Energy 144 (2018) 243–264

Contents lists available at ScienceDirect

Energy

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

Analysis and forecasting of the oil consumption in China based on combination models optimized by artificial intelligence algorithms

Jingrui Li [a], Rui Wang [b], Jianzhou Wang [b, *], Yifan Li [c]

[a] School of Accounting, Dongbei University of Finance and Economics, Dalian, China
[b] School of Statistics, Dongbei University of Finance and Economics, Dalian, China
[c] University of California, Los Angeles, USA

ARTICLE INFO

Article history:

Keywords:
Gray prediction
Gray neural network
GA-GNNM (1, n)
Combination forecasting

ABSTRACT

Forecasting petroleum consumption is a complicated and challenging task because many parameters affect the oil consumption. Whereas a highly accurate prediction model can help one utilize data resources reasonably, an inaccurate model will lead to a waste of resources. Thus, choosing an optimization model with the best forecasting accuracy is not only a challenging task but also a remarkable problem for oil consumption forecasting. However, a single model cannot always satisfy time series forecasting and the variations in oil consumption. In this paper, a total of 26 combination models using traditional combination method were developed to increase the prediction accuracy and avoid the problem of individual risk prediction methods "over-fitting", which would reduce the accuracy. Our conclusion is that the proposed combination models provide desirable forecasting results compared to the traditional combination model, and the combination method of TCM-NNCT is the most feasible and effective one. This paper also discussed the factors related to the statistical models and the results can be used by policy makers to plan strategies. Numerical results demonstrated that the proposed combined model is not only robust but able to approximate the actual consumption satisfactorily, which is an effective tool in analysis for the energy market.

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1. Introduction

Oil is one of the three major types of fossil fuels (the other two are natural gas and coal), and it is widely utilized in many economic activities, such as construction, industry, residential activities and electricity generation [1]. Although oil can be directly consumed, in most cases the fuel is refined into oil products such as diesel fuel, gasoline, heating oil and jet fuel, which are then consumed. Despite the stagnation in oil production, the consumption of oil displays a consistent upward trend, which is facilitated by the rapid population growth and the increasing demand for oil in developing countries [2].

The OECD (Organization for Economic Cooperation and Development) countries that are used in our sample are still the primary consumers of oil. According to the BP Statistical Review of World Energy, approximately 89,773 thousand barrels of oil and liquid fuels were consumed per day worldwide in 2015. This figure amounts to nearly 32 billion barrels a year and represents an 18% rise compared to the consumption in 2003 [3].

Petroleum is the critical component of modern technology and its operations, as economic and scientific development are positively linked to oil consumption [4]. Oil is not only a non-renewable resource, but a strategic resource related to a nation's prosperity, as it has a significant effect on the security of the national economic development and national defense. Therefore, accurate predictions of oil production and consumption have been necessary for policy making in recent years [5].

Moreover, when the oil consumption is integrated of order one, shocks to it are permanent. In 2014, the oil consumption in the transport industry composed 23.1% of China's total oil demand. China's petroleum consumption growth is estimated at $6.9 \times 10^3 t$ for the year 2013. In 2014 and 2015, the consumption growth of the world was, respectively, estimated at 1.0 million bbl. and 0.9 million bbl [6]. Therefore, scientific inquiries, predicting the change of the oil consumption in China and selecting corresponding measures in time to avoid the risk of energy insecurity are important measures to ensure a steady increase of the national economy and energy supply [7].

* Corresponding author. School of Statistics, Dongbei University of Finance and Economics, Dalian 116000, China.
E-mail address: wangjzh@lzu.edu.cn (J. Wang).

https://doi.org/10.1016/j.energy.2017.12.042
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Nomenclature

Y	vector of dependent variables
y_n	input parameter
X	matrix of independent variables
y_1	output parameter
ε	vector of random errors
t	number of input parameters
σ^2	error variance of ε
ω	weight
I_n	$n \times n$ identity matrix
g	current iteration number
$\widehat{\beta}$	parameter vector to be estimated
$Iter$	maximum number of iterations
B	matrix with the generated data
n	node number of the hidden layer
$S_t^{(1)}$	value of single exponential smoothing
o_i	predicted output of ith node
$S_t^{(2)}$	value of quadratic exponential smoothing
k	coefficient
$\widehat{X}_{t+T}$	prediction of stage T
F_i	the fitness value of i
α	smoothness index $(0 < \alpha < 1)$
a_k	kth chromosome
a_l	lth chromosome
$a_{\max}$	upper bound of a_{ij}
$a_{\min}$	lower bound of a_{ij}
r	random number
x_i	population i
$Gen_{\max}$	maximum number of iterations
$x_i(t)$	observed value of the tth data point
d	the number of dimensions
$\widehat{x}_i(t)$	forecasting value of the tth data point
l_{it}	combined weighted coefficients
$E_t E'_t$	covariance matrix of forecasting error
e	error of $\widehat{X}$
GM	Gray prediction method
$GNNM$	Gray neural network model
GNN	Gray neural network
GA	Genetic algorithm
ANN	Artificial neural network
SSE	the sum of squared errors
$GA\text{-}GNNM$	Gray neural network model improved by genetic algorithm
$TCM\text{-}NNCT$	traditional combination method with the proposed no negative constraint theory

