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Regulating effect of the energy market—Theoretical and empirical analysis based on a novel energy prices–energy supply–economic growth dynamic system

Minggang Wang, Lixin Tian *

School of Mathematical Science, Nanjing Normal University, Nanjing 210042, Jiangsu, China
Center for Energy Development and Environment Protection Strategy Research, Jiangsu University, Zhenjiang 212013, China

HIGHLIGHTS

- A novel non-linear system of energy prices, supply and economic growth is proposed.
- Dynamic behaviors of the system and its subsystems are analyzed.
- The evolving paths of the system under different control strategies are obtained.
- The effects of control strength on energy intensity are described vividly.
- The effects of different control strategies on energy intensity are obtained.

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ABSTRACT

It is known that the invisible hand – energy market can reflect the energy price. Follow this perspective, a net structure that every element can conduct mutually has been founded based on the causal relationships among energy price, energy supply and economic growth during a given economic period. Furthermore, a novel dynamic system model of energy price–energy supply–economic growth which can make sure the balanced development of energy market is proposed. Later, four types of regulatory strategies are offered with considerations of both the background of China's certain economic transforming periods and the visible hand of control policies. Then regulating effect of the energy market is obtained. Dynamic behavior of the system and its subsystems are analyzed by means of Lyapunov exponents and bifurcation diagrams. Evolutionary behavior of the energy market affected by changes of energy prices, energy supply and economic growth is described with the method of numerical simulation. A practical system of energy prices is achieved, based on the data of the total energy production, the GDP index, the energy price index in China between 1980 and 2010 and the use of artificial neural network. Model analysis indicates that economic growth will lead to increase of energy supply and there will be two turning points of energy supply in the rapid growth of the economy. Multiple regulatory strategies in the established system are investigated. It is shown that Strategy 1 (exploring new energy sources), Strategy 2 (enhancing the self-regulating market), Strategy 3 (industrial restructuring, appropriately lowering the speed of economic growth, and enhancing the systematic and scientific management) can all stabilize the energy market, but Strategy 4 (purely relying on administrative interventions) cannot stabilize the system, as it will only make the system stay in the state of cycle shocks. An evolutionary analysis is made to show the impacts of different control strengths under the same strategy and that of different control strategies on the energy intensity. It is shown that the regulating effect is periodic and takes time. Reasonable control efforts can effectively reduce the energy intensity, but excessive regulation will be counterproductive. In the short term, Strategy 2 is an effective means to reduce the energy intensity to 0.4886 in about two years. However, in the long term, Strategy 1 and Strategy 3 are effective means to reduce the energy intensity, which are 0.4221 and 0.4343. And they will take about twelve and six years respectively. In general, the expected effect, that is, reducing the energy intensity to 0.3425 in about seven years can be achieved on the premise of maximizing the autonomous function of the market (Strategy 2), exploring new energy sources (Strategy 1) and industrial restructuring (Strategy 3) with appropriate macro-control policies (Strategy 4).

* Corresponding author. Tel.: +86 51188797671; fax: +86 51188791467.
E-mail addresses: magic821204@sina.com (M. Wang), tianlx@ujs.edu.cn (L. Tian).

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1. Introduction

Evolution of energy prices contains a variety of information in the energy market. Energy prices, as the reflection of the invisible hand of the energy market, play an important role in the world economy. With the growth of economy, the issue of energy prices has drawn world-wide attention. Such problems as how to coordinate the relationship between energy supply, economic growth and energy prices, how to explore the mechanism of fluctuations of energy prices, and how to examine the effects of energy prices on economic growth and the energy intensity have become the hot topics of current academic researches.

On the other hand, as the visible hand of the energy market, the government's policy regulations and control have played a guiding role in the orderly development of the energy market. Therefore, the maximization of the function of energy prices, the manifestation of the influence of the energy market as the invisible hand, and the better utilization of policy regulations and control as the visible hand are the guarantees of the orderly and healthy development of the energy market. From the perspective of the evolution of energy prices, energy supply, and economic growth in the energy market, this paper will construct a novel dynamic system in the energy market, discuss the functions of energy prices. Focusing on the influence of the energy market by its role as the invisible hand, four kinds of regulatory strategies will be presented, whose evolution and development will be analyzed in order to achieve the regulating effect of the energy market.

