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# The Benefit Assessment of the Specific User Water Source Facilities: the Case of Reclaimed Water, Desalination Plants, and Artificial Lake

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## Abstract

Kaohsiung has been suffering from water shortage and 265,100 CMD of water was recently transferred from the agricultural sector into the industrial and residential sectors. Since the price of water is regulated to be artificially low, it cannot reflect the value of water. A method that combines the Contingent Valuation Method (CVM), the water footprint and a regional input-output (IO) model that includes the residential sector is proposed in this paper to evaluate the benefits and sectoral impacts of water source facilities. Three water source facilities, a reclaimed water plant (RC), a seawater desalination plant (SD) and the phase one of Gaoping Lake (GL) are evaluated. Since the water from the RC is only for the industrial sector, the most highly impacted sectors are the industry, electricity and gas supply, and water supply sectors. The most highly impacted sectors by the water supplied from the SD and GL are residential, accommodation and food services, and industry sectors. The most highly impacted sectors by the returned agricultural water are the agricultural, residential, and wholesale and retail sectors. GL has the lowest unit cost of water and the highest output effects even when the output reduction from land use change is subtracted。

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## 1. Introduction

Water shortages often cause many inconveniences to daily life as well as economic losses to industries. In Taiwan, approximately 440 million NTD more cost and revenue loss from industries was caused within 19 days in Taoyuan in 2004 due to a water shortage. González (2011) simulated an extreme water supply restriction scenario and found a loss of 2.8% in the GDP in 2005 in the Catalonia region in Spain. The Kaohsiung area has been suffering from a water shortage for decades due to uneven temporal rainfall distribution and a lack of reservoirs. According to a report issued by the Southern Region Water Resources Office in 2014, the water supply for use in the industrial and residential sectors use in the Kaohsiung area is 1,414,000 CMD (m3 per day), and the daily demand for water is 1,679,100 CMD. The gap in the water demand is filled by transferring agricultural water to the industrial and residential sectors, particularly during the period from January to May. In order to meet the water demand, three water source facilities were proposed. To choose water supply alternatives, a cost-benefit analysis is usually adopted. According to the economic theory, the WTP for a production factor is the value of marginal production (VMP). When the VMP equals the production factor price, a firm can maximize its profit. However, the benefit of the water supply cannot be easily assessed when the water price is artificially low. The average price of tap water in Taiwan, including Kaohsiung, is around 10 NTD (0.31USD) per ton, which is almost the lowest in the world. The marginal cost (price) of water for agricultural use is almost nothing in Taiwan. Therefore, another method must be found to evaluate the benefits of water.

In addition to the regulated tap water price, some water sources have different water quality and stability and therefore should be valued differently. Chiueh et al. (2011) used the Contingent Valuation Method (CVM) method to analyze the willingness-to-pay (WTP) of industrial water users for the use of reclaimed water. The results showed that factories are willing to purchase reclaimed water at an average price of 13.97NTD per ton under many assumptions. The direct value of production and the repercussion effect through the industrial chain can be assessed using the input-output (IO) model. Furthermore, the construction of large water source facilities, such as reservoirs and artificial lakes, causes land use changes, which should be assessed together with the benefits of the additional water supply. This paper evaluates the benefits and sectoral impacts of water source facilities. A literature review of the loss and economic impacts of water shortages is provided. Then, the IO model and the results are introduced. Finally, the conclusions and policy recommendations are provided at the end of the paper.

## 2. Literature Review

There have been many economic impact studies on water shortage, but few studies have analyzed the economic gains or benefits of the water supply. Ross and Lott (2003) provided a review of 10 droughts in the U.S between 1980 and 2003, whose economic impact exceeded one billion U.S. dollars (2002 dollars). Hayes et al. (2004) collected drought-loss estimates for the 2002 drought event that hit many states in the U.S., and it also mentioned that Riebsame et al. (1990) made a controversial estimate of the economic damage caused by the 1988 drought in the central and eastern U.S., amounting to 39.4 billion USD. Back in 1995, the Federal Emergency Management Agency (FEMA) estimated the average annual drought-related economic losses to range from six to eight billion in the US. Howitt et al. (2009) estimated that in the short-run, the losses due to the 2009 drought in California (Central Valley) may have amounted to 2.2 billion USD, and some 80,000 jobs may have been lost.

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Mubako et al. (2013) found that increasing pressures on water resources in two economically important states in the US (California (CA) and Illinois (IL)) have created a need for critical information related to sustainable water use and management. In their research, an input–output (IO) analysis was adopted to assess water use and to quantify virtual water transfers involving the two states. The results revealed that aquaculture requires the largest input of direct water per unit of economic output, followed by crops, power generation, livestock, mining, services, domestic, and industry. Low water use intensity industries and services sectors were shown to contribute the largest proportions of value added and employee compensation. Their paper also highlighted the need to consider water use efficiency and opportunity cost when managing water under scarcity conditions.

González (2011) simulated the economic impacts of two kinds of water restriction scenarios in Catalonia, Spain. For the first scenario, a minor drought was considered with no restrictions on priority water uses. In the second scenario, an extreme drought was considered, with larger restrictions affecting urban water supply networks. The research was analyzed by creating an aggregate production function that introduced a variable of water consumption initially in order to calculate the effects of variations in the amount of water used by economic sectors on their aggregate production. That was combined with a supply side IO model to simulate the economic impacts of each scenario. The results revealed a loss of 0.34% GDP in the case of modest restrictions on the water supply and 2.8% in the case of more extreme restrictions.

Butcher and Ford (2009) used a standard input-output model to estimate the impacts of a 2007-08 drought in New Zealand by simply applying farming multipliers to the changes in the farm gate output arising from the drought. The results showed that over the two year period of the drought, output declined by 1.49 billion USD, and farm value added declined by 1.89 billion USD and also led to a potential loss of almost 3,000 jobs.

