UDC 517.958:52/59

Sibirskii Gosudarstvennyi Aerokosmicheskii Universitet
imeni Akademika M. F. Reshetneva. Vestnik
Vol. 18, No. 1, P. 88–92

MATHEMATICAL MODEL OF OIL PRICE FORMING ADJUSTED FOR TIGHT OIL FACTOR

K. V. Safonov*, A. S. Yushkov, L. I. Lytkina

Reshetnev Siberian State Aerospace University
31, Krasnoyarsky Rabochy Av., Krasnoyarsk, 660037, Russian Federation
*E-mail: safonovkv@rambler.ru

This article deals with the development of the mathematical model of oil price forming. To develop a proper mathematical model the methodological principles are defined: three axioms that establish specific properties of oil as a commodity including tight oil. Among the factors of oil pricing the major factor was selected, the dominant factor is an imbalance of supply and demand for oil in the world market. The principles of the mathematical model are presented in three theorems. The first one assumes that for any excess of supply over demand, the price of oil tends to zero, i. e., for a sufficiently large number of auctions it is below any given level. The second theorem states that, in the case of the excess of demand over supply price of oil tends to infinity (a finite number of sessions exceeds any given level), in case of the dominance of the imbalance. The third theorem asserts that the most probable forecast implied by the hypothesis that the mathematical model is accurate is a longstanding process of price auto-fluctuations in so called the tight oil range.

Keywords: mathematical model of price forming, dominant factor in pricing, supply and demand imbalance, price auto-fluctuation process.

Вестник СибГАУ
Том 18, № 1. С. 88–92

МАТЕМАТИЧЕСКАЯ МОДЕЛЬ ФОРМИРОВАНИЯ ЦЕНЫ НА НЕФТЬ С УЧЕТОМ ФАКТОРА СЛАНЦЕВОЙ НЕФТИ

К. В. Сафонов*, А. С. Юшков, Л. И. Лыткина

Сибирский государственный аэрокосмический университет имени академика М. Ф. Решетнёва
Российская Федерация, 660037, г. Красноярск, просп. им. газ. «Красноярский рабочий», 31
*E-mail: safonovkv@rambler.ru

Разработана математическая модель формирования цены на нефть. Для построения такой математической модели определены методологические основания: три аксиомы, устанавливающие специфические свойства нефти как товара, в том числе сланцевой нефти. Среди факторов ценообразования нефти выбран первостепенный, доминирующий фактор – дисбаланс предложения и спроса на нефть на мировом рынке. Основа математической модели представлена в трёх теоремах. Первая утверждает, что при любом превышении предложения над спросом цена нефти стремится к нулю, т. е. за достаточно большое количество аукционов становится ниже любого заданного уровня. Вторая теорема утверждает, что при условии превышения спроса над предложением цена нефти стремится к бесконечности (за конечное число сессий превысит любой заданный уровень) при условии доминирования дисбаланса. Третья теорема утверждает, что наиболее вероятным прогнозом, вытекающим из гипотезы о том, что построенная математическая модель верна, является длительный процесс автоколебаний цены в так называемом сланцевом диапазоне.

Ключевые слова: математическая модель формирования цены, доминирующий фактор ценообразования, дисбаланс предложения и спроса, процесс автоколебаний цены.

Introduction. The aim of this paper is to improve the mathematical model of oil price forming that was first developed in paper [1]. The improved model accounts for tight oil phenomenon, which role has recently grown, and gives answer to the three questions: why oil price has fallen more than by half since 2014, why the price drop ceased being changed to price movement which still takes place and what the price will be in the foreseeable future. The answers to the questions are stated in the final part of the article.

It should be noted that since the autumn of 2014, when the oil price fall became obvious, experts have been forecasting a “fair” price which will steady the market [2–11], however, no reliable forecasts have been made yet. Moreover, not all the experts realize the current state of affairs.

