Energy Policy 91 (2016) 64–74

Contents lists available at ScienceDirect

Energy Policy

journal homepage: www.elsevier.com/locate/enpol

A study on the future of unconventional oil development under different oil price scenarios: A system dynamics approach

Seyed Hossein Hosseini [a,*], Hamed Shakouri G. [a,b]

[a] School of Industrial and Systems Engineering, College of Engineering, University of Tehran, 14395-515 Tehran, Iran
[b] Institute for Resources, Environment and Sustainability (IRES), University of British Colombia (UBC), Vancouver, Canada

HIGHLIGHTS

- Variables and loops affecting oil production are formulated mathematically.
- Shares of conventional and unconventional oil in the global oil market is analyzed.
- Oil production rate under different oil price scenarios up to 2025 is simulated.
- Unconventional oil would obtain a considerable share in market in the short-term.
- A late peak for the conventional oil resources would occur.

ARTICLE INFO

Article history:
Received 9 July 2015
Received in revised form
9 December 2015
Accepted 23 December 2015
Available online 11 January 2016

Keywords:
Conventional oil production
Unconventional oil production
Oil price
Scenario analysis
System dynamics

ABSTRACT

Fluctuations in the oil global market has been a critical topic for the world economy so that analyzing and forecasting the conventional oil production rate has been examined by many researchers thoroughly. However, the dynamics of the market has not been studied systematically with regard to the new emerging competitors, namely unconventional oil. In this paper, the future trend of conventional and unconventional oil production and capacity expansion rates are analyzed using system dynamics approach. To do so, a supply-side modeling approach is utilized while main effective loops are modeled mathematically as follows: technological learning and progress, long and short-term profitability of oil capacity expansion and production, and oil proved reserve limitations. The proposed model is used to analyze conventional and unconventional oil production shares, up to 2025, under different oil price scenarios. The results show that conventional oil production rate ranges from 79.995 to 87.044 MB/day, which is 75–80 percent of total oil production rate, while unconventional oil production rate ranges from 19.615 to 28.584 MB/day. Simulation results reveal that unconventional oil can gain a considerable market share in the short run, although conventional oil will remain as the major source for the market in the long run.

1. Introduction

The global oil market has observed variations in market players' strategies since the first energy cricis. The main evolutions are on the demand side, where it has been trying to reduce the dependency on imported oil after 1970s. The most important strategies are: renewable energy development (Lund, 2007; Lund and Mathiesen, 2009), utilization of oil substitutes (Aleklett, 2008; Henriques and Sadorsky, 2008; Samii and Teekasap, 2010), controlling energy intensity and promoting efficiencies (Energy Outlook 2030, 2013; Geller et al., 2006; Liddle, 2012; Matheny, 2010), supporting financial market to increase market power and oil price control (Foster, 1996; Silvério and Szklo, 2012).

A recently emerging strategy, influencing the structure of the market's supply side, is to increase the rate of exploitation of unconventional oil resources. Specifically, the first three countries with major unconventional oil resources are the USA, Russia, and China (Kuuskraa et al., 2013) and it is discussed that the era of cheap oil in the world finished (Owen et al., 2010) and production from unconventional oil resources gradually becomes more economical.

The most important factor which affects unconventional oil development is the oil price dynamics, which directly affects the profitability of unconventional oil production and capacity expansion rate. An increase in the oil price will result in an increase in the oil production rate in the short run and a raise in the

* Corresponding author.
E-mail address: s.h.hosseini@ut.ac.ir (S.H. Hosseini).

http://dx.doi.org/10.1016/j.enpol.2015.12.027
0301-4215/

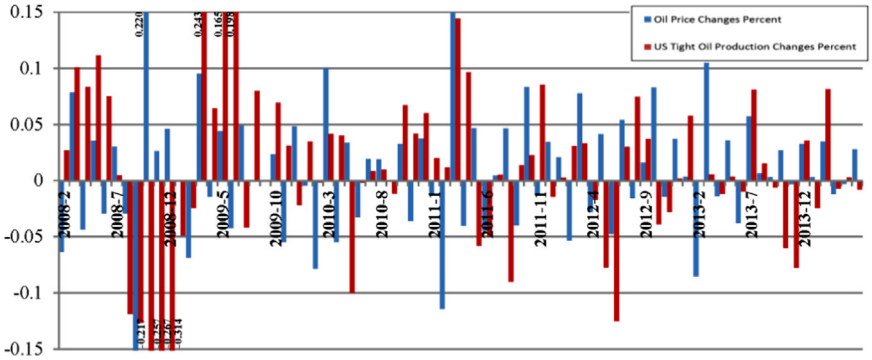

Fig. 1. Annual changes in the oil price and US tight oil production (percents) (Ratner and Tiemann, 2014).

