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Sectoral comparison of electricity-saving potentials in China: An analysis based on provincial input–output tables

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ABSTRACT

China's electricity generation is mainly dependent on fossil fuel. Promoting electricity conservation in different sectors and regions plays a vital role in reducing China's energy-related CO_2 emissions and other pollutants. This paper contributes to identify the sectors and economic regions with larger electricity-saving potential and make policy recommendations for promoting electricity conservation. Two indicators, namely TEC (technical elasticity coefficient) and PSC (price sensitivity coefficient), are constructed within an input–output analysis framework to measure the electricity-saving potential. The proposed indicators are applied to analyze the electricity-saving potentials of 20 sectors and 30 provinces in China. We also use EFC (electricity forward correlation coefficient) to examine the relationship between power consumption and electricity-saving potential. Our empirical results show that Mechanical industry, Construction industry and Chemical industry have the largest electricity-saving potential. Meanwhile, the east region of China also shows greater electricity-saving potential. It is suggested that Chinese government adopt pricing regulation and technology innovation policies jointly to promote China's energy conservation. Some important policy implications according to our empirical study are also proposed.

1. Introduction

Electricity industry as a strategic sector plays an important role in supporting other sectors. As shown in Fig 1, China consumed 3.63 trillion kWh of electricity in 2010, which accounted for 20% of the world total electricity consumption [1]. With the increasing demand for electricity, China is suffering from serious shortage of power supply. According to the information released by China Electricity Council, 24 provincial power grids are suffered from a supply shortage as high as 30 million kWh in 2011. With the rapid development of national economy, the gap between supply and demand for electricity will keep increasing in the near future.

According to the Outline of Mid-long Term Energy Development in China (2004–2020), thermal power still dominates the electricity production for quite a long time. It implies that power generation will still be heavily dependent on the coal in the future ten years. Thermal power plants emit a large amount of SO_2 and CO_2 which respectively accounts for about 45% and 50% of the total emissions [2]. Since China plans to reduce its carbon intensity (CO_2 emissions per unit of gross domestic product, or GDP) to 40–45% of 2005 levels by 2020, it is now still under huge pressure to control the energy consumption and CO_2 emission [3]. The purpose of this paper is to offer policy suggestions by examining the electricity saving potentials for different sectors and regions.

Various methods have been employed to study the issue of energy conservation and CO_2 emission reduction, e.g. CSCs (conservation supply curves) [4–6], econometric model [7–9], DEA (data envelopment analysis) [10–14] and input–output analysis [15–19].

Input–output analysis has been widely used to examine the impact of technology improvement and pricing policies on energy conservation and CO_2 emission reduction. Several earlier studies have also employed input–output analysis to analyze sectoral electricity consumption. For instance, Tarancón et al. analyze the direct and indirect consumptions of electricity for eighteen manufacturing sectors in fifteen European countries [15]. Mu et al. identify dominant sectors which have significant impacts on Chinese electricity consumption by using the IOTED (input–output

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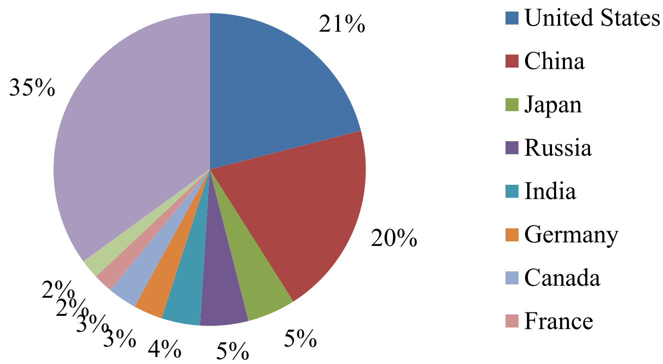

Fig. 1. The share of world electricity consumption in 2010.

table of electricity demand) [20]. Alcántara et al. use input–output approach to identify those sectors that contribute most to electricity consumption in Spain [21]. Tarancón et al. measure the impacts of consumption structure and technology improvement on electricity consumption for manufacturing sectors [22]. Similar studies can also be found in Refs. [16,23–25].

