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Article

Domestic and International Drivers of the Demand for Water Resources in the Context of Water Scarcity: A Cross-Country Study

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Abstract: Global warming, while increasing human demand for water, is reducing water availability by reducing runoff flows and the effective amount of water between seasons, making water scarcity a growing problem globally. Water management plays an important role in mitigating global warming, improving the water cycle, reducing carbon emissions, and providing clean energy, and pricing water is considered a good approach to water management. Pricing water needs to take into account all sectors and aspects of society, such as domestic water, food and agriculture, energy, transport, industry, urban provision, human health, ecosystems, and the environment, and their interrelationships through water, within the context of the fundamental human rights to water and sanitation. This requires that every stakeholder should contribute to the development of water-related policies at every stage of the water interrelationship. This study investigated the relationship between water demand across different sectors of the economy using indicators for China, Australia, Japan, and the UK. Using panel analyses, this study finds that economic growth and population expansion increases the demand for water in all aspects. These findings have significant policy implications for water management. Because water prices can have an impact on global trade and, more importantly, are a major solution to global warming, water management policies should be considered at the global level, not only at the national level.

Keywords: global warming; water scarcity; water pricing; water management; China

1. Introduction

Global warming¹ affects climate change, ecosystems, living conditions, urban development, and economic development in a variety of ways, and water has become one of the main channels by which human feel these changes. These effects are becoming increasingly evident; for example, between 1901 and 2010, the global mean sea level rose by 0.19 m at the highest rate ever recorded (Church et al. 2013). Even a small amount of mean sea level rise will significantly increase the frequency and intensity of global flooding (IPCC 2019), with about 1.3% of the global population exposed to a 100-year flood (Muis et al. 2016). Increased water temperatures also alter the biogeochemical balance of freshwater ecosystems, leading to water quality degradation through frequent algal outbreaks

¹ Global warming is caused by human emissions of large amounts of carbon dioxide and other greenhouse gases that are accumulating in the atmosphere through the burning of fossil fuels, primarily coal, oil, and natural gas (IPCC 2019), resulting in an additional increase in global surface temperatures compared to pre-industrial revolution levels.

and rapid growth of pathogens (Chapra et al. 2017). In the last 100 years, it is estimated that the world has lost half of its natural wetlands and, as a result, a large number of freshwater species² (UN Environment/UN-Water 2018).

Countries such as Singapore are surrounded by water reserves but do not have sufficient potable water for human consumption and so must rely on imports, harvesting rain water, and recycling sewage water. Water scarcity is an issue globally, for example in South Africa, Australia, and India, and even in countries such as Vietnam, despite its abundant water from natural rivers, streams, and significant rainfall. Some cities, such as Amman, Cape Town, and Melbourne, may experience a 30% to 49% decline in future freshwater availability, while Santiago may experience a decline of more than 50% (C40 Cities 2018). Policy makers focus on adjusting the policy framework for managing fresh water supplies, in terms of managing water scarcity, but the rise in water demand is accelerating. Global water demand is characterized by several features. Firstly, it is worth noting that water consumption has grown more than twice as fast as population growth in the last century (FAO 2013). The report finds that the global demand for water has been increasing at a rate of about 1% per year during recent decades as a result of population growth, economic development, and changing consumption patterns, among other factors. Secondly, by 2050, 685 million people living in more than 570 cities will face an additional reduction in freshwater supplies of at least 10% as a result of global warming. More seriously, water shortages will continue to worsen in the future, with 52% of the world's population expected to be living in water-scarce areas by 2050 (Kölbel et al. 2018). Thirdly, industrial and domestic demand for water will increase significantly more quickly than agricultural demand, although agriculture is expected to continue to have the largest overall demand, at least in the short to medium term. Finally, the report also shows that the vast majority of growth in the demand for water will occur in countries with developing or emerging economies (World Water Development Report 2018).

Growing populations, industrialization, and globalization contribute to this increase in demand for water. Research thus far has examined direct water consumption in agriculture, in addition to the impact of agriculture and industry on water pollution and, therefore, on water scarcity.³ At an international level, the availability of water at lower prices provides a competitive advantage for firms (and at the national level for countries) in production and trade. In an environment in which water is scarce, the availability and accessibility of cheaper water of good quality will provide an essential resource for production. Access to essential resources will provide firms and countries with a competitive advantage in international trade. This comparative advantage is likely to enhance international trade and thus improve economic growth, because a positive relationship exists between international trade and economic growth. A report by Frontier Economics finds a 5% increase in economic growth (measured by GDP) by achieving millennium development goals (MDG) and a 15% increase in economic growth if universal access to safe drinking water is achieved. However, the reliable supply of water has become more volatile and uncertain because water and sanitation services, including water and wastewater treatment facilities, are highly vulnerable to global warming (UNU-INWEH/UNESCAP 2013; FAO 2017; IPCC 2018).

Climate change affects global water resources through complex spatial and temporal patterns, feedback effects, and interactions between physical and human processes (Bates et al. 2008). This impact on water resources can be observed in two ways: increasing demand (e.g., population growth, the need to produce more food, and economic growth) and decreasing supply (e.g., pollution and changes in precipitation patterns) (Wada and Bierkens 2014). It is estimated that approximately 4 billion people live in conditions of severe physical water shortages for at least one month of the year (Mekonnen and Hoekstra 2016; UN-Water 2020). In addition, approximately 1.6 billion people, nearly one-quarter of the world's population, face economic water shortages, meaning they lack the

² Freshwater species have suffered the greatest decline, falling by 84% since 1970 (UN-Water 2020).

³ The World Bank report shows that, of all water withdrawals, 70% is for agriculture purposes http://www.circleofblue.org/wp-content/uploads/2012/06/HSBC_June2012_Exploring-the-links-between-water-and-economic-growth.pdf.

necessary infrastructure to access water (UN-Water 2014). Urban water supplies are particularly vulnerable due to high urban population density and increasing urbanization. The social consequences of water scarcity are severe; for example, water shortages exacerbated by climate change may cost up to 6% of GDP in some regions, while also stimulating migration and triggering social conflict, and creating problems regarding human rights, food security, human health, energy production, biodiversity, and famine (FAO 2018).

Nonetheless, it is not necessary for water to only be a problem; it can also be part of the solution to global warming. Water management can play a big role in mitigating climate change, improving water recycling, reducing carbon, and providing clean energy, as follows: (1) Water-related ecosystems, such as wetlands, lakes, forests, and even agriculture and other nature-based solutions, can help sequester carbon in biomass and soil. (2) Wastewater in some areas can generate clean energy, biogas, to reduce greenhouse gas emissions. (3) Hydropower is already the world's largest source of renewable energy (IEA 2017). (4) Excellent and proactive water management can enable industries to reduce water use by more than 50% (Andrews et al. 2011; WBSCD 2017). (5) Enterprises can adopt circular water management, in which water use moves from a linear process of increasing pollution (into wastewater) to a circular process in which water is recycled for further use (Stuchtey 2015). (6) Measures to improve water use efficiency can help mitigate climate change by reducing the energy demand for treating, transporting, and disposing of water and wastewater, and for better treatment and disposal of sludge and other forms of waste (UN-Water 2020). Therefore, water managers must consider the potential impacts of climate change and manage water as a social resource that is essential for sustainable development.

To provide the most efficient use of resources in a free market, resources are allocated based on demand and supply. Prices, considered to be a driving force in this resource allocation, have been found to be an effective tool even in cases of disaster recovery (Rose 2004). Prices have three levels of advantage for water management: (1) Governments can use revenues from pricing water to control waste, pollution, and eutrophication, and subsidize clean energy technologies to increase the use of clean energy. (2) Following the setting of water prices by governments, the market price of water-consuming commodities will increase and market profits will decrease. As a result, the market will be forced to improve water use efficiency in a cost-effective manner by developing more energy-efficient technologies or alternative renewable energy sources to hedge against double environmental taxes on water and carbon. (3) Water pricing can help governments design and monitor long-term water management goals in response to water shortages and global warming. However, global water prices are likely to shift less water efficient⁴ production processes to territories where water is cheaper, and shift products with higher water efficiency from territories where water is more expensive. This is likely to hurt developing countries, where water is cheaper and a paucity of capital causes less effective water management. This will potentially exacerbate the water situation in these countries, due to the cyclical effect of water consumption in the production process without effective measures for managing recycling and investing in water management. This means that effective water management will be paramount, and must occur prior to the establishment of a global water pricing system. Furthermore, the word "water" rarely appears in international climate agreements, despite its key role in issues of food security, energy production, economic development, and poverty reduction.

