Journal of Cleaner Production 207 (2019) 204–213

Contents lists available at ScienceDirect

Journal of Cleaner Production

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

The effects of energy price, technology, and disaster shocks on China's Energy-Environment-Economy system

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ARTICLE INFO

Article history:
Received 30 November 2017
Received in revised form
3 September 2018
Accepted 29 September 2018
Available online 1 October 2018

Keywords:
Energy-environment-economy systems
Low-carbon environment
Dynamic stochastic general equilibrium model
Bayesian estimation

ABSTRACT

This paper constructs a dynamic stochastic general equilibrium (DSGE) model to analyze the effects of energy price, technology, and disaster shocks on China's Energy-Environment-Economy (3E) system. It also studies stylized facts, as well as co-integration and error correction dynamic analyses, of this system. The disaster shock is modeled as a two-state Markov switching process. The results show that both technology and energy price shocks increase the ratio of environmental investment to GDP. The improvement in technology and rising energy prices helps to reduce CO_2 pollution, and improve economic restructuring. Among the three kinds of shocks, technology shock is the most important. The robustness of the model is tested through statistical methods.

1. Introduction

Although there is still no universal agreement on the cause of global climate change, there is a growing consensus among climate scientists that anthropogenic emission of greenhouse gases (GHGs) into the atmosphere is a leading cause of climate change. As a result, China, for the first time, has put forward a plan to achieve its CO_2 emissions peak by 2030, while making an effort to realize this goal earlier. It intends to increase the share of non-fossil fuels in primary energy consumption to approximately 20% by 2030, as stated in the statement issued jointly with the US in 2014. Previously, China's commitment was limited to the relative reduction of carbon intensity. The intent here was to slow the growth of CO_2 emissions as long as the GDP grew. Yet, emissions must be reduced far more drastically—a significant step in the global response to climate change. However, this also presents an inordinate challenge to the rapid development of the Chinese economy.

As a major developing country, and one of the largest CO_2 emitters, China is now under greater pressure to reduce its energy consumption and emissions. Moreover, as its per capita income is still low, it also needs to prioritize long-term economic development. Hence, China's plan to reduce energy consumption and CO_2 emissions faces a greater challenge. Thus, the means required to coordinate the relationship between energy, the economy, and the environment have become the focus of the government, academia, and the international community.

We focus on two of the three aspects of the Energy-Environment-Economy (3E) system, that is, on the environment-economy system and energy-economy system that have been extensively studied so far. First, environment-economy system research has historically attracted attention from researchers in different countries (Song et al., 2016, 2017, Chen and Li, 2015). George implied that policies to control pollution must consider both specific economic situations and the structure of industrial and business sectors of each region. Tienhaara (2014) claimed that the proposed varieties of green capitalism increase opportunities for more targeted critiques of each model and, thus, enable a constructive debate on the options available to create sustainable economies in the developed world. Böhringer and Rutherford (2013) showed that more comprehensive flexibility provisions at the European Union level and a diligent policy implementation at the national level could make the transition toward a low-carbon

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https://doi.org/10.1016/j.jclepro.2018.09.256
0959-6526/

economy more cost-effective and, thus, broaden social support for it. Borda and Wright (2016) studied the role of disaster shock by using a single-sector, representative agent dynamic stochastic general equilibrium (DSGE) model. Second, scholars have comprehensively researched the energy-economy system too. Energy is the material basis for the survival and development of human society; it has an important strategic position in national economies. Energy concerns have always been the focus of critical global issues and hotspots, especially the two major events, the 1973 Oil Crisis and the record oil price hike in 2005. Energy prices, as an important factor that influences economic development, have, thus, become the focus of studies on energy issues. The sharp rise in energy prices, such as the international oil prices, has significantly influenced world economy. Using a vector auto regression (VAR) framework, Hamilton (1983) found that the oil price change had a strong causal and negative correlation with real US GNP growth from 1948 to 1980. Davis and Haltiwanger (2001) discussed how energy price shocks affected the labor market. Their study found that the short-run employment effects were significant, and responded negatively to an oil price increase. However, the response of long-term employment to any oil price shock was small. Finn (2000) analyzed how oil price shocks affected output and economic activity based on the perfect competition market hypothesis. The study's results showed that, for every 10% rise in oil prices, there would be an output reduction of less than 0.5%. Barnett and Straub (2008) studied the impact of monetary policy, private absorption, and technological and oil price shocks on current account fluctuations in the US using the DSGE. Barnett and Straub found that the negative effects of contractionary oil price on the current account would last for approximately three years. Van et al. (2016) identified supply, aggregate demand, and residual shocks on energy prices in order to estimate their changing influences on energy prices and GDP based on data of the UK covering the last 300 years. Kilian (2010) explored the effects of both global crude oil market and the US gasoline market by using the VAR model. Schwark (2016) found how oil price shocks had influenced the US economy over the last few decades, especially focusing on the productivity slowdown in the years following an oil price shock. Atalla et al. (2017) analyzed the primary fossil fuel mix in the US, and compared it with Germany and the UK by calibrating and simulating a DSGE model. Aminu (2017) studied the impact of energy price shock by using a DSGE model with a New Keynesian Philips curve. By decomposing changes in the output caused by all the stationary structural shocks. Aminu found that the fall in output during a financial crisis period was driven by three demand shocks—domestic, energy prices, and world.