Only a few studies simulated the economic impacts of the water supply. For example, both Xiang et al. (2015) and Ke et al. (2016b) had the water supply sector in their models and simulated the economic impacts of increasing reclaimed water supply and the reuse rate. The reclaimed water supply in those simulations was not for a specific sector. Moreover, their residential water usage did not have economic impacts. This method was mainly be applied to an optimal allocation of water resources, like Freire-González, Decker and Hall (2018). The optimization can multi-objects. For example, Ke, et al. (2016a) also consider water pollution and gross regional product (GRP). He, et al. (2019) designed the optimization objective function as prospect theory which is like most human. However, the optimization papers tried to allocate water resources efficiently rather than assessing a specific water supply plan which is the target of this paper.

Another category of literature is virtual water which uses the input-output model to estimate the total water consumption of industry. Velázquez (2006) conducted research analyzing intersectoral water relationships in Andalusia with an extended Leontief input-output model combined with the model of energy use developed by Proops. This study provided a new model by which to determine which economic sectors consume the greatest quantities of water, both directly and indirectly, and to what extent this natural resource may become a limiting factor in the growth of certain production sectors. The model allows simulation of possible changes in water consumption caused by certain environmental measures, as well as their consequences on the regional economy. Kondo (2005) explored the cause-and-effect relationship between the exports of manufactured goods and water resources (virtual water) based on the Japanese input-output tables and a factor decomposition analysis. In the analysis, the change in virtual water exports was decomposed into three determinant factors: the direct water coefficient change, the indirect water coefficient change, and the export volume change. The findings implied that the export volume change was the most influential factor in determining the total volume of Japanese virtual water exports in the early 1980s; however, the volume of indirect

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water change has a stronger influence on the virtual water exports now than it did before, and it is greatly affected by subsidiaries.

Another simulation method for the economic impact of a disaster is CGE (computable general equilibrium). Unlike those reviewed IO papers above, Rose and Liao (2005) used CGE models to analyze the sectoral and regional economic impacts of a disruption to the Portland Metropolitan Water System in the aftermath of a major earthquake. Their study specified individual business and regional macroeconomic resilience and adopted producer adaptations in emergencies, etc. Zhong, et al. (2016) measured the economic impact of droughts by CGE with multi-regional irrigation water in China. Zhong, Shen, Liu, Zhang and Shen (2017) focused on the welfare change when irrigation subsidies were reduced. Since CGE can consider behavioral changes and input substitutions, the calibration and verification are required. However, this is not possible in the case of a city where previous impacts and sectoral output data do not exist. In this paper, an IO model was adopted to estimate the economic impact of water supply because IO table is based on industrial census and statistics. The economic losses/impacts of water shortage (drought) and the benefits/impacts of water supply increase may be the same when the percentages of shortage and increase are the same for all economic sectors. However, due to the demand of water quality and/or the water supply arrangement, the water supply could be only targeted to some economic sectors. Since the industrial linkage of water users is different, the economic impacts of various water source facilities will be different. In addition, the economic impact of water supply to the residential sector should be included in any analysis of this topic but there is no residential sector in a typical IO table.

## 3. Input and Output Model of Kaohsiung

According to the literature review, many previous studies have used IO models to evaluate the economic impacts of water shortage. In order to analyze the economic impact of a local water source facility, two modifications of a national IO table are required. The first one is adding the residential sector when the water is supplied to residents. The second one is transforming the national IO to a regional IO table. This section introduces the IO model, the residential sector and the location quotient method.

### 3.1 Input and Output Model and Its Analysis

The IO analysis was originally developed from Walras's general equilibrium model and simplified by Leontief in the 1930s. It probes into the relationship between the production and consumption occurring in all industries and is used to show the inputs of each sector needed to produce one unit of production during a given period or the distribution of production to each intermediate demand and eventually to the final demand. If a matrix is used to show the statistics for the output of all industries, then these statistics form an industrial linkage table, which is also referred to as Leontief's inverse matrix. This model is based on the following three basic hypotheses: (a) the hypothesis of a single product, (b) the hypothesis of fixed coefficients, and (c) the hypothesis of fixed proportions. The above hypotheses also show that this production function is Leontief's production function and has the following three characteristics: (a) there are constant returns to scale in production; (b) output is produced by inputs in fixed proportions, and (c) there is no substitution among inputs (Wang 1986).

The IO analysis is based on the following transaction table (see Fig. 1). The summation of the intermediate demand and net final demand is the net aggregate demand. Intermediate demand refers to the demand for the products of other industries as raw materials during the production of certain products or services by industry. Net final demand refers to products that are to be ultimately consumed

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by economic entities, but not used as intermediate products in production, and can be classified as household consumption (C), private investment (I), government expenditure (G), and net exports (exports minus imports) according to their functions. The summation of the intermediate inputs and primary inputs is the net aggregate inputs. The primary input, which is also called the basic input, refers to the inputs that are not produced by other sectors. The payments for the means of production include the labor remuneration for labor, the rent for land, the interest for capital, the profit for entrepreneurship, and the tax for government services. Thus, the original input is also referred to as the value added.

The IO analysis can be divided into two models: the demand side model and the supply side model. The demand side model can be written as Eq.1:

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

where $(I - A)^{-1}$ is the Leontief inverse matrix, which means that a sector needs to purchase from each of the other sectors when the sector needs to produce one more unit of product. Eq. 1 demonstrates the effect on X—the output of each sector caused by the change in net final demand $\Delta \mathrm{Y}$. In the demand side IO model, the output effect of each sector (repercussion effects) can be estimated by the matrix operation with a change in the demand of a specific sector, such as the construction of water facility. The supply side model can be written as Eq.2:

$$\Delta \mathrm{X} = (I - A^{*})^{-1} \Delta \bar{X} \tag{2}$$

Eq.2 demonstrates the effect on X—the output of each sector caused by the change in the output of the other sector $\Delta \bar{X}$. These models and their matrix operations can be found in Lin et al. (2012). Miller and Blair (2009b) provided a method of income and employment multipliers to estimate the changes in income and employment when the output effect is estimated.

