Research on a Model of Oil Production Forecast Based on Technical Development and Dynamic Change of Reserves

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Abstract. The Hubbert model is widely used in forecasting the oil production. However, many scholars compared the history data to the data calculated by Hubbert model and got the conclusion that the Hubbert model was not suitable for forecasting oil production. In this paper the Hubbert model is modified and the technical progress is considered in the model. An oi production forecast system is presented, which can be used to analyze the technical progress and dynamic change of reserves. This forecast system is decomposed into three models namely the technical model, dynamic reserves model and production forecast model. The purpose of this paper is to show the powerful effect of technical progress and dynamic reserves on oil production. It is an innovative view that less research focus on this side. Furthermore, seismic technology, exploration theory, drilling technology and oil production technology are considered in technical model. These models are used to forecast world oil production from 2018 to 2030.

1.   Introduction

Since oil consumption keeps increasing and remaining reserves goes down, modeling and forecasting oil production are of great interest because measuring oil production is an important component of the oil market. Thus, a better understanding of the dynamics of oil production should be useful to energy researchers, market participants, and policymakers.

The most well-known institutions for oil production studies are the International Energy Agency(IEA) and the U.S. Energy Information Administration(EIA). The IEA has provided medium to long-term energy projections using a World Energy Model(WEM) from 1993. The current WEM, which is comprised of nearly 16000 equations, is designed to analyze oil market including global oi prospects.

EIA has built a World Energy Projection System(WEPS) in 1985 and has updated this model to World Energy Projection System Plus (WEPS+) in 2008. The World Energy Projection System is a comprehensive, mid-term energy forecasting and policy analysis tool. WEPS+ projects energy supply, demands, and prices by country or region, given assumptions about the state of various economies, international energy markets, and energy policies.

There are a number of commonly used oil production forecast methods. Statistical method is widely used. Hubbert(1956) first advanced the Hubbert model and predicted that oil production in US would reach its peak in 1969-1971. The statistical model has proved successful and has been applied

worldwide(Wang, J.L., Feng, L.Y.,2011,). Maggio and Cacciola (2009) use a variant of Hubbert curve for world oil production forecasts. Brandt(2007) tests three assumptions of the modern Hubbert theory using data from 139 oil producing regions and finds that production is more bell-shaped in larger regions than in smaller regions. Chavez-Rodriguez et al. (2015) evaluates scenarios for the oil production in Peru applying a Hubbert model. Saraiva et al.(2014) estimate Brazil's oil production curves applying a modified multi-Hubbert model.

However, many scholars compare the history data to the data calculated by Hubbert model and get the conclusion that the Hubbert model is not suitable for forecasting oil production. Maggio and Cacciola(2009) summarize the disadvantages and limitations of the Hubbert model that the model does not take into account the effect of possible technological or economical factors and provides a forecast with only one peak in oil production.

Because of the limitation of Hubbert model, scholars try to amend Hubbert model. Wang et al. (2011) divide the amended Hubbert model into two types. The first type is modification by the addition of extra production cycles.

The second modification expands the typical Hubbert model called the Generalized Hubbert-Bass model. Weng(1984) used Weng Cycle model to forecast the oil production. Hu et al. (1995) put forward HCZ model. Chen and Hu(1995) proposed the Weibull model.

However, the present oil production forecast model is limited in less considering technical progress and the dynamic character of reserves. Technical progress is one of the essential elements in oil production system. This paper attends to show the effect of technical progress in reserves model.

The paper is arranged as follows. Section 2 presents the general structure of the model and reviews the history of technical progress in oil exploration and development field. Section3 presents the forecasting results. Section 4 outlines some innovative points and provides some suggestion for future research efforts.

2.   The general structure of the model

Oil and gas is a very technology-oriented industry. Technical progress is a major contributor to the growth of oil reserves and production. This paper divides the history of technical progress into five phases: The early stage of technical progress, the first stage of technical revolution, the second stage of technical revolution, the third stage of technical revolution and the fourth stage of technical revolution.

