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Research article

Impact of socio-economic growth on desalination in the US

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ABSTRACT

In 2013, around 1336 desalination plants in the United States (US) provided purified water mainly to municipalities, the industry sector and for power generation. In 2013 alone, ~200 million m^3 of water were desalinated; the amount that could satisfy annual municipal water consumption of more than 1.5 million people in the US.

Desalination has proven to be a reliable water supply source in many countries around the world, with the total global desalination capacity of ~60 million m^3/day in 2013. Desalination has been used to mitigate water scarcity and lessen the pressure on water resources. Currently, data and information about desalination are still limited, while extensive socio-economic analyses are missing. This paper presents an econometric model to fill this gap. It evaluates the impact of selected socio-economic variables on desalination development in the US in the time span 1970–2013. The results show that the GDP and population growth have significantly impacted the desalination sector over the analyzed time period. The insights into the economics of desalination provided with this paper can be used to further evaluate cost-effectiveness of desalination both in the US and in other countries around the world.

1. Introduction

1.1. Background and research objectives

Since 2000, recurring droughts in many regions in the US put a tremendous pressure on water resources and caused considerable financial losses in all economic sectors. For instance, the 2011 drought in Texas caused $7.2 billion in losses in the agricultural sector alone (Fannin, 2012), while the current drought in California has been estimated to cost $2.2 billion in losses as of 2014 (Chaussee, 2014). Desalination can provide a solution to those problems by supplying purified water in times of water scarcity. It has proven as a reliable water supply source in many countries (Drouiche et al., 2011; Tapsuwan et al., 2014; Sahin et al., 2015) and has been appreciated, among others, for its independency from climatic conditions (Crisp and Swinton, 2008; Ghaffour et al., 2013).

The global desalination market has experienced a rapid growth since the mid-1990s, with seasonal highs and lows and an anticipated annual growth rate of almost 9% in 1990–2018. Also the desalination capacity and the amount of desalinated water have been growing up to ~60 million m^3/day in 2013 at the global scale and up to ~4.9 million m^3/day in the US (GWI, 2013).

The developments of the desalination technology and sector are determined by many factors, among others, the economic growth, R&D, technology investment rates, and demand for desalinated water resulting, for example, from the population growth. Most of the studies addressing economics of desalination focus on technological cost-effectiveness, comparisons and improvements of the desalination technology and filtering membranes as well as decreasing the total desalination costs at the micro scale (Tian et al., 2005; Kaldellis and Kondili, 2007; Mezher et al., 2011; Kesieme et al., 2013). However, studies are missing that would depict macro-economic factors impacting desalination developments over time. This paper seeks to fill this gap and provide an added-value to the literature in the field by means of an econometric socio-economic model with time series analysis for the US desalination sector. The main goal of this paper is to analyze the impact of selected socio-economic factors, such as Gross Domestic Product (GDP), population growth, crude oil prices, and water withdrawals on the development trends in the US desalination sector. The analysis can be used to extrapolate and forecast future

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developments and improve planning and investments in the desalination sector in the years to come.

1.2. Desalination sector and the US economy

The US desalination sector provides desalinated water mainly for municipalities as drinking water, for industrial processes, and for thermoelectric power generation (Fig. 1). Desalination is also used for irrigation, military purposes, tourist facilities, although the application in those sectors is miniscule.

The analysis of desalination patterns in different sectors shows several irregularities. Industrial water use embraces water for fabricating, processing, washing, diluting, cooling, incorporating water into a product or transporting the final product. As most of those processes require freshwater quality, desalinated water provides a valuable source that does not impact surface water flows. Desalinated water used for municipal purposes as drinking water is mixed with water from treatment plants at roughly 10% of the total municipal water portfolio. On the one hand, desalinated water used for municipal purposes helps to lessen the pressure on groundwater and surface water resource, on the other however, higher prices of desalinated water mixed with traditional municipal water sources could have a slight impact on the final water rates paid by consumers. According to AMTA (2007), the mix percentage ratio of 90–10 of traditional and desalinated seawater, respectively, generates a 22% increase in water rates for the final consumers. Water used for power generation is applied mainly for cooling purposes. According to USGS (2009), in 2005 thermoelectric power generation was the main water user (49% of the total water use), while municipalities used 11% and the industry sector used only 4% of the total water withdrawals in the country.

