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History and future of the coal and coal chemical industry in China

Jin Li, Shanying Hu*

Center for Industrial Ecology, Department of Chemical Engineering, Tsinghua University, Beijing 100084, China

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ABSTRACT

In recent years, the traditional coal and coal chemical industries in China have suffered from overcapacity. Although the development of new coal chemical industries is receiving increasing attention, the constraints of new environmental laws and carbon emission reduction targets continue to increase. Therefore, it is necessary to judge the developmental scale trend of the industries and, furthermore, to provide guidance to businesses and governments. Based on the coal and coal chemical industries, this research recognizes significant factors affecting industrial development in terms of market, enterprise reform, policy, technology, industrial structure adjustment, and so on and carries out a qualitative analysis and quantitative evaluation of the industry developing driving force. A dynamic mathematical model is set up to fit the historical trend of industrial development, and the fitting parameters are modified based on the actual data. As the fitting result shows, the Driving Force Model is practical for characterizing the scale of industrial development. The developing trends in the coal and coal chemical industries in China are predicted based on the model. The results show that the Shanxi coal industry will have to emerge from a difficult period of industrial development, and the development of the coal chemical industry in China will greatly depend on the price ratio between crude oil and coal. Ultimately, this research proposes suggestions for the sustainable development of the two industries in terms of circular economies, technical breakthroughs, policy making, and so on.

1. Introduction

With the energy resource structure of "rich coal, less gas, lack of oil" in China (Xie et al., 2010), coal occupies the dominant position in terms of China's energy demand and consumption (Yang et al., 2016), and this position will not substantially change in the coming decades (Wang et al., 2011; Fan and Xia, 2012).

As energy-savings, emission-reductions and sustainable development are receiving increasing attention, the cleaner use of coal is being promoted throughout the entire industry and industrial chain (Geng et al., 2010). However, China is faced with two severe challenges: energy shortages and environment protection (Fang and Zeng, 2007; Ma et al., 2010). Shanxi Province, which owns approximately 10% of China's proven coal reserves (Ma et al., 2009), represents the developmental level of China's coal industry. Therefore, the healthy development of the coal industry in Shanxi Province will play a leading and exemplary role for other provinces.

The consumption of petroleum and natural gas in China relies greatly on import, and is expected to further expand in the next few years. What's more, the proven reserve of coal in China is over 1 billion tons (Zhang et al., 2016a), much more than the proven reserves of oil and gas in China, which are respectively 0.2 billion tons and 500 billion m^3. The growing consumption and limited reserve imply that the degree of dependence on foreign trade will further expand for China. The development of new coal chemical industry could realize some replacement of oil and gas and transform coal resources into oil and natural gas for strategic energy reserves, showing far-reaching significance from the national strategic perspective. Therefore, for the application of coal resources, the coal chemical industry plays a rather important role. With technical breakthroughs constantly being achieved in coal-to-gas, coal-to-liquid, coal-to-olefin and coal-to-ethylene-glycol (Xie et al., 2010), some large new demonstration projects of the coal chemical industry have gradually begun operations in recent years. China's new coal chemical industry is beginning to enter a stage of rapid development.

The development of an industry is influenced by many factors, such as policies, market, resources, environment, technology, and so on (Gambatese and Hallowell, 2011). With the influence of factors, such as the macro-control of national policy, domination of market supply and demand, constraints on resources and the environment and the supporting of technology progress, the industry will experience different stages, including growth, rapid growth, stabilization, decline and other multiple stages (Balland et al., 2013; Kai et al., 2005; Jovanovic and MacDonald, 1993). Therefore, it is

* Corresponding author.
E-mail address: hxr-dce@tsinghua.edu.cn (S. Hu).

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important to identify and express the driving force for these various factors.

In previous studies, when performing driving force analysis on an industry or indicator, the following methods are usually used. One is to use index decomposition analysis (IDA), which begins by defining the governing function that will be decomposed into several factors. With the governing function defined, these factors are quantified to gauge the driving force on the target industry or indicator, whereas quantification methods have no consensus among researchers and analysts (Ang, 2004; Ang and Zhang, 2000; Xu and Ang, 2014a). In past research, IDA has been widely used for energy demand (Ang et al., 2015; Lin and Du, 2014; Xu and Ang, 2014b; Nie and Kemp, 2014), energy efficiency (Ang and Xu, 2013). and gas emissions (Lyu et al., 2016; Yan et al., 2016; Donglan et al., 2010). Another method is to use structural decomposition analysis (SDA), which is often combined with an input-output (I-O) analysis and applied to energy consumption or emissions in an economy (Su and Ang, 2012; Xie, 2014; Cellura et al., 2012). To measure how the factors affect the problems, the Analytic Hierarchy Process (AHP) and Fuzzy Analytic Hierarchy Process (FAHP) are other commonly used methods, and these methods calculate the weights between factors of each hierarchy by establishing a pairwise comparison matrix for computing the weight of each hierarchy (Ho, 2012). AHP and FAHP are widely used for all types of problems, such as safety evaluation (Wang et al., 2016), power location selection (Kabir and Sumi, 2014), selection among renewable energy alternatives (Tasri and Susilawati, 2014), and so on.