The study was motivated by a desire to investigate the domestic and international drivers of the demand for water by focusing on the situation in China. China was selected as an example of a country traditionally dependent on agriculture that, in recent decades, has shifted its focus to manufacturing. China's shift in economic structure from agriculture to manufacturing industries began in the 1950s. In 1952, more than 83% of China's workforce was employed in agriculture; these values fell to 55.31%

⁴ This paper interprets water efficiency in production as the processes in which less water is needed in production to yield relatively higher prices for the finished product (UN-Water 2020).

and 17.51% in 1991 and 2017, respectively (Cheremukhin et al. 2015; World Bank 2020). Currently China, the biggest exporter of manufactured goods in the world and a leading economy in international trade, is also the largest consumer in the world, due to its economic growth in recent decades and the size of its population, which is the world's largest. Notably, in addition to economic benefits, the most fundamental value of water is that it provides effective enjoyment of the human rights to water, food, and sanitation for billions of people. Thus, it is important to address the issue of pricing water separately from that of agriculture water, household water, and industrial water consumption. To provide international relevance for the study, three developed countries—Australia, Japan, and the United Kingdom—were also analyzed. This is the first study to examine the internal and external drivers of the demand for water at the aggregate, sectoral, and provincial levels. The findings of the study will initiate debate and promote further research for the formulation of relevant strategies for the efficient management of scarce water resources at both domestic and global levels.

2. Literature Review

The relationship of water with economic growth and trade is a new research area, although it may appear that the issue is disparate. However, this important issue needs attention from both academic research and policy perspectives. The literature review regarding this issue highlights the scarcity of water globally, its importance for sustenance, and the role that water plays in growth and global trade. The review provides a backdrop to water scarcity. The theoretical framework uses pricing as a tool for resource reallocation, which can be applied to the water sector as a global pricing mechanism, rather than via different systems used globally that mix the market mechanism with government-controlled mechanisms. The review also provides a justification for using China as test case and discusses the applicability of the study to the global context.

2.1. Overview of Water Scarcity

Immediately following industrialization, global CO₂ emissions rose slowly, reaching less than 1 billion tons per year. This increased to emissions of about 5 billion tons per year by the mid-20th century and then soared to more than 36 billion tons per year at present (IPCC 2019). As a result, the world's average temperature has risen by about 0.9 °C above pre-industrial levels and continues to grow at a rate of 0.1 to 0.3 °C per decade (IPCC 2013; IPCC 2018). Continued emissions of greenhouse gases are leading to further warming and long-term changes in all components of the climate system, resulting in serious, widespread, and irreversible impacts on humans and ecosystems (UNCTAD 2016), including extreme weather, meteorological disasters, global generalized heat increase, and sea level rises (Min et al. 2011). The impact of these disasters is staggering; for example, global flooding and extreme rainfall events have risen by more than 50% in the current decade (EASAC 2018) and have killed 166,000 people over the past two decades, resulting in total economic losses of nearly USD700 billion (EM-DAT 2019).

Global warming has led to reductions in runoff flow and effective water volume across seasons (IPCC 2018). These reductions have a direct impact on water withdrawals for irrigated agriculture, industrial production, and domestic supply, in addition to power generation, navigation, fisheries, recreation, and ecosystems (UN-Water 2020). At the same time, water demand is increasing due to global warming (Gato et al. 2007). Due to population growth, rapid economic development, and shifts in consumption patterns, global water consumption has increased dramatically by a factor of six over the past 100 years (AQUASTAT 2010) and continues to grow rapidly at a rate of about 1% per year (AQUASTAT 2020).

Problems relating to the scarcity of freshwater are growing globally. Water scarcity is amplified by increasing water demand and decreasing water supply, with at least 1.1 billion people globally suffering from water shortages (CRED/UNISDR 2015). This scarcity is especially acute in the arid and semi-arid regions: the Middle East, Africa, Mediterranean Europe, Australia, North West China, Northern Mexico, parts of South America, the west of the U.S.A., and Vietnam (Kanakoudis 2002;

WWC 2009; Kanakoudis et al. 2016; Huang et al. 2017; Kanakoudis et al. 2017a; Kanakoudis et al. 2017b; IPBES 2018; Gheuens et al. 2019). In the American West, providing a sufficient fresh water supply to meet the growing demand is a particular problem in urban areas. Rapid population growth rates and the occurrence of persistent droughts are outstripping available water supplies. Furthermore, greater environmental and recreational demands for water are creating additional pressures on the existing supplies of water (Libecap 2005).

It is important to note the pace of economic change in China, which has been extremely rapid since the start of economic reforms in 1978. The acute water scarcity problem in China is similar to that of other rapidly developing economies. The key characteristic is the mismatch between the spatial distributions of water resources, economic development, and the other primary factors of production; this mismatch leads to the separation of production and consumption of water-intensive products; for example, the northern, northeastern, and northwestern parts of China have 57% of the country's land area but only 15% of its freshwater resources, whereas the eastern, central, and southern areas, with 43% of freshwater resources, have 57% of China's population and contribute 64% of GDP (Zhang and Anadon 2014).

2.2. Water Pricing

A large amount of the literature has raised concerns regarding the growing scarcity of water and suggested strategies for the pricing and allocation of water resources (Kanakoudis et al. 2012; Loch et al. 2013; Bakker et al. 2014; Lund 2015). However, there appears to be neither a consensus nor an optimal solution to water pricing due to a number of reasons. Firstly, there is a lack of awareness that water is finite, which is evident from the fact that water is rarely discussed in international climate agreements (UN-Water 2020). Secondly, the most basic value of water is the human rights of living water, food, and sanitation, and therefore the welfare nature of water pricing means it is difficult to measure the value of water in terms of purely market prices. Thirdly, pricing water needs to take into account all sectors and aspects, including agriculture, energy, transport, industry, cities, human health, ecosystems, and the environment, in addition to their interrelationships through water (UN-Water 2020).

The management of available supplies of water involves thousands or even millions of operating, financial, planning, policy, and use decisions made at hourly to decadal time scales (Lund 2015). Water users and operators make most decisions, whereas relatively few decisions are made by the system administrators. Harmonizing these many decisions across a complex and interdependent water system requires an effective social and economic framework, with a larger social and economic system for support. Resource allocation within the water sector at present is inefficient. This inefficient allocation is guided mainly by incomplete markets for water (Lund 2015).

Typically, water prices are set three to five years in advance by a pricing regulatory authority. The prices are set to avoid "monopoly pricing" by water suppliers, who could take advantage of being single-source suppliers. Even so, the traditional fixed price ignores the impact of weather on supply. With fixed pricing, the amount charged to consumers is unchanged and the price is set too low to balance demand and supply in dry years (Grafton 2010). To correct this imbalance, alternative measures (such as mandatory water restrictions) are used. Where mandatory water restrictions have not been sufficient, or where on-going water restrictions have been considered to be too costly, investments augmenting water supplies have been made. In Australia, the cost of mandatory water restrictions amounts to almost one billion dollars per year (Productivity Commission 2008, p. 28). Inefficient water pricing has long-term costs for water consumers and taxpayers.

Thus, climate change has fundamentally changed the way in which water resources are managed. Traditionally, water managers have used historical trends to predict future water availability and water pricing but, as temperatures rise, all aspects of the hydrological cycle are affected and, in many cases, the historical baseline is no longer a reliable indicator of water availability (Milly et al. 2008; Rodell et al. 2018).

Discussion about the efficient allocation of resources has taken place over a long period of time (Koopmans 1951). An efficient allocation of resources is essential to reaching a desirable situation in which our scarce resources are used to produce particular types of goods and services that best maximize the overall satisfaction of society's needs and wants, wellbeing, or living standards. Common access goods, including environmental and natural resources such as air, minerals, oil, forests, river water, and ocean-going fish, are both non-excludable and rival each other. With common access goods, the market fails to send the proper price signals that lead to an efficient allocation of resources. This is a serious problem for society because the survival of current and future generations may be jeopardized when these goods are depleted.