In the supply side IO model, the output effect of each sector (repercussion effects) can be estimated by the matrix operation with a change in the output of a specific sector, such as water supply. There are two traditional ways to estimate the output change in the industrial sector when new water is supplied to it. The first one is the value of the water supplied which regards the value of water supplied equals the increases of output. As per the introduction section, the total value of water cannot be adopted in this case because the water price is regulated and is artificially low. The second one is building a production function of the industrial sector. González (2011) used this method. However, building a production function requires a sufficient amount of data for output and the adoption of all production factors, which is difficult for the local industry to acquire. Thus, in this paper, a method using the CVM and water footprint is proposed to estimate the direct gain from water supply.

### 3.2 Data - Residential Sector and Sector Aggregation

A new water source facility supplies water to residents, but there is no residential sector in a transaction table. In order to estimate its economic impact, it is necessary to establish a residential sector. This is a closed model that uses household consumption in the final demand and labor remuneration as the primary input of a transaction table to create the endogenous residential sector (Miller and Blair 2009a). The idea of this method is that households (the residential sector) use their

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wages (labor remuneration) as intermediate input for their production (consumption). This method is shown in **Fig. 1**.

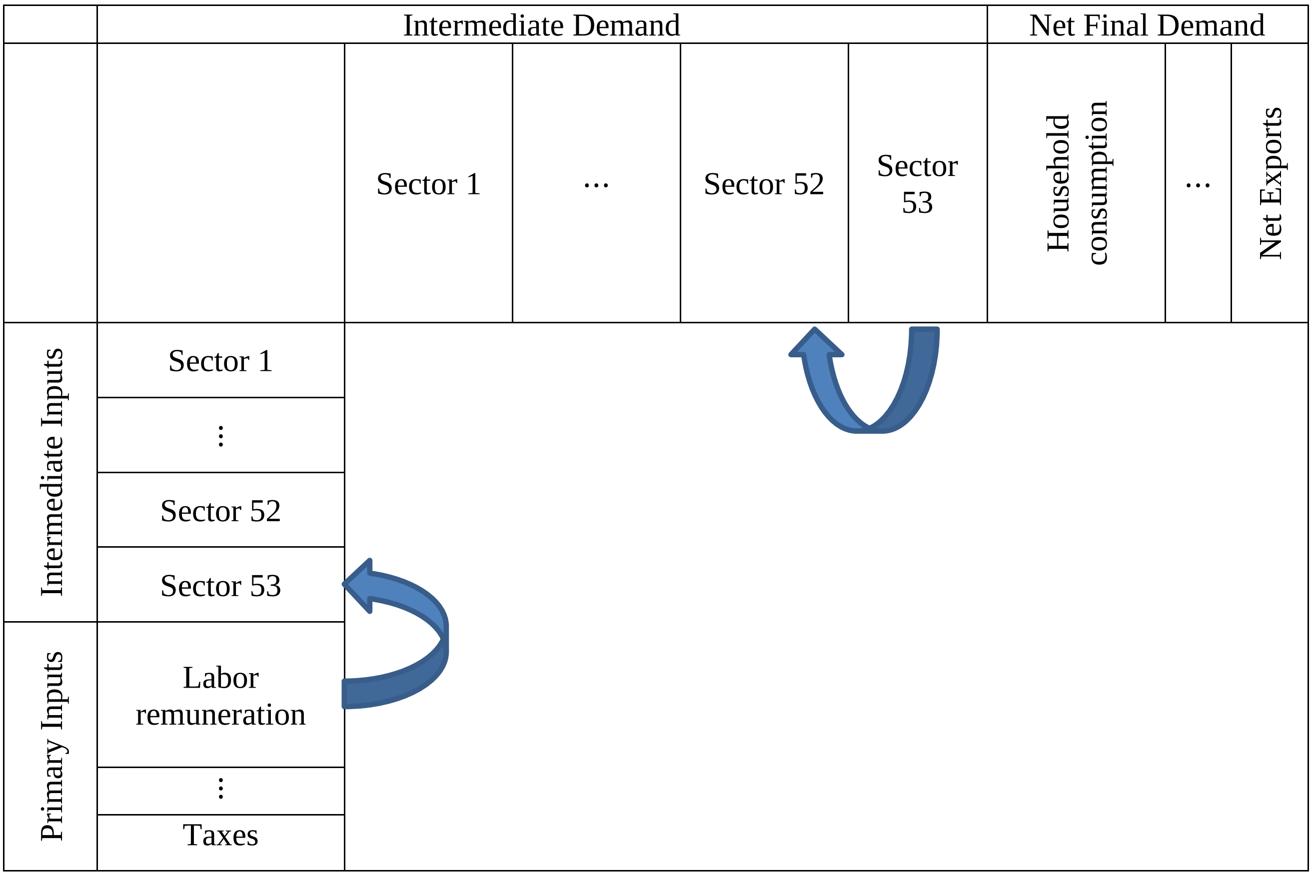


**Fig. 1 The creation of a residential sector in a transaction table**

The transaction table of domestic goods and services with 52 sectors compiled by Directorate-General of Budget, Accounting and Statistics, Executive Yuan, Taiwan in 2011 was adopted in this study. The reason for choosing the transaction table of domestic goods and services is that the water supply will all be consumed locally, and directly-produced goods are seldom exported from Taiwan. In order not to overestimate the results of economic impacts, the effects of imported goods and services must be excluded. The residential sector became the 53rd sector in the IO table.

