P_2(t) \quad (2)$$

Proved reserves of oil depend on annual production and discoveries via the relationship Eq. (3)

$$P_1(t+1) = P_1(t) - P_2(t) + D(t) \quad (3)$$

We might employ a damped trend, on geological and engineering conditions, to obtain an Ultimate estimate of the Known reservoir. Logistic equation is introduced to show the decreasing slope over time in the form of Eq. (4).

$$\frac{dR_k(t)}{dt} = r \left[1 - \frac{R_k(t)}{(R_k)_{\max}} \right] \quad (4)$$

Where r is the intrinsic growth or decay factor, R_k approaches to $(R_k)_{\max}$ over a sufficiently long

horizon. Total Ultimate Recovery R_u is equal to $(R_k)_{\max}$.

We would sooner or later run out of nonrenewable oil and confront with the year of depletion without taking any conservative measures. The important subject will impact our future lifestyle, the health and wealth of our generation. Despite the dire need to address the twin issues of oil reverses and depletion, we try to find out the lack of reliable information on these subjects.

The Remaining Ultimate Recovery can be represented as Eq. (5). $C_p(t)$ is known by statistics

$$R_r(t) = (R_k)_{\max} - C_p(t) = R_u - C_p(t) \quad (5)$$

The oil Depletion would occur in a neighborhood of t_0 , provided $\lim_{t \rightarrow t_0} R_r(t) = 0$. Thus t_0 is the year of depletion.

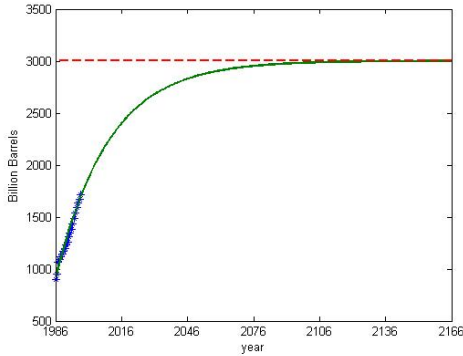


Figure 1. The trend of Known reservoir

Given the paucity of reliable data, we need to choose those sources that are most likely to be accurate and then adjust them as appropriate to our needs. For historical data, we chose to use the data and analysis published by BP (once known as British Petroleum) in their BP Statistical Review of World Energy, June 2006. This valuable information resource provides historical data on oil, natural gas, coal, nuclear energy, hydroelectricity, and power consumption.

The people who are responsible for this data appear to be very concerned about the accuracy of their work. A consistency of methodology has been applied across multiple years.

By digital fitting, we obtain The prediction of the Total Ultimate Recovery R_u equals 3.402 Tbl.

CERA believes we have 3.7 Tbl. USGS data from the analysis they did in 2000 appears to support a figure of approximately 3.4 Tbl. Oil and Gas Journal, along with oil company BP, also appears to support data in the 3.6 to 3.8 Tbl range. The result of our model suggests a maximum recovery of 3.402 Tbl, which is almost consistent with the other predictions.

Respectively, we fit linear and quadratic models to the original data, and get prediction models of Cumulative production.

TABLE I.
THE RESULT OF FITTING

$C_p(t)$	quadratic model	Linear model
Depletion Year	2080	2118
Geometric meaning	Annual production Keep increasing	Annual production remains constant

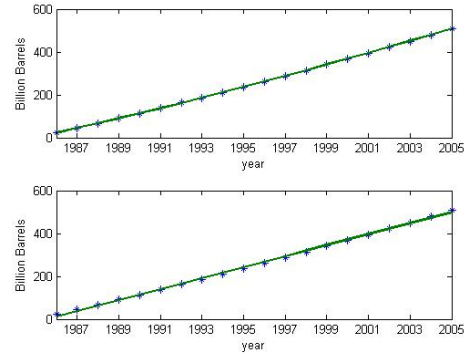


Figure 2. The trend of Known reservoir

III. THE MULTI-FACTOR SIMULATION MODEL

Of all the issues we confront in the 21st Century, resource depletion promises to have the greatest impact on our future economic, demographic, political and environmental destiny. And of nonrenewable resources, none will have a greater effect than the decline of oil.

Statistical correlations suggest that long term economic output is determined mostly by human population and the price of fossil fuel.

Energy use and production, demography and the world-market oil price influencing economic performance and environmental degradation.

The multi-factor statistical model derived from the analyses of the factors casts serious concerns on future oil production, social development perspectives and the environment. Corresponding mathematical models can be represented as Eq. (6).

$$P_2(t) = a_1 + a_2 P_3(t) + a_3 P_4(t) + a_4 P_3^2(t) + a_5 P_4^2(t) \quad (6)$$

We substitute the annual prices per barrel of oil in the past years for the one in the year of 2005 to compare the variable on the same price level.

The price of oil randomly fluctuates in a bounded range. Generally, we take the mean value for calculating.