Water, one of the fundamental natural resources, is crucial for social development. Increasing world population, improving living standards, changing consumption patterns, and expanding agricultural irrigation have increased global demand for water (FAO 2013; Mekonnen and Hoekstra 2016; Veldkamp et al. 2015; Kölbel et al. 2018), leading to growing problems of fresh water scarcity throughout the world. Mekonnen and Hoekstra (2016) document that four billion people, i.e., two-thirds of the global population, experience severe water scarcity. Given this water scarcity, in coming decades, water may become the most strategic resource, especially in arid and semi-arid regions of the world.

In response to growing water scarcity, efficient allocation of water resources and proper water pricing become crucial. The key discussion is centered on water rights and water pricing; for example, one group of scholars recognizes water as an economic good (Bauer 2010; Hanemann 2006; Rogers et al. 1998; Rogers et al. 2005). Such shifts have prompted interest in market mechanisms that allocate water for direct human uses and ecosystem needs, involving transfers of established water rights between willing buyers and sellers, based on agreed prices.

Water pricing can be used as an efficient mechanism to manage water uses. Switching to a more appropriate pricing scheme can adjust inefficient levels of water use by changing water demand (Wang et al. 2010). For example, Kanakoudis (2002) present residential water conservation techniques that validate the practicality and effectiveness of the operational measures included in a comprehensive residential water conservation program. This urban water pricing policy program was implemented in a rapidly growing area under water-scarce conditions in Athens, Greece. However, implementation of water pricing has been a challenge for both governmental and nongovernmental decision makers. Developing countries, for example, usually suffer from inadequate water supply facilities and lack sophisticated and comprehensive water pricing systems. Thus, they are in need of more practical and effective water pricing methods. Drought and climate change are unevenly distributed geographically, and risks are generally higher for vulnerable populations and communities in countries at all levels of development (IPCC 2014). Moreover, developing countries have less capacity to cope with the impacts of climate change, and the poorest groups and societies are most vulnerable to both small and large shocks. Many developing countries lack financial resources for adaptation and mitigation efforts, and, for some, the ability to act may also be hampered by poor governance (Das Gupta 2013).

Current water pricing mechanisms are in line with the classical economic theory of the supply and demand relationship. The pricing mechanism can be further divided into the supply-side strategy and the demand-side strategy, which focus on balancing the investment and revenue of the water supply service, in addition to capturing the value of water use to users at given prices (Wang et al. 2010). Various reasons cause this price inefficiency, including an incorrect estimation of the average price, a low evaluation of the social value of water, a weak enforcement of economic regulation by local governments, and a non-discriminatory price (Garcia and Reynaud 2004).

Because of the growing number of areas facing water scarcity, it is essential to adapt water management strategies beyond traditional water supply and demand management methods (Wang et al. 2010). Consumption of water primarily relates to the usage of freshwater and the discharge of wastewater that contains a certain amount of pollutants. Water management can either be done by directly controlling the use of water or by controlling the pollution that can be added to water. Controlling water pollution is similar to controlling environmental pollution via the use of carbon

trading schemes in carbon markets. Carbon was not initially priced; to make it cheaper for companies and governments to meet emissions reduction objectives, carbon trading was designed in two forms: “cap and trade” and offsetting.

Under the cap and trade scheme, governments or intergovernmental bodies, such as the European Commission, hand out licenses that effectively allow pollution (known as carbon permits) to major industries. Rather than reducing pollution, one polluter can then trade these permits with another who might make “equivalent” changes more cheaply (Gilbertson et al. 2009). The trading component of such a scheme gives companies greater room to maneuver when addressing the emissions problem; thus, carbon trading proposals are sometimes also referred to as “flexible mechanisms”. In the second type of carbon trading—offsetting—companies, and sometimes international financial institutions, governments, and individuals, finance “emission-saving projects” outside the capped area instead of cutting emissions at the source.

Water trading differs from carbon trading, which focuses on the concept of pollution. A carbon tax is a form of explicit carbon pricing, which refers to a tax directly linked to the level of CO₂ emissions, often expressed as a value per tonne of CO₂ equivalent (Marron and Toder 2014). The purpose of levying carbon taxes is to motivate firms and households to reduce the usage of fossil fuels, and shift the trends of the fuel mix toward less carbon intensive fuels and renewable energy (Jorgenson et al. 1992). As mentioned before, pricing water needs to take into account all sectors and aspects, such as household water consumption, food and agriculture, energy, transport, industry, city supplies, human health, ecosystems, and the environment, in addition to their interrelationships through water (UN-Water 2020). However, this requires that each stakeholder should pay a relatively fair price for the costs associated with each stage of the water interrelationship to achieve socially just pricing of the “product” (Kanakoudis and Papadopoulou 2014; Kanakoudis 2015). This requires resilient government water management and integrated water resource management, and is deeply rooted in a multi-stakeholder approach that engages citizens, the private sector, and civil society in water resource governance processes (Saravanan et al. 2009; Schoeman et al. 2014). Indeed, managing water resources through greater public participation is a means of building adaptive capacity at multiple levels, avoiding institutional pitfalls, and prioritizing risk reduction for socially vulnerable groups (Tompkins and Adger 2005; Oliveira 2009; Lebel et al. 2011; Ayers et al. 2014; Coirolo and Rahman 2014; UN-Water 2020).

Water reallocation, in contrast, which combines the idea of carbon trading and resource reallocation, aims at mitigating water scarcity under changing socioeconomic, climatic, and environmental conditions by using a more flexible water management approach. In dealing with the available water resources in an economically efficient way, the notions of virtual water flows have been introduced. The term “virtual water”, introduced by Allan (1998), referred to water used to produce agriculture products that are internationally traded. Virtual water has three levels at which decisions can be made and improvements achieved. The first level aims to achieve local water use efficiency, the second level aims to achieve water allocation efficiency, and the third level is for the purpose of global water use efficiency (Hoekstra and Hung 2002).

The existing virtual water studies, however, suffer several drawbacks. First, most of these studies focus mainly on water consumption, without accounting for water scarcity; for example, by applying a multiregional input-output model, Zhang and Anadon (2014) calculated virtual water trade and water footprints at the provincial level in China. However, their study focused on virtual water flow only, with all flows being treated equally, without taking relative scarcity and the environmental impacts of water flow into account. In reality, consuming the same amount of water in water-rich and water-scarce regions would have very different impacts on local water resources and ecosystems. Therefore, it is of fundamental importance to focus on virtual water scarce flows instead of traditional virtual water flows because the key factor in water planning and management is the flow of virtual scarce water rather than of neutral or abundant water. Second, overall water efficiency can be categorized into three

levels, but most attention from scientists and politicians has been paid to local water use efficiency due to the lack of virtual water trade data (Hoekstra and Hung 2002).

3. Water Consumption in China: An Overview

The pace of economic change in China has been extremely rapid since the economic reforms in 1978. China has accomplished a remarkable feat in transforming itself from one of the poorest countries to becoming the world's second largest economy over the past three decades (Liu et al. 2013). As previously noted, China has an enormous use of resources but water, as one of its most exhaustible resources, has been priced cheaply and used extensively.

Regarding the water scarcity problem in China, the key characteristic is the mismatch between the spatial distributions of water resources, economic development, and other primary factors of production, which leads to the separation of production and consumption of water-intensive products. For instance, the northern, northeastern, and northwestern parts of China account for 57% of land area, but only 15% of the freshwater resource, whereas the eastern, central, and southern areas, with 43% of freshwater resources, account for 57% of China's population and contribute 64% of its GDP (Zhang and Anadon 2014). Furthermore, half of the wheat output in China is produced in the North China Plain, which is heavily dependent on groundwater irrigation in winter. The resulting over-exploitation of groundwater for irrigation has become a major challenge to sustainable social economic development in the arid northern region, having severe adverse impacts on the environment and ecosystems due to drying up of rivers, land subsidence, and sea water intrusion (Foster et al. 2004; Zheng et al. 2010).

The production and consumption of water intensive products are to a large extent separated, and water intensive products are not always produced in regions with water abundance. This study of global water scarcity links the demand for water with its major drivers. Currently, water is not efficiently priced and, in most cases, water prices are kept low for two reasons: water for sustenance and water for political reasons, because higher water prices may be detrimental to the short-term political interests of the policy makers.