The economic sectors in the transaction table were aggregated from 53 sectors into 12 sectors because the water supply users can only be categorized into residents, industry (mainly manufacturing) and agriculture. The water consumption of other sectors, such as the wholesale and retail trade and transportation and storage, are part of the industrial and/or residential sector depending on their location. The water consumption of these sectors is less than the industrial and residential sectors. The economic sectors and the sector aggregation are shown in **Table 1**.

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**Table 1 The economic sectors and the sector aggregation**

| Industry Number | Industry Group in this study | Original Industry Group |
|---|---|---|
| 01 | Agriculture | Aggregated from sector 1 (farm sector) to sector 4 (fishery) |
| 02 | Mining | Sector 5 |
| 03 | Industry | Aggregated from sector 6 (mining sector) to sector 32 |
| 04 | Electricity and Gas Supply | Aggregated from sector 33 to sector 34 |
| 05 | Water Supply and Remediation Activities | Aggregated from sector 35 to sector 36 |
| 06 | Construction | Sector 37 |
| 07 | Wholesale and Retail Trade | Sector 38 |
| 08 | Transportation and Storage | Sector 39 |
| 09 | Accommodation and Food Services | Sector 40 |
| 10 | Finance and Insurance Services | Sector 44 |
| 11 | Other Services | Aggregated from sector 41 to sector 43 and sector 45 to sector 52 |
| 12 | Residential Sector | Housing consumption and labor remuneration farmland for the residential sector. |

### 3.3 Location Quotient (LQ)

In Taiwan, the IO table is made by the Directorate General of Budget, Accounting and Statistics (DGBAS), Executive Yuan according to the Agriculture, Forestry, Fishery and Animal Husbandry Census and the Industry and Service Census. In Taiwan, a water source facility supplies water to a city or two adjacent cities/counties at most. A survey of all firms would be required for making a city's IO table. The location quotient (LQ) is a method that uses the ratio of economic indicators, such as employees, income, household consumption, between the national and regional levels to adjust the national input coefficients to regional input coefficients. The LQ of industry i ($LQ_i$) can be written as:

$$LQ_i = (E_{ir}/E_r)/(E_{in}/E_n) \tag{3}$$

where $E_{ir}$ denotes local employees of industry i in region r; $E_{in}$ denotes the total employees of industry i in the nation; $E_r$ denotes the total employees in region r, and $E_n$ denotes total employees in the nation. If $LQ_i$ is larger than one, the national input coefficients are adopted. If $LQ_i$ is smaller than one, the national input coefficients should be adjusted by multiplying the LQ. The idea can be shown with the following equation:

$$d_{ij}^r = \begin{cases} d_{ij}^n & \text{If } LQ_i \geq 1 \\ d_{ij}^n \times LQ_i & \text{If } LQ_i < 1\text{'} \end{cases} \tag{4}$$

where $d_{ij}^r$ denotes the regional input coefficient, and $d_{ij}^n$ denotes the national input coefficient. This method is based on studies of Schaffer and Chu (1969), Morrison and Smith (1974), and Sawyer and Miller (1983). The empirical results of one investigation also showed that the errors between the regional IO table established with the non-survey method (location quotient) and the one established by the survey method (actual investigation) are quite small, which means the location quotient method can obtain good results in terms of regionalizing the IO table (Lee and Lin 2000).

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## 4. The Direct Gain/Loss from Water Source Facilities

Three water source facilities, a reclaimed water plant (RC), a seawater desalination plant (SD) and Gaoping Lake (phase one) (GL), are proposed and assessed in this study. The amount of water supply and the supply objects for these three cases are listed in Table 2. These water source facilities have several effects on economic sectors. Fig. 2 shows the framework of these effects and their economic impacts. During the construction period, the facility increases the final demand because its investment belongs to government expenditure. The demand side IO model was adopted to evaluate the economic impacts of facility investments. During the operational period, water facilities increase industrial output because water is a production factor. These new water source facilities can supply water to the industrial and/or residential sectors, and they can reduce water transferals from the agriculture sector. This means that water source facilities change the output of the industrial, residential and/or agriculture sectors. Since the output of these sectors is the intermediate input of other sectors, the supply side IO model was adopted to evaluate their economic impacts. The water supply from SD and RC consumes more energy. Since the energy cost is included in regular cost benefit analysis (unit cost of water), its economic impacts are not included in this paper.

**Table 2 The water supply and objects of facilities**

| Name of Facility | Water Supply (CMD) | Supply Object |
|---|---|---|
| Reclaimed Water Plant | 45,000 | Industrial sector only |
| Seawater Desalination Plant | 100,000 | Industrial and residential sectors |
| Gaoping Lake (Phase One) | 100,000 | Industrial and residential sectors |

