A general equilibrium approach to model water scarcity in Israel

By

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Abstract

Water is a scarce resource in Israel. With fluctuating supplies and an increasing demand, the need for using alternative water sources such as reclaimed wastewater, brackish groundwater and desalinated seawater increases. This paper investigates the economy-wide effects of a declining supply of natural fresh water (ground and surface water) and the increasing utilization of alternative water sources (recycled wastewater, brackish water, desalinated seawater). To account for different production structures and usage options, a single country Computable General Equilibrium (CGE) model is used, in which several water activities produce differentiated water commodities. These water commodities are used as intermediate inputs in other production activities or are consumed by households.

Results suggest that especially the agricultural sector would be affected by a reduction of natural fresh water availability, as it is the largest water user. However, the effect can be mitigated if substitution possibilities with alternative water sources are increased, especially the desalination of seawater can contribute to this. The rest of the economy is affected to a lesser extent, as water is only a minor input in other sectors and the water sector itself is small compared to the whole Israeli economy.

Keywords: CGE, water, wastewater reclamation, desalination, CES nesting structure**,** Israel

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1 Introduction

Water in Israel is a very scarce resource (Fleischer et al., 2008). With an annual provision of less than 250 m³ per capita, Israeli supply lies 50% below the threshold of severe scarcity according to the internationally recognized Falkenmark indicator (Tal, 2006).

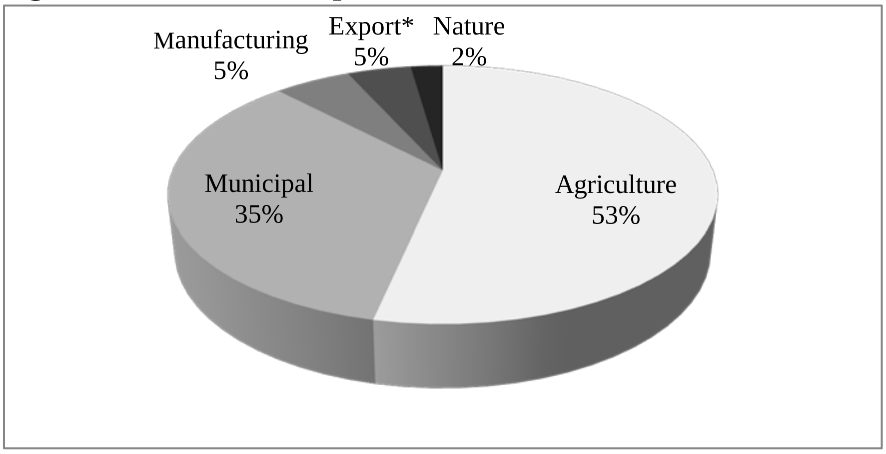
The long term potential of total annual renewable supply of freshwater from natural sources is estimated to be around 1,800 million m^3 (Israeli Water Autority in Shachar, 2009). However, depending mainly on winter-precipitation in the north this amount is subject to variation. In recent years Israel is facing an ongoing drought and replenishment rates of aquifers were found to be much lower with about 830 million m³ in 2008 (Shachar, 2009).

To meet the annual demand of about 2,220 million m^3 and to mitigate overexploitation of aquifers, alternative water sources have been explored in recent years. As a result of these efforts, about 387 million m^3 reclaimed wastewater and 123 million m^3 desalinated seawater have been supplied in addition to natural sources in 2007 (CBS, 2010). By the same year the extraction of brackish groundwater, mainly directly used for irrigation of salt tolerant crops, has increased to 235 million m³ (Shachar, 2009).

On the consumption side, agriculture uses about 1,190 million m^3 of water (about 50% of which is recycled wastewater and brackish water), followed by municipalities[1] with 760 million m^3. Around 120 million m^3 are consumed by the manufacturing sector. Furthermore, about 100 million m^3 are diverged to Jordan as agreed in the 1994 peace treaty and to the Palestinian water authority. Finally, 50 million m^3 are reserved for the rehabilitation of natural habitats (Figure 1) (MEP, 2005; Zaide, 2009; CBS, 2010).

[1] Municipality consumption is composed of intermediate consumption by the service sector and final household consumption

Figure 1: Water consumption in Israel in 2007



**water diverged to Jordan and the Palestinian Water Authority*
Source: MEP, 2005; Zaide, 2009; CBS, 2010, own calculations.

