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Decoupling of oil use from economic growth in Northeast China

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Abstract. Research for the decoupling of oil use from GDP growth has significance meaning to promotion and implementation of energy conservation in Northeast China. According to the calculation formula of decoupling index (Dr), the Dr of Northeast China are calculated respectively in 2000-2012, respectively. Radial Basis Function (RBF) neural network forecasting model is established, and the accuracy of the model is verified. Using the model to predict the Dr value 2013 - 2020. The results show that: the values of Dr are greater than 0 in Northeast China, where the Jilin average annual Dr is the maximum value about 0.97. RBF neural network forecasting results shows that Dr is greater than 0 in 2013-2020, and no-decoupling state doesn't appear.

1. Introduction

Northeast China is an important industrial base and source of energy in China. Northeast China GDP showed a continuous trend of rapid growth from 2000-2013, and exposed the problem that economic development depends greatly on the oil consumption ^[1]. Although the Northeast is the major oil product area, accounting for about 30 % of total oil production of China in 2013 ^[2], but the contradiction between the growing consumer demand for oil exploration with limited capabilities are increasingly prominent ^[1]. So, how to break the Northeast between oil consumption and economic growth has important implications for rational optimization of energy consumption.

Environmental resource is the material basis of human survival and development. In recent years, rapid economic development brings more convenience and enjoyment, while the environment resources are facing enormous pressure and challenges ^[3]. The field of environment resources for the "decoupling" the problem is to carry out a lot of research scholars, such as: resource consumption ^[4], land resources ^[5], CO₂ emissions ^[6], traffic volume ^[7]. However, there is little literature study on the decoupling relations of oil use and GDP growth. Therefore, this paper based on the decoupling index (Dr) calculation formula, oil use Dr is calculated respectively in Northeast China from 2000-2012. Then the Dr of oil use and GDP growth are predicted by RBF neural network, and discussed predictable results. In order to providing a basis for local energy-related policy development.



2. Methods

2.1. Mathematical formulas

Decoupled exponential formula was derived from IPAT formula proposed by Ehrlich []. Due to the $P \times A = G$ (where G is GDP), IPAT formula eventually pushed to come IGT formula:

$$I = G \times T \quad (1)$$

Resource consumption growth rate k_r is:

$$k_r = \frac{I_1 - I_0}{I_0} = (1 + g)(1 - t) - 1 \quad (2)$$

where g is the GDP growth rate, t is the decline rate of resource use per unit GDP. Then $k_r = 0$, the formula can be obtained t_k , the critical value of t :

$$t_k = \frac{g}{1 + g} \quad (3)$$

Where t_k is on the threshold of resource consumption per unit of GDP decreased rate of t . When $t_k > t$, resource consumption is an increasing state; When $t_k = t$, the consumption remains unchanged; When $t_k < t$, consumption is declining state. Thus the relationship, t_k and t determines the decoupling between the resource consumption and GDP growth. Therefore, the definition of decoupling index D_r :

$$D_r = \frac{t}{t_k} = \frac{t}{g}(1 + g) \quad (4)$$

2.2. Decoupling curve

Resources decoupling formula curve can be obtained by D_r . When $g > 0$, $D_r \geq 1$, represents the absolute state of decoupling between resource consumption and GDP; Then $0 \leq D_r < 1$ represents the relationship state; Then $D_r < 0$, the relationship in non-decoupled state.

3. Analysis and discussion

3.1. Historical Data

According to the definition of D_r formula, oil consumption, GDP and growth rate of the three provinces in Northeast China from 2000 to 2012 were collected, respectively. Among them, the oil consumption and GDP data from the China Energy Statistical Yearbook and China Statistical Yearbook.