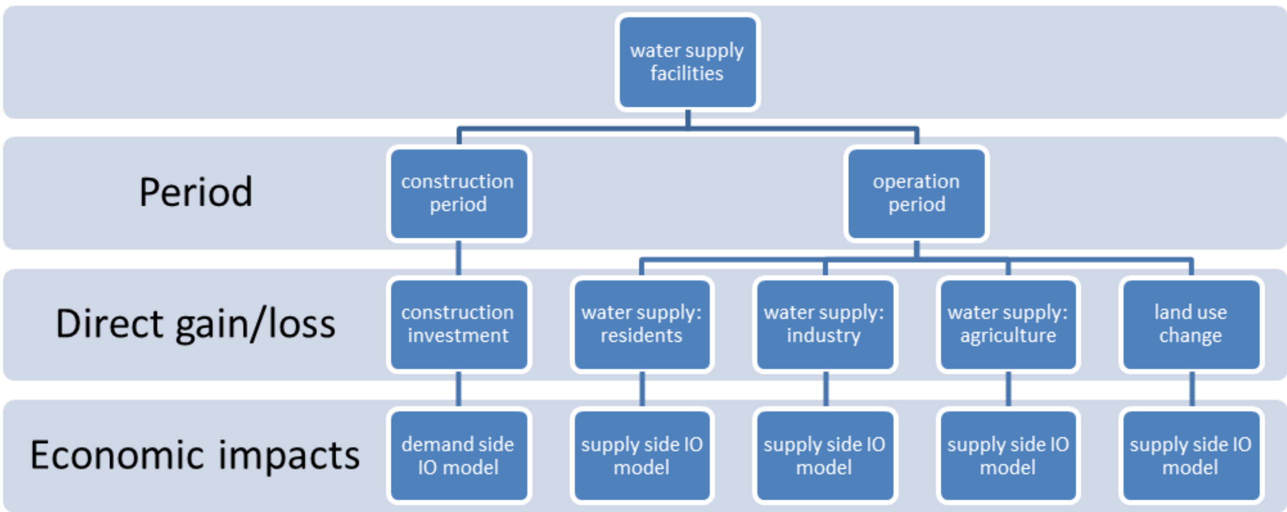


**Fig. 2 The framework of the economic impacts of water source facilities**

### 4.1 The Direct Gain from Construction Investment

Since the transaction table is annual, in this study, the annual investment is used to assess the economic impact of increasing the final demand of the construction sector. The investment of each

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water source facility increases the final demand in the construction sector which is $\Delta Y$ in Eq.1. Table 3 shows the related information about the investment required for each water source facility.

**Table 3 The investment of water source facilities**

Unit:1000 NTD

| Name of Facility | Total Investment [4] | Construction Period | Annual Investment |
|---|---|---|---|
| Reclaimed Water Plant[1] | 2,482,330* | 3 | 827,443 |
| Seawater Desalination Plant[2] | 5,495,561* | 2 | 2,747,781 |
| Gaoping Lake (Phase One)[3] | 5,812,811* | 2 | 2,906,405 |

Note:

1. Kaohsiung City Sewage System - The Fourth Phase Implementation Project of Fongshan Creek Area, 2nd ed., 2014, Kaohsiung City Government.
2. Planning and Investigation for a Seawater Desalination Plant in Tainan, 2007, Water Resources Planning Institute.
3. Review and Planning for the Gaoping Lake Phase One Construction, 2012, Southern Region Water Resource Office, WRA, MOEA.
4. "*" The amount of investment was adjusted to the price level of 2011 using the GDP deflator for the construction sector because the 2011 IO table was adopted.

The investment for the reclaimed water plant only included construction funds. The investment for the seawater desalination plant included intake and drainage engineering, structural engineering, water conveyance engineering and management fees, etc. The investment for Gaoping Lake included the construction of the artificial lake and the engineering expenses related to deploying the pipeline system.

### 4.2 The Direct Gain from Providing Water to Industry and Residents

The concept of the supply side IO model is to estimate the overall output effect caused by the amount of change in industrial input, i.e. changes in intermediate input as raw material, of a sector. The annual value of the reclaimed water provided by the reclaimed water plant for industrial use is:

$$\text{The annual value of reclaimed water from industrial use} = \text{Annual reclaimed water supply} \times \text{WTP for reclaimed water} \quad (5)$$

In Taiwan, reclaimed water is only used for industrial use through a dedicated pipeline. There is no market or transparent price for reclaimed water. The WTP for reclaimed water can be retrieved using the CVM method. It was first proposed by Ciriacy-Wantrup (1952) but was adopted by Davis (1963) to evaluate environmental goods. The most popular way to elicit WTP for nonmarket goods is the CVM method suggested by the NOAA (National Oceanic and Atmospheric Administration, US Department of Commerce) panel (Arrow, et al. 1993). Chiueh et al. (2011) used this method to estimate the WTP for reclaimed water and found it to be 0.48 USD/ton (13.97NT/ton). The contingent issue is "the government guarantees that the quality of reclaimed water conforms to city water specifications, with no interruption of supply 365 days a year, with assured quality and loss indemnification on supply

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interruption.” When the water price is manipulated and/or the features of new water source are different from the current system, CVM can be adopted to elicit the WTP for the new water source.

Since the water from the desalination water plant (SD) and Gaoping Lake (GL) is the same quality as that of the current tap water and is supplied through the tap water system, the annual economic value of water from SD and GL is:

The annual economic value of water from SD and GL=

Annual water supply × Average price of water (6)

The average price of water is 10 NTD per ton. The proportions of water demand for the industrial and residential sectors were 43% and 57% in the year 2012, respectively. This proportion was adopted in this study as the water demand of the industrial and residential sectors, respectively.

### 4.3 The Direct Gain from Decreasing Water Transferal

After the new water resource facility has been built, the transfer of agricultural water will be reduced. The water returned to the agricultural sector could be used for producing crops, thus increasing production. Hence, the returned agricultural water was transferred to rice production because rice production consumes the most agricultural water in Taiwan. The economic value of rice production is the intermediate input of the agricultural sector. Since the price of water for agricultural use is also manipulated to be almost free, the economic value of production cannot be estimated by the agricultural water supply times its price. In this research, the water footprint was used for this estimation. The water footprint measures the amount of water used to produce each of the goods and services under consideration. It can be categorized into blue, green and grey water footprints. The green water footprint is water from precipitation that is stored in the root zone of the soil and evaporated, transpired or incorporated by plants. The blue water footprint is water that has been sourced from surface or groundwater resources and is either evaporated, incorporated into a product or taken from one body of water and returned to another, or returned at a different time. Both are particularly relevant for agricultural products. However, grey water footprint is the amount of fresh water required to assimilate pollutants to meet specific water quality standards. The water pollution of agricultural production is non-point source. The non-point water pollution is mainly from land use change and the control of it is management practices rather than discharge standard. Because the grey water footprint depends on regional water environment, it is not included in this paper. The economic value of returned agricultural water is thus:

The increase of rice production =

[Annual returned agricultural water / (blue and green) water footprint for producing a ton of rice] × Average price of rice per ton

(7)

The value of the water footprint is from Yao et al. (2013), who estimated the sum of the blue and green water footprints of the first rice crop in southern Taiwan to be 1956 m3 per ton.