The problem of water scarcity is expected to become more severe in the future, as climate models predict an increase in temperature and changes in rainfall amount and distribution (Fleischer et al., 2008). Moreover, the remaining potential for wastewater reclamation is limited with 78% of total effluents already being reclaimed (Shachar, 2009). In addition, domestic water demand in Israel is increasing mainly driven by population growth (Bar-Shira et al., 2006; MARD, 2006) and the question of transferring more water rights of shared aquifers to the Palestinian National Authorities is yet to be negotiated within the peace process (Saleth and Dinar, 1999; MARD, 2006).

This study attempts to analyze the effects of a reduced natural fresh water (groundwater and surface water) supply, while increasing supply from alternative sources. For this purpose, an extended version of the standard STAGE model (McDonald, 2009) is employed, which is a single country computable general equilibrium (CGE) model. The model is combined with a detailed Social Accounting Matrix (SAM) for Israel that is developed for the year 2004 (Siddig et al., 2004).

The remaining part of this paper is structured as follows: Chapter 2 further elaborates on the Israeli water economy with background information about the relevant policies. Chapter 3 introduces the database used for analysis, highlights the extensions accommodated to the standard STAGE model for the purpose of this study, and describes the specifications of the simulation scenarios. In chapter 4 the scenario results are presented and discussed. Chapter 5 gives some concluding remarks and an outlook towards further modification possibilities of the model.

2 The Israeli Water economy

The Israeli law recognizes groundwater as well as surface water as state property (FAO, 2009). The National Water Authority (NWA) implements the water law and sets the water prices which are revised annually. Different prices are charged for agriculture, industry and municipal usage. Although the domestic sector is considered as first priority, its water prices are the highest. For the agricultural sector prices are considerably lower (Table 1). However, water usage in agriculture is also governed by quota allocation (Fleischer et al., 2008).

Most of the country's water resources are managed by Mekorot, a state owned company, which distributes about 70% of the water supply to agriculture, industry and municipalities (Zaide, 2009). The remaining 30% are provided by municipal and private wells. Private water extraction from the ground is metered and subject to an extraction fee. This fee is kept on a level, which assures that in most cases costs are comparable to the price of water provided by Mekorot (Kan, 2011).

In recent years, amplified by a lasting drought, the exploration of new water sources came on the agenda of the NWA. Although a large share of wastewater is reclaimed and distributed via a separate network to farmers for irrigation since the mid-1980s already, the NWA aims to further increase this share, from 78% in 2007 to 100% by 2020 and by that to provide about 600 million m³ of reclaimed wastewater to the agricultural sector (Shachar, 2009).

Furthermore, in 2002 the Israeli government took the decision to install five new reverse osmosis seawater desalination plants to be constructed within few years. These desalination plants are built on the base of BOT (Build-Operate-Transfer) contracts by private companies. The first plant opened in 2005 in Ashkelon with a capacity of 100 million m³ per year (Tal, 2006). The aim is to produce 505 million m³ annually by 2013 (Zaide, 2009) and finally 750 million m³ per year till 2020 (FAO, 2009). By that, most of the municipal demand shall be covered by desalinated seawater.

Besides increasing supplies the NWA aims at decreasing potable water consumption. This particularly applies to the agricultural sector as the main water user, which the NWA tries to shift towards a higher usage of reclaimed wastewater. This is achieved by firstly cutting the fresh-water quotas allocated to agriculture and secondly by increasing the subsidized freshwater price for farmers (Amir and Fisher, 2000; Zhou, 2006). Thus using reclaimed wastewater becomes more and more attractive. However, due to sanitary constraints not all reclaimed wastewater can be used for unrestricted irrigation, as this requires a special tertiary treatment. Up to now this quality is only reached by the biggest reclamation facility operated by Mekorot, which is producing about 35% of the total reclaimed wastewater in Israel (Shachar, 2009).

In addition, the usage of brackish groundwater mainly for the irrigation of salt tolerant crops such as cotton, tomatoes and melons has been fostered, such that the consumption of brackish water in agriculture rose from 76 million m³ in 1996 to 201 million m³ in 2007 (MARD, 2006; Shachar, 2009).