Thus, most people think that if oil supply exceeds demand by 5 %, the tender price is to be reduced by 5 % and a new price making 95 % of the previous one will steady the market. Of course it is not so: in paper [1] it has been pointed out that 5 % excess of supply will lead to longtime sequential multiple-stage markdown, therefore theoretically it may make 5 % of the starting price being decreased by 20 times! However, the comprehension of this situation is not sufficient for oil price forecasting.

The lack of reliable forecasts can be accounted for the fact that at the present time there is no comprehensive oil price behaviour model suitable for the events of the past two years. The aim of this article is to develop and to analyse the integrated model of oil price forming adjusted for tight oil factor which is not entirely taken into consideration in paper [1], as its influence on price forming became evident later.

To develop the mathematical (logical-economical) model we use simple mathematical regularities but what we actually rely on is the solid methodological basis in the form of safe axiomatic method of theory construction.

Improvement of mathematical model of oil price forming adjusted for tight oil factor. In the process of mathematical modeling of any phenomenon its local mathematical theory is actually created. Axiomatic method of theory construction has historically proved itself effective.

It should be noted that mathematical model method is a general-purpose and powerful instrument of human perception, especially efficacious in the cases when experiment conduction is impossible [12]. Mathematical model development implies a certain simplification of a complex phenomenon, its particular idealization basing on the identification of major factors which characterize the evolvement of the phenomenon and on neglecting minor, less important factors [13–16].

Mathematical modeling normally includes the following range of stages:

– development of the mathematical model of the phenomenon based on its simplification, identification of dominant factors which cause this phenomenon;

– exploration of the model by means of mathematical methods, gaining the information which describes the further evolvement of the phenomenon;

– comparing of the theoretically forecast model response with what will actually occur;

– specification and correcting of the mathematical model in case there is a difference between theoretical and practical aspects;

– exploration of the specified model, description of its response;

– repeated correcting of the mathematical model basing on the comparison of theory and practice etc.

It is the comparison between the primary mathematical model and real experience that showed that tight oil factor determining price development was not fully clarified which lead to the necessity of improving the mathematical model developed in paper [1], which will be done as follows.

In respect to oil price, axiomatic method is about obtaining logically adjusted consequences of oil price forming process from fundamental properties of oil as a commodity. Thus, the mathematical model can be called logical-economical as well.

In our opinion, initial fundamental properties of oil as a commodity are described by the following three statements which are practically proven and play the role of axioms:

– oil is a commodity with the price determined at auction sellings on several fixed venues and is not directly related to its cost as a measure of abstract labor invested and to the market price of other commodities which, unlike oil price, are determined by multiple market transactions (A1);

– unlike many other commodities, oil has a specific property; oil price markdown does not trigger increase in demand determined by the economy state of the demander; certain increase in demand is possible only for oil reservation purposes, but not to be used as intended (A2);

– tight oil differs from “regular” oil in significantly larger extraction prime cost and in case oil price nears this level from below, tight oil extraction may be ceased or resumed quickly (A3).

Indeed, if average regular oil prime cost equals several US dollars, then tight oil prime cost lies within the range of $ 35–55 what we will call the *tight oil range*.

It has the following properties. When market price lies beyond the range, tight oil is economically indistinguishable from regular oil; at the price above $ 55 tight oil extraction is close to the maximum rate, at the price below $ 35 it is almost ceased. If the oil price lies in the tight oil range, its manufacturers reduce or increase the extraction depending on the expenses, thereafter, tight oil market supply changes between the maximum and minimum.

Mathematical modeling provides simplification of the object basing on its dominant properties. We consider *the dominant price forming factor to be steady excess of supply over demand initially formed by the middle of 2014, mainly by means of tight oil extraction increase*.

Basing on the axioms and the dominant factor, we obtain the mathematical model of oil price forming in the form of the following three theorems.

Theorem 1. If oil market supply exceeds demand for any arbitrarily small value $\Delta_1 > 0$, realized by market participants, and the current oil price exceeds tight oil range, in the process of repeated auction selling oil price falls tending to the upper limit of the tight oil range.

