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Assessing the Macroeconomic Effects of Water Scarcity in South Africa using a CGE Model

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Abstract
We develop a dynamic computable general equilibrium (CGE) model to assess the macroeconomic impacts of water scarcity and water (in)security in South Africa. The CGE model which includes a detailed representation of water resources (surface water, groundwater, wastewater, and seawater) has been calibrated with an updated social accounting matrix enabling to conduct policy simulations up to 2030. With the 17% expected increase of water scarcity (population growth, climate change, and poor management of water resources), the CGE model predicts a decrease of South African GDP by −0.44% in 2030. The long-term impact of water scarcity varies from one sector to another, the most negatively impacted sectors being those related to water. Due to water scarcity, unemployment will increase in the short term by 0.76%. In the long term (2030), unemployment is however expected to recover its baseline level. The increase in water scarcity is also predicted to have a negative impact on household welfare, household consumption being reduced by −0.47% in 2030. A particular concern for policy-makers might be that low-income households are expected to be more impacted by water scarcity than high-income households. Some policies may mitigate the negative impacts of water scarcity, the most promising ones being to promote water saving and to decrease non-revenue water.

Keywords Computable general equilibrium model · South Africa · Water · Economic growth · Households · Firms

1 Introduction

South Africa is facing a water crisis in particular due to a lack of water-infrastructure maintenance and investment, and to recurrent droughts. Water insecurity is recognized as one of the most prominent challenges for South Africa's public authorities [1]. In April 2017, 14.1 million people still used sanitation facilities below the Reconstruction and Development Programme standard. Only 10.3 million households (64%) had access to a reliable water supply. Approximately 56% of South Africa's municipal wastewater treatment works and approximately 44% of water treatment works were in poor or critical condition and in need of urgent rehabilitation. Between 1999 and 2011, the extent of South Africa's main rivers classified as being in poor ecological condition increased by 500%, with some rivers pushed beyond the point of recovery. South Africa has lost over 50% of its wetlands, and a third of the remaining 3.2 million hectares are already in a poor condition. This water crisis is already having significant negative effects on the economy [2], including loss of revenue, of economic productivity and growth, and of wellbeing of the population. If water demand in South Africa continues to grow at current levels, the deficit between water supply and demand could rise to between 2.7 and 3.8 billion m^3 per year by 2030, a gap which represents about 17% of available surface water and groundwater resources [1].

Although the macroeconomic impacts of increased water scarcity by 2030 remain largely unknown, specific policies dedicated to mitigating them should be designed and implemented as soon as possible. The National Water and Sanitation Master Plan has identified a number of critical

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priority actions to be implemented: reducing water demand, increasing supply, ensuring universal, reliable and safe supply and sanitation, protecting infrastructure through effective asset management, improving raw water quality, and ensuring equity in access to water [3]. Some priorities seem to be particularly promising. First, the water and sanitation sector being not financially sustainable, an increase in prices of water and sanitation services should be considered in addition to water conservation and demand management measures. Second, addressing high levels of water loss also appears to be a critical element for reducing water use. Third, non-revenue water should be limited as much as possible. Non-revenue water levels in municipalities are indeed estimated at an average of 41% resulting in a loss of around R9.9 billion of potential revenue per year. Lastly, development of alternative water sources such as desalination and water reuse should also be considered.

Establishing and quantifying how various possible policies can mitigate the impacts of water scarcity on economic growth and on the wellbeing of populations is challenging since it requires the development of complex macroeconomic models. Water is used in most economic activities and the allocation of water resources involves many economic agents (firms, households, government) and sectors with complex interactions. A way to account for the complex relationships between water resources and economic sectors is to rely on computable general equilibrium (CGE) models, a class of economic computer-based simulation models which rely on a large system of equations that describe the whole economy and their sectoral interactions [4]. CGE models have proven to be a powerful tool to analyze the macroeconomic effects of environmental policies [5, 6]. It is however fair to recognize that CGE models rely on some strong assumptions [7, 8]. First, they are by construction normative models and resource allocation across sectors and across economic agents is driven by market efficiency. Second, CGE models tend to focus exclusively on homogeneous economic agents with rational behaviors. Third, uncertainty is usually not accounted for. Fourth CGE models are also heavily dependent on complex calibration processes, and their predicted power is rarely assessed. Despite these limitations, CGE models are viewed as useful prospective tools to assess the macroeconomic impacts of a large range of policies, including environmental policies [9].

Adapting CGE models to include water resources is still relatively undeveloped, possibly due to the limited availability of data related to water use and water costs that would provide the basis for calibrating a CGE model. In their recent review of the literature addressing the water-energy-food Nexus, Bardazzi and Bosello [7] have pointed out several important challenges to embed water into CGE models. First, an explicit representation of water as an explicit production factor is still needed. Second, the public good dimension of water may be difficult to consider in CGE models where allocation of resources is driven by market efficiency. Third, the lack of detailed data on water use by sector and on water availability by type of resource (i.e., surface water, groundwater, water reuse) may result in a lack of model reliability. Fourth, since CGE models are often developed for a given country or for a particular region with a yearly time frame, they may be unable to accurately represent some important issues such as seasonality of water resources or variability of water resources over space. Bardazzi and Bosello [7] conclude their review by mentioning that methodological improvements are still needed to make CGE models effective for producing robust policy analyzes of the water-energy-food Nexus.

Here, we propose a new CGE model focused on water for South Africa, and we show how such a model can provide recommendations for decision-making related to water policy. Several characteristics of the CGE make its use relevant for evaluating water policies. First, the CGE model is dynamic which allows to assess impacts of water scarcity in the short run but also in the long run (up to 2030). Second, the CGE model considers all water users and sectors, while taking full account of macroeconomic constraints and intersectoral linkages. Third, the CGE model includes a detailed representation of water allowing to distinguish tap water, reused wastewater and desalination of seawater. To our best knowledge, it is the first time that these elements are included altogether into a CGE model. We then provide an answer to the lack of realistic representation of the water dimension in CGE pointed out recently by Bardazzi and Bosello [7].

