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Economic effects analysis of seawater desalination in China with input–output technology

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HIGHLIGHTS

- The paper made seawater-desalination investment effects in China innovatively with input-output analysis.
- The results showed the seawater desalination had a large investment multiplier 2.488.
- It had obvious demand pulling and supply pushing effects on Chinese economy.

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ABSTRACT

Seawater desalination is an important way to alleviate the shortage of water resources in the coastal area. To provide reference for investment decisions on seawater desalination, this paper made the economic effects analysis of seawater desalination investment in China. The competitive partial closed input–output model was applied. The results showed that the seawater desalination sector had a large investment multiplier 2.49 (ranked 9th in 18 sectors). Its influence coefficient and sensitivity coefficient were 1.09 (ranked 8th) and 1.14 (ranked 6th) separately, which revealed that it had obvious demand pulling and supply pushing effects on the national economy.

1. Introduction

China is severely short of water, which accounts for about 6% of global freshwater resources and its water consumption per capita is less than 2200 m^3 which is a quarter of the world's average. In 2014, more than 400 cities out of 561 cities were deficient in water resources in China. Most of them are located in the north, semi-arid and arid regions of northwest China. In 32 megalopolises that the population is over one million, there are 30 cities plagued by water shortages for a long time; in 14 open coastal cities, there are 9 cities that seriously lack of water resources. Due to excessive exploitation of groundwater, land subsidence, regional underground funnel area increase, the ecological deterioration and geological disasters and other issues happen more frequently in some water shortage cities. Water scarcity has restricted the economic development of China.

Fresh water accounts for about 97% of the total seawater, equivalent to the maximum steady and reliable fresh water reservoir, and seawater desalination is a promising way to release water scarcity. Analyzing economic effects of seawater desalination could help the government and investors make appropriate investment decisions. Notwithstanding, the related literatures we retrieved were mostly from the perspective of direct cost analysis, and we haven't found literatures which made economic effects analysis of seawater desalination through inter-industries. There are different processes of seawater desalination such as MSF, ED, thermal and membrane. The costs of them are different, generally thermal and membrane processes with economic advantages [1–5]. For example, [5] carried out firstly an extensive economic evaluation of FO–RO hybrid, benchmarked against stand-alone RO system, the results showed that FO–RO hybrid could be beneficial only for high energy costs and/or substantial operational cost savings, comparatively to RO. It was also demonstrated that improvement in water permeation flux was an absolute prerequisite to lower investment costs down to an economically acceptable level. For the impact of project scale on the cost of seawater desalination, it is found that expansion of the scale of seawater desalination projects could reduce the unit cost [6–7]. Some research is concerned with the cost comparison of seawater desalination projects which consumed different kind of energy [8–11]. There are several literatures on direct cost analysis and assessment of seawater desalination, such as Ref. [12] explored the development of seawater desalination costs over time which included the transport cost of desalinated water to the destination cities; [13] provided an overview of factors that determined seawater desalination cost, typical

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seawater desalination cost estimation models and approximate cost estimate; [14] reviewed seawater desalination cost literatures to allow meaningful comparisons. Ref. [15] provided an in-depth cost and price analysis of desalination with country specific examples, depicted a comprehensive picture of cost variability of desalinated water and pointed out challenges for cost-effective desalination in the future. Ref. [16] analyzed the economics of desalination by cost analysis and its potential application to Australia, and showed that in Australia the cost of traditional fresh water sources may rise which will promote the development of desalination. For estimating methodologies of seawater desalination cost, Ref. [17] reviewed the history of seawater desalination cost estimations; Ref. [18] presented a clear and easy methodology for estimating seawater desalination costs; Ref. [19] presented a techno-economic evaluation and review of the costing aspects and the main parameters influencing the total water cost produced by different seawater desalination technologies in detail; The IAEA DEEP software has been applied for economic evaluation of seawater desalination plants [20–22]. Ref. [23] analyzed costs of more than 24 thermal desalination plants to evaluate the reliability of them. However, we didn't find research on the investment effects, the demand pulling and supply pushing effects of the seawater desalination on the other industries in a national economic system, which could help the government and investors make appropriate investment decisions and development planning. Input–output analysis method is one of the most widely applied methods in economics, which can analyze effectively the interdependence of industries in an economy. It was developed by Wassily Leontief in the late 1930s, in recognition of which he received the Nobel Prize in Economics Science in 1973. The model is widely applied throughout the world, such as the United Nations has promoted input–output as a practical planning tool for developing countries and has sponsored a standardized system of economic accounts for constructing input–output tables; the US Department of Commerce applied input–output routinely in national economic analysis, and in regional economic planning and analysis by states, industry, and the research community [24]. Input–output method is used to identify the best approach when we reveal knowledge about an area's economy, estimate total impact of certain events or policy changes and evaluate and assess specific goals, scenarios, etc. [25]. With respect to China, it was frequently used to estimate the effect of policy implementations on water use efficiency, water pricing; buildings' energy saving potentials etc. [26–32]. In this paper we compiled an input–output table with seawater desalination industry as a separate sector based on China Input–Output table in 2010. The competitive partial closed input–output model was applied to make the economic effects analysis of seawater desalination investment in China economic system.