Indeed, if it were not for tight oil phenomenon, the price would tend to zero, i.e. in finite number of steps becoming lower than any predefined level. Approaching tight oil range from above halts the fall.

Theorem 2. If oil market demand exceeds supply for any value $\Delta_2 > 0$, realized by market participants, and the current oil price exceeds tight oil range, in the process of repeated auction selling oil price tends to infinity, i. e. in finite (sufficiently large) number of steps it will exceed any predefined level becoming nonproportionally high in relation to the cost of other commodities.

The situation when the current price lies below the tight oil range which is not covered by theorems 1 and 2 is also clear: tight oil is not extracted and oil price either increases or falls depending on supply and demand equilibrium.

Finally, the situation when the current oil price is within the tight oil range is described by the following theorem.

Theorem 3. If the current oil price lies within the tight oil range, then periodic sine wave fluctuations occur in this range in several months' span which is required for tight oil branch to react to price change; in this process oil price is regulated automatically, i. e. on its own accord, auto-fluctuating, according to scientific terminology.

Of course, the mathematical model describes the process approximately, as a trend, which is the result of the simplification of the case and the detection of the dominant factor. Multiple trend departures are caused by auction participants' changeable understanding of supply and demand balance which is influenced by a number of dynamic factors.

We point out that paper [1] contains the primary mathematical model of oil price forming which does not take the tight oil factor into account. It does not have either axiom 3 or, consequently, theorem 3 which is of crucial significance for describing oil price behavior.

The represented theorems can be proved with a certain level of rigor. The theorem 1 proof has the following main point. The hypothesis of the theorem has it that tight oil extraction is at the peak level and does not change. As supply exceeds demand, the seller is ready to bring the price down at the auction by a certain amount, for example $ 0.5, to make the offer more attractive comparing to the others. Determining oil price at the next stage of the auction (A1), the participants will see that the demand has not grown (A2) and is still $\Delta_1 > 0$, which encourages the sellers to reduce the price by $ 0.5 again. After a finite number of stages the oil price will approach the upper limit of the tight oil range (if there were no range, the price would tend to zero). Theorem 2 is proven likewise.

The theorem 3 proof has the following main point. If the current price, gradually falling, gets into the tight oil range, tight oil branch quickly reacts in oil extraction decrease (A3). This case shifts supply and demand balance, and the situation turns from the hypothesis of theorem 1 to the hypothesis of theorem 2: the price starts to grow encouraging quick resuming of tight oil extraction. Therefore, the market assigns it to the forthcoming excess of supply over demand which triggers a new price fall period. There appears a periodic process of sine wave auto-fluctuations in the range $ 35–55 lasting for several months which take tight oil branch to react.

We lay emphasis on the fact that the price behaviour, described by theorems 1–3, is caused by the results of auctions indicating no abstract labour measure. If milk price were determined in the same way, it would change.

Analysis of the improved mathematical model. The analysis of the improved mathematical model shows that, relating to the current state of events, the price forming mechanism described by theorems 1–3 results in the following statements.

Firstly, the developed model can give answers to the three questions which have been put in the beginning of the article and adequately describe price movements since the middle of 2014 until now. Actually, this period can be divided into two stages. At the first stage, influenced by the oversupply, the oil price was falling practically tending to zero, according to theorem 1. This stage was over as the price, having fallen more than by half, first approached the tight oil range, gradually reducing tight oil extraction and halting the price fall. The second stage was opened with a slight price growth turning into the auto-fluctuation process within the tight oil range described by the proof of theorem 3; these auto-fluctuations take place till now. As for the question on the oil price in the foreseeable future, the answer to it is given below.

Therefore, this mathematical model is a scientific hypothesis with the theoretical justification and is practically proven.

Secondly, there is no certain fair price, moreover, it generally cannot be steady: it rises in case of slightest deficit and it falls in case of excess, tending to zero. In 2014 the excess of supply over demand triggered the price falling process which cannot be halted as long as the excess takes place. As a result, the price might reach the extremely low level of about $ 20 per Brent oil barrel, halting due to the fact that further decrease has no sense, as it is economic zero for today's oil price.