2.1 The history of technical progress

The early stage of technical progress is from 1900 to 1920. This stage presents two aspects. First, Petroleum geology is put forward in US. In 1917, the American Association of Petroleum Geologists was founded. The original purpose of AAGP is to foster scientific research, to advance the science of geology, to promote technology, and to inspire high professional conduct. Second, anticlinal theory and rig technique get improved. In 1920, Seismic reflection method is successfully applied in the drawing of underground structure.

The first stage of technical progress is from 1930 to 1940. Seismic reflection, electric detecting technology and waterflooding technology make a great progress at this stage. Billions of barrels of additional oil have been recovered through waterflooding method, which is the most important method for improving recovery from oil reservoirs.

The second stage of technical progress is from 1970 to 1980. During the midterm of 70th., US get its peak production. The Middle East and former USSR are becoming the center of oil production. Oil offshore exploration and development technology is successful applied in North Sea and Gulf of Mexico. PDC Bit, directional drilling, and hydraulic fracturing get to use.

The third stage of technical progress is from 2000 to 2010. The Middle East and Russia are the most important production areas. Oil exploration and development technology have made great improvement, such as imaging technique, logging while drilling technique, horizontal multilateral well technique, tertiary oil recovery technique, SAGD and offshore petroleum Drilling Platform. Three-

Dimensional (3D) Seismic is used in oil exploration. The development of three-dimensional (3D) seismic allows the industry to develop fairly accurate models of the subsurface.

The fourth stage of technical progress is after 2010. The representative technology is microseismic, deepwater pre-salt seismic imaging and Multi Zone Fracture System. The depth of offshore exploration reaches 3000 meters. Hydraulic fracturing is the most effective stimulation treatment for the tight sandstones typically encountered in older, more consolidated continental sediments.

2.2 The function of technical progress model
This paper divides upstream technology into exploration technology and development technology. Exploration technology includes theories of petroleum exploration, remote sensing technology, seismic exploration, geological logging technology, exploration logging technology, geochemical exploration, microbial prospecting and geomagnetic exploration. Development technology includes reservoir engineering technology, drilling engineering technology, oil production engineering technology, and surface engineering technology.

In the early 1990s, the literature growth was introduced to measure technology trend (Joseph, 2003; Porter et al., 1991; Daim, 2006). The common literature growth models such as the exponential growth model (Price 1983), the logistic growth model(Price 1963), the linear-growth model and the transcendence function model are put forward. Compared with these curves, the logistic curve, which is divided into three phases: birth, growth and maturity, is better fit for the lifecycle of technology. Therefore, the logistic growth model is used to present the technical progress.

In the model, the literature growth is selected to show the technical progress in oil exploration and development and the logistic growth model is applied to analyze the technical progress. The logistic growth model is given by:

$$A(t) = \frac{K}{1 + ae^{-bt}} \tag{1}$$

where $A(t)$ is the number of literature at time t . K is the limitation of literature. There are no special meaning for parameters a and b.

The life cycle of technology progress can be represented as.

$$TM = \frac{A(t)}{K} = \frac{1}{1 + ae^{-bt}} \tag{2}$$

2.3 The function of dynamic reserves model
In most of literatures, Reserves is settled in Hubbert model. However, Reserves is variable actually. The aim of this paper is to describe the variation of Reserves and to propose an innovative approach that some important parameters are set to present the variation of Reserves. Few literatures refer to this approach. After testing lots of models to simulate the Reserves, the following model is the best fit to the actual data. The function of dynamic reserves is given by.

$$N_R(t) = a + b \ln price(t) + c \ln TM(t) \tag{3}$$

Where N_R is Reserves, price is oil price.

The reserves in this paper are taken to those quantities that geological and engineering information indicates with reasonable certainty can be recovered in the future from known reservoirs under existing economic and operating conditions.

2.4 The function of production forecast model
The production forecast model essentially differs from previous production forecast model. The Hubbert model is amended, where Reserves is dynamic.

The function of the production forecast model is given by.

$$Q_t = \frac{\alpha_t \beta_t N_R(t) e^{-\alpha_t t}}{(1 + \beta_t e^{-\alpha_t t})^2} \tag{4}$$

where Q_t is the oil production.

3. The calculation of the model

Based on the character of oil market, the paper build three sub-models: technical progress model, dynamic reserves model and production forecast model. The lifecycle of technical progress is demonstrated in Figure 1.