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### 4.4 The Direct Loss from Land Use Change by Water Source Facility

The reclaimed water plant and the seawater desalination plant are designed to be built in industrial areas where there are vacancies. However, Gaoping Lake will be built in an agricultural area. There are 188 hectares of green soybean land that will become a part of Gaoping Lake, which means the production of green soybeans will be decreased, which will in turn pose a negative impact on local farmers. According to statistics from the Kaohsiung District Agricultural Research and Extension Station, COA, Executive Yuan, Taiwan, the production of green soybeans in the spring is about 8,938-9835 kg per hectare; while in autumn, it is about 8,987-9,529 kg per hectare. In 2011, the unit price of green soybeans was 35NTD per kg, based on data from the Kaohsiung Meinong Farmers' Association. The production of green soybeans would therefore drop by about 122.68 million NTD annually.

The water from Gaoping Lake and the seawater desalination plant will be provided to both the industrial and residential sectors, and the water from the reclaimed water plant will be provided to only the industrial sector. The water transferred from agriculture will be reduced, and thus the output of the agricultural sector will be increased. Since some agricultural areas will be used for Gaoping Lake, the agricultural output (green soybeans) will be reduced. All these direct gains/losses from the water supply are estimated and listed in Table 4 which are $\Delta\bar{X}$ in Eq.2.

**Table 4 The Amount of Change in Intermediate Input**

| Water source facility | The Amount of Change in Intermediate Input (1,000 NTD) |
|---|---|
| Reclaimed Water Plant | Industrial Sector: 229,457<br>Agricultural Sector: 83,000 |
| Seawater Desalination Plant | Residential Sector: 208,050<br>Industrial Sector: 156,950<br>Agricultural Sector: 184,000 |
| Gaoping Lake (Phase One) | Residential Sector: 208,050<br>Industrial Sector: 156,950<br>Agricultural Sector: 184,000<br>Land Use Change (Agricultural): (-) 122,680 |

## 5. The Economic Impacts

The analysis of economic effects was divided into three sections in this study. Section one is a discussion of the economic impacts of constructing water source facilities through increasing the final demand of the construction sector using the demand side IO model. Section two is a discussion of the economic impacts of water supply to various sectors through increasing the intermediate input of sectors using the supply side IO model. Section three is a discussion of the economic impacts of land use change through decreasing the intermediate input of the agriculture sector using the supply side IO model.

### 5.1 The Economic Impacts of Water Source Facility Construction

Construction of water source facilities will lead to the development of other related economic sectors, for example, when constructing such facilities, the demand for ingredients such as steel, electricity, gas, water, timber, parts, components, etc. will also increase, which means the outputs of other related economic sectors will be also promoted due to the construction. Moreover, more workers

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will be hired for economic sector production, thus, the income of workers will also be increased. These effects are called the employment effect and income effect.

The construction of a reclaimed water plant requires an investment of 827,443 thousand NTD annually (Table 3) in the final demand of the construction sector. The output effects can be estimated through multiplying the changed final demand matrix by the inter-industry interdependence coefficients matrix $(I - A)^{-1}$. The results indicate that this investment is expected to create a 2,235.6 million NTD output effect in the Kaohsiung area annually. The construction of the seawater desalination plant requires an investment of 2,747,781 thousand NTD annually toward the final demand of the construction sector. The results indicate that this investment would create a 7,423.99 million NTD output effect in the Kaohsiung area. The construction of Gaoping Lake increases the final demand of the construction sector by 2,906,405 thousand NTD annually. The results indicate that this investment will create a 7,852.57 million NTD output effect on the Kaohsiung area annually. The output effect is 2.7 times the investment in the construction sector. Since the investment for Gaoping Lake is the largest among these three water source facilities, it generates the highest output effect.

Since the income multiplier, the employment multipliers and industrial linkage are constant, the income and employment effects are only estimated for Gaoping Lake. The construction of Gaoping Lake will increase income by 2,711.18 million NTD and create 3,162 job opportunities annually during the construction phase. The most affected sectors will be construction, industry and other services sectors, in that order.

### 5.2 The Economic Effects of Water Supply

The use of water can increase the production of an economic sector during the period of a water shortage because water is the critical intermediate input for many economic sectors. In this study, the supply side IO model was used to estimate the output effect of the water supply. The reclaimed water supply to the industrial sector is expected to create 1,766.71 million NTD output effect on the Kaohsiung area annually. Among the 12 economic sectors, the industrial sector produces the highest output effects of 368.97 million NTD, which accounts for 20.7% of the total output effect, followed by the electricity and gas supply sector with 249.64 million NTD and the water supply and remediation activities sector, with 236.14 million NTD. Production in the industrial sector uses a lot of resources, including electricity, water, and gas as the intermediate input for production, so the outputs of the electricity and gas supply and the water supply sectors can experience significant growth.