In terms of results, our work then showcases how a CGE model can inform policy-makers regarding links between water security and economic growth. We show that water scarcity will have an impact on the South African economy. With the 17% expected increase of water scarcity (related to population growth, climate change and poor management of water resources), the CGE model predicts a decrease of South African GDP by −0.44% in 2030. The long-term impact of water scarcity varies from one sector to another, the most negatively impacted sectors being those related to water. Due to the increase of water scarcity, unemployment is expected to increase in the short term by 0.76%. In the long term (2030), unemployment is however expected to recover its baseline level. The increase in water scarcity is also expected to have a negative impact on household welfare, household consumption being reduced by −0.47% in 2030. Some policies may mitigate the negative impacts of water scarcity, the most promising ones being to promote water saving and to decrease non-revenue water.

This remainder of this article is organized as follows. Section 2 summarizes the literature having used CGE models to assess macroeconomic impacts of water insecurity on economic growth and population welfare, and it presents SAWAT, the South African WATer-CGE model we have developed. Section 3 provides a macroeconomic assessment of water policies in South Africa using SAWAT. We conclude in Section 4 by discussing policy implications of our work.

2 Building a Water-CGE Model to Inform Decision-Making in South Africa

2.1 Using CGE Models for Assessing Macroeconomic Impact of Water (In)security

Using CGE models for assessing macroeconomic impact of water (in)security raises conceptual and empirical challenges. In their review of the literature on the introduction of water into CGE models, Ponce et al. [10] stress the lack of sufficient details for representing non-agricultural sectors (including water-intensive industrial sectors) and the need to explicitly account for reduction of water availability. As indicated by Bardazzi and Bosello [7], further methodological improvements are still needed.

Despite these concerns, CGE models including water resources have been developed, and they have contributed to the literature on trade [11] in particular by pointing out the role of virtual water flows for providing food security in water-scarce regions [12]. Using a multi-region, multi-sector CGE model, Berrittella et al. [13] find that water taxes reduce water use and lead to shifts in production, consumption and international trade patterns, even for countries that do not levy water taxes directly. More recently, Liu et al. [14] use a CGE model operating at global scale to demonstrate that it can be extremely demanding due to the absence of standardized data, the sheer dimensions caused by intersecting river basins with countries, and difficulties to model demand for and supply of water.

Some water-CGE models have been used in developed countries. Berck et al. [15] have evaluated scenarios of water allocation in the San Joaquim area (California). Horridge et al. [16] assess the risks of water shortages associated with investment and pricing strategies in Melbourne. Seung et al. [17] consider water resource transfers from agricultural to recreational use in the Walker River Basin (California). A dynamic CGE is proposed by Seung et al. [18] to analyze the temporal effects of water reallocations in the county of Churchill (Nevada). Studying the Arkansas River Basin, Goodman [19] shows that temporary transfers of water resources should be preferred to building new dams or increasing existing storage facilities. With a similar modeling, Gomez et al. [20] analyze the welfare gains resulting from improving the allocation of water rights in the Balearic Islands (Spain). A multi-regional water-CGE model for Australia has been proposed by Qureshi et al. [21] and, more recently, the implications of uncertainty in the technology of irrigation water management has been introduced in a CGE model in Spain [22].

A large number of applications of water-CGE models have been conducted in developing countries, with a strong focus on agriculture. Goldin and Roland-Holst [23] have examined the relations between water management policies and foreign trade in Morocco using a CGE model. Diao and Roe [24] have developed a CGE model to analyze the consequences of a protectionist agricultural policy in Morocco. Dixon [25], Decaluwé et al. [26], and Thabet [27] have proposed static CGE models representing the agricultural sector. In Senegal, Briand [28, 29] has simulated two water-pricing policies considering all water-user sectors (agricultural, industrial, and services) in a context of climate change. Recently, some water-CGE have been developed in China, see for instance Zhang et al. [30].

Water-CGE models have also been proposed for South Africa (see Table 1). They vary according to the number of economic sectors, the number of production factors and the disaggregation of households into income classes. Mukherjee [31] provides the first CGE model for South Africa with an explicit representation of water. This CGE model is applied to the Olifants River Watershed (Transvaal) to evaluate scenarios of water scarcity. Although changes in most economy-wide indicators such as GDP are relatively

Table 1 Water-CGE models for South Africa

	Coverage	Economic sectors	Production factors	Household types	Year of the SAM
Mukherjee [31]	Olifants River Watershed (Transvaal)	10	15 including a land-water aggregate	11	NA
Letsoalo et al. [33]	South Africa	65	NA	48	1998
Van Heerden et al. [35]	South Africa	39	14 (11 labor types, land, capital, water)	48	1998
Juana et al. [32]	South Africa	13	5 (water, capital and 3 labor types)	5	1998
Hassan and Thurlow [34]	South Africa (19 regions)	40	6 (3 labor types, agricultural land, irrigation water, and capital)	10	2000

NA not available

small, agricultural output is shown to decline strongly (by nearly 10% when water availability is reduced by 60%). Another CGE model proposed by Juana, Strzepek and Kirsten [32] analyzes the impact of water reallocation on economic growth. The simulation results show that market allocation of water among the production sectors generally leads to a growth of sectoral output, although the negative impacts are documented for agriculture and related sectors. A more disaggregated model has been provided by Letsoalo et al. [33] to test if water taxes may simultaneously stimulate economic growth, poverty reduction and environmental protection (triple dividend hypothesis). Letsoalo et al. [33] concludes that the triple dividend is possible for water policy in South Africa. Finally, Hassan and Thurlow [34] use a detailed multi-regional CGE model which includes rainfed and irrigated crop production. They point out several tradeoffs between economic gains and higher water prices which raises serious questions about subsidizing water supply for irrigated agriculture. The authors estimate that the benefits of water reallocation within the agricultural sector and across water board regions within the country would amount to a recurring economic gain equal to 4.5% of agricultural value added.

One common feature of all models presented in Table 1 is that they are all static CGE models. The main focus of these works has been to assess the impact of water charges [33, 34] and to simulate macroeconomic changes resulting from intra-sectoral water reallocation [32, 34].

2.2 SAWAT: A Water-CGE Model for South Africa

Developing the water-CGE model SAWAT took place within the Natural Resources Stewardship Programme (NatuReS) commissioned by the German Federal Ministry for Economic Cooperation and Development (BMZ). The implementation of the project followed a highly participative process, involving national stakeholders in the discussion. A reference group has been established at the national level to provide regular feedbacks on the study, and to validate the main components of the model. This national reference group was made up of representatives from various public institutions in charge of water management in South Africa (in particular from the Department of Water and Sanitation, the Water Research Commission and the South African Local Government Association). Three meetings have been organized with the national reference group (in April, August, and November 2019) at different stages of the development of the water-CGE model.