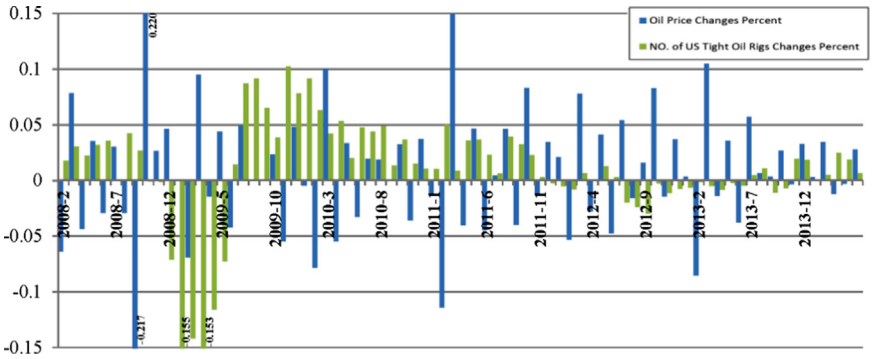

Fig. 2. Annual changes in the oil price and number of US tight oil active rigs (percents) (Ratner and Tiemann, 2014).

Table 1
Granger causality test results for changes in the oil price and changes in US tight oil production.

Lags	Cause var.	Affected Var.	*P*-value
1	ΔPrice	ΔProduction	0.721
2			0.7171
3			0.0312 (✓)
4			0.0128 (✓)
5			0.0231 (✓)
6			0.126
7			0.128
8			0.2058
9			0.0201 (✓)
10			0.0122 (✓)
11			0.1607
12			0.2024
13			0.0349 (✓)
14			0.0799
15			0.0975
16			0.1775
17			0.3993
18			0.0878
19			0.1827
20			0.1722

Table 2
Granger causality test results for changes in the oil price and changes in the number of US tight oil active rigs.

lags	Cause Var.	Affected Var.	*P*-value
1	ΔPrice	ΔRig NO.	0.2319
2			0.0583
3			0.1147
4			0.1229
5			0.0924
6			0.1091
7			0.0073 (✓)
8			0.0018 (✓)
9			0.0050 (✓)
10			0.0080 (✓)
11			0.0313 (✓)
12			0.0868
13			0.0703
14			0.0143 (✓)
15			0.0346 (✓)
16			0.0052 (✓)
17			0.0093 (✓)
18			0.262
19			0.5406
20			0.624

production capacity expansion in the long run, which are caused by investments in technological progress (i.e. increases in recovery factor). Figs. 1 and 2 depict the annual changes in oil price[1] along with those in the US tight oil production rate and the number of active production rigs, respectively. Moreover, Tables 1 and 2 summarize the results of several Granger causality tests, between changes in the oil price versus those in the US tight oil production rate and the number of active production rigs, respectively. A Granger causality test evaluates statistical causality between two variables with various time lags (TSAY, 2005). It reveals that increases in the oil price will result in more tight oil production with a 3–5 month lag in the USA. Furthermore, it will result in more active rigs with a 7–11 month lag and more oil production with a 9–10 month lag. Since unconventional oil production has still a minor share in the global oil market, a significant statistical causal relationship from its production to price could not be found yet.

The analysis and estimation of the world oil production rate has been seriously considered by many researchers. Using a logistic equation, Hubbert introduced his method for prediction of oil production. For the USA, he predicted that it peaks between 1965 and 1970 (Hubbert, 1982, 1956). Since then, researchers have tried

[1] Here, OPEC's reference basket price (in 1993 US $) is considered as the oil price basis.