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Coal production forecast and low carbon policies in China

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ABSTRACT

With rapid economic growth and industrial expansion, China consumes more coal than any other nation. Therefore, it is particularly crucial to forecast China's coal production to help managers make strategic decisions concerning China's policies intended to reduce carbon emissions and concerning the country's future needs for domestic and imported coal. Such decisions, which must consider results from forecasts, will have important national and international effects. This article proposes three improved forecasting models based on grey systems theory: the Discrete Grey Model (DGM), the Rolling DGM (RDGM), and the *p* value RDGM. We use the statistical data of coal production in China from 1949 to 2005 to validate the effectiveness of these improved models to forecast the data from 2006 to 2010. The performance of the models demonstrates that the *p* value RDGM has the best forecasting behaviour over this historical time period. Furthermore, this paper forecasts coal production from 2011 to 2015 and suggests some policies for reducing carbon and other emissions that accompany the rise in forecasted coal production.

1. Introduction

1.1. Historical backgrounds

Coal is an important strategic resource for the development of human society. Coal is a rich, worldwide, but non-renewable resource, especially in China, where 95% of coal comes from underground mines. The advantages of coal resources have contributed to China's rapid socio-economic development and helped to support the rate of population growth. Coal is also China's main energy source, and despite the country's mining strength, substantial reserves and high-volume coal market, consumption is so great that there is considerable tension in the market.

China is presently the world's largest producer of coal, accounting for approximately 45% of the world's total annual coal production (XMECC, 2011). China is also the world's greatest consumer of coal, accounting for more than 47% of the world's total annual coal consumption. During the last decade, China has exported its surplus coal to other markets in Asia. However, from 2009 to 2011, China became a net importer of coal. Although coal production has increased significantly since 2000, the future supply and demand balance of coal in China will have a significant effect on world energy markets.

China's coal industry is an important foundation for global energy industry, dominating both the energy supply structure and the energy consumption infrastructure. Just like the first oil crisis of 1973 spurred many discussions, recent surges in worldwide coal demand have sparked public attention. Environmentalists emphasise the importance of non-renewable resources and call for replacing fossil resources, such as coal, oil and natural gas, with new energy resources. However, renewable resources cannot immediately substitute for all non-renewable resources. Most projections suggest that the existing energy infrastructure will remain in place for at least 60 years.

The Netherlands Environmental Assessment Agency reported that a large increase in emissions from fast-developing parts of the world, like China and India, cancelled out any effect of the sharp decline in emissions elsewhere. Emissions from fossil-fuel combustion decreased by 7% in 2009 across parts of the world like the European Union, Japan and the United States. According to the Dutch agency, emissions from China by 9%, and emissions from India increased by 6%. India surpassed Russia in 2009 as the fourth largest emitter, following China, the United States and the EU-15 (Live, 2010). Within the framework of global governance, China is facing increased international pressure to mitigate carbon emissions. To take a leading role in this global political game, China must undertake new policies to achieve a lower-carbon economy. Such policies must consider the two aspects of achieving 'low-carbon economy' and maintaining 'economic growth'. A 'low-carbon economy' is a model of human society that mitigates climate change and achieves sustainable economic and social developments.

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'Low-carbon' means that economic development must minimise or eliminate dependence on carbon-based fuels, achieving both an energy transformation and an economic transformation. 'Economic growth' means that the transition in energy use and processes must maintain the stability and sustainability of the overall economy. The development of a 'low-carbon economy' would, ideally, solve all of the above problems by achieving long-term sustainable development. The Chinese government proposed a target to reduce carbon emissions 40–45% per unit of GDP from 2005 levels by 2020.