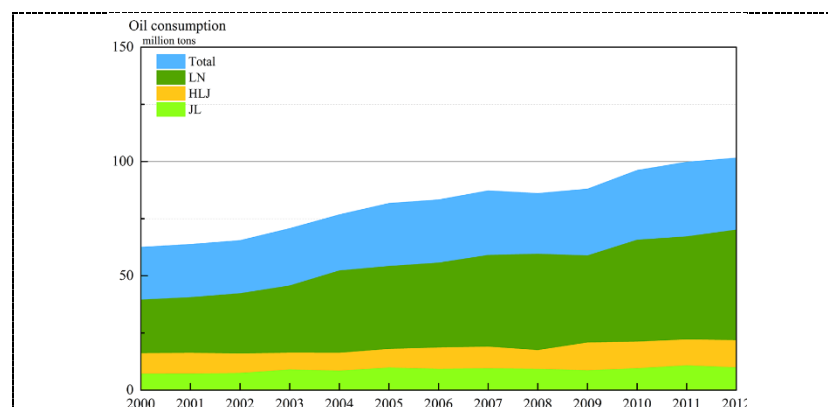
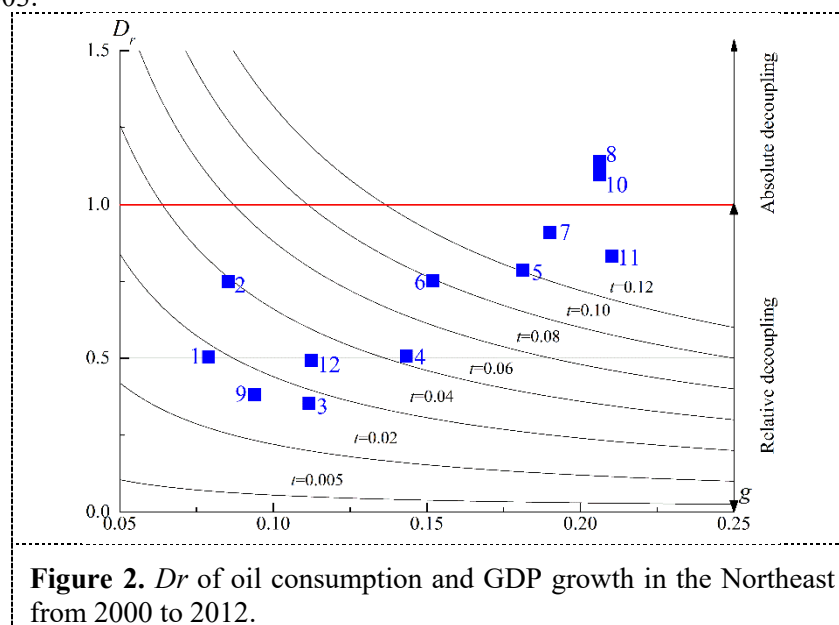


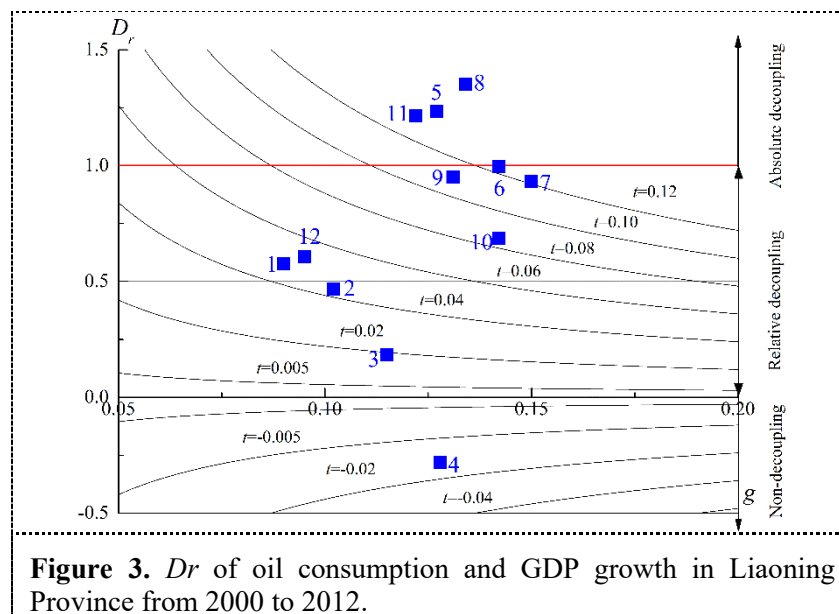
Figure 1. Oil consumption in Northeast China from 2000 to 2012.