Figure 1 refers to four technical progress curves and a comprehensive curve, every technical progress curve is calculated by Eq(2). The comprehensive curve is added by these four technical progress curves. History literature data is taken from OnePetro which includes SPE, SEG, WPC,IPTC and OTC.

The technical progress of drilling is calculated as below.

$$TM(t) = \frac{1}{1 + 1691 * e^{-0.06t}} \tag{5}$$

The technical progress of seismic exploration is calculated as follows.

$$TM(t) = \frac{1}{1 + 200 * e^{-0.08t}} \tag{6}$$

The technical progress of oil exploration theory is calculated as follows.

$$TM(t) = \frac{1}{1 + 923 * e^{-0.07t}} \tag{7}$$

The technical progress of production engineering is calculated as follows.

$$TM(t) = \frac{1}{1 + 2427 * e^{-0.06t}} \tag{8}$$

To summarize, our results has led to the conclusion that the exploration technology is more mature than development technology. The progress on the development of the exploration technology, including 3-D seismic, 4-D seismic, multi-component seismic and seismic imaging techniques, is brought out from 1990 to 2015, while the development technology such as Fracturing technique is at the early stage before 2008. The period in 2008-2040 is fast growth stage of the development technology.

Comparisons of the result of the exploration technology and development technology, we can find that the strong interaction between the exploration technology and the development technology is shown in our results. In Figure 1, the exploration technology and the development technology both make a great progress after 1990. However, the development of exploration technology is prior to the development technology. Therefore, in this study, the exploration technology drives the development of the development technology, the development technology supports the development of the exploration technology.
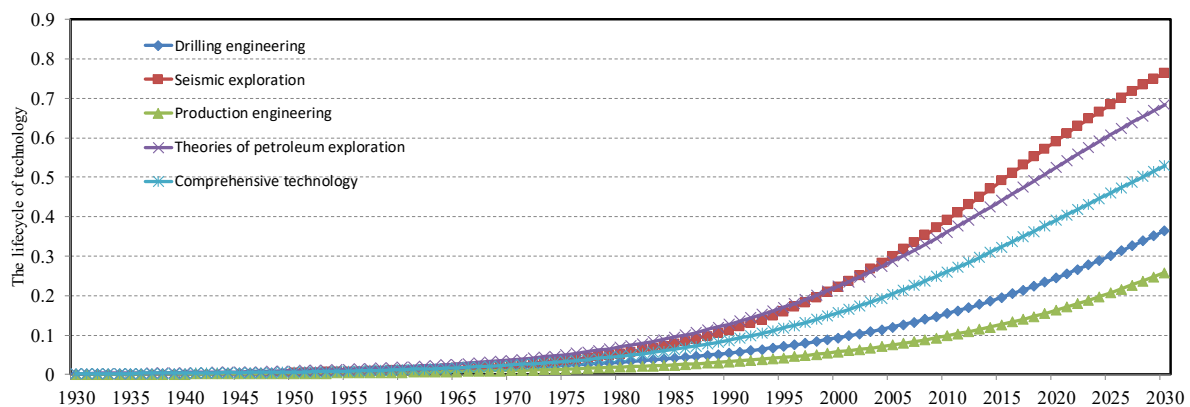

Figure 1. The lifecycle of technical progress

In the dynamic reserves model, oil price and reserves are available from BP statistical review of world energy 2018. Date from 2013 to 2017 are used to evaluate the accuracy of the reserves forecast. Table1 presents the history reserves from 2013 to 2017and reserves calculated by the dynamic reserves model. The difference between history oil reserves and reserves calculated by the model is small. Table 1 indicates that the reserves model could simulate the same trend with the history data. For example, when the history reserves increase or decrease, the reserves calculated by the model keep the same trend.