3 Methods

3.1 Data

This analysis is based on an extension of a SAM developed by the Agricultural and Food Policy Group at Universität Hohenheim (Siddig et al., 2011). This SAM represents the Israeli economy in the year 2004 and incorporates 43 sectors, 37 factor accounts, 10 household groups, and 18 tax categories.

Water is represented by only one sector in the original SAM; hence it is sub-divided for this study such that the water sector can be explicitly modeled. Using additional information provided by the NWA, FAO and other sources, the water sector is disaggregated to four activities producing three types of water commodities, namely: potable water, reclaimed wastewater and brackish water. Thereby, potable water can be produced by either the purification of natural fresh water or desalination of seawater. This reflects the fact, that water derived from both production activities is distributed via the same network.

Table 1 depicts the usage of the three water commodities in 2004, whereby reclaimed wastewater and brackish water are only used in the agricultural sector. Data on water quantities are taken from the NWA (Zaide, 2009) and FAO (2009). Average water prices were adopted to coincide with the value of water provided by the original SAM, such that the SAM remains balanced after the introduction of the new water commodities. The 50 million m^3, which are reserved for nature conservation, are not considered in this model, as this is a politically fixed quantity, which cannot be altered.

Table 1: Water in the Israeli SAM of 2004

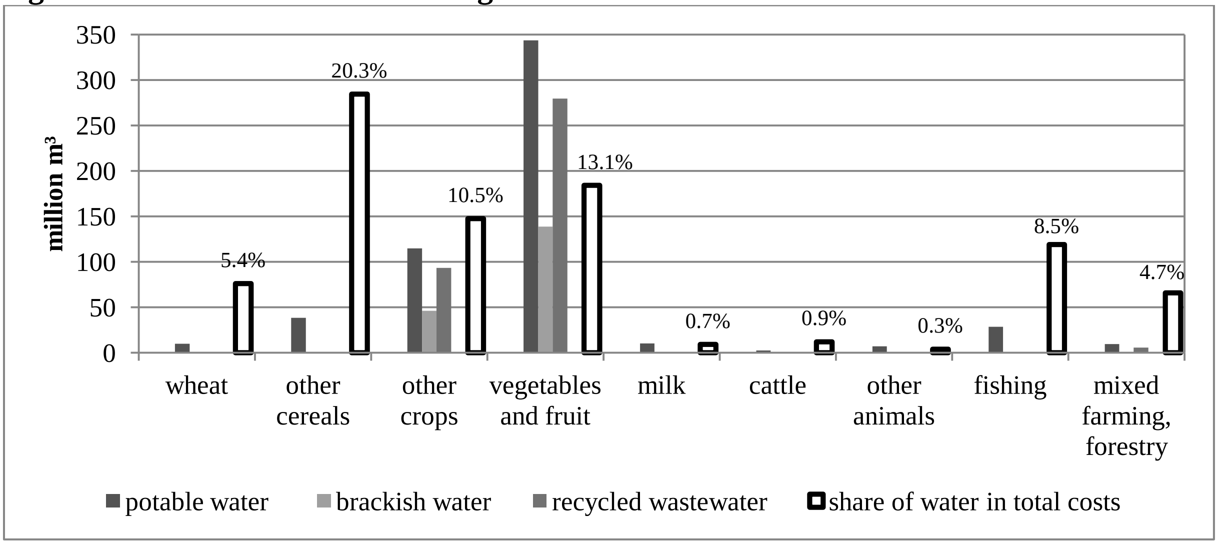
Use	Water quality	Water quantity [million m³]	[%]	Average water prices [USD/m³]	Value [million USD]	[%]
Agriculture	potable	565	27	0.37	207.62	13
	reclaimed	379	18	0.22	83.00	5
	brackish	185	9	0.27	50.34	3
Manufacturing	potable	113	6	0.79	88.82	6
Municipalities	potable	712	35	1.53	1088.19	69
Export*	potable	100	5	0.67	67.12	4
Total		2054	100	0.77	1585.31	100
thereof	potable	1490	73	0.97	1451.74	92

**water diverged to Jordan and the Palestinian Water Authority*
Source: own compilation based on: Zaide, 2009; FAO, 2009; Siddig et al, 2011.