In this paper, to evaluate the development of the coal and coal chemical industries in China, a Driving Force Model is built to distinguish how an industry is influenced by driving factors and to predict how the industry will develop in the future. Although IDA, SDA, AHP, FAHP methods are used in the previous researches for driving force analysis, they are not so suitable for this research. IDA and SDA could generally use at most 7 indicators, while this research may involve in more than 10 items. AHP and FAHP ask for actual quantitative data for each item, while it may be difficult for this research to get too much data. Therefore, the model will decompose the industry into some factors, such as IDA and SDA, and these factors will then be divided into several categories to further identify the structure, such as AHP and FAHP. The coal industry in the Shanxi Province since 1993 and the coal chemical industry in China since 2001 will be fitted and evaluated using this model.

This paper is organized as follows. Section 2 introduces the methodology. Sections 3 and 4 apply the model to the Shanxi coal industry and China coal chemical industry, respectively, and provide predictions for the industrial development rate for the period prior to 2020. Section 5 provides the main conclusions and advice on the development of these industries.

2. Methodology

2.1. Driving force model construction

The development and expansion of one industry is influenced by many factors, such as policies, market, resources, environment, technology, and so on. The growth ratio of an industry at a certain time can be expressed as the sum of the influencing degree of each factor at the present time (Narbel and Hansen, 2012; Ferioli et al., 2009; Pan and Köhler, 2007; Gan and Li, 2015):

$$Y(t) = \sum_{i=1}^{n} y_i(t) \tag{1}$$

where t is the time, $Y(t)$ is the growth ratio of the industry at the time t, n is the number of types of influencing factors involved in the calculation, i is the type of influencing factor, and $y_i(t)$ is influence degree of the factor i at time t. The factor promotes industrial growth if $y_i(t)$ is positive and inhibits industrial growth if $y_i(t)$ is negative.

After determining the factors using qualitative analysis, the influencing degree of each factor is quantitatively evaluated and the Driving Force Model is constructed using the process shown in Fig. 1. For each influencing factor, preliminary judgment and artificial assignment are carried on to determine the value of influence degree and time. After completing the assignment of each factor, the growth ratio of the period can be calculated using formula (1). Then, we compare the calculation result with the actual situation from the industrial growth ratio. If the signs of the growth ratio for each year in the two curves are the same, and if the relative values of the growth ratio are correctly shown, we define the result is acceptable. If the two curves for the growth ratios have an unacceptable difference, we adjust the artificial assignment and repeat the previous process until the result is acceptable. Based on the assignment result, we perform function fitting on the influence degree and time of the factors, which is described in detail in Chapter 2.3. Finally, an industry growth ratio curve is plotted using the function fitting result.

Using this method, managers can identify which type of factors plays a more important role in the process of industrial development, and takes reasonable and effective measures. Additionally, managers can also use this model to predict the industry's developmental trend if they have a general judgment of future influencing factors.

This research applies the model to the coal industry in the Shanxi Province for the period since 1993 and the coal chemical industry in China for the period since 2001. For these two industries, this model is built to present historical developing processes and to predict the future sale of development.

2.2. Yearbook study

In the process of identifying and artificially assigning the influencing factors, large numbers of yearbooks are studied and are listed in Table 1. Significant measures and important influences are recorded in the yearbooks. Thus, the driving forces for an industry in a certain year can all be identified. Additionally, as the yearbooks are published year after year, the period during which the factors are relevant is also be identified.

Table 1
List of yearbooks referred to as part of this research.

Industry applied on	Yearbook name	Time of publishing
Shanxi coal industry	Shanxi Energy Economics 60 Years	2010
	Yearbook of Shanxi Economy	1991–2014, once a year
	Shanxi Statistical Yearbook	2015
China coal chemical industry	China Chemical Industry Yearbook	2001–2014, once a year
	Petroleum and Chemical Industries Yearbook	2001–2005, once a year
	China Statistical Yearbook	2015