1.2. Modelling backgrounds

Modern science and technology, on the basis of high differentiation between disciplines, have initiated the trend of synthesis, which integrates cross-disciplinary theories of systems science. Systems science has found profound and important internal relationships among various disciplines. These relationships have deeply expedited the integrative progress of modern science and technology, as demonstrated by Liu and Lin (2006). New theories can help to successfully resolve many perplexing or unsolvable problems. These theories include systems theory, information theory, cybernetics, synergetic theory and general systems theory. For example, Höök and Aleklett (2009) applied established analytical methods, such as logistic curves, to project future outlooks for U.S. coal production. Lin and Liu (2010) used logistic curves and Gaussian's curves to predict the coal peak in China. Their results suggested that the peak of production would occur between the late 2020s and the early 2030s. Based on the predictions of coal production and consumption, China's net coal import needs can be estimated for coming years. The net import needs in 2009 and 2010 are 1.03 (National Energy Bureau, 2010) and 1.458 (International Development and Reform Commission of China, 2011)hundred million tons, respectively. Due to the effects of China's potential import needs in world coal markets and long lead times in developing coal mining and transportation infrastructure, it is necessary to examine different approaches for forecasting coal production.

Moghram and Rahman reviewed five short-term load-forecasting methods, concluding that there is no one best approach. Model performance under specific conditions should be analysed and understood, and incremental improvements should be made based on the knowledge gained from the models.

The structure of this paper is organised as follows. Section 2 provides background, including the physical distribution of China's coal, the production and consumption of coal and energy demand in China. Section 3 presents four forecasting models, including the traditional Grey Model (1, 1) (GM), a novel model named the Discrete Grey Model (DGM), a rolling Grey forecasting model called Rolling Discrete Grey Model (RDGM) and a new RDGM named '*p* value RDGM', which is optimised by a PSO algorithm. Section 4 describes numerical results by applying the four models. Section 5 discusses the policies for reducing carbon emissions. Finally, Section 6 presents the conclusions of this paper.

2. Coal resources assessment for China

2.1. The distribution of China's coal resources and the data set

The distribution of China's resources and the corresponding data are shown in Figs. 1 (Hiphptos, 2007) and 2 (Zlcoal, 2005), respectively.

2.2. Production

Coal production in China has risen since 1990 and is likely to continue rising due to increasing demand. From 1999 to 2010, China's coal production increased from 10.44 hundred million tons to 32 hundred million tons, as shown in Fig. 2. In 2011, the rise in coal production in China is still driven by high coal prices and tight domestic supply and demand conditions. However, China became a net importer of coal for the first time in 2009. From 2009 to 2011, coal imports have constantly risen. China has expanded indigenous coal production and taken steps to access coal resources in Russia, Australia and other countries.

2.3. Consumption (NYJ, 2011)

China's coal consumption had experienced a rapid and continuous increase, with an average annual increase of 5.3% from 2009 to 2010. In 2010, the volume of China's coal consumption reached 32.5 hundred million tons, accounting for more than 70% of China's overall energy consumption. In recent years, the industrial sector consumed almost 95% of China's coal, including electricity generation. According to the statistics of the China Electricity Council, the electricity sector alone accounted for about 50% of the country's coal consumption. Coal has played a crucial role in China's economic growth. In 2010, coal generated about 80.3% of China's power, with 1.77% from nuclear and 1.04% from wind. (Finance, 2011)

3. The forecasting models

3.1. GM (1, 1)

Assume that $X^{(0)}=\{x^{(0)}(1),x^{(0)}(2),\ldots,x^{(0)}(n)\,|\,n\geq 4\}$ is an original non-negative data series taken in consecutive order and at equal time intervals. The procedures for applying the GM (1, 1) to predict the future value $x^{(0)}(n+k)$ with $k\geq 1$ can be described in the same manner as past studies (Hsu and Chen, 2003; Yao et al., 2003; Yao and Chi, 2004).

Through systematic analysis, we know that in GM (1, 1), the method of estimating parameters applies the discrete equation, and the method of simulating and forecasting applies the continuous equation. The different forms of the discrete equation and the continuous equation could not be determined with equal accuracy. The transition from the discrete equation to the continuous equation is an important cause of simulation and forecasting errors, even in those cases with a pure sequence of data for all indices. In this paper, we will propose a novel model to solve this problem. Furthermore, different iterative data values will influence the simulation and the forecasted results (Lin and Lee, 2007). We use the optimum method to solve this sensitive problem of iterative data values. In this part, we have conducted research to define the proposed forecasting model, and we will define the DGM (Xie and Liu, 2009).

3.2. DGM

The equation:

$$x^{(1)}(k+1)=\beta_1 x^{(1)}(k)+\beta_2 \tag{1}$$

is named the "discrete grey model", abbreviated as DGM.