The water-CGE model SAWAT has been adapted from the neoclassical model EXTER developed by Decaluwé et al. [36], and here, we only provide a short description of its main components. The interested reader may refer to Appendix A for a more extended presentation.

SAWAT represents an economy made of nine activities (production sectors): agriculture, hunting, forestry, fishing (AGR); mining, food, textiles (MIN); oil, mineral products, transport equipment, electricity, gas (OIL); construction (CNS); services (TRA); public services (GVT); standard production of tap water (TAPWS); reuse of wastewater (TAPWR); desalination of seawater (TAPWD). The last three sectors (standard production of tap water, reuse of wastewater and desalination of seawater) contribute to tap water production with differentiated costs since they rely on different technologies. The water-CGE model SAWAT distinguishes six production factors: two standard production factors (labor, capital) and four water-related production factors (surface water, groundwater, wastewater, seawater). Surface water and groundwater are viewed as "standard" water resources which have to be transformed into tap water. Wastewater and seawater require a specific treatment before use (specific technology with differentiated production costs). All production factors are mobile across sectors at the exception of capital assumed to be fixed per sector. Compared to the EXTER model, the production technologies have been modified to account for substitutions between labor, capital and water-related production factors [33]. We have thus distinguished three different nested structures of production (water-using sector, water-producing sector, non-water-using sector) which combine Cobb-Douglas, constant elasticity of substitution (CES), and Leontieff forms (see Appendix A).

The economy produces eight goods with endogenous market prices. Those goods correspond to the typical output of each production sector (the public sector supplies a service which is not marketed). Drinking water is the final good consumed by economic agents, in particular by households. To take into account household "poverty," the model integrates a linear expenditure system (LES) in which each commodity has a minimum consumption level (to respond to subsistence needs). To account for household heterogeneity, three types of households have been included in SAWAT depending upon their income level (low income, middle income, high income). The model takes into account all the transfers between households, firms, government and the rest of the world. Unemployment is endogenously determined. The SAWAT model is composed of seven blocks of equations: production with perfect competition, income and savings, taxes, demand, prices, foreign trade, and equilibrium conditions (see Appendix A). SAWAT distinguishes quantity effects (changes in volume) from price effects (changes in value).

The CGE model belongs to the family of sequential dynamic CGE models which enables to conduct long-term simulations. The dynamic component of the model is not the result of an intertemporal optimization by economic agents who are assumed to have myopic behaviors. With a sequential dynamic approach, a sequence of static CGE models is linked across time using exogenous and endogenous variables. In SAWAT, capital stock is updated endogenously with a capital accumulation equation whereas the dynamic of the population and the labor supply are updated exogenously at an annual growth rate of 1.2%. The annual growth rate of capital has been fixed at 3% for all sectors. The capital user cost is equal to the replacement capital price (price index of investment) multiplied by the sum of capital depreciation rate and real interest rate (exogenous).

Compared to existing water-CGE models, the main originality of SAWAT is to consider four types of water-related production factors (surface water, groundwater, wastewater or seawater) and to explicitly represent three production sectors dedicated to their transformation (production of tap water, reuse of wastewater and desalination of seawater). To our best knowledge, this is the first time such a level of detail in the representation of how water resources are used by an economy, is introduced in a CGE model. A few modelling assumptions we have made need however to be pointed out. First, water resources in SAWAT are considered as production factors, and not as intermediate or final goods. Following Berck et al. [15], Robinson and Gehlar [37], Goodman [19], Gomez et al. [20], Thabet [27], and Briand [28, 29], water is then viewed here as a "normal" production factor and substitution between water and other inputs (labor and capital) is then allowed (see Appendix B for a sensitivity analysis regarding substitution between production factors). Second, for water-using sectors, the four water-related production factors (surface water, groundwater, wastewater, seawater) are combined to produce a composite water factor (see Appendix A). Due to the lack of detailed information regarding substitution possibilities across water-related production factors in South Africa, we have decided to use a Cobb-Douglas technology which hence imposes the elasticities of substitution to be equal to one. We recognize that it may be a strong assumption, and that substitution possibilities may in fact differ across water-related production factors. Third, although we consider a dynamic model, transfers of water over time are not allowed. In the context of South Africa, this assumption is motivated by the fact that water storages allowing inter-annual water transfers are not considered as a relevant water policy option. Finally, we have assumed that water-related production factors are mobile across economic sectors. This mobility assumption implies that water-related production factors can be freely reallocated from one sector to another. We believe that working with mobile water-related production factors is relevant when considering a country-level CGE model such as SAWAT. An interesting extension of our model could be however to disaggregate South Africa into different regions in order to account for the uneven distribution of water across space. In such a case, the assumption of water mobility across sectors (and regions) could be questionable.

2.3 SAM to Calibrate SAWAT

We rely on a social accounting matrix representing the economic transactions within South Africa. Our starting point is the social accounting matrix (SAM) developed by Seventer et al. [38] for 2012. Many adjustments have been made on this SAM, in particular in order to include an explicit representation of water.

Some sectors have been aggregated to obtain a level of detail that better corresponds to the needs of the study. We initially considered the 62 economic sub-sectors of the original matrix and clustered them into nine sectors. Table 2 represents the GDP share in the SAM of each sector. Using data from World Bank [39], households have been classified into three income classes. Low-, middle-, and high-income classes correspond to households belonging to income deciles 1 to 6, 7 to 9, and 10, respectively.

To introduce water accounts into the SAM, we have first relied on the report Statistics South Africa [40] released by the National Statistics Office which allowed us to identify expenditures and revenues for electricity, gas and water. Then, sectoral disaggregation of the water accounts has been conducted using Maila et al. [41]. We have also used detailed production cost data provided by Barry Martin, Director of Water & Sanitation at Nelson Mandela Bay Metropolitan Municipality, adapting them at the national level to distinguish production costs among various water-supply technologies. Eventually, the different types of water (surface water, groundwater, wastewater, seawater) have been classified and quantified using data from the National Water and Sanitation Master Plan, Department of Water and Sanitation [1–3].

The calibration step of the CGE model has consisted in reproducing the baseline equilibrium of the SAM (year 2012) which corresponds to our initial situation (T0). Then, different scenarios of change have been simulated and assessed.