3.2. Oil consumption decoupling in Northeast China

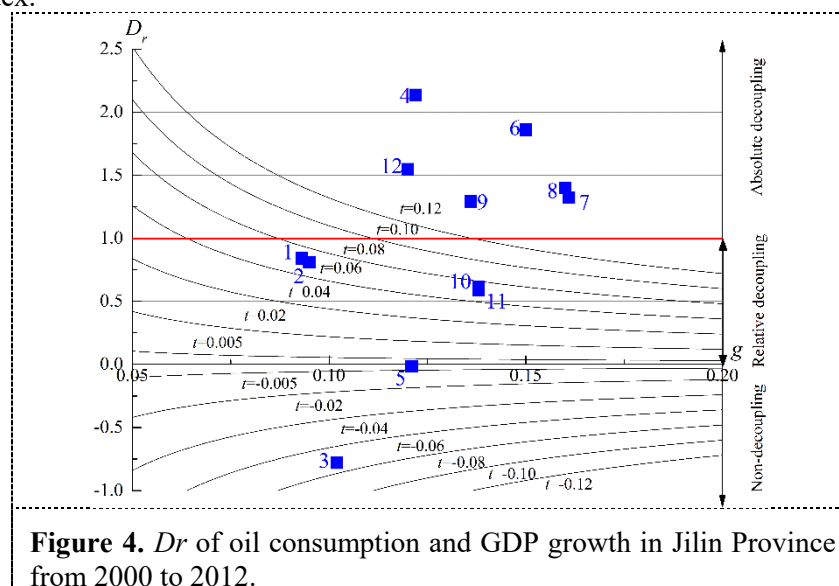
3.2.1. Total oil consumption decoupling in Northeast China. As depicted in figure 2, total oil consumption decoupling index were greater than 0, the average annual decoupling index was 0.71 in the three northeastern provinces in 2000 to 2012. During this period, the overall high level of decoupling of total oil consumption and GDP growth, decoupling index over one year period between 2007-2008 and 2009-2010. Presents a decoupling between the absolute state of total oil consumption and GDP growth. Because there are Daqing, Liaohe, and Songyuan Oilfield, etc. and a lot of oil production, reserve is rich in the Northeast. Therefore, oil consumption structure is relatively reasonable and stable, and large fluctuations in oil consumption does not usually occur, the decoupling level of oil consumption and GDP is relatively high. Minimum D_r of oil consumption (0.353) appeared in 2002 and 2003.



3.2.2. Liaoning Province oil consumption decoupling. As shown in Figure 3, D_r of oil consumption had three years (2004-2005, 2007-2008, 2010-2011) greater than 1, the relationship was in absolute decoupling state in Liaoning Province from 2000 to 2012. Only between 2003-2004, the relationship between oil consumption and GDP growth was in non-decoupled state, other years were in relatively decoupled state. Liaoning Province average D_r of oil consumption was about 0.74, slightly higher than the decoupling index average oil consumption in 2000-2012 years. The maximum value of the index on the decoupling of oil consumption appeared in 2007-2008 (D_r : 1.35).



3.2.3. Jilin Province oil consumption decoupling. As depicted in figure 4, Jilin oil consumption decoupling index is the largest of the three northeastern provinces, the average value of about 0.97 from 2000 to 2012. Among them, the decoupling index values are greater than 1 in six years, achieving absolute decoupling. Continuous decoupled state was absolute decoupling state from 2005 to 2009; Oil decoupling index value distributed in $[0,1]$, showing a relative decoupling of state from 2000 to 2002 and 2009 to 2011; In 2002 to 2003 and 2004 to 2005, oil decoupling index is less than 0, showing not decoupled state. During the "Eleventh Five-Year", Jilin overall coordination and integration of resources to promote sustainable economic development in the region and resources. Extensive development mode which is "high input, high energy consumption, low output, low-income" improved, changing the economic development model, effectively reducing the growth rate of consumption of oil resources in Jilin Province, thereby increasing the consumption of oil resources decoupling index.



3.2.4. Heilongjiang Province oil consumption decoupling. In the years 2000 to 2012, Heilongjiang province oil consumption decoupling index located in $[0.5, 2]$ and had smaller fluctuations (Figure 5),

in addition to oil consumption decoupling index is less than 0 (D_r : -1.44) in 2008 to 2009, in a non-decoupled state. Oil consumption decoupling index was greater than 0 in other years, which in 2003 to 2004, 2006 to 2008 and 2009 to 2011, oil consumption D_r was greater than 1, in absolute decoupling state and other years in relative state. During the twelve years, oil consumption decoupling index in Heilongjiang province was between Jilin and Liaoning provinces, the average value of about 0.90. Heilongjiang Province is the largest province in China's oil production, petroleum product consumption in the province occupies a stable proportion of energy consumption structure.