Because the seawater desalination plant and Gaoping Lake water supplies are the same (both with 100,000 CMD and both supply to the industrial and residential sectors, 43% and 57%, respectively), the annual water supply from either the seawater desalination plant or Gaoping Lake is expected to create a 2,731.1 million NTD output effect on the Kaohsiung area annually. Among the 12 sectors, the residential sector produces the highest output effects, with 395.52 million NTD, which accounts for 14.5% of total output effect. This can be explained as 57% of the water supply to the residential sector. The accommodation and food services sector has a 303.76 million NTD output, and the industry sector has a 295.23 million NTD output. The electricity and gas supply sector has a 295.23 million NTD output. The economic impacts of the seawater desalination plant and Gaoping Lake are higher than that of the reclaimed water plant. The increase in the water supply from either the seawater desalination plant or Gaoping Lake is expected to create a 1,034.54 million NTD income effect on the Kaohsiung area annually, and a total of 1,004 job opportunities could be created in the Kaohsiung area annually.

The agricultural water transfer will be reduced after one of three water resource facilities has been constructed, which means that the equivalent agricultural water will be returned to the agriculture sector, and the agricultural output will be increased. The reclaimed water plant could return 6.75

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million m3 of agricultural water to the agricultural sector. This return could create a 112.47 million NTD output to the Kaohsiung area annually. The agricultural water transfer will be reduced by 15 million m3 after either the seawater desalination plant or the Gaoping Lake has been constructed. These results indicate that this return could create a 246.36 million NTD output to the Kaohsiung area annually. This is higher than the economic effect caused by the reclaimed water plant. From an individual economic sector point of view, agriculture has the highest output effect, with 203.62 million NTD, which accounts for 82.6% of the total output effect, followed by the residential sector, with a 6.26 million NTD output effect, and the wholesale and retail sector, with a 5.77 million NTD output effect. Approximately 103 million NTD in income and 205 job opportunities would be expected in the Kaohsiung area annually as a result. It should be noted that none of the analyses on the economic effects of the residential sector include income and employment effects. This is because the residential sector is created by labor remuneration and household consumption. That is to say, there is no information about the employment of the residential sector. The robustness check for the economic impact assessment of water supply is not required. The reasons are that the IO table is based on industrial census and statistics, and the economic impact is from matrix operations from IO table. Even the water supply amount from the water source facility has uncertainty, the results would be fixed ratios to the water supply amount.

### 5.3 The Economic Impacts of Land Use Change

The 122.68 million NTD loss for green soybeans due to the construction of Gaoping Lake will have a repercussion on the other related economic sectors through industrial linkage effects. The results show that this impact would cause losses of 164.26 million NTD for output, 68.67 million NTD in income and 137 jobs annually in the Kaohsiung area. However, most of these negative impacts are concentrated in the agricultural sector. The agricultural sector has the highest loss of 135.76 million NTD in output, followed by the residential sector, with 4.17 million NTD, and the wholesale and retail trade, with 3.84 million NTD in output losses.

## 6. Conclusions and Policy Recommendations

In this study, Kaohsiung region input and output (IO) models were built from the 2006 national transaction table of domestic goods and services using the location quotient method in order to evaluate the economic impacts of three water sources: a reclaimed water plant (RC), a seawater desalination plant (SD) and phase one of Gaoping Lake (GL). A residential sector was added into our Kaohsiung regional IO model in order to estimate the economic impact of the increased water supply on the residential sector. The costs of water were 17.7 NTD per ton from GL, 25.7 NTD per ton from RC, and 35.4 NTD per ton from SD.

The results revealed that the GL construction would create 7,852.57 million NTD in output; the construction of the SD would create 7,423.99 million NTD in output, and the construction of the RC would create 2,235.6 million NTD in output annually in the Kaohsiung area during the construction period. As for the economic impacts on water supply, the water from the RC is only for the industrial sector, which can generate 1,776.71 million NTD in output annually to the Kaohsiung area. The most highly impacted sectors are industry, electricity and gas supply, and water supply and remediation activities sectors, in that order. The water from the SD and GL are for both industrial and residential sectors, and each facility can generate 2,731.1 million NTD in output. Increasing one CMD water supply from SD and GL to residential and industrial sectors can increase 74.82 NTD (2.32USD) output a year which is much valuable than the current water price. Since the industrial sector has a higher forward linkage than the residential sector, providing more water to the industrial sector has more

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repercussion effects. The most highly impacted sectors are residential, accommodation and food services, and industry sectors, in that order. Since new water sources reduce water transferred from the agricultural sector, SD and GL each can increase water for agricultural use by 1 million CMD, and each facility can generate 246.36 million NTD in output. The RC can increase water for agricultural use by 45 thousand CMD, which can generate a 112.47 million NTD output annually to the Kaohsiung area. The most highly impacted sectors are the agricultural, residential, and wholesale and retail sectors, in that order. However, since building GL will cause a loss of 188 hectares of green soybean land, there will be a loss of 164.26 million NTD in output annually. Among these three new water sources, GL has the lowest unit cost of water and the highest total output effects, including the construction demand and water supply, even when the output reduction from farmland loss is subtracted. If only the operation period is considered, SD generates the highest total output. Since the amount of water supply of facilities is different, RC has the highest output effect per ton supplied during the operation period.

The combination of regional IO with the residential sector, CVM and water footprint proposed in this paper provides a relative comprehensive benefit evaluation tool that can turn economic impacts of water source facilities into monetary term and the decision maker can compare them with its own criteria like the comparison above. However, some non-economic impacts, such as the objection from land use change by GL and the environmental impacts from SD and RC, are not considered in the procedure built in this study.