Table 2 GDP shares per sector in the SAM of SAWAT (2012)

	Sector	GDP share
AGR	Agriculture, hunting, forestry, fishing	2.2%
MIN	Mining, food, textiles	6.1%
CHM	Oil, mineral products, transport equipment, electricity, gas	14.7%
CNS	Construction	1.9%
TRA	Services	46.2%
GVT	Public services	27.1%
TAPWS	Standard production of tap water	1.4%
TAPWR	Reuse of wastewater	0.3%
TAPWD	Desalination of seawater	0.1%

3 Evaluating Water Policies with SAWAT

3.1 Defining Scenarios and Impact Variable with SAWAT

The development of scenarios to be simulated by the CGE model followed a participative and iterative process. A first set of scenarios was proposed by modelers in April 2019 to the national reference group. These scenarios were further discussed and validated in August 2019. Final simulations have been presented in November 2019 at the last meeting with the national reference group, Table 3.

We have considered two scenarios related to water. Scenario S0 "No water scarcity" is a hypothetical situation in which water scarcity remains at its current level. This is clearly unrealistic, but it provides a benchmark corresponding to a situation without the predicted 17% water deficit in South Africa. Scenario S1 "Water scarcity" represents a situation in which, compared to 2012, there is a 17% additional water deficit by 2030. This scenario refers to the projected 17% shortage in water supply with "business as usual" that is without implementing any particular policy [1–3].

The aim of the CGE models is to compare different water policies in terms of mitigating the economic impacts of water scarcity. Therefore, four water-policy scenarios to mitigate water scarcity have been tested. Scenario S2 "Non-revenue water" corresponds to a reduction of non-revenue water (i.e., non-priced water) from 44 to 30%. Non-revenue water is a crucial issue in South Africa. According to the Department of Water and Sanitation 2018 Master Plan, South African municipalities are losing about 1,660 million m^3 per year through non-revenue water. At a unit cost of R6/m^3, this amounts to R9.9 billion each year. The implementation of scenario "Non-revenue water" S2 in the CGE model corresponds to a decrease in the quantity of non-revenue water from 44 to 30% by 2030, and so an equivalent increase in the quantity of water that is priced. Scenario S3 "Water pricing" corresponds to a tap water price increase for all consumers by 10% relatively to the initial situation (SAM). This scenario uses the water price increase as a way to signal water scarcity to all water users. Scenario "Water savings" S4 introduces water savings as a potential way to limit economic and social impacts of water scarcity. Within the National Water Resource Strategy, water conservation and water demand management are indeed viewed as one of the seven most urgent priorities to meet the social and economic needs of South Africa (see [42]). This is why the National Water Resource Strategy has set a dedicated national water-conservation and demand-management program, with clear national and local targets, and sub-programs focused on municipalities, industry and agriculture. For instance, it is expected that the promotion of water conservation and demand side management activities in all sectors will "reduce water demand in urban areas to 15% below business-as-usual scenario by 2030." Here, scenario "Water savings" S4 is modeled by introducing more efficient water use for all economic sectors. The decrease in the quantity of available water resources linked to climate change (scarcity) is partially compensated within this scenario, through improvement of water efficiency and demand-side policies (for instance better management of leaks, use of drip irrigation). The implementation of scenario S4 in the CGE model consists in a 10% increase of the scale coefficient in the CES production function for the agricultural sectors and the three tap water sectors (at each period relative to T0). In particular, this scale parameter captures productivity gains (a better use of water resources) by allowing to produce more output with the same quantity of water or to produce the same output quantity with less water resources. Lastly scenario "Water reuse and desalination" S5 corresponds to

Table 3 Summary of prospective scenarios

Scenario name	Description	Modeling in SAWAT
S0 "No water scarcity"	Water scarcity remains at its current level (reference year 2012)	Baseline scenario.
S1 "Water scarcity"	Water scarcity increase of 17%	17% reduction of water resources (groundwater and surface water).
S2 "Non-revenue water"	Reduction of non-revenue water from 44 to 30%	An additional 14% of water resources becomes available for the economy. The simulation consists of a 14% increase in water resources of all types.
S3 "Water pricing"	Increase of water price by 10%	Tap water price increases by 10% for all consumers (at each period relative to T0).
S4 "Water saving"	Water productivity increase by 10%	10% increase of the scale coefficient in the CES production functions for the agricultural sectors and the three tap water sectors (at each period relative to T0).
S5 "Water reuse and desalination"	Increase in water reuse and in desalination of seawater by 50%	50% increase of water reuse and desalinated seawater resources.

Table 4 Impact variables considered in the scenario analysis

Impact variable	Description
Gross domestic product (GDP)	Sum of added value produced by all sectors of the economy (annual).
Total investment	Sum of all savings of all economic agents (households, firms, government and foreign via current account of the nation).
Unemployment	Share of the labor force out of work (%).
Savings	For each economic agent, difference between income and consumption, direct taxes paid, and transfers paid to other agents.
Household welfare	Consumption in volume for all commodities.

an increase of water reuse and desalination of seawater, two policies promoted in the National Water Resource Strategy. In the CGE model, for each period relative to T0, the quantity of wastewater and seawater is increased by +50% so that the supply of these water-related factors of production increases. Endogenously, the model indicates the sectorial demands for these additional factors taking into account the needs and the implicit new prices of these resources (relative scarcity rents of each water resource). In clear, the implicit prices of wastewater and seawater decrease relatively to the implicit prices of surface water and groundwater. Reused water and desalinated water become more attractive as water resources for sectors.

CGE models can produce a large variety of outcomes. The focus here is on the following five variables of interest (see Table 4): the gross domestic product (GDP), the total investment in the economy, the unemployment rate, savings for each economic agent and household welfare. Different indicators exist to measure household welfare, and household consumption has long been favored by economists as an indirect measure of well-being. Here, consumption in volume for all commodities and for all types of households is used as a proxy of welfare.

As indicated previously, the CGE model SAWAT is dynamic. Scenario impacts can be assessed in the short term and in the long term. We define short-term impacts as impacts occurring 1 year after implementing a particular policy or a particular shock into the model. Short-term impacts are those observed in 2013 (T1), the policy or the shock being assumed to occur in 2012. We define long-term impacts as impacts that will be visible in 2030 (T18).

3.2 Scenario Analysis with SAWAT

We use SAWAT to simulate the scenario with a water-scarcity increase of 17% (S1) and the scenarios where the water-scarcity increase is mitigated by different water policies (S2, S3, S4, S5). A sensitivity analysis regarding scenario definition is provided in Appendix C.