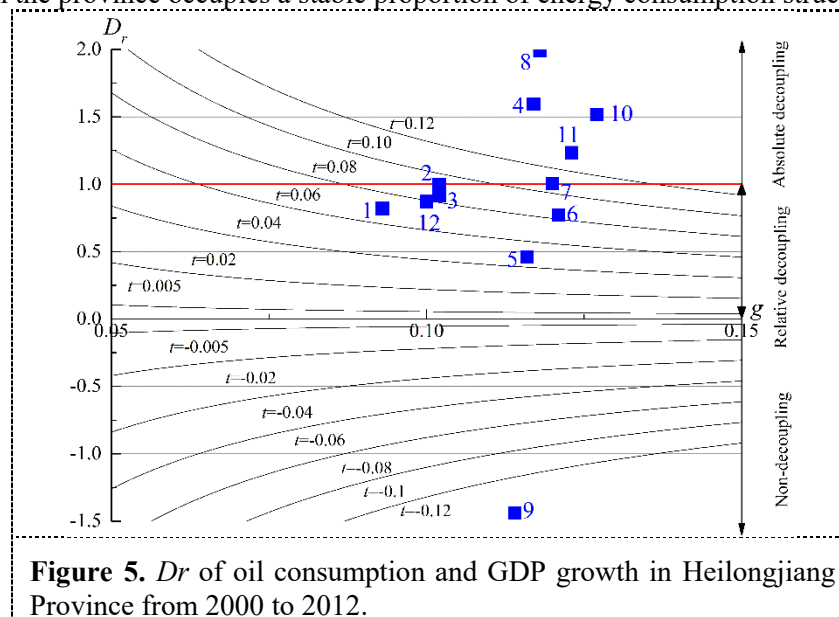


Figure 5. D_r of oil consumption and GDP growth in Heilongjiang Province from 2000 to 2012.

4. Prediction and discussion

4.1. Forecast Model

RBF neural network is a feed-forward back-propagation network which including the input layer (input), hidden layer and output layer (output) three layers

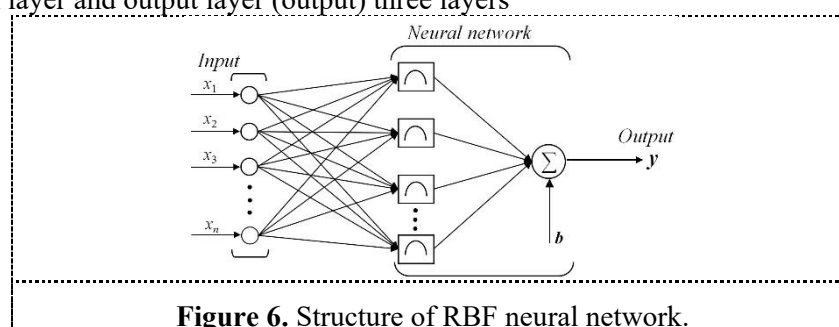


Figure 6. Structure of RBF neural network.

4.2. Training prediction model

Base on the RBF neural network models and mathematical functions, using MATLAB compile RBF neural network forecasting program. Selecting the one-dimensional vector space in each year from 2001-2012 consisting of $x = [2001, 2002, \dots, 2012]$ as the RBF neural network training input vectors; Selecting each year corresponding D_r of oil consumption in Northeast posed vector b as a target vector network training; And respectively to the data input vector x and the vector b in the target are normalized. Selecting MATLAB neural network toolbox provides functions for creating new RBF neural network. Selecting radbas transfer function used to implement RBF network.

4.3. Analysis predicted results

Respectively of the total consumption of oil and natural gas decoupling index is predicted by using RBF neural network which has been achieved forecasting accuracy in the Northeast region in 2013-2020. The predicted results are as shown in Table 1.

Table 1. Decoupling index predictive value of oil and gas consumed in the Northeast in 2013-2020.

Year	2013	2014	2015	2016	2017	2018	2019	2020
D_r	0.503	0.513	0.590	0.746	0.993	0.485	1.006	0.489

Data from Table 1 shows, between 2013 to 2020, D_r of oil consumption in addition to 2019 in the absolute decoupling state, the rest of years are in state of relative decoupling. Annual D_r is about 0.665, similar to the level of oil consumption decoupling in 2000 to 2012. At present, the development of the oil industry in the Northeast into mature stage, in view of a large oil field in the region and large oil refining companies and crude oil and products pipeline and other infrastructure improvement and adequate supply of oil, oil products accounted for the region's primary energy consumption structure stabilized; In addition, in the end of Twelfth Five-Year Plan, GDP growth is expected to slow down. Above is the main reason for the state to maintain the relative decoupling between oil consumption and GDP growth in the future Northeast.

5. Conclusions

From 2000 to 2012, Northeast China oil consumption D_r are greater than 0, except 2007 to 2008 and 2009 to 2010 in absolute decoupling state, the rest of the year are in state of relative decoupling; In Liaoning Province, the oil consumption decoupling index is less than 0 only in 2003 to 2004, and the rest of the year decoupling index are greater than 0; From 2000 to 2012, the average oil consumption decoupling index value in Jilin is the largest in three provinces, is about 0.97; Decoupling index of oil consumption in Heilongjiang province except 2008 to 2009, the rest of the year decoupling index are distributed in [0.5, 2]. The value is relatively concentrated.

The prediction results of RBF neural network shown that Northeast China total oil consumption decoupling index is greater than 0 from 2013 to 2020, the proportion of oil consumption in energy consumption structure is stable. This is the main reason for the region's oil consumption decoupling in higher levels.

Acknowledgments

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