Applied Energy 155 (2015) 728–739

Contents lists available at ScienceDirect

Applied Energy

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

The research on setting a unified interval of carbon price benchmark in the national carbon trading market of China

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HIGHLIGHTS

- GDP increased slightly under carbon price policies.
- Carbon emission intensity decreased within different simulation scenarios.
- Energy demand appeared a steady decline after 2017 according to discussions.
- The alternative interval of carbon price benchmark as 30 yuan/tCO_2 to 50 yuan/tCO_2 is suggested.

ARTICLE INFO

Article history:
Received 23 December 2014
Received in revised form 5 June 2015
Accepted 14 June 2015

Keywords:
Carbon price benchmark
Energy demand
Empirical Mode Decomposition
Computable General Equilibrium
China

ABSTRACT

The prioritized purpose of this dissertation is to put forward a scientific and plausible interval of carbon price benchmark on the unified carbon trading market, of which will be scheduled to be established in the year of 2016. A model named EMD–GARCH that integrated Empirical Mode Decomposition (EMD) with Generalized Autoregressive Conditionally Heteroskedastic (GARCH) together is presented here in order to forecast the carbon price of the five pilots (Shenzhen, Shanghai, Beijing, Guangdong, and Tianjin) in 2016 so as to provide exogenous data for later analysis. For further study, a recursive dynamic Computable General Equilibrium (CGE) model will be structured to explore the impacts on China's macroeconomics, environmental quality, and energy demand respectively under 8 different simulation scenarios, which are being designed in terms of the aforementioned calculated carbon price outcome. The simulation results illustrate that the unified carbon price policy will exert a comprehensive effect on China in various perspectives that we discussed in this paper. Moreover, regarding the carbon price scenarios, the price level by itself generates a different degree of impacts in improving the environmental quality, decreasing the energy demand, and increasing the macroeconomic growth. Consequently, based on the analysis of those three approaches mix in this study, we suggest the alternative interval of carbon price benchmark in the national unified carbon trading market with a lower bound of 30 yuan/tCO_2 to an upper bound of 50 yuan/tCO_2.

1. Introduction

Since the implementation of reform and opening-up policy, China's national economy growth has significantly increased by over 80-fold [1]. But China's high speed development is at the expense of high energy consumption, high pollution and high emission, China has become the world's largest emitter of carbon dioxide currently as a result [2]. At the Copenhagen Climate Summit, China committed that carbon intensity would be reduced 40–45% lower than in 2005 by 2020 [3]. Chinese government has been slow to embrace new perspectives on environmental problem-solving to manage resources in an adaptive, multilateral manner in order to achieve the reduction target and accelerate the process of the resource-saving and environment-friendly society [4]. Currently, low carbon economic development mode, which would mainly through carbon trading scheme to complete, is regarded as a suitable choice in China. Carbon emissions trading scheme is considered to be one of the most efficient mitigation regimes to reduce greenhouse gas emission worldwide [5]. From the perspective of economics, carbon emission is endowed with the property of goods and owns value, this concept first referred by the America economist Dales in his book "Pollution, Property,

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http://dx.doi.org/10.1016/j.apenergy.2015.06.018
0306-2619/

and Prices" [6]. Actually, carbon emission trading is served as the "invisible hand" of the carbon market to achieve the ideas of low carbon development and energy conservation.

In August 31, 2014, China announced that it is expected to test run a nationwide unified carbon emissions trading market in 2016 [7]. And then, China would be the largest carbon emissions trading market in the world. Therefore, setting a scientific and reasonable carbon price benchmark in the national carbon trading market has an overwhelmingly significance on the growth of China's macro-economy, the optimization of energy structure, and the implementation of the carbon emission mitigation target. For the sake of achieving this national unified carbon trading market in 2016, Shenzhen, Shanghai, Beijing, Guangdong, Tianjin have set up regional carbon emissions trading market as a pilot successively since June in 2013, aimed at preparing for the establishment of the unified carbon emissions trading market.

The first urban-level "cap-and-trade" carbon emissions trading scheme (ETS) operated in China, is Shenzhen, with an average transaction price of 29 yuan/tCO_2 in the opening day of June 18, 2013. Jiang et al. [8] projected that the cap and allocation of Shenzhen ETS are determined by carbon intensity reduction targets and economic output; meanwhile, the design of the Shenzhen ETS attaches great importance to coordinate the dynamic relationships between economic growth, industrial transition, and emissions control. Followed by Shenzhen, Shanghai environment and energy exchange started the initial transaction with a closing price of 27 yuan/tCO_2 in November 26, 2013. Wu et al. [9] suggested that adjusting the allowance allocation principles to facilitate change in the domestic energy structure to advance the Shanghai ETS. As the third carbon trading pilot, Beijing held a relatively high carbon price of 51.25 yuan/tCO_2 at the beginning day on November 29, 2013. Zhu et al. [10] developed a full-infinite interval-stochastic mixed-integer programming (FIMP) method to apply to a real case study for managing carbon emissions with trading scheme of Beijing's electric power system. Afterwards, Guangdong dealt with seven transactions by a highly closing price of 60.17 yuan/tCO_2 in December 19, 2013. Wang et al. [11] considered 5 cases to achieve Copenhagen target toward 2020 in Guangdong based on its carbon emission trading scheme and analyzed the economic impacts of carbon ETS. Moreover, Tianjin started to run the carbon emissions trading pilot on December 26, 2013, and appeared with an average deal price of 29.78 yuan/tCO_2.