3.2.1 Cost of Water Scarcity for South Africa

We first focus on the impacts of scenarios and water policies on the main macroeconomic variables of interest (GDP, total investment, and unemployment rate). Impacts in the short and in the long term are reported in Tables 5 and 6.

In the short term (baseline +1 year), compared to a situation without water scarcity (scenario S0), SAWAT predicts a decrease in GDP due to water scarcity (scenario S1) equal to −0.37% for the year following the water-scarcity shock, see Table 5. In the short term, the South African economy is not able to totally mitigate the impact of water scarcity. In addition, the total investment decreases by –2.31% and the unemployment rate increases by +0.76%. The productive structure of the South African economy is constrained by water scarcity, which cannot be fully compensated by additional investments or by reallocation of other production factors.

Table 5 Macroeconomic impacts of scenarios for South Africa (short-term)

	S0 No water scarcity	S1 Water scarcity		S2 Non-revenue water		S3 Water pricing		S4 Water savings		S5 Water reuse and desalination	
	2013	2013	S1-S0	2013	S2-S1	2013	S3-S1	2013	S4-S1	2013	S5-S1
GDP	−0.02	−0.39	−0.37	0.22	0.61	−0.31	0.08	0.27	0.66	0.09	0.48
Total investment	−0.06	−2.37	−2.31	0.61	2.98	−0.08	2.29	1.25	3.62	7.84	10.21
Unemployment rate	0.04	0.8	0.76	−0.28	−1.08	0.39	−0.41	−0.43	−1.23	−1.06	−1.86

For each variable and each scenario (S1 to S5), the first column gives the % change compared to 2012. The second column provides the difference between the considered scenario and S0 (no water scarcity)

Table 6 Macroeconomic impacts of scenarios for South Africa (long-term)

	S0 No water scarcity	S1 Water scarcity		S2 Non-revenue water		S3 Water pricing		S4 Water savings		S5 Water reuse and desalination	
	2030	2030	S1-S0	2030	S2-S1	2030	S3-S1	2030	S4-S1	2030	S5-S1
GDP (% change)	19.82	19.38	−0.44	20.29	0.91	19.36	−0.02	20.19	0.81	20.03	0.65
Total investment (% change)	16.35	19.31	2.96	17.12	−2.19	17.59	−1.72	20.44	1.13	17.8	−1.51
Unemployment rate (level)	29.6	29.6	0	29.5	−0.1	29.6	0	29.4	−0.2	29.5	−0.1

Unemployment rate in level (in %). SA workforce in 2012 was 18 million. An increase in unemployment rate of 0.1% corresponds to a loss of 18,000 jobs

GDP % change compared to 2012, *Total investment* % change compared to 2012

In the long term (i.e., in 2030), an increase of water scarcity by 17% (scenario S1) induces a decrease in GDP by −0.44%, see Table 6. The South African economy is trying to adapt to this constraint on water resource availability by increasing total investment (+2.96%) and so production capacities. The economic sectors have some flexibility to modify their mix of production factors, increasing the quantities of capital and keeping labor unchanged in a context of more water scarcity. The decrease in GDP by −0.44% provides some rationale for implementing specific water policies.

3.2.2 Water Policies to Mitigate the Impacts of Water Scarcity

We first consider S2 which corresponds to decreasing non-revenue water from 44 to 30%. In this scenario, a greater quantity of water resources is "internalized" by the market by decreasing the volume of non-revenue water. In the short term, this policy results in a GDP increase (+0.61%) and a decrease of the unemployment rate (−1.08%). In the long term, GDP is expected to increase by 0.91% compared to S1, and the unemployment rate to decrease by −0.1%. Since total savings slightly decreases (firms have to pay more to access water resources), total investment also slightly decreases (−2.19%).

Next, we focus on S4, the policy consisting in increasing water saving by 10%. This policy is particularly beneficial for the GDP in the short term (+0.66%). The unemployment rate decreases significantly (−1.23%). Total investment increases by +3.62%. Payment for access to water resources allows agents to benefit from an additional income. In the long term as well, S4 is still beneficial when considering GDP (+0.81%), unemployment (−0.2%), and total investment (+1.13%).

The policy scenario S5 consists in increasing wastewater and seawater by +50%. This policy is beneficial for the economy in the short term. The comparison with S1 shows that the gain in terms of GDP represents 0.48%. The unemployment rate decreases by −1.86%. This policy is particularly beneficial in terms of investment for the future (total investment increases by +10.21%). In the long term, this policy is beneficial for the economy in terms of GDP (+0.65%), unemployment (−0.1%). However, total investment decreases by −1.51% because aggregate savings available in the economy decreases.

Additionally, a "regulation by prices" policy is tested in S3, in which tap water prices are increased for all consumers by 10%. GDP increases marginally (+0.08%) in the short term, and it slightly decreases in the long term (−0.02%). The unemployment rate decreases in the short term (−0.41) but does not change in the long term since, by construction, this policy has less impact in terms of job creation. Total investment increases in the short term (+2.29%), but this effect does not hold in the long term and is even reversed (−1.72%) because the increase of the tap water production cost (at each period) negatively impacts on production sectors and on households. These results differ from Letsoalo et al. [33] who report that there is a triple dividend associated to increasing water charges in South Africa. In their CGE analysis, they indeed find that water charges may simultaneously limit water scarcity, improve economic growth (reduce unemployment), and reduce poverty. Discrepancies in water demand price elasticities and in the way production technologies are represented in the two CGE models may explain these contradictory results.

To summarize, in the short term, with water policy S2, S4, and S5 it appears possible to cancel out water-scarcity impacts and to generate some additional positive macroeconomic effects on the South African economy. The strongest impacts are observed with the water saving policy S4. In the long term, combining non-revenue water policy S2 with the water saving policy S4 appears promising from a water policy perspective.