Besides, predicting the petroleum consumption is not a problem exclusive for China, according to Energy Information Administration (2012) [8], consumption of oil and other liquid fuels is estimated to increase from 85.7 million barrels per day (Mb/d) in 2008 to 112.2 Mb/d in 2035 in the whole world. What's more, there are other countries like Malaysia, Saudi Arabia, and the United States having the same situation like China. Based on Malaysia Energy Information Hub (MEIH), 23,923 ktoe (kilotons of oil equivalent) of oil products was consumed in 2011, which accounts for 55.1% of total energy consumption in 2011, and the percent of petroleum consumption stays over 50% of total energy consumption every year since 1978. Domestic oil consumption in Saudi Arabia has increased sharply in the past four decades, from 0.41 million barrels per day (Mb/d) in 1970 to 3.07 Mb/d in 2013, and this petroleum consumption is one quarter of Saudi Arabian oil production [9]. In addition, the US and UK are petroleum producing countries contrary to France. In 2013, the total oil supply of the United States was 12342 thousands b/d, more than ten times less in the United Kingdom with 914 thousands b/d, and merely 62.3 thousands b/d in France [10]. Therefore, by contrast with France, the US and the UK, to a lesser extent, can be regarded as influential on the supply side of the petroleum market. Also, concerning their oil consumption as of 2013, it ranges from 1508 thousands b/d in the UK and 1767 thousands b/d in France to about 18900 thousands b/d in the US. Thus, on the demand side of the market, the UK and France can be treated as small oil importing countries, however, the US is a large country, whose petroleum demand can influence the market price [11]. The EU, US, China, Japan and India together represent about 60% of total primary energy use in the world, 53% of total oil use, and nearly 80% of total net oil imports [12,13]. The average annual growth rate of energy consumption in Japan was higher than the nation's remarkable rate from the end of World War II until the early 1970s. However, after the 1973 oil crisis, the Japanese economy was obliged to make some efforts to reduce its energy intensity, and was largely successful in slowing the growth rate of energy consumption without an accompanying decrease in GDP. Nevertheless, the fact implies that energy consumption has kept on growing in the long term, with Japanese energy use rising by 50% from 1973 to 2010.

In recent years, the energy demand in general and the oil demand in particular have been the subject of numerous theoretical and empirical analyses in China. Given the vital role of crude oil as a strategic commodity and source of energy to the economies of major countries, the impact of oil on economic activity has been a matter of great concern to scholars and policy makers. Therefore, empirical estimations of the oil demand and consumption have received considerable attention and have been examined using a variety of model specifications and estimation methods for different countries [14,15]. Due to oil's importance in China, predicting oil consumption has become a very significant research subject recently. The commonly used methods at home and abroad to make such predictions are described below.

(1) Traditional analysis

The earlier set of studies used traditional analysis to examine the aggregate oil consumption for the past few decades. Traditional analysis is divided into several parts, including sector analysis, time series analysis methods, strategy planning methods, and gray prediction. Pantelis Caro (2015) presented a consistent EU energy and energy-related emissions outlook from 1995 to 2030, and the baseline scenario was developed by the PRIMES model. He found a relationship among the energy indexes, energy demand, GDP and other economic indicators [16]. Guo Li (2011) forecasted the demand for oil, coal and gas in China from 2011 to 2020 based on Gray forecasting, and gave advice on oil exploitation in the future [17].

Traditional prediction methods are commonly used in the energy planning of the government. The Gray predicting model, time series analysis method, input-output analysis, strategy planning method, and elasticity coefficient method are suited to modeling systems with small samples and poor information, and hence, they are widely used. As for the intelligent models, researchers often chose the existing regression model, such as ANN based models [18]. The gray prediction models play an important role in the gray

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