Prices, effective in reallocating resources, have also been found to be effective in the event of natural disaster recovery (Rose 2004). China is developing its economy: water prices are relatively low in China and Chinese exports may have benefited from these lower water prices. As such, this study hypothesizes that water consumption has a positive relationship with exports and economic growth in China. Total water consumption in China is related to the economic level of the underlying areas. The consumption of water in China varies both by sector and by region. East China is the most developed of the seven regions and therefore has the highest water consumption, both in terms of total water use and sectors, including agriculture, industry, and households (Figure 1). Compared to other regions, East China has also performed well in terms of GDP, exports, imports, and the flow of foreign direct investment (FDI) (Figure 2). Analysis of the demand for water is therefore carried out separately for each sector and region. This study also examines the regional distribution in China to determine if the results are different for economically disadvantaged regions, e.g., South East China is economically more advanced compared to the North East and North West regions. The study also accounts for water consumption via foreign investment, in addition to export and import companies. FDI inflows and investment in trading companies are expected to encourage advanced technological development and more efficient use of economic resources including water.

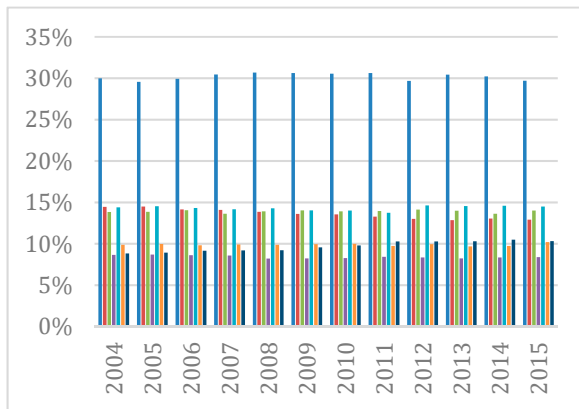
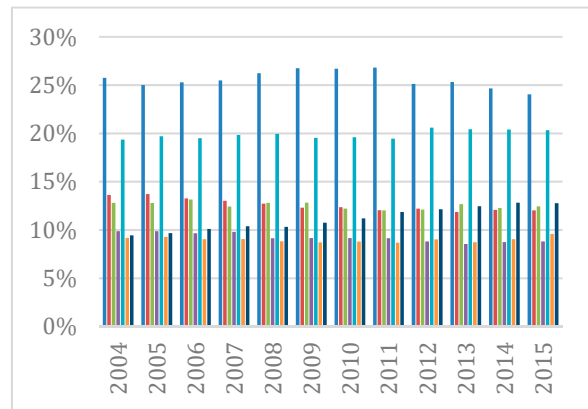
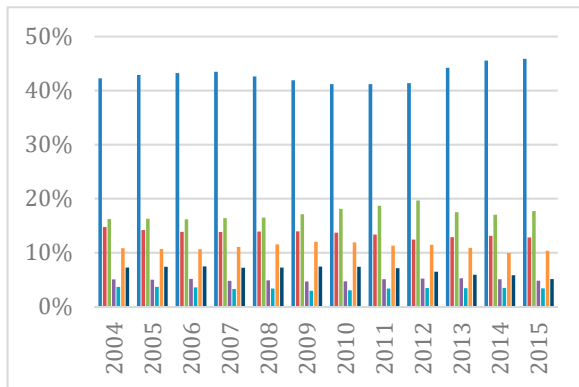
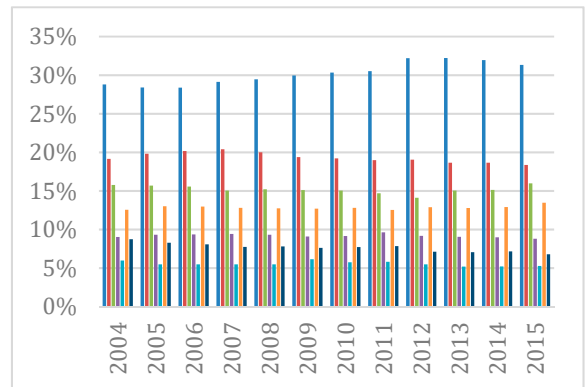
(a) Percentage of total water consumption by region in China.**(b)** Agricultural water consumption as a percentage of total agricultural water consumption by region in China.**(c)** Industrial water consumption by region in China as a percentage of total industrial water consumption.**(d)** Household water consumption as a percentage of total household water consumption by region in China.**Figure 1.** Water consumption in China by sector and by region.



Figure 2. Economic and environment performance in China by sector and by region.

4. Data and Methodology

4.1. Nature and Measurement of Data

Annual data from 2004 to 2015 (12 observations for each province) was collected from the National Bureau of Statistics of China website database for the major 31 municipalities and provinces within China (Table 1). For empirical analysis, this study divides the Chinese 31 municipalities and provinces into 7 major commonly known regions.

Table 1. The seven major regions in China.

Region	Provinces Included in the Region	Number of Provinces in the Group	Number of Observations in Each Panel
East China	Shandong, Jiangsu, Anhui, Zhejiang, Fujian, Shanghai, Jiangxi	7	84
South China	Guangdong, Guangxi, Hainan	3	36
Central China	Hubei, Hunan, Henan	3	36
North China	Beijing, Tianjin, Hebei, Shanxi, Neimeng	5	60
North West China	Ningxia, Xinjiang, Qinghai, Shanxi, Gansu	5	60
South West China	Sichuan, Yunnan, Guizhou, Xizang, Chongqing	5	60
North East China	Liaoning, Jilin, Heilongjiang	3	36
Whole China	All regions	31	372

Note: There are 12 observations per region.

The variables included in the model are measured as follows (Table 2): Total water consumption (WCT), total water consumption for agriculture (WCOA), total water consumption for industry (WCOI), and total water consumption for living (WCOL). All of these variables are measured in per hundred million cubic meters. GDP per capita (GDPPC) is GDP hundred RMB per person for each region; population (POP) represents the total population for different regions per 100,000 people; exports (EXP) and imports (IMP) are measured as 100 million USD; foreign direct investment (FDI) is foreign company investment in different regions of China as 100 million USD; sulfur dioxide emissions (SO₂) are measured in 10,000 tons. For the purpose of comparison, this study also analyzed the demand for water for a set of developed countries, namely, Australia⁵, Japan⁶, and the United Kingdom (UK)⁷. Annual data for the variables used in the model from 2005 to 2013 (9 observations for each country), were collected from each country's national statistical department website database⁸. This implies that the variables of this study are measured in different units; therefore, before commencing the empirical analysis, it is important to normalize and transfer the data series into natural logarithms to avoid the problems associated with distributional properties of the data series (Paramati et al. 2017).

⁵ Data resource, <https://www.abs.gov.au/statistics/economy/key-indicators>.

⁶ Data resource, <http://www.stat.go.jp/english/data/nenkan/1431-11e.html>.

⁷ Data resource, <http://www.defra.gov.uk/statistics/environment/inland-water/>.

⁸ Data resource, <http://www.stats.gov.cn/english/Statisticaldata/AnnualData/>.

Table 2. Definitions of the variables.

Acronym	Description	Unit
WCT	Total water consumption	Hundred million cubic meters
WCOA	Total water consumption for Agriculture	Hundred million cubic meters
WCOI	Total water consumption for Industry	Hundred million cubic meters
WCOL	Total water consumption for Living	Hundred million cubic meters
GDPPC	GDP per capita for each region	Hundred RMB/person
POP	Population	Hundred thousand people
EXP	Export Total	Hundred million USD
IMP	Import Total	Hundred million USD
FDI	Foreign direct investment	Hundred million USD
FDINI	Foreign direct investment net inflows	Hundred million USD
FDINO	Foreign direct investment net outflows	Hundred million USD
SO2	Sulfur dioxide emissions	Ten thousand tons

4.2. Correlation among Variables

The dependent variable, water consumption, includes WCT, WCOA, WCOI, and WCOL. The independent variables include EXP, GDPPC, IMP, SO2, FDI, and POP. The independent variables with the same nature will be very highly correlated with each other. Therefore, this study derived the correlation matrix for all of the variables to assess the possible problem of multi-collinearity (Table 3). Variables with high correlations were not included in the same model. This study used a number of alternative specifications to avoid the problem of multi-collinearity.

