Energy Conversion and Management 79 (2014) 128–139

Contents lists available at ScienceDirect

Energy Conversion and Management

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

Energy demand in China: Comparison of characteristics between the US and China in rapid urbanization stage

Boqiang Lin [a,b,*], Xiaoling Ouyang [c]

[a] Newhuadu Business School, Minjiang University, Fuzhou 350108, China
[b] Collaborative Innovation Center for Energy Economics and Energy Policy, China Institute for Studies in Energy Policy, Xiamen University, Xiamen, Fujian 361005, China
[c] School of Energy Research, College of Energy, Xiamen University, Xiamen 361005, China

ARTICLE INFO

Article history:
Received 2 October 2013
Accepted 5 December 2013
Available online 31 December 2013

Keywords:
Energy demand
Comparison of characteristics
Urbanization
US
China

ABSTRACT

China's energy demand has shown characteristics of rigid growth in the current urbanization stage. This paper applied the panel data model and the cointegration model to examine the determinants of energy demand in China, and then forecasts China's energy demand based on the scenario analysis. Results demonstrate an inverted U-shaped relationship between energy demand and economic growth in the long term. In business as usual scenario, China's energy consumption will reach 6493.07 million tons of coal equivalent in 2030. The conclusions can be drawn on the basis of the comparison of characteristics between the US and China. First, energy demand has rigid growth characteristics in the rapid urbanization stage. Second, coal-dominated energy structure of China will lead to the severe problems of CO_2 emissions. Third, rapid economic growth requires that energy prices should not rise substantially, so that energy conservation will be the major strategy for China's low-carbon transition. Major policy implications are: first, urbanization can be used as an opportunity for low-carbon development; second, energy price reform is crucial for China's energy sustainability.

1. Introduction

Exploring characteristics of energy demand in China during the rapid urbanization process, which is considered a crucial step in the development of national energy strategies and the transition to a low-carbon society, has recently attracted increasing interest from both the academic researchers and the general public, as China has become the world's biggest energy consumer and carbon dioxide emitter. It should be noted that China's energy demand is constrained by its development stage [1]. Since the policy of reform and opening-up, China has entered into the growth stage of rapid urbanization and industrialization. The average annual growth rate of the urban population in this period was 4.3%, and 520 million people (about 1.6 times of the current total resident population in the United States) have been transferred from rural to urban areas over the last 34 years [2]. China's industrial structure was dominated by secondary industry, and the average proportion of industrial value added in GDP was 40%. The extensive growth has led to the rapid increase in energy consumption. In 2009, China surpassed the US as the world's largest consumer of energy at breakneck pace. Meanwhile, China's oil consumption and imports were just ranked after the US in 2011, China became the world's largest consumer of coal, accounting for approximately 50% of the world's total [3]. With an average annual growth in emissions of 10% during 2000–2006, China overtook the US in 2006 as the world's leading CO_2 emitter [4].

In order to cope with the rising energy demand, the Chinese government proposed to control the total energy demand in 2015 within 4000 Mtce (million tons of coal equivalent) [5]; indicating that China's energy strategy has transformed from ensuring sufficient supply to controlling the quantity of energy consumption. Since China is still in the stage of on-going urbanization and industrialization, no major changes are likely for the overall trend of energy demand growth and energy structure. In this context, it is important to study questions such as: (i) What are the characteristics of energy demand in the rapid urbanization stage? (ii) Is it reasonable for China to set the targets of energy consumption? (iii) What can be done from the perspective of policy design to ensure these achievements? In this paper, we intend to answer the above questions and draw policy implications.

Recalling the development history of the United States, we find that energy demand shows strong periodical characteristics. As the world's most developed economy, the urbanization and industrialization process of the United States occurred more than a century earlier than that of China. As a major energy consumer, the United States has been a dominant force in the global energy market. Comparison of characteristics of energy demand between the US and China at the same development stage is conducive to exploring

* Corresponding author at: Newhuadu Business School, Minjiang University, Fuzhou 350108, China. Tel.: +86 5922186076; fax: +86 5922186075.
E-mail addresses: bqlin@xmu.edu.cn, bqlin2004@vip.sina.com (B. Lin).

0196-8904/$ - see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.enconman.2013.12.016

determinants of China's energy consumption. Such study can also provide a reference for subsequent research in other developing countries.

China's rapid growth of energy demand has greatly influenced the world energy market and challenged global efforts on carbon emission reductions [6]. It is important to understand the characteristics of energy demand at a certain stage of development. The contributions of our study lie in two aspects: first, we fill the research gap by exploring factors that influence energy demand and providing a thorough comparison between the United States and China during the urbanization and industrialization process; second, we forecast China's energy demand in 2030 and suggest future policy priorities on energy development and CO_2 emissions reduction.

The remainder of this paper is structured as follows. Section 2 compares determinants of energy demand in the United States and China in the urbanization and industrialization stage. Section 3 presents a literature review. Section 4 describes the methodology and data source. Section 5 offers the empirical results of our models and discussions. Section 6 concludes with some policy implications.