However, the tight oil range protects the oil price against the extremely low level. Its approaching the upper limit quickly reduces the extraction and supply of tight oil, hence, as it is pointed out in the proof of theorem 3, periodical price auto-fluctuations in the tight oil range are induced. This is a new phenomenon which has not taken place previously.

Finally, we have the following oil price forecast: present price auto-fluctuations within the range of $ 35–55 will last for a long period of time. Quick reaction of tight oil branch will prevent from oil deficit, important for price growth; to make it bring auto-fluctuation process to an end, deficit must exceed tight oil extraction potential. Thus, it does not seem possible to have the oil price either above $ 55, or below $ 35 for a long period of time, consequently, in the foreseeable future the year-average price equals $ 45.

We should note that according to the forecast of the Ministry of Finance of the Russian Federation made by the head of the Department of budgetary policy and strategy planning of the Ministry of Finance V. Kolychev, in 2017 the year-average price of $ 40 per Urals oil barrel is expected [17]. With regard to the fact that the price of this oil makes approximately 90 % of Brent oil price, the Ministry of Finance forecast equals the price of $ 44.4 per Brent oil barrel which strictly corresponds to our conclusions.

Or course, there is a crucial question which demands answer: what will happen, if tight oil range defense mechanism cannot prevent from the fall of the price to the extremely low level of $ 20 and supply still exceeds demand? Theoretically, this situation can occur in the long term in case tight oil prime cost drops significantly, as much as two or three times. This situation is described by another mathematical model lying beyond the scope of this paper.

However, it may be only caused by sharp multiple fall of tight oil prime cost, which is very unlikely, that is why the longstanding auto-fluctuation process within the tight oil range is most likely to take place.

Conclusion. This article presents and works out the problem of developing the mathematical model of oil price forming adjusted for tight oil factor.

The methodological foundation is determined for the development of such a mathematical model. The three axioms stating the unique properties of oil as a commodity are chosen as the basis. The first axiom says that oil is the commodity which price is determined at auctions on 2–3 world venues and is not directly related to its cost as a measure of abstract labor invested and the prices of other commodities which are determined as a result of a great number of market transactions.

The weak connection of the forming oil price with its actual cost which is objectively determined by average market production expenses postulates the possibility of a considerable gap between the price and the cost, both downward and upward.

The second axiom states that the markdown in oil prices involves no demand increase for it, as the demand is determined by the economy state of a demander; market demand increase is possible at a lower price as a part of demanders can purchase oil for reservation purposes, however, extra demand exists only under condition of a low price and it vanishes if the price increases. This commodity property of oil is essential as it differs oil from the majority of commodities, cheapening of which leads to a significant increase of consumption.

The third axiom describes the properties of tight oil as a commodity: its relatively large prime cost, the possibility to reduce and increase extraction volume quickly depending on market oil price changes. It emphasizes the importance of so called tight oil factor which determines tight oil extraction volume having an effect on world oil prices.

These statements are empirical basing on the long-term experience of oil extracting and marketing and are axiomatic from the logical point of view.

Among the factors that determine oil price the imbalance of supply and demand on the world market is chosen as a major, dominant factor. Neglecting multiple minor factors allows to develop the mathematical model basing on the mentioned dominant factor and to analyze it, describing the price behavior as a trend that tolerates fluctuations induced by minor factor influence.

The mathematical model is presented in three theorems. Theorem 3 is conceptually new, stating that the oil price has now entered a longstanding process of autofluctuations in tight oil range.

The developed mathematical model is simple, it has a clear reasoning and is practically confirmed: it is the only model to adequately describe the oil market situation for the past two years.

References

1. Safonov K. V. [A mathematical model of oil price assessment]. *Vestnik SibGAU*. 2016, Vol. 17, No. 1, P. 79–83 (In Russ.).

