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China's energy consumption under the global economic crisis: Decomposition and sectoral analysis

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HIGHLIGHTS

- We analyze the reasons for China's energy consumption change under the global economic crisis during 2007–2010.
- Domestic final use growth, especially in construction and manufacturing of machinery and equipment, resulted in energy consumption increase.
- International trade is identified as a driver of energy consumption reduction during and after the crisis.
- Increasing China's share of consumption or reducing its share of investment in the GDP can reduce national energy intensity.

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ABSTRACT

It is now widely recognized that there is a strong relationship between energy consumption and economic growth. Most countries′ energy demands declined during the economic depression of 2008–2009 when a worldwide economic crisis occurred. As an export-oriented economy, China suffered a serious exports decline in the course of the crisis. However, it was found that energy consumption continued to increase. Against such a background, this paper aims to assess and explain the factors causing the growth of energy consumption in China. First, we will explain the impact of domestic final use and international trade on energy consumption by using decomposition analysis. Second, embodied energy and its variation across sectors are quantified to identify the key sectors contributing to the growth. Lastly, the policy implications for long-term energy conservation are discussed. The results show that the decline in exports was one of the driving forces for energy consumption reduction in the crisis, but that the growth of domestic demand in manufacturing and construction, largely stimulated by economic stimulus plans, had the opposite effect on energy consumption. International trade contributed to decreasing energy consumption of China during and after the crisis because the structure of exports and imports changed in this period.

1. Introduction

China's energy consumption has increased dramatically since the turn of the millennium, a period which is considered to be a result of rapid economic development and urbanization (Feng et al., 2009; Tsani, 2010; Liao and Wei, 2010; Li et al., 2011). From 2001 to 2007, China's energy consumption increased from 1504 million tons coal equivalent (Mtce, 1 kgce can produce 29,270 kJ of heat in China, so 1 Mtce can produce 29270 billion J of heat) to 3249 Mtce (Chinese Nat Prod. Type: ional Bureau of Statistics, or CNBS, 2008–2011a). A combination of sustained high growth rates of exports and domestic consumption is responsible for this rapid growth in energy demand (Kahrl and Roland-Holst, 2008; Yuan and Zuo, 2011; Zhang and Wang, 2011). Exports have become an important engine of China's economic development since the country joined the World Trade Organization (WTO) in 2001 (Naughton, 2007). In 2002–2008, the total value of China's imports and exports increased from $ 620.8 billion to $2561.6 billion, with an annual growth rate of 26.6%. The contribution of exports to China's gross domestic product (GDP) grew from 20.2% in 2001 to 27.0% in 2007. In some manufacturing sectors, such as textiles, chemical products, metal products, and machinery and equipment, the contribution was more than 50% in 2007 (Liu et al., 2009). Kahrl and Roland-Holst (2009) examined emerging energy-expenditure relationships in China and found that most of the growth in China's energy demands has been driven by investment and exports, the combination of which accounted for more than

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70% of energy consumption growth from 2002 to 2004, while exports have been the fastest growing contributor to energy consumption growth.

As a strong driving force of economic growth, trade is also a strong bond connecting China and the world (Liu et al., 2010b). When the global economic crisis caused a significant decline in international economic activity in 2008 and 2009 (most of the economic entities in the world began growing again in 2010, although it was disputed whether the crisis was not over in 2010), China's economy was also affected. It has become increasingly clear that a substantial reduction in exports has been the primary impact of the crisis on China. The EU, US, and Japan, China's three largest trading partners, all suffered economic depression, a decrease in employment, and a decline in demand in mid-2008. China's international trade declined sharply after mid-2008, from $243.3 billion in September 2008 to $141.9 billion in January 2009; a decrease of 41% in four months (Liu et al., 2009). Total exports fell by 18% in 2009 compared with 2008 (CNBS, 2008–2011a), which was the most serious decrease since its accession to the WTO. The mining of coal and metal ores, iron and steel, and the manufacture of motor vehicles were the most impacted industries, with a decrease rate of over 40%. Along with the declining trade, the influence of the crisis on China's economy, employment and consumption was felt during and after 2009 (Fidrmuc and Korhonen, 2009; Diao et al., 2012; Liu et al., 2012a; Voon and Voon, 2012). Economic adjustments always affect energy consumption. Yuan et al. (2010) predicted that the Global Financial Crisis would lead to a 9.21% reduction in China's energy consumption in 2009 compared with 2008. Instead of decreasing, however, the total energy consumption continually increased during the global economic crisis, with an increase of 5.2% in 2009 compared with 2008. In the same period, energy demand declined in most developed countries. The change rate was −7.1% in the United States, −5.7% in all European countries, and −9.7% in Japan. However, the trends for energy consumption differed in developing countries. For example, the rate was −4.5% in Russia, 3.9% in Brazil, and 15.8% in India (British Petroleum (BP), 2011). China and India were the fastest growing countries in terms of energy consumption during the crisis. Given the decline in China's exports in 2009, there must be certain factors that led to the increase in energy consumption. Meanwhile, China has proposed reducing its CO_2 emissions and energy intensity in the future. Cutting its energy intensity by 40–45% of the 2005 levels by 2020 is an important mission for China, as declared at the Copenhagen Climate conference in late 2009. Historical evidence, however, suggests that this target is extremely ambitious and that it may be very challenging to meet in the process of rapid industrialization and urbanization. With this background, any factor that can bring changes in energy consumption and energy intensity is worthy of an in-depth study. Our focus is on the behavior and drivers of China′s energy consumption during the global economic crisis, and on bridging the quantitative decomposition and sectoral analysis with the qualitative policy analysis.