Table 3. The correlation matrix (whole of China).

	WCT	WCOA	WCOI	WCOL	GDPPC	POP	EXP	IMP	FDI	SO2
WCT	1.0000									
WCOA	0.9170	1.0000								
WCOI	0.7983	0.5568	1.0000							
WCOL	0.7698	0.5467	0.8839	1.0000						
GDPPC	−0.0203	−0.1790	0.1042	0.1497	1.0000					
POP	0.7614	0.6074	0.8439	0.9268	0.0538	1.0000				
EXP	0.4479	0.1966	0.5979	0.6757	0.6918	0.5859	1.0000			
IMP	0.3503	0.0920	0.5395	0.6644	0.7023	0.5668	0.9206	1.0000		
FDI	0.5000	0.6640	0.6348	0.0111	0.7914	0.3725	0.3760	0.3803	1.0000	
SO2	0.6029	0.5068	0.6208	0.5901	0.0060	0.7679	0.3444	0.3212	0.3200	1.0000

Note: The variables for water consumption WC_{it} (WCT, WCOA, WCOI, and WCOL) are dependent variables in this study; all other variables are independent variables.

5. Model Specification

The analysis of the demand for water in China was carried out at the aggregate level for the economy as a whole, and at the disaggregated level. The analysis at the disaggregated level examines the demand for water in the agricultural, industrial, and household sectors. Both agriculture and industry consume water for production purposes, whereas households consume water for the purpose of living. The models used to investigate the drivers of the demand for water in China are specified as follows:

$$WC_{it} = f(IMP_{it}, SO2_{it}) \quad (1)$$

$$WC_{it} = f(IMP_{it}, SO2_{it}) \quad (2)$$

$$WC_{it} = f(FDI_{it}, POP_{it}) \quad (3)$$

$$WC_{it} = f(FDINI_{it}, POP_{it}) \quad (4)$$

$$WC_{it} = f(FDINO_{it}, POP_{it}) \quad (5)$$

Equations (1) to (3) were estimated for China using annual data from 2004 to 2015⁹. Equations (1), (2), (4) and (5) were estimated for Australia, Japan, and the UK using annual data from 2005 to 2013. Water consumption (WC) in Equations (1)–(5) was measured alternatively in terms of WCT, WCOA, WCOI, and WCOL for China, and WCT and WCOL for Australia, Japan, and the UK. The expected signs of the coefficients of different independent variables are given in Table 4. GDPPC is expected to have a positive correlation with water consumption in the early stages of development, when water saving technologies and water management strategies are not very well developed. As an economy develops, it is able to afford better water saving technologies and to have efficient water management strategies. GDPPC is therefore expected to have a negative correlation with water consumption in the early stages of development. The expected sign of the coefficient, therefore, could be positive or negative.

Table 4. The expected signs of the coefficients of the different independent variables.

Variable	WCT	WCOI	WCOA	WCOL
EXP	+	+	+	+
GDPPC	+/-	+/-	+/-	+/-
IMP	-	-	-	-
SO2	+	+	+	+
POP	+	+	+	+
FDI	+/-	-	+/-	+/-
FDINI	+/-	-	+/-	+/-
FDINO	+/-	-	+/-	+/-

6. Empirical Results and Discussion

6.1. Estimates for China, by Sector and by Region

The empirical analysis began with the panel unit root tests, which were performed to test the stationarity of the variables. To examine the distributional properties and the order of integration of the variables, two generations of tests were undertaken: a first generation IPS (Im et al. 2003) panel unit root test that assumes cross-sectional independence across all units; a second generation (Pesaran 2003) CADF (cross-section augmented Dickey–Fuller) panel unit root test that assumes heterogeneous panels with cross-section dependence across all units (Barbieri 2006). The null hypothesis of a unit root is non-stationary, compared to the alternative hypothesis of a stationary series with no unit root (Barbieri 2006). The results of the IPS and Pesaran CADF unit root tests for the whole of China are listed in Table 5. The results of the unit root tests confirm that that all of the variables are non-stationary at level I(0) and stationary at their first order differences I(1). This implies that all of the variables have the same order of integration and may have a long-run cointegration relationship. Thus, a cointegration test is applied for all models in the next section.

Based on the results of the panel unit root tests shown in Table 5, it can be confirmed that all of the variables have the same order of integration and may have a long-run cointegration relationship. Thus, this study applied a Fisher-type Johansen panel cointegration test to explore the long-run equilibrium relationship among the variables of Equations (1)–(3). The Johansen cointegration test includes two unrestricted cointegration rank statistics: Trace and Maximum Eigenvalue. The results for the cointegration test in Table 6 reject the null hypothesis of no cointegration at the 5% level of significance. Thus, all variables in Equations (1)–(3) are cointegrated.

⁹ The environmental data are only updated to 2015 prior to the completion of this paper.

Table 5. Panel unit root tests (whole of China).

	IPS Panel Unit Root Tests Assumes Cross-Sectional Independence				Pesaran's CADF Unit Root Tests Assumes Cross-Sectional Dependence			
	At Level		At First Difference		At Level		At First Difference	
	Statistic	p-Value	Statistic	p-Value	Z[t-bar]	p-Value	Z[t-bar]	p-Value
WCT	−0.6312	0.2640	11.2416 ***	0.0000	−0.3650	0.3570	−3.9610 ***	0.0000
WCOA	−0.9506	0.1709	11.3518 ***	0.0000	1.6730	0.9530	−7.4100 ***	0.0000
WCOI	−0.4658	0.3207	−5.4322 ***	0.0000	0.2000	0.5790	−4.0860 ***	0.0000
WCOL	−0.7349	0.2312	−9.1580 ***	0.0000	2.5430	0.9950	−5.1270 ***	0.0000
POP	−1.3118	0.0948	−4.5583 ***	0.0000	4.7250	1.0000	−4.5640 ***	0.0000
GDPPC	0.4308	0.6667	−5.0217 ***	0.0000	0.3280	0.6290	−1.8050 **	0.0360
EXP	−1.1679	0.1214	−8.5861 ***	0.0000	4.0800	1.0000	−2.0080 **	0.0220
IMP	−0.9459	0.1721	−5.3735 ***	0.0000	0.4160	0.6610	−3.6510 ***	0.0000
FDI	1.8448	0.9675	−3.8473 ***	0.0001	1.7520	0.9600	−5.3060 ***	0.0000
SO2	1.9714	0.9757	19.9768 ***	0.0000	3.1450	0.9990	10.1800 ***	0.0000

Note: (1) The symbols *** and ** indicate that the t-test is significant at the thresholds of 1% and 5%, respectively, which means that the null hypothesis is rejected. (2) The unit root tests are estimated using constant and trend variables. (3) All tests are undertaken using Stata software.

The cointegration test confirmed that there is a long run equilibrium relationship among these variables. Thus, the fully modified ordinary least squares (FM-OLS) method was employed on Equations (1)–(3) to explore the long-run elasticities among these variables. (Ozcan 2013; Chao et al. 2014; Farhani and Shahbaz 2014). The results obtained from the model estimated for China using the fully modified ordinary least squares (FM-OLS) method are presented in Table 7. The comparison of the expected signs of the coefficients is summarized in Tables 8 and 9, in which the actual sign is circled when it is different from the expected sign. These results suggest that GDPPC is highly significant at the 1% level in almost all of the sectors and regions, except in North East China. The elasticity of demand for water is close to one in many cases, suggesting a proportionate increase in the demand for water in response to the increase in GDPPC. The increase in population leads to an increase in water consumption for household purposes. The POP variable is significant; it has the expected positive sign in most cases of models estimated for both total and household water consumption. Exports of goods implicitly involves the export of water, particularly in the case of exports of agricultural products. The EXP variable significantly affects the demand for water, at both the aggregate and sectoral levels, and for all the regions. Similarly, the import of goods implicitly involves the import of water, particularly in the case of the import of agricultural products. The results for the IMP variable are somewhat mixed in terms of the sign and significance of its coefficient across sectors and regions. Similarly, the evidence for the effects of FDI is mixed across sectors and regions. The elasticities of water consumption with regard to FDI and IMP remain low (less than 0.5) in most cases. SO2 positively and significantly affects the demand for water.