According to Logistic equation, the trend of world population is showed in Figure 3.

RP was a rule-of-thumb measure of security of supply of the oil business. If the reserves remaining at the end of the year are divided by the production in that year, the result is the length of time that those remaining reserves would last if production were to continue at that level.

$$RP = \frac{(R_k)_{\max} - C_p(t)}{P_2(t)} = \frac{(R_k)_{\max} - \sum_i P_2(t)}{P_2(t)} \quad (7)$$

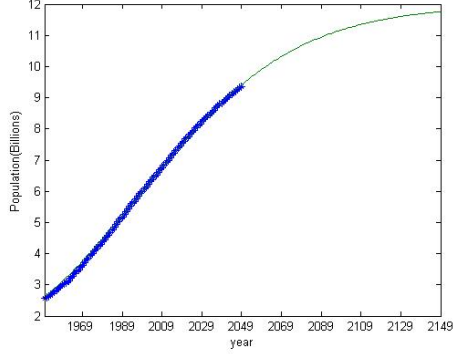


Figure 3. The constraint policy determined by RP

We elected to marry two functional forms, the first of which extends production from history along a constant percentage growth path until the production peak is reached, the second of which declines production post-peak at a constant RP ratio (not to be mistaken for a constant decline rate). The estimated time of peak production is therefore determined by the choice of these functional forms, the rate of pre-peak production growth, the post-peak RP, and the estimated size of the technically recoverable resource base. EIA selected an RP ratio of 10 as being representative of the post-peak production experience. The United States, a large, prolific, and very mature producing region, has an RP of about 10 and was used as the model for the world in a mature state. Provided graphically in Figure 4 are the results of productions while post-peak decline is varied at an RP ratio of 10, 20 and 30.

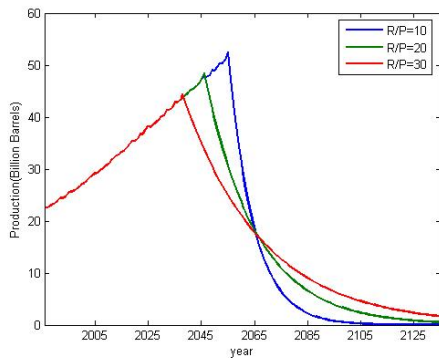


Figure 4. The production determined by RP

We make a sensitivity analysis of the variation of the annual production, population and price. Figure 5. shows the variation of annual production depending on population and price. The result is remarkably insensitive. figure agreeably shows that our model is robust.

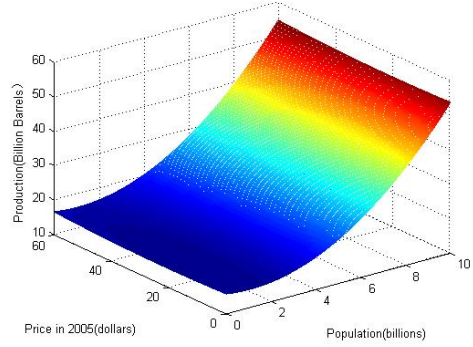


Figure 5. Sensitivity analysis of annual production

IV. THE MULTI-FACTOR SIMULATION MODEL

Obviously, as the price of oil increases on the world market, it becomes economically feasible to spend more money on production enhancement.

We assume that annual production is simply correlative with price of the year. That is to say we neglect the growth of population during one single year. Then according to Task 2, we know that the 1 variety of production is linear-correlative with that of price. In this case,

$$\Delta P_2 = E \Delta P_4 \quad (8)$$

Where E is a constant.

The estimated amount of incentives or disincentives

Then we may efficiently develop economic policies including incentives or disincentives to control the harvest (productions) by adjusting the oil price in the year.

There is, however, an upper limit to the world price P_4^{Th} and production P_2^{Th} for oil. At some point, we humans simply can not afford it, or the government is strictly determined the threshold of the production on the basis of the economic and engineering condition in favor of continual development. Then the income from oil is denoted by Eq. (9).

$$I = (P_4^{Th} + \Delta P_4)(P_2^{Th} + \Delta P_2) - P_4^{Th} P_2^{Th} \quad (9)$$

Correspondingly, take RP^{Th} as threshold of RP. Determine when to incentive or disincentive

If $RP > RP^{Th}$ award $\lambda_1 I$ economic incentives

$RP \leq RP^{Th}$ find $\lambda_2 I$ economic disincentives

$\lambda_1 \lambda_2$ are also controlled by the government or organization.

V. CONCLUSION

This paper devises the Irreversible Depletion Model, and use global statistics data in logistic regressions to predict the total ultimate oil recovery. Relying on the estimated cumulative production, we make a prediction of the remaining ultimate recovery, and finally obtain the

estimate of depletion year. We conclude that the prediction of the total ultimate Recovery equals 3.402 Tbl and the depletion year is in 2080. As a result, our model is robust.

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