Figure 2 depicts the water use in the agricultural sector according to the agricultural activities considered in the model database, as it is the biggest user of water and only some agricultural activities allow for the usage of marginal water (brackish and reclaimed wastewater). Vegetable and fruit plantations are the by far biggest water users, followed by the production of other crops, which include cotton, sunflowers and other field crops. The usage of brackish water in this study is limited to these two sectors ("vegetables and fruit" and "other crops"), as they include plants which are tolerant towards increased salinity levels (e.g. tomatoes, melons, cotton). Due to sanitary restrictions also the usage of recycled wastewater in this model is limited to these two activities besides the "mixed farming and forestry" activity. These activities either produce non-food outputs (e.g. cotton and timber-products) or crops for which lower sanitary restrictions apply, as they can be irrigated without the water touching the harvested parts (e.g. olive and citrus trees).

No data on the use of marginal water in the different agricultural sectors is available. Therefore, the brackish and reclaimed water commodities are split amongst the activities which allow for their usage according the total water consumption of the respective activities in the SAM.

Figure 2: Water use in the Israeli agricultural sector in 2004 in million m³



Source: own compilation based on FAO 2009; Zaide, 2009; Siddig et al, 2011.

3.2 Model

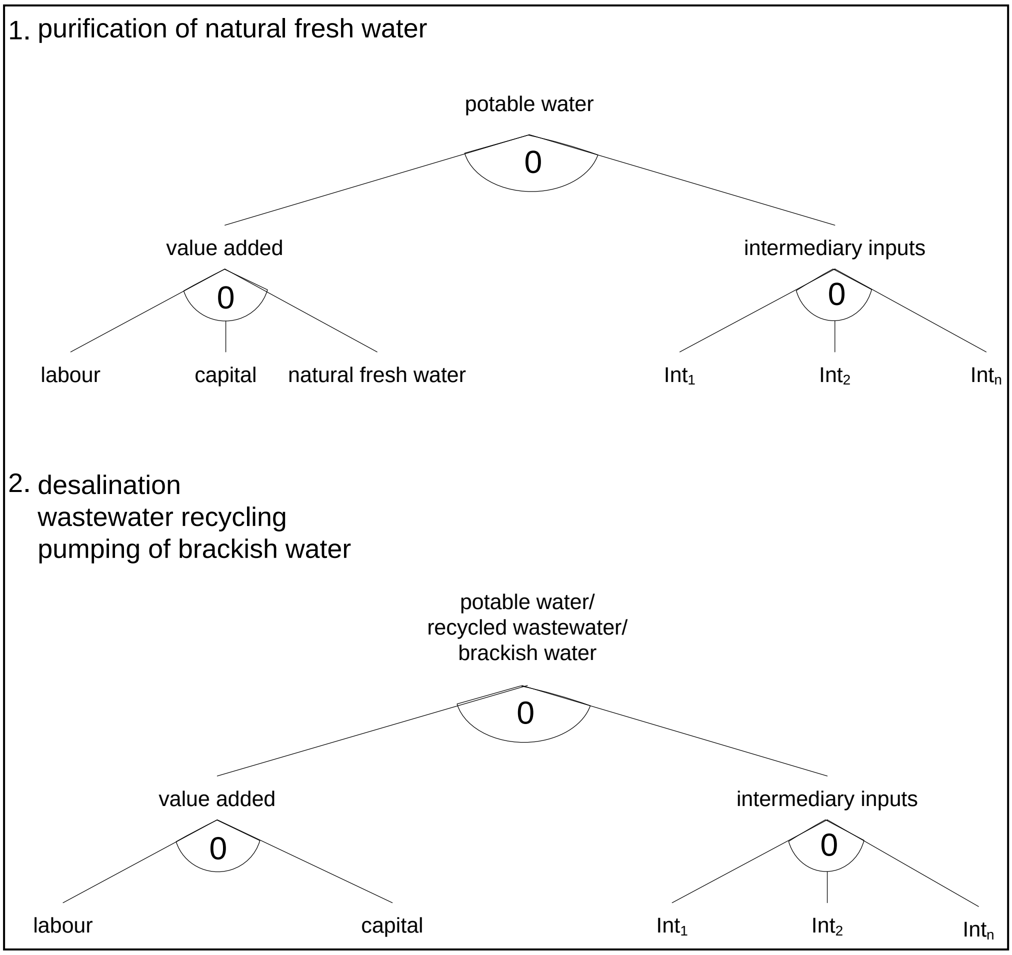
3.2.1 General structure of the model

This study employs a single country CGE model which builds on the standard STAGE model (McDonald, 2009). In the original STAGE model, production functions are nested in two levels. The functional form applied at the top-level is Constant Elasticity of Substitution (CES) or Leontief function, combining aggregate value added and intermediate inputs. On the second level, a multi-factor CES-function is used to combine production factors on the one side and a Leontief function to combine fixed rates of intermediate inputs on the other side (McDonald, 2009).

3.2.2 Water producing activities

For the activities which produce the different water commodities (potable water, recycled wastewater and brackish water), we combine factors and intermediate inputs in fixed proportions with the help of Leontief functions on both levels, assuming no substitutability as suggested by Tirado et al. (2006), as shown in Figure 3. This ensures that the activity specific cost structure is kept. Natural fresh water is introduced as an additional production factor to represent the quantity of water which can be sourced from aquifers. As described in the introduction, this is the limiting factor in the production of potable water in Israel.