Table 6. Fisher-type Johansen cointegration test—whole of China.

Hypothesized	Fisher Stat. *		Fisher Stat. *		Fisher Stat. *		Fisher Stat. *		Fisher Stat. *		Fisher Stat. *	
No. of CE(s)	(Trace Test)	Prob.	(Max-Eigen Test)	Prob.	(Trace Test)	Prob.	(Max-Eigen Test)	Prob.	(Trace Test)	Prob.	(Max-Eigen Test)	Prob.
Variables	$WCT_{it} = f(IMP_{it}, SO2_{it})$				$WCT_{it} = f(IMP_{it}, SO2_{it})$				$WCT_{it} = f(FDI_{it}, POP_{it})$			
None	518.30 ***	0.0000	421.50 ***	0.0000	385.10 ***	0.0000	305.60 ***	0.0000	436.10 ***	0.0000	360.90 ***	0.0000
At most 1	179.70 ***	0.0000	150.60 ***	0.0000	163.50 ***	0.0000	148.80	0.0000	164.30 ***	0.0000	137.40 ***	0.0000
At most 2	98.39 ***	0.0022	98.39 ***	0.0022	82.49 ***	0.0420	82.49	0.0420	98.92 ***	0.0020	98.92 ***	0.0020
Variables	$WCOI_{it} = f(EXP_{it}, GDPPC_{it})$				$WCOI_{it} = f(IMP_{it}, SO2_{it})$				$WCOI_{it} = f(FDI_{it}, POP_{it})$			
None	543.10 ***	0.0000	442.30 ***	0.0000	424.30 ***	0.0000	330.90 ***	0.0000	564.90 ***	0.0000	440.80 ***	0.0000
At most 1	198.80 ***	0.0000	158.00 ***	0.0000	179.90 ***	0.0000	149.60 ***	0.0000	210.60 ***	0.0000	196.20 ***	0.0000
At most 2	124.10 ***	0.0000	124.10 ***	0.0000	106.60 ***	0.0004	106.60 ***	0.0004	85.47 **	0.0258	85.47 **	0.0258
Variables	$WCOA_{it} = f(EXP_{it}, GDPPC_{it})$				$WCOA_{it} = f(IMP_{it}, SO2_{it})$				$WCOA_{it} = f(FDI_{it}, POP_{it})$			
None	422.10 ***	0.0000	364.10 ***	0.0000	399.70 ***	0.0000	335.30 ***	0.0000	491.60 ***	0.0000	377.10 ***	0.0000
At most 1	140.60 ***	0.0000	120.10 ***	0.0000	150.00 ***	0.0000	132.50 ***	0.0000	209.20 ***	0.0000	188.80 ***	0.0000
At most 2	87.67 ***	0.0176	87.67 **	0.0176	88.41 **	0.0155	88.41 **	0.0155	89.42 **	0.0129	89.42 **	0.0129
Variables	$WCOL_{it} = f(EXP_{it}, GDPPC_{it})$				$WCOL_{it} = f(IMP_{it}, SO2_{it})$				$WCOL_{it} = f(FDI_{it}, POP_{it})$			
None	361.80 ***	0.0000	279.70 ***	0.0000	471.30 ***	0.0000	401.40 ***	0.0000	521.50 ***	0.0000	402.60 ***	0.0000
At most 1	163.60 ***	0.0000	145.70 ***	0.0000	165.50 ***	0.0000	139.40 ***	0.0000	215.30 ***	0.0000	192.40 ***	0.0000
At most 2	84.94 **	0.0282	84.94 **	0.0282	94.18 **	0.0052	94.18 ***	0.0052	96.18 ***	0.0035	96.18 ***	0.0035
Variables	$WCT_{it} = f(EXP_{it}, GDPPC_{it})$				$WCT_{it} = f(IMP_{it}, SO2_{it})$				$WCT_{it} = f(FDI_{it}, POP_{it})$			
None	518.30 ***	0.0000	421.50 ***	0.0000	385.10 ***	0.0000	305.60 ***	0.0000	436.10 ***	0.0000	360.90 ***	0.0000
At most 1	179.70 ***	0.0000	150.60 ***	0.0000	163.50 ***	0.0000	148.80	0.0000	164.30 ***	0.0000	137.40 ***	0.0000
At most 2	98.39 ***	0.0022	98.39 ***	0.0022	82.49 ***	0.0420	82.49	0.0420	98.92 ***	0.0020	98.92 ***	0.0020
Variables	$WCOI_{it} = f(EXP_{it}, GDPPC_{it})$				$WCOI_{it} = f(IMP_{it}, SO2_{it})$				$WCOI_{it} = f(FDI_{it}, POP_{it})$			
None	543.10 ***	0.0000	442.30 ***	0.0000	424.30 ***	0.0000	330.90 ***	0.0000	564.90 ***	0.0000	440.80 ***	0.0000
At most 1	198.80 ***	0.0000	158.00 ***	0.0000	179.90 ***	0.0000	149.60 ***	0.0000	210.60 ***	0.0000	196.20 ***	0.0000
At most 2	124.10 ***	0.0000	124.10 ***	0.0000	106.60 ***	0.0004	106.60 ***	0.0004	85.47 **	0.0258	85.47 **	0.0258
Variables	$WCOA_{it} = f(EXP_{it}, GDPPC_{it})$				$WCOA_{it} = f(IMP_{it}, SO2_{it})$				$WCOA_{it} = f(FDI_{it}, POP_{it})$			
None	422.10 ***	0.0000	364.10 ***	0.0000	399.70 ***	0.0000	335.30 ***	0.0000	491.60 ***	0.0000	377.10 ***	0.0000
At most 1	140.60 ***	0.0000	120.10 ***	0.0000	150.00 ***	0.0000	132.50 ***	0.0000	209.20 ***	0.0000	188.80 ***	0.0000
At most 2	87.67 ***	0.0176	87.67 **	0.0176	88.41 **	0.0155	88.41 **	0.0155	89.42 **	0.0129	89.42 **	0.0129
Variables	$WCOL_{it} = f(EXP_{it}, GDPPC_{it})$				$WCOL_{it} = f(IMP_{it}, SO2_{it})$				$WCOL_{it} = f(FDI_{it}, POP_{it})$			
None	361.80 ***	0.0000	279.70 ***	0.0000	471.30 ***	0.0000	401.40 ***	0.0000	521.50 ***	0.0000	402.60 ***	0.0000
At most 1	163.60 ***	0.0000	145.70 ***	0.0000	165.50 ***	0.0000	139.40 ***	0.0000	215.30 ***	0.0000	192.40 ***	0.0000
At most 2	84.94 **	0.0282	84.94 **	0.0282	94.18 **	0.0052	94.18 ***	0.0052	96.18 ***	0.0035	96.18 ***	0.0035

Note: *, **, *** indicate that the estimated coefficients are significant at the confidence levels of 10%, 5%, 1%, respectively.

Table 7. Fully modified ordinary least squares (FM-OLS) estimates and the long-run elasticities for the whole of China and all regions.