In the following parts of the paper, Section 2 described the present situation of seawater desalination in China. Section 3 made cost analysis of seawater desalination in China. Section 4 introduced input–output method. Section 5 made economic effects analysis of seawater desalination in China. Section 6 presented conclusion.

2. The development of seawater desalination in China

In China, the capacity of seawater desalination increased very slowly before 2005, after that it increased rapidly and the average annual growth rate reached to 73.32% during the '11th five-year plan'(see Fig. 1). By the end of year 2013, China had built 103 seawater desalination projects, which produced 900,830 m^3/d desalted water, increased 16% compared with 2012, and 8 seawater desalination projects were newly built in 2013 whose total capacity is 125,465 m^3/d. In China, the largest low-temperature multi-effect desalination project produced 200,000 m^3/d and the largest reverse osmosis desalination project produced 100,000 m^3/d at the moment.

China's seawater desalination projects mainly locate at coastal cities and islands, most of them are in North China which has shortage of water resources. The desalinated seawater is consumed by industries such as the electric power, iron and steel and other high-water consumed industries. These industries are mostly concentrated in Tianjin, Hebei, and Shandong province of China. In South China, desalination projects mostly locate at Zhejiang, Fujian and Hainan whose capacity is hundreds of tons or thousands of tons usually. Tianjin has the largest seawater desalination project whose capacity is 3,172,000 m^3/d, and the capacity of seawater desalination projects in Hebei, Shandong and Zhejiang is also more than 100,000 m^3/d. Among them, Shandong province had the biggest expansion of seawater desalination capacity in 2013, the capacity increased from 65,200 m^3/d to 165,200 m^3/d and the increased rate was 153.37% compared with 2012.

The two main processing technologies of seawater desalination named reverse osmosis (RO) and low-temperature multi-effect distillation (MED) are adopted in China. In 2013, there were 90 projects applying RO which produced 573,540 m^3/d and accounted for 63.67% of the total capacity. There were 11 projects that applied MED which produced 321,090 m^3/d and accounted for 35.64% of the total capacity.

Concentrated seawater was a by-product of the seawater desalination process. It can be recycling used or discharged directly into the sea. Caofeidian Industrial Zone set a good example in the concentrated seawater recycling. Annually, 18 million cubic meters of concentrated seawater is treated, 600,000 t crude salt is produced, 10 million cubic meters of water resources is saved, 40,000 t of carbon dioxide emissions is reduced. The annual benefit is about 80 million RMB [34]. The successful experience of Caofeidian Industrial Zone has been popularized in China.

3. Cost analysis of seawater desalination in China

Seawater desalination costs were mainly composed by investment cost, comprehensive water cost and transportation cost. In this paper,

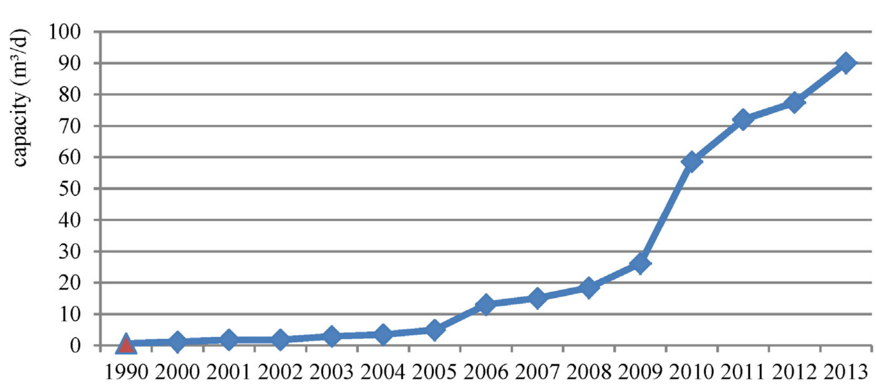

Fig. 1. Change trend of seawater desalination capacity in China during 1990–2013.
Source: the data of 2012 and 2013 years are from the 2012 National Seawater Utilization Report and 2013 National Seawater Utilization Report published by the State Oceanic Administration, other data are from Ref. [33].