Figure 3: Nesting structure of water production activities



Source: own compilation.

The use of natural fresh water is only relevant to the purification of natural fresh water activity. As effluents, brackish groundwater and seawater do not pose a limit on the production of water commodities (at least in the current situation) and are freely available, they are not explicitly modeled.

All water producing activities use different shares of inputs and thus have different cost structures as depicted in Table 2. For all activities energy is the most important input, as all activities require pumping of water, either from the ground, which can be from a depth of up to 1000 m in case of brackish water (Brimberg et al., 1994) or through micro-membranes in case of desalination, which is a very energy-intensive process (Garb, 2010). Capital requirements are the highest for wastewater recycling and desalination, as these activities require larger investments. The same holds true for consumables, which are mainly chemicals in case of wastewater recycling and materials such as membrane replacements in case of desalination. Only the purification of natural fresh water activity relies on the natural fresh water resource and thus has to pay an extraction levy to the state, which intends to reflect the scarcity of the resource (Kislev, 2001). Finally, other inputs mainly include construction activities and other services, which are consumed by all water producing activities to a minor extend.

The three water commodities produced by these activities are included as intermediate inputs in the production functions of the other sectors. In addition, potable water is consumed as a final product by households.

Table 2: Production cost and cost structure of water producing activities

Inputs	purification of natural fresh water	wastewater recycling	pumping of brackish water	desalination
Total production cost [USD/m³]	0.97	0.22	0.27	0.97
Energy	30.2%	30.0%	34.8%	40.0%
Labour	30.1%	22.8%	34.2%	10.0%
Capital	14.6%	20.0%	17.2%	20.0%
Consumables	8.3%	20.0%	5.0%	14.5%
Natural fresh water	7.2%	0.0%	0.0%	0.0%
Machinery	6.2%	4.6%	5.0%	10.0%
Taxes	1.1%	0.9%	1.3%	1.8%
Other	2.3%	1.7%	2.6%	3.7%

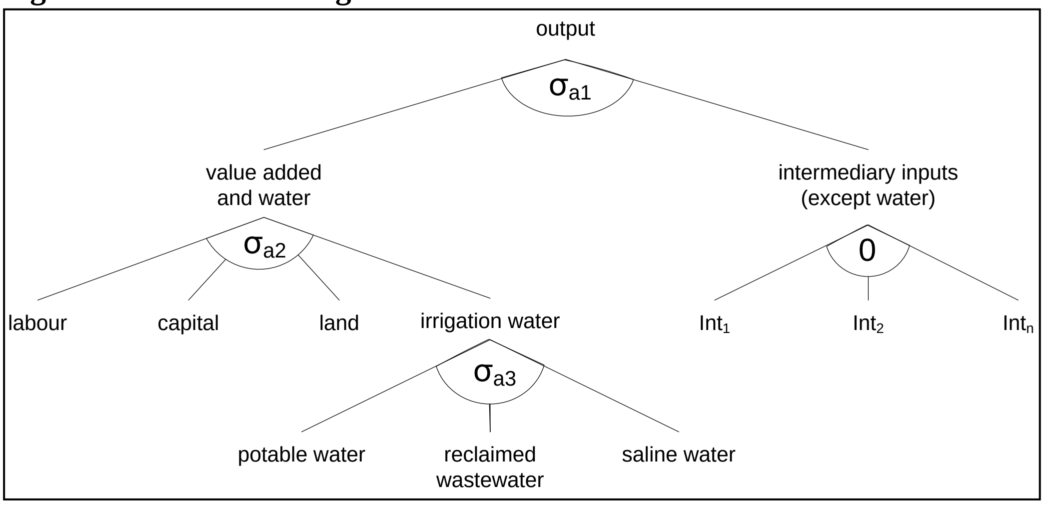
Source: own compilation based on Feinerman and Rosenthal, 2002; Beltran and Koo-Oshima, 2006; Stevens et al., 2008; Siddig et al, 2011.

