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A comparative study of energy consumption and efficiency of Japanese and Chinese manufacturing industry

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HIGHLIGHTS

- Energy consumption and efficiency of Japan and China's manufacturing industry are compared.
- Energy efficiency is critical given Japan and China's energy consumption scale.
- Results show strong association of energy efficiency improvement with energy policies.
- Results show importance and challenge of realizing structural change.

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ABSTRACT

The industrial sector consumes about 50% of the world's delivered energy and thus has a large impact on the world's energy production and consumption. Japan is one of the leading countries in industrial efficiency while China is the world's largest industrial energy consumer. This study analyzes the energy consumption and efficiency of the Japanese and Chinese manufacturing industry. Analysis shows that the energy intensity of both Japanese and Chinese manufacturing industry has decreased significantly. Decomposition analysis shows that the efficiency effect played an important role in reducing energy intensity; improvement of the energy efficiency of both Japanese and Chinese manufacturing industry showed a trend of exponential decay. Structural effect significantly reduced the energy intensity of the Japanese manufacturing industry while having a relatively small influence on the energy intensity of the Chinese manufacturing industry. Our analysis also shows a strong association of industrial energy efficiency improvement with energy policies, highlighting that energy efficiency policies can play an important role in the reduction of industrial energy intensity. The results of this study also underscore the important, yet very challenging, task of achieving structural change to further improve efficiency.

1. Introduction

Japan has been one of the most developed and advanced economies in Asia and the world, and now China is also striving to become an economic leader in Asia and the world. Japan and China share many of the same cultural roots, but have vastly different geographical landscapes and natural resource availability. While China has only recently become more dependent on imported oil and gas, Japan has always faced severe shortage of oil and gas and has been a significant oil and gas importer from the world market. Economically, the two countries are in very different stages of development, but both of them are among the largest manufacturers in Asia and the world.

Japan's economy grew rapidly from the 1950s through the early 1990s, while China's economy began its rapid growth in the end of 1978. Fig. 1 shows Japanese and Chinese gross domestic product (GDP) from 1970 to 2010, at constant 2005 prices in US dollars (USD). As seen in Fig. 1, Japanese GDP at the 2005 constant prices in USD was still higher than that of China by 2010, although Chinese GDP at the current prices in USD exceeded that of Japan beginning in 2010 (UN, 2011). Fig. 1 also shows the Japanese and Chinese primary energy consumption in 1970–2010. With the

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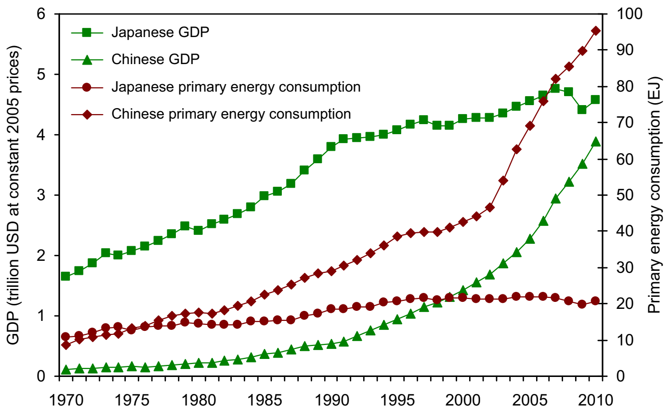

Fig. 1. Japanese and Chinese gross domestic product (GDP) and primary energy consumption, 1970–2010. *Note*: Chinese GDP at the current prices in USD exceeded that of Japan by 2010 (UN, 2011).
Source: GDP (UN, 2011); Japanese primary energy consumption (IEA and World Bank, 2012); Chinese primary energy consumption (NBS, 1987, 1990, 1992, 2010, 2011).

rapid growth of GDP, Chinese energy consumption increased significantly, especially after 2002. By 2010, Chinese total primary energy consumption was nearly 5 times of that of Japan.

Manufacturing industry plays an important role in both Japanese and Chinese economy. Manufacturing industry has led the Japan's economy, while it developed rapidly in China with the fast growth of economy and urbanization. Both countries are also heavy exporters of industrial products. The manufacturing industry accounts for 90% of Japan's exports (METI, 2010). Although Japan is a major leader of manufacturing industry in the world, the manufacturing industries in China and other emerging countries have significantly increased their importance and competitiveness globally (METI, 2010). China has already become a major manufacturer in the world, but its manufacturing is not very competitive and lack of competitiveness in many areas, especially in high-tech, high-level and high-end products. China has been one major importer of Japanese high value-added electronics and components, automobiles and advanced industrial production lines and equipments.