1.1. Literature review

In recent years, numerous scholars research on the interrelation of energy prices, energy supply and economic growth. Tang and Tan [1] investigated the relationship between electricity consumption, economic growth, energy prices and technology innovations over the period of 1970–2009. Berkand Yetkiner [2] theoretical and empirically investigates the long run relationship between energy prices and economic growth. Jin et al. [3] analyzed the effects of energy prices and energy conservation on economic growth. Mahadevan and Asafu-Adjaye [4] examined the relationship between energy consumption and economic growth by means of the panel data of 20 net importers and exporters of energy from 1971 to 2002 and Vector Error Correction Models. Lee and Chiu [5] examined the dynamic interrelationship among nuclear energy consumption, product oil prices, product oil consumption, and real income in six highly industrialized countries over the period 1965–2008. Odhiambo [6] studied the causal relationship between energy consumption and economic growth in South Africa, Kenya and Congo. Doroodian and Boyd [7] observed the relationship between fluctuations of oil prices and inflation. Lee and Chiu [8] examined the short-run and long-run dynamic relationships among nuclear energy consumption, oil prices, oil consumption, and economic growth in developed countries over the period of 1971–2006 with panel data analysis. These are basically studies that have used econometric models and empirically examined the relationships among energy prices, energy supply and economic growth. However, the conclusions vary a lot due to different sample periods being examined [1–8]. It is now imperative that we construct nonlinear models to describe the complex relationships among energy prices, energy supply and economic growth in the energy market, incorporate regulatory policies into the nonlinear model, and analyze qualitatively the evolutionary path of energy prices, energy supply and economic growth under different regulatory policies in order to achieve the regulating effect of the energy market.

Energy intensity is an important indicator for evaluating the achievements of economic growth. What drives the energy intensity to change and how to reduce the energy intensity are the hot topics in current researches. Lin and Du [9] proposed a comprehensive framework combining index decomposition analysis (IDA) and production-theoretical decomposition analysis (PDA) to investigate the mechanism of the energy intensity change. Gómez et al. [10] explored the reasons for the high the energy intensity of the Kazakh economy. Li and Lin [11] discussed the impacts of the industrial structure on the energy intensity in China, suggesting that China should reduce the ratio of industry output to the GDP and that only promoting technological progress can effectively reduce the energy intensity. Zeng et al. [12] used input–output structural decomposition analysis to find the contributions of changes in the energy structure, increases in the sectoral energy efficiency, and adjustments of the production structure to reducing the energy intensity. Li et al. [13] assessed the effects of the economic structure, the energy consumption structure, and technological progress on the energy intensity in three regions of China. Fang et al. [14] examined the impacts of carbon tax on the energy intensity and economic growth in a four-dimensional energy-saving and emission-reduction system with carbon tax constraints. Hatzigeorgiou et al. [15] studied the causal relationship between the GDP, The energy intensity and CO2 emissions in Greece from 1977 to 2007. It is obvious that how to reduce the energy intensity has become a hot topic in current researches. Many scholars have analyzed the means to reduce the energy intensity effectively, such as economic restructuring, adjustments of the energy consumption structure, technological progress and so on. However, most of the literatures are only qualitative descriptions of policies, lacking quantitative analyses, more particularly discussions of various comprehensive means of reducing the energy intensity.

Researches that use nonlinear dynamics theory to study the complexity of economic systems have borne quite a lot of fruit. Sun et al. [16,17] established a three-dimensional demand–supply system of energy resources, based on analyses of the status quo of energy consumption in Jiangsu Province and the West, as well as the complex relationship of interdependence and influence between energy demands of Jiangsu, energy supplies in the West and the amount of energy import of Jiangsu. If we add the variable of regenerative energy to the three-dimensional demand–supply system of energy resources, we can achieve a much more realistic four-dimensional demand–supply system of energy resources, which has richer dynamic behaviors. Fang and Tian [18–20] established a novel three-dimensional energy-saving and emission-reduction evolution system in accordance with the interrelationship between energy-saving and emission-reduction, carbon emissions and economic growth.

1.2. Problems need to be solved

The system of energy prices, energy supply and economic growth is a complex nonlinear one that involves many factors such as energy prices, energy demands, supplies, economic growth, energy efficiency, energy intensity and so on. A question worth noting is how to conduct a research on the system of energy prices with models of non-linear dynamics. Most of the previous studies on energy prices mainly focused on empirical analyses [1–5,9–15] of existing statistics, thus lacking systematic theoretical analyses. Therefore, it is necessary to do some deeper research from the perspective of the following aspects. (1) As a matter of fact, there are a lot of factors being involved in the energy market. What is more, they form a complex coupling relationship. Because of this, it is significant for a steady energy market to make their interacted conduction relationship clear and then analyze them quantificationally. (2) By using this non-liner dynamics model, energy prices, supplies and economic growth are included into the system as