Variable	Whole China	East China	South China	Central China	North China	North West China	South West China	North East China
$WCT = f(EXP, GDPPC)$								
<i>EXP</i>	0.4823 *** (0.0000)	0.4006 *** (0.0027)	0.5560 *** (0.0000)	−0.5012 *** (0.0001)	−0.8805 *** (0.0000)	0.7582 *** (0.0000)	0.6093 *** (0.0000)	0.0799 (0.6385)
<i>GDPPC</i>	−1.0201 *** (0.0000)	−0.8800 *** (0.0011)	−1.2058 *** (0.0017)	0.7443 *** (0.0001)	1.0565 *** (0.0026)	−0.6675 *** (0.0045)	−1.0927 *** (0.0000)	−0.0958 (0.7890)
$WCT = f(IMP, SO_2)$								
<i>IMP</i>	0.0665 (0.1293)	−0.0117 (0.8342)	0.0637 *** (0.0052)	−0.0643 (0.1215)	0.5661 *** (0.0007)	0.2125 (0.4036)	0.1872 *** (0.0052)	−0.1047 (0.6558)
<i>SO₂</i>	0.3824 *** (0.0000)	0.3865 *** (0.0041)	0.5687 *** (0.0000)	−0.4440 *** (0.0000)	1.3811 *** (0.0000)	0.6718 (0.1790)	0.1148 ** (0.0342)	−0.0481 (0.9099)
$WCT = f(POP, FDI)$								
<i>POP</i>	0.8440 *** (0.0000)	−0.0117 (0.8342)	1.0963 *** (0.0000)	−0.5959 *** (0.0004)	0.8257 *** (0.0002)	1.1395 *** (0.0001)	0.5541 *** (0.0000)	2.3960 *** (0.0000)
<i>FDI</i>	−0.0828 (0.1027)	0.3865 *** (0.0041)	−0.1443 *** (0.0000)	−0.0011 (0.9877)	−0.4122 *** (0.0054)	−0.6423 ** (0.0112)	−0.0033 (0.9462)	−0.5208 *** (0.0000)
$WCOI = f(EXP, GDPPC)$								
<i>EXP</i>	0.7926 *** (0.0000)	0.2452 (0.2310)	0.8305 *** (0.0000)	−0.5653 ** (0.0233)	−0.6690 *** (0.0001)	0.4472 *** (0.0000)	1.2721 *** (0.0000)	0.0280 (0.8581)
<i>GDPPC</i>	−1.3809 *** (0.0000)	−0.2874 (0.4826)	−1.6330 *** (0.0008)	0.9627 *** (0.0080)	0.6591 ** (0.0233)	−0.6514 *** (0.0012)	−2.0276 *** (0.0000)	−0.19026 (0.4805)
$WCOI = f(IMP, SO_2)$								
<i>IMP</i>	0.2509 *** (0.0000)	0.1541 * (0.0662)	0.17870 *** (0.0000)	−0.0169 (0.5383)	0.4109 *** (0.0000)	0.3305 *** (0.0062)	0.1897 *** (0.0001)	−0.2556 (0.1445)
<i>SO₂</i>	0.5074 *** (0.0000)	−0.3649 * (0.0650)	0.7720 *** (0.0000)	−0.8305 *** (0.0000)	1.1142 *** (0.0000)	0.1948 (0.3947)	0.4657 *** (0.0000)	0.0491 (0.8752)

Table 7. Cont.

Variable	Whole China	East China	South China	Central China	North China	North West China	South West China	North East China
$WCOI = f(POP, FDI)$								
POP	1.0864 *** (0.0000)	−0.1939 (0.4360)	1.5056 *** (0.0000)	−1.2894 *** (0.0000)	0.7103 *** (0.0000)	0.8807 *** (0.0000)	0.9824 *** (0.0000)	1.5521 *** (0.0000)
FDI	0.1485 ** (0.0116)	0.2383 ** (0.0286)	−0.0654* (0.0521)	0.1620 *** (0.0006)	−0.394 *** (0.0000)	−0.1867 ** (0.0118)	0.1708 * (0.0973)	−0.4183 *** (0.0000)
$WCOA = f(EXP, GDPPC)$								
EXP	0.38601 *** (0.0000)	−0.2208 ** (0.0188)	0.4645 *** (0.0000)	−0.5559 *** (0.0002)	−1.1851 *** (0.0000)	0.7716 *** (0.0000)	0.4355 *** (0.0003)	0.0660 (0.7484)
GDPPC	−1.1243 *** (0.0000)	1.0215 *** (0.0000)	−1.1335 *** (0.0033)	0.7581 *** (0.0003)	1.2848 *** (0.0039)	−0.6421 ** (0.0260)	−0.9567 *** (0.0016)	−0.1049 (0.8089)
$WCOA = f(IMP, SO2)$								
IMP	−0.0669 (0.2064)	−0.2563 *** (0.0029)	−0.0077 (0.7323)	−0.1060* (0.0772)	0.5039 *** (0.0051)	0.1772 (0.5411)	0.1629 (0.2103)	−0.1134 (0.6853)
SO2	0.4367 *** (0.0000)	1.0369 *** (0.0000)	0.5298 *** (0.0000)	−0.3755 *** (0.0043)	1.5952 *** (0.0000)	0.7314 (0.1997)	0.0213 (0.8404)	−0.1249 (0.8054)
$WCOA = f(POP, FDI)$								
POP	0.9566 *** (0.0000)	1.4796 *** (0.0000)	1.0037 *** (0.0000)	−0.4587 ** (0.0324)	0.924 *** (0.0011)	1.1420 *** (0.0007)	0.6030 *** (0.0024)	2.7821 *** (0.0000)
FDI	−0.2659 *** (0.0000)	−0.1416* (0.0985)	−0.2232 *** (0.0000)	−0.0850 (0.3849)	−0.7137 *** (0.0003)	−0.7251 ** (0.0123)	−0.1920 (0.1571)	−0.6353 *** (0.0000)
$WCOL = f(EXP, GDPPC)$								
EXP	0.6443 *** (0.0000)	0.3086 *** (0.0000)	0.6135 *** (0.0000)	−0.3872 *** (0.0068)	−0.1712 (0.2965)	0.6575 *** (0.0000)	1.0031 *** (0.0000)	0.2864 *** (0.0000)
GDPPC	−1.0577 *** (0.0000)	−0.4352 *** (0.0031)	−1.1123 *** (0.0021)	0.5490 *** (0.0074)	0.3121 (0.3003)	−0.7964 *** (0.0022)	−1.7667 *** (0.0000)	−0.1983 *** (0.0002)
$WCOL = f(IMP, SO2)$								
IMP	0.2589 *** (0.0000)	0.0797 *** (0.0065)	0.1547 *** (0.0000)	−0.0562 (0.3936)	0.6826 *** (0.0000)	0.5434 *** (0.0019)	0.2433 *** (0.0000)	−0.0497 (0.3389)
SO2	0.3265 *** (0.0000)	0.2773 *** (0.0001)	0.5611 *** (0.0000)	−0.1500 (0.2805)	1.0346 *** (0.0000)	0.1027 (0.7533)	0.2780 *** (0.0000)	0.5631 *** (0.0000)
$WCOL = f(POP, FDI)$								
POP	0.8672 *** (0.0000)	0.4451 *** (0.0000)	1.1029 *** (0.0000)	−0.0681 (0.7427)	0.7447 *** (0.0000)	1.1705 *** (0.0000)	0.8411 *** (0.0000)	1.0820 *** (0.0000)
FDI	0.1406 *** (0.0000)	0.1516 *** (0.0000)	−0.0229 (0.2090)	−0.0370 (0.7044)	0.1271 (0.1698)	−0.1724* (0.0663)	0.0782* (0.0787)	0.0654 *** (0.0094)

Note: *, **, *** indicate that the estimated coefficients are significant at the confidence levels of 10%, 5%, 1%, respectively.

Table 8. FMOLS (Fully modified ordinary least squares) estimates and the sign comparison—actual signs.

Variable	Whole China	East China	South China	Middle China	North China	North West China	South West China	North East China
WCT								
EXP	***	***	***	***	***	***	***	+
GDPPC	***	***	***	***	***	***	***	—
IMP	+	—	***	—	***	+	***	—
SO2	***	***	***	***	***	+	***	—
POP	***	—	***	***	***	***	***	***
FDI	—	***	***	—	***	***	—	***
WCOI								
EXP	***	+	***	***	***	***	***	+
GDPPC	***	—	***	***	***	***	***	—
IMP	***	+	***	—	***	***	***	—
SO2	***	—	***	***	***	+	***	+
POP	***	—	***	***	***	***	***	***
FDI	***	***	—	***	***	***	+	***

Table 8. Cont.

Variable	Whole China	East China	South China	Middle China	North China	North West China	South West China	North East China
WCOA								
EXP	+	−	+	−***	−***	+	+	+
GDPPC	−	+	−	+	+	−	−	−
IMP	−	−	−	−	+	+	+	−
SO2	+	+	+	−	+	+	+	−
POP	+	+	+	−	+	+	+	+
FDI	−	−	−	−	−	−	−	−
WCTL								
EXP	+	+	+	−	−	+	+	+
GDPPC	−	−	−	+	+	−	−	−
IMP	+	+	+	−	+	+	+	−
SO2	+	+	+	−	+	+	+	+
POP	+	+	+	−	+	+	+	+
FDI	+	+	−	−	+	−	+	+

Note: *, **, *** indicate that the estimated coefficients are significant at the confidence levels of 10%, 5%, 1%, respectively. (2) The actual sign is circled when it is different from the expected sign.

