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Forecasting energy consumption using a new GM–ARMA model based on HP filter: The case of Guangdong Province of China

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ABSTRACT

Guangdong's energy reduction requirements developed by the State Council of China under the 12th Five-year Plan reflect a reality: the restriction brought by energy consumption on economic development in Guangdong is tougher. To obtain a detailed understanding of the future amount of Guangdong's energy consumption in the coming years, this paper establishes a new model with improved GM–ARMA based on HP Filter to forecast the final energy consumption. Compared with traditional statistical approaches, the case study of Guangdong indicates that the improved GM–ARMA model has excellent accuracy and higher level of reliability. Moreover, based on this model, this paper predicts the energy consumption under different future economic scenarios and forecasts the future changes in the structure of the final energy consumption in Guangdong from 2013 to 2016 to discuss Guangdong's possibility of achieving the reduction goal. Finally, this paper finds that the issue of energy saving and emission reduction is very serious in the next few years.

1. Introduction

Guangdong Province, located in the southern part of China with a population of more than 100 million people, is one of the strongest economic areas in China. Since the adoption of the reform and opening-up policy and the national preferential policies, Guangdong's economy has achieved spectacular growth. From 1990 to 2012, the GDP of Guangdong Province has increased at an average annual growth rate of 18.1%. Meanwhile energy consumption has been climbing gradually from only 39.36 million tons of Standard Coal Equivalent (SCE) in 1990 to 283.8 million tons of SCE in 2012 at an annual growth rate of 9.96% (Table 1). Energy use is one of the driving forces behind the rapid economic growth, with the acceleration of urbanization and industrialization process in Guangdong. However, energy consumption is imposing more and more serious constraints on economic growth simultaneously (Nordhaus, 1974). That is to say, energy use contributes to the critical issue of energy security on the national and regional levels, mainly involving the conflict of growing energy demand and unstable limited energy supply, and the serious ongoing threats of energy pollution and environment damage. It was not surprising that energy conservation and efficiency programs under China's 12th Five-year Plan for National Economic and Social Development (2011–2015) have been regulated by China's State Council, requiring Guangdong Province to cut energy use per unit of gross domestic product (GDP) by about 18%.

There is a growing concern with Guangdong's possibility of achieving the above-mentioned emission reduction goal and bringing a rapid economic development at the same time. It is therefore necessary to obtain a detailed understanding of the future amount of Guangdong's energy consumption in the coming years. To get at this question, this paper establishes a prediction model for energy consumption and we use this model to analyze the predictions under different future economic scenarios, which could help build on foundations of strict government schemes on energy efficiency and economic development.

The relationship between energy consumption and economic development is not a new issue, but researches on the prediction of energy consumption have attracted special attention in recent years. Kalogirou and Bojic (2000) realized that most of the commercial modeling programs are time-consuming with annual results, and proposed Artificial Neural Networks (ANNs) model for prediction of energy consumption. However, using ANNs model, it is difficult to derive a clear forecasting equation. Then some studies tried to develop ANNs model to solve this problem. For instance, a new neural network algorithm (Support Vector Machines) based on ANNs model was presented to forecast energy consumption (Dong et al., 2005; Ekonomou, 2010; Tso and Yau, 2007). And other studies applied new methods to construct a clear forecasting equation. For instance, ARMA, ARIMA and SARIMA methods were used to estimate the future primary energy demand respectively (Ediger and Akar, 2007; Pappas et al., 2008). Crompton

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Table 1
Average annual growth rates of energy consumption and GDP in Guangdong.

	Coal	Oil products	Electricity	Others	Total energy consumption	GDP
1990–1995	7.61%	11.10%	16.81%	16.50%	12.49%	30.81%
1996–2000	−4.95%	8.69%	10.25%	12.60%	6.50%	12.65%
2001–2005	5.88%	15.22%	16.80%	13.64%	13.77%	16.04%
2006–2010	10.53%	4.19%	7.29%	18.87%	8.86%	15.40%
2011–2012	5.05%	−0.96%	6.22%	2.18%	3.80%	11.45%
1990–2012	5.26%	8.83%	12.28%	14.27%	9.96%	18.06%

Source: Guangdong Statistical Yearbook (1991–2013).

and Wu (2005) applied the Bayesian Vector Autoregressive methodology to forecast China's energy consumption and to discuss potential implications. However, the forecasting accuracy of their approaches is poor when the time series data of energy consumption is few or incomplete. To prevent inaccurate forecasting using small and incomplete data sets, some studies have adopted the grey model (GM) to forecast energy consumption. For instance, the grey theory was introduced to characterize this problem (Akay and Atak, 2007; Guo et al., 2011; Kayacan et al., 2010). And in order to pursue better precision and solve nonlinear data problem, Lee and Tong (2012) improved a novel hybrid dynamic approach that combines a dynamic grey model (HDGM) with genetic programming to forecast energy consumption. However, HDGM is more suitable when the structure of the historical observations of energy consumption is integrity and complex. The new method presented in this paper could use to predict the future energy consumption values based on few but regular historical data and improve the prediction accuracy at the same time. Moreover, the method of ARMA can be a supplement to the residual sequence which is computed by the grey system theory. After discussing some structural features of energy consumption in Guangdong, this paper proposes a new improved method GM–ARMA based on HP Filter to forecast energy consumption of Guangdong Province.