The results of our research show that the industry sector experienced a major increase in desalinated water use starting in 1970. Between 1970 and 2000 the desalination capacity was growing as did the number of desalination plants providing purified water for industrial processes. Between 2000 and 2008 only a few desalination plants for industrial purposes were built, while the previously established plants maintained their usual operation. Another wave of new emerging desalination plants started in 2008, with their production capacity levels similar to those from before 2000 (Fig. 2). The economic crisis in 2000 did not affect the use of desalinated water either for municipal purposes or for thermoelectric power generation. Desalinated water use for municipal drinking increased over time, both in terms of the production capacity and the number of new plants (Fig. 3). This indicates that municipal water demand was not affected directly by external or internal factors or possible economic and political events, like it was the case with the industry sector. Moreover, the developments of desalination for municipal purposes shows a steady and consistent trend over years indicating that a large number of plants operating at a similar capacity has been established in the consecutive years, especially since the 1990s. Desalination for power generation can be characterized as random, which is substantiated by several gaps in the data points denoting irregular and inconsistent developments in this sector. There is no clear trend or pattern in desalination for power generation, while also the number of new plants is smaller than in the other two sectors (Fig. 4).

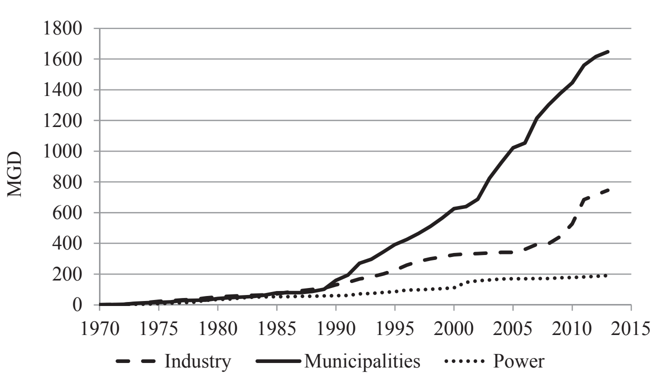

Fig. 1. Sector specific cumulative capacity of desalination plants in the US in 1970–2013.
Source: Authors' calculations based on DesalData.com.

1.3. Socio-economic determinants of desalination

The main factors determining desalination developments in the US have been specified in this study as follows: economic growth expressed with GDP, market stability measured with crude oil prices, population growth, and water withdrawals for different sectors and uses. Studies have shown that water withdrawals consistently increase with growing population needs (Engelman and LeRoy, 1993; GWI, 2013; Wiltshire et al., 2013; Murray, 2012). This indicates that with the growing water demand, and simultaneously occurring water shortages due to aquifer depletion or drought, both the interest in the desalination technology and the demand for desalinated water will increase as the population rates go up. Several studies confirmed that desalination could augment water supply in different regions (Dawoud, 2005; Chen et al., 2015). In 1970–2013, the average total water withdrawals in the US amounted to 398.4 billion gallons/day, with annual fluctuations and consumption spikes in 1980 and 2000, and local lows in 1985 and 2010 (USGS, 2014). Those changes might have been determined by industrial needs (possibly, but not necessarily triggered by political events) and regional droughts that substantially influenced human water consumption patterns.

Furthermore, many studies analyzed economic efficiency of different desalination processes and membranes (Alhazmy, 2014; Ayoub and Malaeb, 2014; Shahabi et al., 2015; Mazlan et al., 2016). Most studies investigating economic impacts at the micro and macro scale have found that investments in different sectors can influence economic growth (Rolfe, 2013; Mitchener and Wheelock, 2013; Samargandi et al., 2014; Silaghi et al., 2014). Only a few studies analyzed the opposite relation and the impact of economic growth on sectoral performance in a country (Prahdan et al., 2014). Referring to the desalination sector that provides only 2–3% of the total water supply in the US, and thus takes a small share in the entire water portfolio, it is relevant to determine if and how far economic growth in the US has impacted the development of the still unstable desalination sector over time. This will allow for evaluating future perspectives of the desalination sector. Moreover, given the fact that the economic growth rates impact entrepreneurial risk aversion, investment rates and finally the expenditures, we hypothesize that economic growth will directly and significantly affect investments and developments in the desalination sector in the years to come.

Since 1970, the US population has been continuously growing reaching 316 billion people in 2013 (US Census Bureau, 2014). In this time, the US economy has been fluctuating due to a multitude of economic events, such as: oil crises in 1973–1975, 'double-dip' recession in 1980, the oil price shock in 1990, dot-com bubble and September, 11th attacks in 2001, and finally the global financial crisis in 2008. All those events considerably affected the US economy, the operations of all economic sectors and thus the national Gross Domestic Product (Fig. 5).

Crude oil prices are very variable and have been constantly fluctuating in the analyzed time period due to a series of political events and global economic changes. The oil production peak in