Table 9. FMOLS estimates and the sign comparison—expected versus actual.

Variable	WCT		WCOI		WCOA		WCOL	
	Expected	Actual	Expected	Actual	Expected	Actual	Expected	Actual
Whole China								
EXP	+	***	+	***	+	***	+	***
GDPPC	+/-	***	+/-	***	+/-	***	+/-	***
IMP	-	+	-	***	-	-	-	***
SO2	+	***	+	***	+	***	+	***
POP	+	***	+	***	+	***	+	***
FDI	+/-	-	-	*	+/-	***	+/-	***
East China								
EXP	+	***	+	+	+	**	+	***
GDPC	+/-	***	+/-	-	+/-	***	+/-	***
IMP	-	-	-	*	-	***	-	***
SO2	+	***	+	*	+	***	+	***
POP	+	-	+	-	+	***	+	***
FDI	+/-	***	-	*	+/-	*	+/-	***
South China								
EXP	+	***	+	***	+	***	+	***
GDPPC	+/-	***	+/-	***	+/-	***	+/-	***
IMP	-	***	-	***	-	-	-	***
SO2	+	***	+	***	+	***	+	***
POP	+	***	+	***	+	***	+	***
FDI	+/-	***	-	*	+/-	***	+/-	-

Table 9. Cont.

Variable	WCT		WCOI		WCOA		WCOL	
	Expected	Actual	Expected	Actual	Expected	Actual	Expected	Actual
Middle China								
EXP	+	***	+	**	+	***	+	***
GDPPC	+/-	***	+/-	***	+/-	***	+/-	***
IMP	-	-	-	-	-	*	-	-
SO2	+	***	+	***	+	***	+	
POP	+	***	+	***	+	**	+	
FDI	+/-	-	-	***	+/-	-	+/-	-
North China								
EXP	+	***	+	***	+	***	+	
GDPPC	+/-	***	+/-	**	+/-	***	+/-	+
IMP	-	***	-	***	-	***	-	***
SO2	+	***	+	***	+	***	+	***
POP	+	***	+	***	+	***	+	***
FDI	+/-	***	-	***	+/-	***	+/-	+
North West China								
EXP	+	***	+	***	+	***	+	***
GDPPC	+/-	***	+/-	***	+/-	**	+/-	***
IMP	-	+	-	***	-	+	-	***
SO2	+	+	+	+	+	+	+	+
POP	+	***	+	***	+	***	+	***
FDI	+/-	**	-	**	+/-	**	+/-	*

Table 9. Cont.

Variable	WCT		WCOI		WCOA		WCOL	
	Expected	Actual	Expected	Actual	Expected	Actual	Expected	Actual
South West China								
EXP	+	***	+	***	+	***	+	***
GDPPC	+/-	***	+/-	***	+/-	***	+/-	***
IMP	-	***	-	***	-	+	-	***
SO2	+	**	+	***	+	+	+	***
POP	+	***	+	***	+	***	+	***
FDI	+/-	-	-	+	+/-	-	+/-	+
North East China								
EXP	+	+	+	+	+	+	+	***
GDPPC	+/-	-	+/-	-	+/-	-	+/-	***
IMP	-	-	-	-	-	-	-	-
SO2	+	-	+	+	+	-	+	***
POP	+	***	+	***	+	***	+	***
FDI	+/-	***	-	***	+/-	***	+/-	***

Note: *, **, *** indicate that the estimated coefficients are significant at the confidence levels of 10%, 5%, 1%, respectively.

6.2. Estimates for Australia, Japan, and the UK

The panel data analysis of the demand for water in the developed economies of Australia, Japan, and the UK was carried out only at the aggregate and industrial levels because of the lack of available data for the agricultural and household sectors. The results suggest that GDPPC and EXP significantly affect the demand for water at both the aggregate and industrial levels (Tables 10 and 11). FDINI is significant, whereas the IMP and FDINO variables are insignificant in all of the equations. These results suggest that there are significant effects of GDPPC, EXP, CO₂, and FDINI on the demand for water in the developed economies. Interestingly, GDPPC has a negative sign. As hypothesized earlier, the developed countries use better water saving technologies and have more efficient water management strategies. An increase in GDPPC therefore leads to a decrease in demand for water.

Table 10. FMOLS estimates and the long-run elasticities (Australia, Japan, and the UK).

Variable	Coefficient	Prob.
Total water consumption		
WCT = f (EXP, GDPPC)		
EXP	1.7810 ***	0.0000
GDPPC	−1.1537 ***	0.0000
WCT = f (IMP, CO ₂)		
IMP	−0.0598	0.9205
CO ₂	1.5919 ***	0.0000
WCT = f (POP, FDINI)		
POP	1.3410 ***	0.0000
FDINI	0.1630 ***	0.0000
WCT = f (POP, FDINO)		
POP	1.4561 ***	0.0000
FDINO	−0.0062	0.9506
Water consumption in industry		
WCOI = f (EXP, GDPPC)		
EXP	1.6818 ***	0.0000
GDPPC	−1.1004 ***	0.0000
WCOI = f (IMP, CO ₂)		
IMP	−0.1415	0.7924
CO ₂	1.5388 ***	0.0000
WCOI = f (POP, FDI)		
POP	1.2967 ***	0.0000
FDINI	0.1261 ***	0.0002
WCOI = f (POP, FDINO)		
POP	1.3760 ***	0.0000
FDINO	−0.0490	0.5350

Note: *** indicate that the estimated coefficients are significant at the confidence level of 1%.

Table 11. Comparison of signs of Regression variables (Australia, Japan, and the UK).

Variable	WCT Expected	WCT Actual	WCOI Expected	WCOI Actual
EXP	+	***	+	***
GDPPC	+/-	***	+/-	***
IMP	−	−	−	−
CO ₂	+	***	+	***
POP	+	***	+	***
FDINI	+/-	***	+/-	***
FDINO	+/-	−	+/-	−

Note: *** indicate that the estimated coefficients are significant at the confidence level of 1%.

7. Conclusions

Motivated by the issue of global water scarcity, this study aimed to investigate the domestic and international drivers of the demand for water in China. China has traditionally depended on agriculture and shifted its focus to manufacturing in recent decades. China is the biggest global exporter of manufactured goods, and the largest global consumer, because of its recent economic growth and the size of its population. Analysis of the demand for water in China was carried out at the aggregate, sectoral, and provincial levels. Similar analysis of three developed countries (Australia, Japan, and the United Kingdom) provides international relevance for our study. Panel data models were estimated using annual data from 2004 to 2015 for China and from 2005 to 2013 for Australia, Japan, and the United Kingdom. The results suggest that per capita GDP is highly significant at the 1% level in most of the sectors and regions, except for North East China. The elasticity of the demand for water is close to one in many cases, suggesting a proportionate increase in the demand for water in response to an increase in per capita GDP. Variables Population (POP), total exports (EXP), and Sulfur di oxide emissions (SO₂) are significant and mostly have the expected positive signs in the models estimated for both total and household water consumption. The results for the Total imports (IMP) and foreign direct investments (FDI) are mixed in terms of the coefficient signs and significance across sectors and regions. Policymakers ought to look at the specific characteristics of the region and stage of economic growth in terms of policies to appropriately manage water demand in the region. The elasticities of water consumption with regard to variables foreign direct investments (FDI) and total imports (IMP) remain low (less than 0.5) in most cases.

The results obtained for the developed economies of Australia, Japan, and the UK suggest that GDP per capita and total exports significantly affect the demand for water at both the aggregate and sectoral levels. Net inflows of foreign direct investments has significant effects on the demand for water, whereas those of total imports and net outflows of investments are insignificant. These results indicate the significant effects of per capita GDP, net exports, Sulfur dioxide emissions and net inflows of foreign direct investments on the demand for water in the developed economies. The findings of the study are useful for the formulation of relevant strategies for the efficient management of scarce water resources at both domestic and global levels. Both economic growth and globalization increase the pressure on the demand for water.

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