3.2.3 Sectoral Impacts of Water Scarcity for South Africa

In Tables 7 and 8, we investigate the winning and losing sectors according to each scenario in the short term and in

Table 7 Impacts of scenarios on sectoral added value for South Africa (short term)

	S0 No water scarcity	S1 Water scarcity		S2 Non-revenue water		S3 Water pricing		S4 Water savings		S5 Water reuse and desalination	
	2013	2013	S1-S0	2013	S2-S1	2013	S3-S1	2013	S4-S1	2013	S5-S1
AGR	0.04	−0.12	−0.16	0.07	0.19	−0.38	−0.26	4.85	4.97	−0.19	−0.07
MIN	0.03	−0.11	−0.14	0.07	0.18	−0.14	−0.03	0.84	0.95	−0.01	0.1
CHM	0.01	−0.02	−0.03	0.03	0.05	−0.03	−0.01	0.09	0.11	−0.02	0
TAPWS	−0.2	−5.51	−5.31	3.4	8.91	−4.85	0.66	−1.76	3.75	−4.9	0.61
TAPWR	−0.14	−0.32	−0.18	4.97	5.29	−0.82	−0.5	−1.16	−0.84	14.28	14.6
TAPWD	−0.03	−0.69	−0.66	3.5	4.19	−1.01	−0.32	−0.14	0.55	7.95	8.64
CNS	−0.03	−1.43	−1.4	0.33	1.76	0.09	1.52	0.74	2.17	5.2	6.63
TRA	0	−0.25	−0.25	0.11	0.36	−0.17	0.08	0.25	0.5	0.09	0.34
GVT	−0.13	−0.09	0.04	−0.07	0.02	−0.22	−0.13	−0.58	−0.49	−0.74	−0.65

% Change compared to 2012

AGR agriculture, hunting, forestry, fishing, *MIN* mining, food, textiles, *CHM* oil, mineral products, transport equipment, electricity, gas, *CNS* construction; TRA, services, *GVT* public services, *TAPWS* standard production of tap water, *TAPWR* reuse of wastewater, *TAPWD* desalination of seawater

the long term, respectively. Considering the impacts of water scarcity on "Agriculture, hunting, forestry, fishing" allows to relate policy scenarios to the issue of food-security in South Africa. In the short term, Table 7 shows that the impact of water scarcity on the "Agriculture, hunting, forestry, fishing" sector is limited with a loss of added value representing 0.16%. Food-security might be however an issue in the long-run since added value is expected to decrease for this sector by −0.41%, see Table 8. In the short term, water scarcity scenario S1 has a particularly strong negative impact on the "standard production of tap water" sector. The volume of added value decreases by 5.31%. The "Public services" and the "Services" sectors appear to be the least impacted. With the water saving policy S4, the model predicts strong positive impacts in terms of sectoral added value for the agricultural sector (+4.97%) and for the standard production of tap water (+3.75%). Both sectors benefit from the increase in the marginal efficiency of water resources in their production technology. The water saving policy S4 is a pro-food-security and pro-water-security policy, in the short term. "Construction" and "Mining, food, textiles" sectors are also positively impacted. Lastly, with the water reuse and desalination policy S5 the model predicts strong positive impacts on added value for the "Reuse of wastewater" sector and the "Desalination of seawater" sector, and to a lesser extent for the "Construction" sector. Those sectors benefit

Table 8 Impacts of scenarios on sectoral added value for South Africa (long-term)

	S0 No water scarcity	S1 Water scarcity		S2 Non-revenue water		S3 Water pricing		S4 Water savings		S5 Water reuse and desalination	
	2030	2030	S1-S0	2030	S2-S1	2030	S3-S1	2030	S4-S1	2030	S5-S1
AGR	20.58	20.17	−0.41	20.96	0.79	20.2	0.03	22.9	2.73	19.96	−0.21
MIN	25.29	24.83	−0.46	25.7	0.87	24.86	0.03	25.84	1.01	24.92	0.09
CHM	25.46	25.05	−0.41	25.8	0.75	25.09	0.04	25.65	0.6	25.61	0.56
TAPWS	11.72	5.94	−5.78	14.79	8.85	6.5	0.56	12.43	6.49	13.15	7.21
TAPWR	10.84	10.6	−0.24	17	6.4	9.7	−0.9	9.35	−1.25	28.61	18.01
TAPWD	11.34	9.75	−1.59	14.04	4.29	9.29	−0.46	10.83	1.08	18.98	9.23
CNS	21.32	23.31	1.99	21.91	−1.4	22.16	−1.15	24.06	0.75	22.77	−0.54
TRA	21.73	21.36	−0.37	22.11	0.75	21.35	−0.01	22.1	0.74	21.83	0.47
GVT	4.67	4.53	−0.14	4.68	0.15	4.59	0.06	4.08	−0.45	4.44	−0.09

% Change compared to 2012

AGR, agriculture, hunting, forestry, fishing; MIN, mining, food, textiles; CHM, oil, mineral products, transport equipment, electricity, gas; CNS, construction; TRA, services; GVT, public services; TAPWS, standard production of tap water; TAPWR, reuse of wastewater; TAPWD, desalination of seawater

Table 9 Impacts of scenarios on household welfare for South Africa (short-term)

	S0 No water scarcity	S1 Water scarcity		S2 Non-revenue water		S3 Water pricing		S4 Water savings		S5 Water reuse and desalination	
	2013	2013	S1-S0	2013	S2-S1	2013	S3-S1	2013	S4-S1	2013	S5-S1
Total welfare	−0.02	−0.71	−0.69	0.36	1.07	−0.5	0.21	0.2	0.91	0.02	0.73
Low income hh	−0.01	−0.43	−0.42	0.28	0.71	−0.47	−0.04	0.51	0.94	−0.51	−0.08
Medium income hh	−0.03	−0.82	−0.79	0.42	1.24	−0.59	0.23	0.14	0.96	0	0.82
High income hh	−0.03	−0.77	−0.74	0.35	1.12	−0.44	0.33	0.09	0.86	0.32	1.09

% Change compared to 2012

Total welfare total household consumption in volume

from the lower implicit prices of wastewater and seawater relatively to the implicit prices of surface water and groundwater. Table 8 provides sectoral added value impacts of scenarios in the long term. With the water scarcity scenario S1, all sectors (at the exception of "Construction") lose in terms of added value. The non-revenue policy S2 is particularly beneficial for the three production sectors of tap water (sectoral added value increases by 8.85%, 6.4%, and 4.29% for standard, reuse, and desalination sectors, respectively). Increasing the share of water resources is a source of income for the economy and a source of better management (more efficient allocation of water resources between sectors). The water pricing policy S3 can hardly counterbalance the negative effects of water scarcity for all sectors. Short-term and long-term effects are negative or small compared to other policies. With the water saving policy S4, the model predicts strong impacts on added value for "Agriculture, hunting, forestry, fishing" sector (2.73%), "Mining, food, textiles" sector (+1.01%) and the "Standard production of tap water" sector (+6.49%). Similarly to the short term, these sectors benefit from an increase of the marginal efficiency of water resources in their production technology.