The causes of variation in the energy consumption and energy intensity of an economic entity are interesting topics that have attracted much attention (Ma and Stern, 2008; Ma et al., 2010; Yu, 2012). Decomposition analysis has been used for many years to identify and assess the contributors to the changes in energy consumption and intensity (Ang and Zhang, 2000; Ma et al., 2010). The two most commonly used decomposition techniques are the index decomposition analysis (IDA) and the structural decomposition analysis (SDA) (Ang, 2004; Ang et al., 2009; Weber, 2009; Dong et al., 2010). SDA uses an input–output (IO) model and data to decompose changes while IDA only uses sector level data. The advantage of the SDA method is that it can distinguish between indirect effects such as technical and final use effects, while the latter cannot be estimated using the IDA method (Song and Zheng, 2012). Chang and Lin (1998) conducted research into the causes of rising CO_2 emissions in Taiwan, using data from 1981 to 1991 and the SDA method. The conclusion was that increased final use and technical progress were the primary causes of the increase and reduction of CO_2 emissions respectively. Similar methods have been used in analyses of the European Union (Alcántara and Duarte (2004)), China (Sinton and Fridley, 2000; Liang et al., 2007; Zhao et al., 2010; Fu et al., 2013), the USA (Weber, 2009) and the UK (Hawdon and Pearson, 1995). This study extends the previous work in the following ways. Firstly, rather than examining the effect of overall final use or one category of final use, we aim to quantify how the proportion of each category of final use contributes to China's increasing energy consumption, focusing on the degree of consumption, capital formation, exports and imports. The contribution of technological progress in the global economic crisis (2007–2010) is not discussed because there is no sufficient data and it is not a primary factor in such a short period. Second, the research period in this study is within the time span of the global economic crisis, which is a key factor in economic adjustment outside China, but has not been researched in detail. More attention needs to be paid to the factors that have changed in the crisis. Third, key sectors that exhibited dramatic change in embodied energy are investigated with regard to whether they support policy implications. These sectors are always ignored in traditional decomposition analysis. In this regard, the aim of this study is to attempt to answer the following questions: (1) What happened to China's energy consumption during the global economic crisis? (2) What led to this change? (3) Which sectors contributed the most to the change during the crisis? This study can provide lessons for future structural shift and energy consumption control by providing deep insights into the adjustments made during the global economic crisis. The remainder of the paper is organized as follows: Section 2 describes the methodology and data resources used. The results of the decomposition and sectoral analysis are presented and discussed in Section 3. Finally, the conclusions and policy suggestions are proposed in Section 4.

2. Methodology and data

2.1. Method

Since Leontief et al. (1936, 1941, 1970, 1972) used their input–output analysis (IOA) method to analyze energy consumption, pollution emissions and energy control policies in the United States, IOA has been widely used in dealing with energy and environmental issues (Alcántara and Padilla, 2003; Liang et al., 2010; Oliveira and Antunes, 2001). Input–output tables are not only data sources, but are also important models that have been used to analyze the linkage of production and consumption at a sectoral level. Therefore, IO table are frequently used to analyze the energy embodied in goods and services to build a linkage between production and consumption (Turner et al., 2007; Liu et al., 2010a; Dong et al., 2010; Chen and Chen, 2011; Liu et al., 2012b). In the input–output model, the total output of an economy **X**, can be expressed as the sum of intermediate use, **AX**, and final use, **Y** (Leontief, 1970).

$$\mathbf{X} = \mathrm{AX} + Y = (\mathbf{I} - \mathbf{A})^{-1}\mathbf{Y} = \mathbf{BY} \tag{1}$$

where **X** is the column vector of total output, **Y** is the column vector of final use, and **A** is the direct input coefficients matrix, which describes the relationship among all sectors of the economy. **AX** denotes the intermediate input vector which can be obtained by multiplying the direct input coefficient matrix by the total output vector. **I** is the identity matrix, and $(\mathbf{I} - \mathbf{A})^{-1}$ is