The rest of this article proceeds as follows. Section 2 gives a brief discussion of energy consumption in Guangdong. In Section 3, we discuss some models, which are used in the prediction of energy consumption and extend the analysis to establish an improved GM–ARMA model based on HP Filter. Section 4 shows empirical analysis. Finally, Section 5 provides a brief conclusion and raises some open questions for future research work.

2. Brief discussion of energy consumption in Guangdong

As the first province to take market reform, Guangdong has emerged as the largest economy of China over the past two decades. Behind the rapid economic growth, its final energy consumption increased more than sevenfold and accounted for 7% of the national total final energy consumption each year. Guangdong's rising energy use is deeply affecting China's future energy consumption. Based on the current situation of energy consumption in Guangdong, which is still in an early stage thus far, its energy consumption increases along with economic growth (Yang and Xu, 2013). The growth rates of energy consumption and GDP exhibit similar movement patterns (Table 1). It might be expected that total energy consumption of Guangdong would keep rising in the next few years.

In the structure of final energy consumption in Guangdong, coal consumption has dominated for a long time. Apparently, Guangdong's coal consumption is following a downward trend. Until 2012, it drops to 11.6%, while electricity represents nearly 50% of total final energy use (Fig. 1). In fact, over 70% of electricity in this region is generated by coal-fired power generating technology, which would create large volume of carbon dioxide and other solid waste and pollute the most among major power generating technologies. Thus Guangdong is still relying heavily on coal consumption, and the structure of final energy consumption needs to be optimized.

Another problem is inefficient use of energy. On the one hand, the industrial energy consumption structure does not match the level of GDP, as a return of energy consumption. Although Guangdong has entered a post-industrial stage of development in recent years, its economic structure is still dominated by secondary sector (manufacturing, construction and mining). For instance, Guangdong's final energy consumption in 2012 reached 283.8 million tons of SCE, with the remarkable growth of the proportion of energy consumption for the secondary sector up to 65%, while this sector only brought 50% of GDP in this region (Fig. 2). On the other hand, energy efficiency data from recent years shows low energy efficiency in the secondary sector of Guangdong, compared with other two sectors, i.e. primary sector and tertiary sector (Table 2). This may be the main reason for the current arduous task of energy saving in Guangdong.

Specifically, in the secondary sector, the share of energy use of the manufacturing industry accounts for more than 98% while the share of energy consumption of the construction industry is only 2% (Table 3). Furthermore, in the manufacturing industry, which is divided into 30 different industries, the top six high-energy consumption industries are Nonmetal Mineral Products, Production and Supply of Electric Power and Heat, Petroleum Refining, Coking, Nuclear Fuel, Smelting and Pressing of Ferrous Metals, Manufacture of Raw Chemical Materials and Chemical, Manufacture of Communication Equipment, and Computers. It is known that these industries are energy intensive and most of these industries are involved in energy production. In Guangdong it is these energy producers that generate high levels of pollution. Guangdong energy producers' energy conversion efficiency, especially the conversion efficiency of coal-fired power generation, is very low (Fig. 3). Thus the purpose of lower energy consumption and higher energy efficiency in Guangdong is challenging.

3. Methodology

3.1. Hodrick–Prescott Filter model

Hodrick and Prescott (1997) put forward HP Filter model in 1997 when they considered the economic problem. They believed that some observed time series can be viewed as the sum of cyclical and

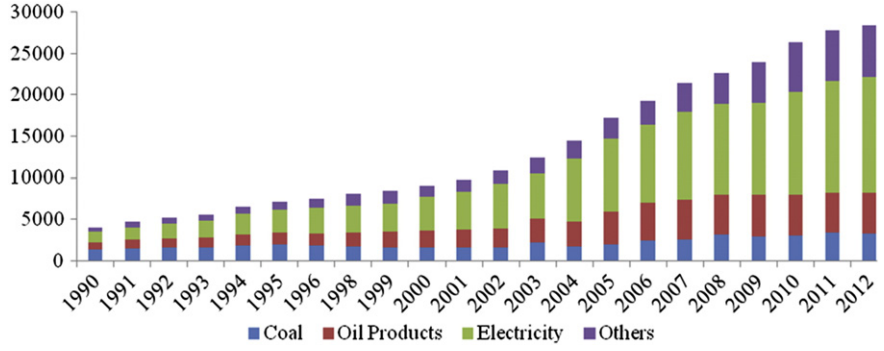

Fig. 1. Total consumption of energy and its compositions in Guangdong. Source: Guangdong Statistical Yearbook (1991–2013).