Both in the short term and in the long term, the water saving policy S4 appears to be the most promising scenario in terms of achieving food security and water security. On the contrary, the benefits of the water reuse and desalination policy S5 are more limited which suggests that spillovers generated by the growth of reuse/desalination sectors are not sufficient to generate gains for other sectors of the South African economy.

3.2.4 Impacts of Water Scarcity on Household's Welfare for South Africa

To proxy welfare, we use household consumption in volume for all commodities. Changes in total consumption in volume are driven by two mechanisms in the CGE model: change in household's income and change in consumer prices (for each commodity). Tables 9 and 10 present the impacts of water scarcity on the welfare of the population, in the short term and in the long term.

In the short term, the total welfare in the South African economy (aggregation of the welfare of all households) decreases by −0.69% with the water scarcity scenario S1. The welfare loss is lower for low income households (−0.42% for low income households and −0.74% for high income households). In the short term, the water saving policy S4 has a strong positive impact on total welfare increase (+0.91%). The water saving policy S4 is the only progressive policy, the welfare gains for low-income and high-income households being +0.94% and +0.86%, respectively. On the contrary, the "Water reuse and desalination" policy S5

Table 10 Impacts of scenarios on household welfare for South Africa (long-term)

	S0 No water scarcity	S1 Water scarcity		S2 Non-revenue water		S3 Water pricing		S4 Water saving		S5 Water reuse and desalination	
	2030	2030	S1-S0	2030	S2-S1	2030	S3-S1	2030	S4-S1	2030	S5-S1
Total welfare	10.84	10.37	−0.47	11.25	0.88	10.36	−0.01	11.15	0.78	11.08	0.71
Low income hh	8.73	8.13	−0.6	9.06	0.93	8.21	0.08	8.92	0.79	8.77	0.64
Medium income hh	11.56	11.01	−0.55	12.02	1.01	11.01	0	11.86	0.85	11.83	0.82
High income hh	11.31	10.96	−0.35	11.71	0.75	10.91	−0.05	11.68	0.72	11.62	0.66

% Change compared to 2012

Total welfare total household consumption in volume

Table 11 Impacts of scenarios on saving for South Africa (short-term)

	S0 No water scarcity	S1 Water scarcity		S2 Non-revenue water		S3 Water pricing		S4 Water savings		S5 Water reuse and desalination	
	2013	2013	S1-S0	2013	S2-S1	2013	S3-S1	2013	S4-S1	2013	S5-S1
Firms	−0.07	−2.42	−2.35	0.4	2.82	0.09	2.51	1.1	3.52	6.34	8.76
Low income hh	−0.02	−0.46	−0.44	0.14	0.6	−0.18	0.28	0.24	0.7	0.73	1.19
Medium income hh	−0.04	−0.81	−0.77	0.23	1.04	−0.25	0.56	0.4	1.21	1.45	2.26
High income hh	−0.04	−0.87	−0.83	0.23	1.1	−0.2	0.67	0.41	1.28	1.69	2.56
Government	−0.67	−11.43	−10.76	3.68	15.11	−4.57	6.86	−2.32	9.11	7.51	18.94
Rest of the world	−0.23	−4.35	−4.12	1.59	5.94	−1.67	2.68	−0.37	3.98	6.12	10.47

% Change compared to 2012. Savings: difference between income and expenditure

appears to be the most regressive policy in the short term (−0.08% for low income households and +1.09% for high income households).

In the long term, with the water scarcity scenario S1 the total welfare decreases by −0.47%. A particular concern for policy-makers might be that low-income households are expected to be more impacted by water scarcity than high-income households. It appears indeed that household welfare in 2030 will be reduced by −0.60% for low-income households and by −0.35% for high-income households. Redistributive policies may be needed to mitigate the impact of water scarcity on low-income households. Once again, the water saving policy S4 appears to be one of the most attractive policies in terms of welfare improvement (+0.78%). In addition, policy S4 remains progressive in the long term (+0.79% for low-income households and +0.72% for high-income households). "Water reuse and desalination" policy S5 also generates welfare improvements for all types of households, but less than S4 or S2. The non-revenue water policy S2 leads to the highest total welfare increase (+0.88%). In addition, this policy is progressive, the welfare improvement being +0.93% and +0.75 for low-income households and high-income households, respectively.

3.2.5 Saving and Water Scarcity in South Africa

Tables 11 and 12 focus on saving structure changes for the South African economy. Saving is the difference between income and expenditure for each "macroeconomic" agent (households, firms, government, rest of the world). For example, firms receive an income from their factors of production (capital, in particular) but they pay some taxes to the government and they provide dividends to other agents. The difference between their income and expenses (taxes and dividends) corresponds to the savings of firms.

In the short term, the South African economy mitigates the impact of water scarcity by reducing savings. Compared to S0, firms' saving decreases in the water scarcity scenario S1 by −2.35%. Savings for other agents (households, government, rest of the world) also decrease. The water price scenario S3 completely offset the negative impacts on household savings, firms' savings and savings for the government and the rest of the world. The water saving policy S4 increases savings for all agents. Public debt (the government has negative savings in the SAM) is reduced since the government earns additional income from direct and indirect taxes.

Table 12 Impacts of scenarios on saving for South Africa (long-term)

	S0 No water scarcity	S1 Water scarcity		S2 Non-revenue water		S3 Water pricing		S4 Water savings		S5 Water reuse and desalination	
	2030	2030	S1-S0	2030	S2-S1	2030	S3-S1	2030	S4-S1	2030	S5-S1
Firms	23.94	26.77	2.83	24.61	−2.16	25.28	−1.49	27.8	1.03	25.42	−1.35
Low income hh	7.49	7.61	0.12	7.75	0.14	7.43	−0.18	8	0.39	7.64	0.03
Medium income hh	11.89	12.24	0.35	12.29	0.05	11.9	−0.34	12.85	0.61	12.21	−0.03
High income hh	11.5	12.02	0.52	11.89	−0.13	11.62	−0.4	12.61	0.59	11.89	−0.13
Government	−73.63	−69.76	3.87	−71.36	−1.6	−72.62	−2.86	−67.48	2.28	−66.89	2.87
Rest of the world	−31.33	−29.04	2.29	−30.34	−1.3	−30.68	−1.64	−28	1.04	−28.69	0.35

% Change compared to 2012

Savings difference between income and expenditure

In the long term, compared to S0, savings increase in a context of water scarcity scenario S1 because agents hold a share of factors (in the SAM) and therefore benefit from additional remuneration due to the increase in the implicit price of the water resource (scarcity rent). The water price scenario S3 has negative impacts on savings mainly for firms, for the government and the rest of the world. The "water saving" policy S4 increases all private savings both in the long term and in the short term.