However, it is difficult to coordinate the development of energy, economy, and environment without using a 3E system. Considering the mutual influences between energy, economic development, and environmental protection, scholars have realized the need to establish a 3E system. This system can analyze the internal relationship between the aforementioned three factors and the law of their development in order to maximize its benefits. It is thus practically significant to develop a model for studying the relationship between energy, economy, and a low-carbon environment.

Currently, research on the 3E system mainly focuses on two aspects. The first one is the construction of a coordinating evaluation model for the 3E system, that is, building an evaluation system or measuring its coordinating degree. Guivarch et al. (2009), using the computable general equilibrium model, presented interesting insights on the relevant modeling methodology to represent an economy's response to a shock, and how short-term mechanisms and policy activities could relieve the negative impacts of energy price shocks or climate policies. Németh et al. (2011) estimated the Armington elasticity of energy and energy-intensive sectors by using the GEM-E3 CGE model. Song and Jia (2012) constructed a vector error correction model of the 3E system, and empirically analyzed its long-term co-integration and short-term adjustment. Pao and Fu (2015) proposed the use of the Lotka-Volterra model for sustainable development (LV-SUD) to analyze the inter-specific interactions, equilibrium, and their stabilities among emissions, different types of energy consumption (renewable, nuclear, and fossil fuel), and real GDP—the main 3E issues.

The aforementioned literature provides us with important references to understand the 3E system correctly, but they are also subject to limitations. First, they lack satisfactory treatment of rational expectations and effective combination with general equilibrium analysis. Instead, they focus mainly on the dynamic effects of the 3E system. Second, they ignore microcosmic foundations by prioritizing the overall performance of the economy and environment in the application process. Hence, they fail to explain the mechanism that determines the influences of shocks on the 3E system.

Since Kydland and Prescott (1982) proposed the real business cycle (RBC) theory, the DSGE model has become a mainstream method in macro-economy studies. A conventional RBC model not only captures the characteristics of economic growth, but also efficiently analyzes the economy based on assumptions about preference, endowments, and technology.

This paper analyzes impacts of technology and energy price shocks on China's economy, carbon environment, and energy consumption by assuming classical hypotheses and constant returns to scale.

In reality, the 3E system is influenced by all kinds of shocks. Since economic development is highly dependent on energy consumption (which affects carbon emissions directly), the latter not only drives the former, but also destroys ecological balance. Since the oil crises in the 1970s, energy prices have become an important topic in macroeconomic research. Energy security problems are now a primary factor that influence the global political and economic order. A sharp rise in China's demands for energy has led to an increase in the energy prices since 2002. Therefore, it is practically significant to analyze the effect of energy price shocks on the 3E system.

Consequently, we introduce environmental investment ratio into utility function and energy prices into the production function to construct a DSGE model. This model is then used to analyze the effects of energy price shocks, technology shocks, and disaster shocks on China's 3E system. Besides analyzing the internal relationship between energy, economy, and environment and the law driving their development, we also study the effects of technology, energy price, and disaster shocks on China's economy, carbon environment, and energy consumption. These approaches can help in understanding comprehensively the inherent law driving the 3E system.

To build on this article, follow-up studies can focus on the following two aspects. First, in the model settings, we can introduce further assumptions, such as a comparison of price stickiness and price elasticity, financial accelerators, and adjustable cost. Second, from the policy application perspective, we can further study the choice of fiscal policy and monetary policy.

The remaining paper is organized as follows. Section 2 presents the stylized facts of the 3E system. Section 3 presents the dynamic relationship in this system. Section 4 constructs a DSGE model to analyze the 3E system. Section 5 provides parameter calibration, Bayesian estimation, impulse response analysis, variance decomposition, welfare loss function, and a robustness test. Finally, the conclusions are presented in section 6.