Another group of studies focus on the direct and indirect impact of electricity pricing policy on social economy and energy consumption by using input–output analysis. For example, Lim &Yoo investigate the impact of electricity price changes on production price [26]. Jiang & Tan propose an input–output model to analyze the impacts of energy subsidies reform on different industries and general price indexes [27]. Their findings show that the removal of energy subsidies will highly increase the energy consumption of energy-intensive industry.

A number of studies have devoted to look into energy-related CO_2 emissions reduction within input–output analysis framework. Tarancón& del Río examine the correlations between CO_2 emissions and different sectors by sensitivity analysis [28]. Tarancón et al. identify sectors' structural responsibilities for emissions in Spanish with an input–output framework [29]. Huang & Wu propose a two-tier KLEM structural decomposition analysis method, and use it to analyze the factors that lead to changes in CO_2 emissions [30]. Recently, Dong et al. calculate production account and consumption account (two of three perspectives of the carbon emission inventories) by applying a single-regional input–output method [31]. Su &Ang study energy-related CO_2 emissions embodied in international trade using the more advanced multi-regional input–output model [32].

In this study, we investigate the impact of technology improvement and price change on electricity-saving potentials for both industrial sectors and different provinces. For this purpose, we develop two coefficients, namely TEC (technical elasticity coefficient) and PSC (price sensitivity coefficient) within an input–output analysis framework, which can be used to identify the sectors and provinces with high electricity-saving potentials. Another indicator called EFC (electric forward correlation coefficient) is also constructed to examine the relationship between electricity-saving potential and power consumption. Based on our empirical study, we propose several policy recommendations. Compared to earlier studies, this study makes a contribution in the following two aspects. Firstly, most of the earlier studies examined electricity demand and conservation at aggregate level. However, it seems to be more practical to study this issue from the perspective of sectors and regions as done by this study in order to provide more insightful policy recommendations. Secondly, following Ref. [15], this study treats technology innovation and pricing police as two important ways for controlling electricity consumption and analyzing electricity-saving potentials, which is different from most of the earlier studies.

The remainder of this paper is organized as follows. Section 2 introduces our methodology. In Section 3, we apply the proposed approach to measure the electricity-saving potentials for 20 sectors and 30 provinces in China based on provincial input–output tables. Section 4 concludes this study with some policy suggestions from our empirical results.

2. Methodology

Input–output analysis refers to an economics term developed by Wassily W. Leontief, in which the interdependence of an economy's various productive sectors is observed by viewing the product of each industry both as a commodity demanded for final consumption and as a factor in the production of itself and other goods. The basic input–output analysis model can be written as:

$$X_i = \sum_{j=1}^{n} x_{ij} + y_i \tag{1}$$

where X_i is the quantity of output produced by sector i, x_{ij} presents the sales of sector i to sector j, and y_i is the sales of sector i to the final demand.

On the other hand, a technical coefficient a_{ij} can be defined as the productions directly provided by sector i required to produce a unit of product by sector j, i.e. $a_{ij} = x_{ij}/X_j$. It reflects the technical and economic connections between two sectors. The smaller a_{ij} is, the less the productions required by sector j from sector i. Then Eq. (1) can be written as follows:

$$X_i = \sum_{j=1}^{n} a_{ij}X_j + y_i \tag{2}$$

In matrix notation, Eq. (2) can be transformed into the following form:

$$X = AX + Y \tag{3}$$

where A is known as the direct consumption coefficient matrix and

$$A = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{bmatrix} \quad X = \begin{bmatrix} X_1 \\ X_2 \\ \cdots \\ X_n \end{bmatrix} \quad Y = \begin{bmatrix} Y_1 \\ Y_2 \\ \cdots \\ Y_n \end{bmatrix}$$

From Eq. (3), we can derive

$$X = (I - A)^{-1}Y \tag{4}$$

Let $(I - A)^{-1} = \overline{B}$, we then have

$$X = \overline{B}Y \tag{5}$$

$\overline{B}$ is called the Leontief inverse matrix, which includes the direct and indirect requirements of goods that each sector must produce to satisfy the final demand. According to the basic theory described above, we shall construct three indexes next, namely technical elasticity coefficient, price sensitivity coefficient and electric forward correlation exponent.

2.1. Technical elasticity coefficient

Following Refs. [15,33], we use TEC (technical elasticity coefficient) to measure the sensitivity of electricity consumption to technical progress. TEC can be defined as