2. *Neft' podorozhala na 3 % v posledniy den' 2015 goda* [Oil surged 3 % on the last day of 2015] (In Russ.) Available at: http://www.vestifinance.ru/articles/66055 (accessed 02.01.2016).

3. *SMI: stoimost' barrelya nefti prevysit v 2016 godu 50 dollarov* [Media: the price of a barrel of oil will exceed in 2016 $ 50] (In Russ.). Available at: http: // www.banki.ru/news/lenta/?id=8564375&r1=rss&r2= common&r3=news (accessed 02.01.2016).

4. *Barrel' Brent opustilsya do $ 36,6* [A barrel of Brent fell to $ 36,6] (In Russ.). Avaliable at: http://www.vedomosti.ru/business/news/2015/12/31/622999-barrel-brent-opustilsya-do-366/ (accessed 02.01.2016).

5. *Brent i WTI poteryali v tsene posle dannykh o roste zapasov v SShA* [Brent and WTI lost value after data on growth stocks in the United States] (In Russ.). Available at: http://www.vedomosti.ru/economics/news/2015/12/30/622986-brent-wti (accessed 02.01.2016).

6. *Mirovye tseny na neft' torguyutsya raznonapravlenno* [Global oil prices traded mixed] (In Russ.). Available at: http://www.gazeta.ru/business/news/2015/12/31/n_8080025.shtml (accessed 02.01.2016).

7. *Tseny na neft' uskorili padenie: zapasy rastut, spros snizhaetsya, prognozy ne obnadezhivayut* [Oil prices accelerated their decline: stocks are rising, demand is slowing, the forecasts are not encouraging] (In Russ.). Available at: http://www.newsru.com/finance/30dec2015/oilafternoon.html (accessed 02.01.2016).

8. *Retsessiya, urezanie raskhodov, revolyutsiya? Kak nizkie tseny na neft' skazyvayutsya na neftyanykh derzhavakh* [The recession, cuts in expenditures, the revolution? How low oil prices affect oil powers] (In Russ.). Available at: http://inopressa.ru/article/30Dec2015/guardian/oil.html (accessed 02.01.2016).

9. *Esli tseny na neft' sorta Brent dostignut $ 30 za barrel', para dollar/rubl' protestiruet uroven' 78* [If the price of Brent crude oil reached $ 30 per barrel, the dollar/ruble will test the level of 78] (In Russ.). Available at: http://www.finam.ru/analysis/marketnews90CFF (accessed 02.01.2016).

10. *Siriya, Turtsiya, OPEK. Samye krutye momenty padeniya i rosta tseny nefti v 2015 g* [Syria, Turkey, OPEC. The coolest moments of the rise and fall of oil prices in 2015] (In Russ.). Available at: http:// neftegaz.ru/news/view/144907 (accessed 02.01.2016).

11. *Sberbank CIB zayavil o nepredskazuemosti ekonomicheskoy dinamiki pri nefti nizhe $25* [Sberbank CIB announced the unpredictability of the economic dynamics in oil below $ 25] (In Russ.). Available at: URL: http://www.vedomosti.ru/finance/news/2015/12/30/622949-sberbank-cib (accessed 02.01.2016).

12. *Matematicheskaya entsiklopediya. T. 3.* [Mathematical encyclopedia. Vol. 3]. Moscow, Sovetskaya entsiklopediya Publ., 1982, 574 p. (In Russ.).

13. Samarskiy A. A., Mikhaylov A. P. *Matematicheskoe modelirovanie: Idei, Metody, Primery* [Mathematical modeling: Ideas, Methods, Examples]. Moscow, Fizmatgiz Publ., 2001, 320 p.

14. Abramov A. P., Ivanilov Yu. P. *Fizika i matematicheskaya ekonomika* [Physics and mathematical Economics]. Moscow, Znanie Publ., 1991, 32 p.

15. Lotov A. V. *Vvedenie v ekonomiko-matematicheskoe modelirovanie* [Introduction to economic-mathematical modeling]. Moscow, Nauka Publ., 1984, 392 p.