4 Main Findings and Conclusions

We have built a new water-CGE dynamic model calibrated with up-to-date data for South Africa. Accordingly, a new SAM with a focus on water use has been constructed. Five scenarios of change have been developed and assessed. An impact assessment has been conducted considering both short-term impacts (baseline +1 year) and long-term impacts (2030). The impacts of scenarios have been assessed considering a large variety of microeconomic (i.e., factor production prices), macroeconomic (i.e., GDP, investments, unemployment, exports), and social outcomes (welfare of households) for informing policymakers. The results have been disaggregated by economic sector (9 economic sectors) or household type (low, medium, and high income).

We find that water scarcity has a significant impact on the South African economy. With an increase of water scarcity by 17%, the SAWAT CGE model predicts a decrease in South African GDP by −0.44% by 2030. Although unemployment will rise in the short term by +0.76%, it is expected to recover its baseline level by 2030. The impact of water scarcity varies from one economic sector to another, public services and services being the least impacted ones. On the contrary, and as expected, sectors directly related to water resources (i.e., the "standard production of tap water" sector) will be the most negatively impacted. This result calls for implementing differentiated support policies by economic sectors. Water scarcity will also negatively affect the welfare of households in South Africa, the loss of welfare representing −0.69% in the short term and −0.47% in the long term. The lower impact in the long term suggests that households have some possible ways for attenuating or mitigating the detrimental effects of water scarcity. We however document heterogeneous impacts of water scarcity on households depending upon their income level. In the long term, a particular concern for policy makers might be that low-income households are expected to be more impacted by water scarcity than high-income households. It appears indeed that household welfare in 2030 will be reduced by −0.60% and −0.35% for low-income households and high-income households, respectively. Although these results may depend on some modelling assumptions made to develop SAWAT (in particular the mobility of production factors across sectors for labor and water-related inputs and the use of Cobb-Douglas production functions for water-dependent economic sectors), we have shown that they are robust to changes in production technology calibration (see Appendix B).

Some policies can counterbalance the macroeconomic impacts of water scarcity. The most promising policy according to the SAWAT CGE model is to increase water saving, for instance by promoting water conservation and demand side management activities in all sectors as suggested in National Water Resource Strategy [42]. In a context of water scarcity, a 10% increase in water saving offers in the long term an additional 0.81% increase in GDP compared to a situation without intervention. This policy also results in the highest increase of total investment (+1.13%) as well as the strongest decrease of the unemployment rate (−0.2%). Decreasing non-revenue water up to 30% may also generate long term benefits for the South African economy. An additional 0.91% increase in GDP is expected, but compared to the water savings policy, the decrease in unemployment rate is lower (−0.1%) and investment for the future is substantially reduced (−2.19% versus +1.13%). The policy consisting in increasing tap water prices has only a limited impact in the long term on GDP and unemployment rate. It should be finally pointed out that the effects of the different policies on households differ depending upon their income. In the short term, the water saving policy S4 is the only progressive policy, the welfare gains for low-income and high-income households being +0.94% and +0.86%, respectively. The three other policies (decreasing non-revenue water, increasing tap water, increasing water reuse and desalination) appear to be regressive in the short term. In the long term, all policies (at the exception of increasing water reuse and desalination) will be on the contrary progressive, with higher benefits to be expected for low-income households than for high-income households.

The policy implications of our work may be summarized as follows. First, the negative macroeconomic impacts of increased water scarcity on GDP, total investment, unemployment, and household consumption call for implementing specific policies. Since all policies will not have the same macroeconomic impacts (on GDP, total investment, unemployment, and household welfare), they must be carefully designed. The CGE model developed offers a useful way to test those policies and to assess their impact ex ante. Second, the most promising policy appears to be to invest in water saving (scenario S4). In contrast, some policies such as increasing water pricing (scenario S3) are predicted to have only limited effects for mitigating long-term impacts of water scarcity. Third, water policies will have differentiated impacts on economic sectors and household income groups. This calls for a careful design of such policies, and the need to consider redistribution schemes across sectors or household income groups. Differentiation of economic policy scenarios according to household type or economic sector (e.g. water pricing may differ for low-income households or for some economic sectors) could be a valid option to consider. Fourth, combining different policy scenarios might be a relevant way to identify an optimal policy mix for mitigating long-term impacts of water scarcity.

Since increasing water savings appears to be the most promising policy scenario, some practical actions already included into the 2018 National Water Resource Strategy should be encouraged. In particular, training and information campaigns regarding the need for a better efficiency of water use should be promoted. Some sector-specific actions could be undertaken. The agricultural sector could be encouraged to modernize water conveyance and irrigation equipment, and to implement preventive maintenance programs. The mining, industry, and power generation sectors could undertake some audits to compare their water consumption to similar activities. The water production sector could increase the technological efficiency of water purification, treatment, and distribution.

Finally, a few extensions of our work may be considered. First, additional policy scenarios may be proposed for simulation by the CGE model. One may think to have differentiated economic policy scenarios according to household type or economic sector (e.g., water pricing may differ for low-income households or some economic sectors). Second, the production functions for water-dependent sectors could integrate more or less substitution possibilities between water-related factors, but the calibration of these functions requires additional data which are not easily available in the case of South Africa. Third, labor heterogeneity may be included, for instance by considering skilled and non-skilled labor. Fourth, the granularity of the model could be increased by introducing more disaggregated economic sectors. Lastly, the water-CGE model could be regionalized to account for the wide heterogeneity of South African Provinces in terms of climate conditions, water availability and structure of the economy. In such a case, the assumption of water mobility across regions and sectors should be abandoned to reflect local constraints in water transfers over space (or between sectors). This will lead to different market equilibrium prices for water depending upon local water scarcity.

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Data Availability Data used in the Water-CGE model are available from authors upon request.

Code Availability GAMS code used for running the Water-CGE model is available from authors upon request.

Declarations

Ethics Approval Not applicable.

Consent to Participate Not applicable.

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