2. Comparison of characteristics of energy demand between the US and China

Energy demand has periodical characteristics [7]. During the urbanization and industrialization process, the growth of energy consumption in both the United States and China showed rigid characteristics. However, there are two important differences between the two countries. First, energy demand per capita of China was much lower than that of the US, which implied the relatively large growth potential of future energy demand in China. Second, energy structure of China was dominated by coal, which cannot be changed in the short-term, implying that China will face more severe problems of CO_2 emissions reduction.

2.1. Comparison of energy demand between the US and China

Before conducting the comparison, we need to clarify the selection principle of the time interval. Basically, the urbanization rate is used as an indicator for measuring the urbanization level. According to China Statistical Yearbook [8], the urbanization rate of China grew from 19.4% in 1980 to 51.3% in 2011. Revisiting the development history of the United States, we found that the urbanization rate increased from 19.8% in 1860 to 51.2% in 1920 [9]. Furthermore, industrialization and urbanization are seen as interdependent processes of modern economic development [10]. The industrial structure of the US during the period also supports the above selection of time intervals. Therefore, we identify the time interval of 1860–1920 of the US as the stage of rapid urbanization and industrialization. A thorough comparison of each factor that influences energy demand in the urbanization stage is presented in Section 2.2.

2.1.1. Primary energy demand

In the urbanization stage, energy consumption of both the United States and China increased significantly. For the case of the US, the primary energy consumption grew from 110.67 Mtce in 1860 to 747.04 Mtce in 1920 – equivalent to a growth of about 575%. The average annual growth rate of energy demand in America was about 3.4% during 1860–1920 (Fig. 1. Panel A). For the case of China, the primary energy consumption increased from 602.75 Mtce in 1980 to 3620 Mtce in 2012 – equivalent to a growth of about 500%. The average annual growth rate of energy demand in China was about 5.7% (Fig. 1. Panel B). The growth speed of China's energy consumption was faster than that of the US because of higher economic growth rate and a more rapid process of urbanization and industrialization. It can be seen from Fig. 1, under the constraints of certain stages of development, energy consumption of both the US and China showed characteristics of rigid growth.

2.1.2. Energy consumption per capita

There are similarities as well as differences of energy demand per capita between the two countries. The common feature is that energy consumption per capita of each country showed an upward trend in the rapid urbanization stage. From 1860 to 1920, the growth rate of energy consumption per capita of America was 1.31%. In the same stage of development, energy consumption per capita of China grew at 4.73% annually (see Table 1). However, energy demand per capita of China was far below that of America. China's energy consumption per capita in 2011 only accounted for 36.55% of America's in 1860. Possible reasons are listed as follows: first, China has a large population base of nearly 1.4 billion people; second, a large number of the urban population in China has no access to social security due to the limitation of the hukou (household registration) system, which leads to the actual purchasing power of urban residents lower than the desired level [12].

2.1.3. Energy consumption structure

Energy consumption patterns of the US have changed from wood-dominant to coal-dominant in the rapid urbanization stage (1860–1920). Before 1885, the primary energy consumption structure in the US was dominated by biomass (wood), which accounted for as high as 80% in total energy consumption. The proportion of coal in total energy consumption increased during 1860–1910 and showed a downward trend after the year 1910 (the highest level). The decreased proportion of coal was replaced by the increased proportions of petroleum and natural gas (see Fig. 2. Panel A).

China's energy consumption structure was dominated by coal (70%) during 1978–2011 (Fig. 2. Panel B). This feature is similar to the United States at the same developmental stage. However, China's coal-dominant energy structure did not show any signs of decreasing due to the following reasons. First, there were relatively abundant coal reserves in China. Second, rapid economic growth required the low-cost energy as a support and coal was the cheapest source of energy. Therefore, China will face more severe problems of CO_2 emissions reduction than the US in the future.

2.2. Comparison of determinants of energy demand

Based on literature in Section 3, determinants such as economic growth, urbanization, industrialization, energy intensity and energy price are chosen in the investigation of characteristics of energy demand. This subsection is a crucial and fundamental step for this study because of the preliminary work for our major conclusions, and the following application of these determinants in the panel data model and the cointegration model.

2.2.1. Economic growth

Economic growth is considered as a decisive factor of energy consumption in most literature [14,15]. During 1860–1920, the average annual growth rate of the US economy was 3.82%. The gross domestic product (GDP) grew from 68,594 million (1996 dollars) in 1860 to 574,987 million (1996 dollars) in 1920; equivalent to a growth of 738% (see Fig. 3. Panel A). In the same stage of development, China's GDP grew from 1,288,268 million (1996 CNY) in 1978 to 31,248,283 million (1996 CNY) in 2012; equivalent to a growth of 2325% (Fig. 3. Panel B). The average annual economic