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## References


1. Arrow, K., et al. (1993), "Report of the Noaa Panel on Contingent Valuation," Federal Register, 58, pp.4601–4614.
2. Butcher, G. V., and Ford, S. (2009), "Modeling the Regional Economic Impacts of the 2007/08 Drought: Results and Lessons," 2009 New Zealand Agricultural and Resource Economics Society Conference.
3. Chiueh, Y., Chen, H.-H., and Ding, C.-F. (2011), "The Willingness to Pay of Industrial Water Users for Reclaimed Water in Taiwan," in Current Issues of Water Management, ed. D. U. Uhlig, INTECH Open Access Publisher.
4. Ciriacy-Wantrup, S. V. (1952), Resource Conservation: Economics and Policies, Berkeley: University of California Press.
5. Davis, R. K. (1963), "Recreational Planning as an Economic Problem," Natural Resource Journal, 3(2), pp.239-249.
6. Freire-González, J., Decker, C. A., and Hall, J. W. (2018), "A Linear Programming Approach to Water Allocation During a Drought," Water, 10(4), pp.363.
7. González, J. F. (2011), "Assessing the Macroeconomic Impact of Water Supply Restrictions through an Input–Output Analysis," Water Resources Management, 25(9), pp.2335-2347.
8. Hayes, M. J., Svoboda, M. D., Knutson, C. L., and Wilhite, D. A. (2004), "Estimating the Economic Impacts of Drought," in 14th conference on Applied Climatalogy and 15th Symposium on Global Change and Climate Variations, Lincoln, NE: American Meteorological Society.
9. He, H., et al. (2019), "Optimal Allocation Model of Water Resources Based on the Prospect Theory," Water, 11(6), pp.1289.
10. Howitt, R. E., MacEwan, D., and Medellín- Azuara, J. (2009), "Economic Impacts of Reductions in Delta Exports on Central Valley Agriculture," Agricultural and Resource Economics Update, 12(3), pp.1-4.
11. Ke, W., et al. (2016a), "Dynamic Simulation of Water Resource Management Focused on Water Allocation and Water Reclamation in Chinese Mining Cities," Water Policy, 18(4), pp.844-861.
12. Ke, W., Sha, J., Yan, J., Zhang, G., and Wu, R. (2016b), "A Multi-Objective Input–Output Linear Model for Water Supply, Economic Growth and Environmental Planning in Resource-Based Cities," Sustainability, 8(2), pp.160.

doi: 10.6858/GE.202001_6.0001


13. Kondo, K. (2005), "Economic Analysis of Water Resources in Japan: Using Factor Decomposition Analysis Based on Input-Output Tables," Environmental Economics and Policy Studies, 7(2), pp.109-129.
14. Lee, K. C., and Lin, L. C. (2000), "A Green Functions Input-Output Analysis on Forestry Sector of Nan-Tou County," Quarterly Journal of Chinese Forestry, 33(4), pp.513-527.
15. Lin, H. C., Kuo, Y. L., Shaw, D., Chang, M. C., and Kao, T. M. (2012), "Regional Economic Impact Analysis of Earthquakes in Northern Taiwan and Its Implications for Disaster Reduction Policies," Natural Hazards, 61(2), pp.603-620.
16. Miller, R. E., and Blair, P. D. (2009a), "2.5 Open Models and Closed Models," in Input-Output Analysis: Foundations and Extensions (2 ed.), New York: Cambridge University Press.
17. Miller, R. E., and Blair, P. D. (2009b), "6.2.2 Income/Employment Multipliers," in Input-Output Analysis: Foundations and Extensions (2 ed.), New York: Cambridge University Press, pp. 250-256.
18. Morrison, W. I., and Smith, P. (1974), "Nonsurvey Input-Output Techniques at the Small Area Level: An Evaluation," Journal of regional science, 14(1), pp.1-14.
19. Mubako, S., Lahiri, S., and Lant, C. (2013), "Input–Output Analysis of Virtual Water Transfers: Case Study of California and Illinois," Ecological Economics, 93(pp.230-238.
20. Riebsame, W. E., Karl, T. R., and Changnon, S. A. (1990), Drought and Natural Resources Management in the United States: Impacts and Implications of the 1987-89 Drought Boulder, Colorado: Westview Press.
21. Rose, A., and Liao, S.-Y. (2005), "Modeling Regional Economic Resilience to Disasters: A Computable General Equilibrium Analysis of Water Service Disruptions," Journal of regional science, 45(1), pp.75-112.
22. Ross, T., and Lott, N. (2003), "A Climatology of 1980-2003 Extreme Weather and Climate Events," Technical, U.S. Dept of Commerce, NOAA, NESDIS, National Climatic Data Center.
23. Sawyer, C. H., and Miller, R. E. (1983), "Experiments in Regionalization of a National Input—Output Table," Environment and Planning A, 15(11), pp.1501-1520.
24. Schaffer, W. A., and Chu, K. (1969), "Nonsurvey Techniques for Constructing Regional Interindustry Models," Papers in Regional Science, 23(1), pp.83-104.
25. Velázquez, E. (2006), "An Input-Output Model of Water Consumption: Analysing Intersectoral Water Relationships in Andalusia," Ecological Economics, 56(2), pp.226-240.
26. Wang, T. F. (1986), "Input-Output Analysis and Application - Empirical Study in Taiwan," Journal of the Bank of Taiwan, 37(1), pp.186-218.

doi: 10.6858/GE.202001_6.0001

27. Xiang, N., Xu, F., Shi, M.-J., and Zhou, D.-Y. (2015), "Assessing the Potential of Using Water Reclamation to Improve the Water Environment and Economy: Scenario Analysis of Tianjin, China," Water Policy, 17(3), pp.391-408.
28. Zhong, S., et al. (2016), "Measuring Drought Based on a Cge Model with Multi-Regional Irrigation Water," Water Policy, 18(4), pp.877-891.
29. Zhong, S., Shen, L., Liu, L., Zhang, C., and Shen, M. (2017), "Impact Analysis of Reducing Multi-Provincial Irrigation Subsidies in China: A Policy Simulation Based on a Cge Model," Water Policy, 19(2), pp.216-232.