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Industrial characteristics and consumption efficiency from a nexus perspective – Based on Anhui's Empirical Statistics

Zi-yue Chen[a], Zhen-hai Huang[b,*], Pu-yan Nie[c,*]

[a] School of Management, Xiamen University, Xiamen 361005, PR China
[b] Institute of Industrial Economics, Jinan University, 601 Huangpu Avenue, Tianhe District, Guangzhou 510632, PR China
[c] Guangdong University of Finance & Economics, 21 Luntou Rd., Haizhu District, Guangzhou 510320, PR China

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ABSTRACT

As energy and water resources are coupled during the process of manufacturing and consumption, the energy-water nexus should be obtained so as to develop a better understanding of sustainable resources consumption and reservation. In this study, we analyzed the consumption status and pattern of eight categorized industrial sectors based on the framework of input-output analysis (IOA) and network analysis. It indicates that the resource consumption status or pattern is influenced by different industrial characteristics, location and the degree that each industry benefits from policy. Similarly, such influences still exist in the energy and water efficiency measured by Finn's cycling index (FCI). The industrial structural transformation affects the resource consumption structure as well. Given that the energy-water nexus can capture the performance of industrial activities in the network and serve as a measurement of self-evaluation, the results also demonstrate the effectiveness of industrial transformation and upgrading in Anhui province. Policy implications extended from the results can provide the authorities with a reference for other transitional areas between less-developed and developed areas in a developing country. The research expands the application of energy-water nexus system in Anhui Province and provides pertinent suggestions according to the unique feature of the area.

1. Introduction

Rising demand for energy and water resulting from economic development, population growth and climate change, poses a threat to both human beings and industrial system. It is estimated that global energy consumption could increase by 48% between 2012 and 2040 (U.S. Energy Information Administration, 2016), most of which will be consumed by densely-populated urban area (Morales-Torres et al., 2016), where rural migrants are heading for as the tide of urbanization runs high. Climate changes will increase global water demand (Parkinson et al., 2016) and impact the water distribution pattern of river basin (Barnett et al., 2005), which may influence terrestrial water and energy balance substantially (Hasper et al., 2016). With the increase of drought-affected areas and drought-damaged areas during the past 5 decades (Wang and Zhang, 2012), more than half of the countries in the world will be threaten by freshwater stress or shortages and three-quarters of the world's population will have to fight for freshwater by 2050 (Hightower and Pierce, 2008), which may further bring about food crisis since consumable water is worthy for agricultural irrigation (Wang et al., 2016). Even now, it is hard to imagine that almost 20% of the world population live in water-deficient areas and 25% suffer from severe water shortages worldwide (UNDP, 2012).

In order to prepare the answer for such a dilemma, correlation study of water and energy is a task brooks no delay through water and energy have long been observed and managed separately. The nexus platform brings an appropriate modeling tool for the issue (Mannschatz et al., 2016). On one hand, a large quantity of water will be used to ensure energy supplies directly or indirectly, like coal washing and electric power generation. It is also indispensable to agricultural production during the process of producing, transporting and storing energy in different forms (FAO, 2011). Conversely, the collection, treatment, distribution, and recycling processes for water production consume energy. The demand for water heating and cooling also incurs a high demand for energy. Most industries need water as a component together with other inputs during the manufacturing process. Thus, energy consumption has a symbiotic relationship with water consumption. On the other hand, the scarcity of resources continues to urge for efficiency, which can be greatly affected by pollution, waste, market power (Jiang et al., 2016), taxation (S. Chen and Chen, 2016; Chen and Nie, 2016), uneven distribution and unsustainable management.

* Corresponding authors.
E-mail addresses: czy_0077@126.com (Z.-y. Chen), huangzhenhai@live.com (Z.-h. Huang), pynie@gdufe.edu.cn (P.-y. Nie).

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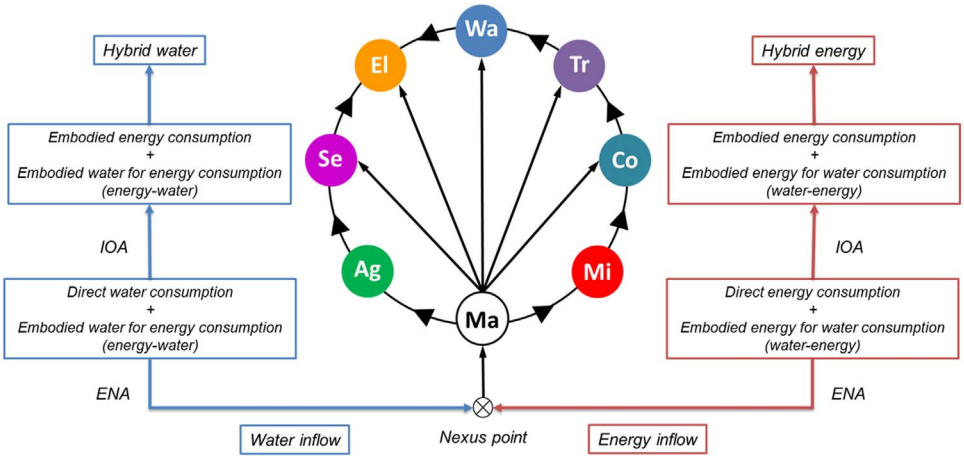

Fig. 1. Framework of provincial nexus (Chen and Nie, 2016; Chen and Chen, 2016; Wang and Chen, 2016). Note: In Fig. 1, the abbreviation Ag refers to Agriculture. Ma refers to Manufacture. Mi refers to Mining. Co refers to Construction. Tr refers to Transportation. Wa refers to Water supply. EI refers to Electricity and gas supply. Se refers to Services industry.