Table 1 History oil reserves and oil reserves calculated by the model, Billion barrels

Year	2013	2014	2015	2016	2017
History	1698	1702	1690	1697	1696
Calculation	1638	1654	1646	1658	1687

Based on the calculation of the model, the forecast of reserves from 2018 to 2030 is shown in Figure 2.The forecast of the oil price is that the price keeps 70 $/bbl from 2018 to 2030. The inflation rate is settled as 2%. The equation of dynamic reserves is given as follows.

$$N_R(t) = 20 - 4.86 \ln(price(t)) + 0.44 \ln(TM(t)) \tag{9}$$
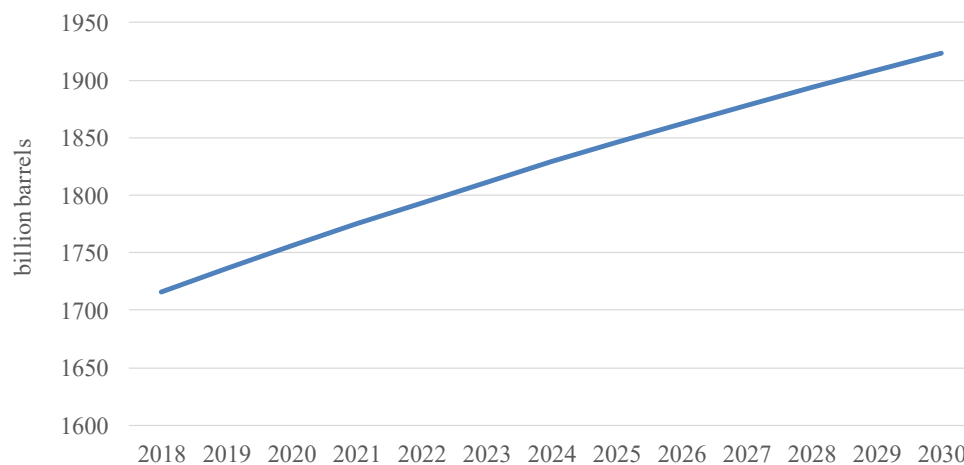

Figure 2. The reserves forecast from 2018 to 2030

Criticism of the production model in terms of the irrelevance of economic, political, and technological factors is valid. In this model, the technology and oil price are the most important factors for Reserves.

The parameters of production forecast model are estimated by matlab.

The α and β are shown in Table 2.

Table 2. The parameters of production forecast model

	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
α	2.39	2.38	2.38	2.38	2.38	2.38	2.38	2.38	2.37	2.37	2.37	2.37	2.37
β	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06

According to the assumption of the model, the forecast of production is shown in Figure 3. In reference scenario, the global production is projected to grow from 95419 thousand barrels daily in 2018 to 97933 thousand barrels daily in 2020 and to 100760 thousand barrels daily in 2030.
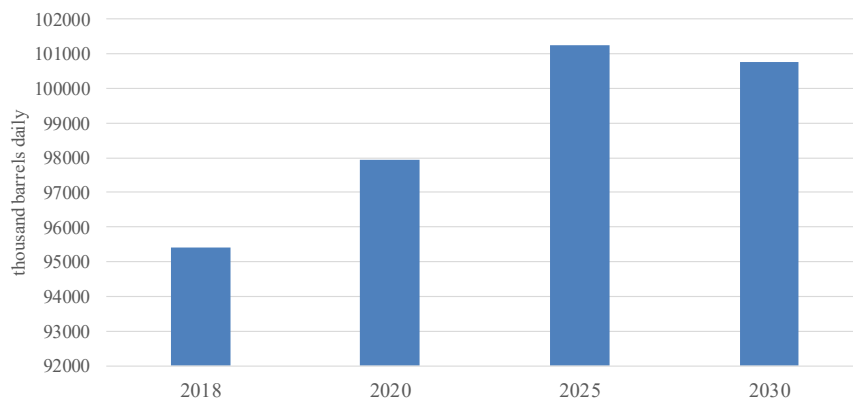
Figure 3. Production forecast from 2018 to 2030

4. Conclusion

This study essentially differs from previous research in regard to two following aspects. First, this paper considers technical progress and oil price in building dynamic reserves model. Moreover, the lifecycle model is used to analyze technical progress in oil exploration and development. Second, dynamic reserves model is added to the Hubbert model making the model more reasonable.

Moreover, some points are not taken into account in the proposed model. First, this paper doesn't emphasize the different weight about different technology in oil exploration and development. Second, this paper only chooses two parameters to discuss the dynamic reserves, which means that the model can be improved by adding more parameters. It may be true that this work significantly improves the results obtained with this model, but it also certainly suffers from some limitations.

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