In terms of these 5 pilots' test running experiences, it is necessary to put forward a carbon price benchmark reference method that encompassing both theoretical analysis and empirical data for policy makers. Thus, we will employ the following three methods to assess this research.

Empirical Mode Decomposition (EMD) technique, first proposed by Huang et al. [12], is a kind of adaptive signal decomposition technique using the Hilbert–Huang transform (HHT) and it has been successfully applied in solving non-stationary regression estimation problems [13]. After years of research and ameliorate, EMD has been applied to different areas. Especially in processing and forecasting the unstable time series [14,15]. A quintessential example should be cited that, Zeng et al. [16] designed a combination of EMD with time-series method to predict the European's carbon futures price, and it incredibly showed a high-precision result. On the basis of this discovery, we make efforts to integrate EMD and the widely used time-series method the Generalized Autoregressive Conditionally Heteroskedastic (GARCH) model to forecast the five pilots' carbon price in 2016.

GARCH model was introduced by Engle [17] and Bollerslev [18]. It can depict the instability, bigger volatility, and agglomeration of carbon price exactly. GARCH model is broadly applied in several fields such as energy investment evaluation [19].

The Computable General Equilibrium (CGE) model derived from general equilibrium theory by Walras, the model focuses on all of the markets of the economic system and required all of the markets cleared [20]. As an effective policy analyzing tool in economics, CGE model can commendably simulate the influence of each economic subjects' performance when executing a policy or measurement. It is applied to a large number of research fields particularly in the aspects of international trade, public finance, and climate policy [21–23]. Additionally, in carbon pricing facet, previous studies have utilized CGE technology to evaluate the influence caused by carbon emissions trading. For instance, Li et al. [24] used a dynamic CGE model to assess the economic and climate impacts of emissions trading system (ETS) in China with a carbon price of 100 yuan/tCO_2.

As has been previously mentioned, it is noted that studies combined the EMD-GARCH method and CGE model together to illustrate the variation characteristics of China's macroeconomic, environmental quality and energy demand in light of the carbon price benchmark perspective, are limited. Despite how outstanding and universal both of the two methods are. In order to provide a more scientific and feasible scenario design basis for CGE simulation part, we will use EMD–GARCH method to forecast China's five pilots' carbon prices in 2016 firstly. Then we will establish a recursive dynamic CGE model to explore the influence of different carbon price scenarios. Consequently, we will conclude an optimal interval of the carbon price benchmark from the simulation results.

In the remaining part of this article, Section 2 employed the EMD-GARCH model to forecast the five pilots' carbon prices in 2016; Section 3 briefly described the recursive dynamic CGE model used in this paper; Section 4 designed different carbon price benchmark scenarios and analyzed the impacts of these scenarios; Section 5 summarized the main results of this study and pointed out some suggestions for further research.

2. Description of EMD–GARCH model

2.1. The principle of GARCH model

Bollerslev proposed GARCH model in 1986, and converted the high order ARCH model into concise GARCH model to portray an autocorrelation of the data variance and explain the volatility clustering phenomenon of the financial time series more accurately [25,26].

$$y_t = x_t\gamma + u_t \tag{1}$$

$$\delta_t^2 = \omega + \sum_{i=1}^{q}\alpha_i u_{t-i}^2 + \sum_{j=1}^{p}\beta_j\delta_{t-j}^2 \tag{2}$$

where $x_t = (x_{1t}, x_{2t}, \cdots, x_{kt})'$ denotes the explaining variable vector, the $\gamma = (\gamma_1, \gamma_2, \cdots, \gamma_k)'$ term denotes the coefficient vector and δ_t^2 represents its variance conditional on the information available at time t. It is a function with perturbations exogenous variables in the mean Eq. (1). There exist three components in Eq. (2).

① Constant term, ω.

② ARCH term, $\sum_{i=1}^{q}\alpha_i u_{t-i}^2$

where q is the order of the ARCH term.

③ GARCH term, $\sum_{j=1}^{p}\beta_j\delta_{t-j}^2$

where p is the order of the GARCH term.

2.2. The algorithm steps of the EMD method

EMD is a new-fashioned self-adapting signal temporal frequency analyzing method and is often used to decompose the original dataset into a finite and small number of intrinsic mode