16. Kantorovich L. V., Gorstko A. B. *Optimal'nye resheniya v ekonomike* [Optimal Solutions in Economics]. Moscow, Nauka Publ., 1979, 229 p.

17. [The ministry predicted the average price of Urals oil in 2017]. *OIL.Ekspert* (In Russ.). Avaliable at: http://www.rosbalt.ru/business/2016/12/22/1578104.html/ V Minfine sprognozirovali srednyuyu tsenu na neft' Urals v 2017 godu/.

Библиографические ссылки

1. Safonov K. V. A mathematical model of oil price assessment // Вестник СибГАУ. 2016. Т. 17, № 1. С. 79–83.

2. Нефть подорожала на 3 % в последний день 2015 года [Электронный ресурс]. URL: http://www.vestifinance.ru/articles/66055 (дата обращения: 02.01.2016).

3. СМИ: стоимость барреля нефти превысит в 2016 году 50 долларов [Электронный ресурс]. URL: http: // www.banki.ru/news/lenta/?id=8564375&r1=rss&r2=common&r3=news (дата обращения: 02.01.2016).

4. Баррель Brent опустился до $ 36,6 [Электронный ресурс]. URL: http://www.vedomosti.ru/business/news/2015/12/31/622999-barrel-brent-opustilsya-do-366 (дата обращения: 02.01.2016).

5. Brent и WTI потеряли в цене после данных о росте запасов в США [Электронный ресурс]. URL: http://www.vedomosti.ru/economics/news/2015/12/30/622986-brent-wti (дата обращения: 02.01.2016).

6. Мировые цены на нефть торгуются разнонаправленно [Электронный ресурс]. URL: http://www.gazeta.ru/business/news/2015/12/31/n_8080025.html (дата обращения: 02.01.2016).

7. Цены на нефть ускорили падение: запасы растут, спрос снижается, прогнозы не обнадеживают [Электронный ресурс]. URL: http://www.newsru.com/finance/30dec2015/oilafternoon.html (дата обращения: 02.01.2016).

8. Рецессия, урезание расходов, революция? Как низкие цены на нефть сказываются на нефтяных державах [Электронный ресурс]. URL: http:// inopressa.ru/article/30Dec2015/ guardian/oil.html (дата обращения: 02.01.2016).

9. Если цены на нефть сорта Brent достигнут $ 30 за баррель, пара доллар/рубль протестирует уровень 78 [Электронный ресурс]. URL: http://www.finam.ru/analysis/marketnews90CFF (дата обращения: 02.01.2016).

10. Сирия, Турция, ОПЕК. Самые крутые моменты падения и роста цены нефти в 2015 г. [Электронный ресурс]. URL: http://neftegaz.ru/news/view/144907 (дата обращения: 02.01.2016).

11. Sberbank CIB заявил о непредсказуемости экономической динамики при нефти ниже $ 25 [Электронный ресурс]. URL: http://www.vedomosti.ru/finance/news/2015/12/30/622949-sberbank-cib (дата обра-щения: 02.01.2016).

12. Математическая энциклопедия. М. : Советская энциклопедия. 1982. Т. 3. 574 с.

13. Самарский А. А., Михайлов А. П. Математическое моделирование: Идеи. Методы. Примеры. 2-е изд. М. : Физматгиз. 2001. 320 с.

14. Абрамов А. П., Иванилов Ю. П. Физика и математическая экономика. М. : Знание. 1991. 32 с.

15. Лотов А. В. Введение в экономико-математическое моделирование. М. : Наука. 1984. 392 с.

16. Канторович Л. В., Горстко А. Б. Оптимальные решения в экономике. М. : Наука. 1979. 229 с.

17. В Минфине спрогнозировали среднюю цену на нефть Urals в 2017 год [Электронный ресурс] // OIL.Эксперт : электрон. журн. URL: http://www.rosbalt.ru/business/2016/12/22/1578104.html/ В Минфине спрогнозировали среднюю цену на нефть Urals в 2017 году/.