Industry accounts for about 70% of China's total primary energy consumption, while manufacturing industry accounts for about 85% of China's industrial energy consumption (NBS, 2010). In other words, manufacturing industry accounts for about 60% of China's total energy consumption. On one hand, energy consumption of the Chinese manufacturing industry has grown rapidly since the early 1980s, which is a major factor accounting for the rapid growth of China's energy consumption. On the other hand, industrial energy efficiency, especially energy efficiency in the manufacturing industry, has greatly improved in China since the early 1980s. Some recent studies (Ke et al., 2012; Zhang and Sun, 2010; Zhou et al., 2013) have focused on the industrial energy consumption and efficiency in China. Xu and Zhang (2011) analyzed the Chinese manufacturing industry using decomposition analysis and showed that improvements in energy efficiency continued to play a major role in reducing industrial energy intensity into the 2000s. Andrews-Speed (2009), Levine et al. (2009), and Price et al., (2001) (2010) all analyzed the industrial energy policies in China.

The Japanese manufacturing industry is regarded as one of the most energy-efficient manufacturing industries in the world (IEA, 2007; METI, 2010), which serves as a real-world example for energy-efficient economic development. Comparing Japanese and Chinese manufacturing industries' energy consumption trends and efficiencies help provide insights into China's relatively high industrial energy consumption and low efficiency and potential for improvement. However, there have been very few studies conducted to compare the energy situations of Japan and China, and, to the authors' knowledge, none evaluating the industrial energy efficiency trends of the manufacturing industries in both countries over 30-year-long period. The insights from this comparison cannot only provide helpful lessons learned for China, but can also be applied to other emerging countries which have been actively developing their manufacturing industries.

This rest of the paper is organized as follows: Section 2 briefly reviews the methodologies and data used in the study; Section 3 analyzes the energy consumption and efficiency trends of the Japanese and Chinese manufacturing industry at the industry-wide level; Section 4 further compares Japanese and Chinese manufacturing industry at the sectoral level; and Section 5 provides discussions and conclusions.

2. Methodologies and data

In this study, we mainly used energy intensity and decomposition analysis to analyze the energy consumption trends and efficiency.

2.1. Decomposition analysis

Decomposition analysis (Ang, 2005; Ang and Liu, 2007a, 2007b) is used to identify the production effect (activity effect), efficiency effect (intensity effect, or real energy intensity change), and structural effect in the changes in manufacturing energy consumption.

For simplicity, we define the following symbols:

P_t – total industrial production in year t;
$P_{i,t}$ – production of the ith sub-sector in year t;
$S_{i,t}$ – share of $P_{i,t}$ in P_t, or $P_{i,t}/P_t$, in year t;
E_t – total industrial energy consumption in year t;
$E_{i,t}$ – energy consumption of the ith sub-sector in year t;
I_t – aggregate industrial energy intensity in year t, $I_t = E_t/P_t$; and
$I_{i,t}$ – energy intensity of the ith sub-sector in year t, $I_{i,t} = E_{i,t}/P_{i,t}$.

The total industrial energy consumption can be expressed as follows (Ang, 2005):

$$E_t = \sum_i P_t(E_{i,t}/P_{i,t})(P_{i,t}/P_t) = \sum_i P_t I_{i,t} \cdot S_{i,t}$$

The change in total energy consumption between the reference year, which is denoted as year 0 here, and the year t can be decomposed in the following form:

$$\Delta E_t = E_t - E_0 = \Delta E_p + \Delta E_e + \Delta E_s + \Delta E_r$$

where ΔE_p, ΔE_e, ΔE_s and ΔE_r are the production effect (activity effect), efficiency effect (intensity effect, or real energy intensity change), structural effect, and a residual term (crossing term), respectively.

The production effect reflects the contribution of the change in production to the change in total energy consumption. The efficiency effect and structural effect indicate the effects resulting from efficiency change (real energy intensity change) and structural change on the total energy consumption, respectively. The structural change in this study characterizes the change of economic contribution of industrial sub-sectors to the overall industrial sector, measured in terms of sub-sectoral industrial value-added. The structural change below sub-sector level, such as the change of composition of different products within one sub-sector is not captured by the calculated structural change.