Tightening environmental regulations and industrial policies present another difficulty. Outdated industrial capacity, which has pollutant emissions, energy consumption and water consumption that are far from certain criteria, are becoming a bottleneck of social development and economic efficiency. Aiming to reduce pollution, save energy, and upgrade industrial structure, national policies directed to the cutting of overcapacity in some industrial sectors like coal, steel and cement, were put forward by the National Development and Reform Commission (NDRC) in 2006 (CRRA, 2006), followed by a series of supporting policies. Under the circumstances where the demand for resources overtakes the prevailing level of supply, efforts can be made to study the complex connections and discover some facts from the statistics under the industrial nexus, which is crucial for measurements and effective consumption.

Being so conductive at considering complex interactions among resource sectors as we manage and make decisions (Bazilian et al., 2011), nexus has been found to have an increasing wide use in the fields of environmental science. However, related domestic empirical research connected with energy-water nexus is seldom seen or published despite the fact that eastern China plays a prominent role as a catalyst to boost national economic growth.

Anhui lags behind other areas of Yangtze River Delta, who is suffering from both inadequate water supply and uneven distribution of water resources both temporally and spatially. It is urgent to optimize the configuration of both energy and water networks for the province. In the article, we first established an Anhui's water-energy systematic model based on ecological network analysis (ENA). Secondly, the input and output of both water and energy in each sector is calculated based on the data of Anhui Province in 2007 and 2012 according to input-output analysis (IOA). Finally, the calculated data are brought into the water-energy systematic model for analyzing the energy-water nexus of Anhui Province. The analysis contains the discussion on the intensity of the energy and water consumption in each sector and the comparison of each sector between 2007 and 2012. Additionally, some policy implications are provided for better development of the area.

The contribution of this article is mainly reflected in two aspects, which are case selection and results and policy implications. From the aspect of case selection, the application of energy-water nexus system is expanded to Anhui Province. Currently, most researches concentrate on the advanced regions while few researches are about the water and energy consumption of developing regions such as Anhui Province in China. In fact, it is pivotal to analyze the energy-water nexus of different sectors in regions where the industries are rapidly developing. The analysis contributes to solving the problems by policies in the process of local development to avoid the developmental pattern of the administration after the contamination. From the aspect of results and policy implications, the feature of energy consumption and water consumption in Anhui Province differs from that in other developed regions in China such as Beijing-Tianjin-Hebei region and Pearl River Delta. It is because the industrial structure and industrial policy of Anhui Province is different from that in developed regions but is similar to that in other central regions in China. As a result, pertinent suggestions are provided in this paper based on the energy consumption and water consumption in Anhui Province. The suggestions not only contribute to the optimization of industrial structure in Anhui Province, but also have a certain reference value to the adjustment of industrial structure and the sustainable development of the economy in other central areas in China.

The rest of this article is structured as follows: The methods needed for data processing are covered in Section 2. As an example for the following text, Anhui province is introduced in detail as well. The results and discussions are shown in Section 3. First, preliminary results concerning consumption proportions are compared in different charts. Then, explanations for various circumstances combined with industrial characteristics and policy are provided. Next, the consumption effectiveness of each sector is discussed respectively. Finally, conclusions and policy implications are presented in the last section.

2. Methodology and data sources

2.1. Model framework

The methods of theory-model and positive analysis are employed in this article. According to the core concept of ecological network analysis (ENA), provincial nexus network (PNN) of energy and water flows will be constructed as a system-based framework (Fig. 1). Industrial consumers from each sector also need a platform to play a role since they are essential to be researched and motivated. Having been introduced to environmental science via ENA, input-output analysis (IOA), advanced by Leontief (Leontief, 1953), helps to quantify estimations of the inputs and outputs. Based on IOA, 42 segmented industries listed in input-output table would be merged and summarized into 8 sectors as the table shown in appendix A: services industry (Se), transportation (Tr), construction (Co), water supply (Wa), electricity and gas supply (El), manufacturing (Ma), mining (Mi) and agriculture (Ag), whose direct and embodied consumption contained by energy and water flows would be merged and calculated under the framework. Based on the data of Anhui province, direct water for energy supply and energy for water supply within the framework would be implicated in IOA. Hybrid energy, the aggregation consumption of direct energy and embodied energy (water-energy), would be converted into equivalent inflows along with hybrid water to the PNN comprised of eight merged sectors through the nexus point. Starting from manufacturing (Ma) and converging to electricity and gas supply sector (El), the figure of PNN