3.2.3 Other production activities

For all other production activities the two stage production nest is extended to three levels: Firstly, the water commodity is taken out of the intermediate input nest and added to the value added side. This allows for the possibility of substituting water with production factors, as for example the irrigation sector in Israel constantly substitutes capital and technology for water by increasingly using water saving drip irrigation systems (Saleth and Dinar, 1999). Secondly, the water commodity is further disaggregated into potable water, reclaimed wastewater and brackish water. The three water types are combined to constitute irrigation water using CES technology (Figure 4). This reflects the possibility for farmers to substitute potable water with marginal water in the sectors where the use of these water commodities is possible or allowed, as previously stated. The production for all other sectors has the same structure, except for the third level, where sectors cannot use reclaimed wastewater and brackish water.

This analysis uses for the top-level of production an elasticity value σ_{a1} of 2.0, to represent a rather high substitutability between intermediaries and production factors. For the substitution between factors of production (σ_{a2}) a medium to low elasticity of 0.8 (Sadoulet and de Janvry 1995) is chosen. On the third level, for the substitution of water commodities σ_{a3}= 3.0 is applied. The comparatively high value at the third level is selected to reflect good substitutability of water commodities in the activities which allow for the use of different types of water.

Figure 4: General nesting structure



Source: own compilation.

3.3 Scenarios

Two scenarios are considered in this study. The basic idea is to investigate a situation in which the availability of fresh water in Israel decreases. The motivation is to analyze the effects on the Israeli economy in terms of production with a focus on agriculture, and on the consumption of different water commodities. The resulting structural changes in the economy are important to anticipate, as a basis for the coping behavior of private actors as well as the consideration of complementary policies. The closure rules applied for this study assume full factor mobility and employment, investment driven savings and fixed tax rates. Two scenarios are analyzed:

Scenario 1: Reducing the availability of natural fresh water without desalination (non-desal).

This scenario simulates a reduction in the availability of natural fresh water to domestic users. This is an expected and widely discussed scenario, due to the factors already mentioned in previous chapters: ongoing drought, climate change and the expected obligations to supply more water to neighboring entities. Another factor as well is the additional water demand for the recovery of overused aquifers (Dreizin, 2006). To implement this scenario in the model, the supply of natural fresh water is fixed at 80% of its base value. Afterwards, the model is solved to analyze the effects on the Israeli economy as a whole as well as on the different economic activities. According to the reality, and the model structure natural fresh water cannot be substituted in the purification of natural fresh water activity (Figure 4). Therefore, the impact of the simulated scenario will directly be transmitted into a loss in the output of this activity, namely a reduced production of potable water.

Scenario 2: Reducing the availability of natural fresh water, while including desalination (desal).

This scenario introduces production of potable water by desalinating seawater. It is motivated by the NWA plans to increase the supply of potable water derived from desalination of seawater to 750 million m³ per year till 2020 (FAO, 2009). In doing so the NWA aims to reduce the reliance on precipitation and the pressure on the overused aquifers. The implications of an increasing share of potable water produced by seawater desalination are investigated in this scenario, considering that seawater desalination is energy intensive and thus comparatively expensive.

Desalination did not exist to a considerable extend in Israel before 2005, while our model's data is for 2004. Therefore, a pre-simulation is implemented to adjust the structure of the water sector in Israel to its situation in 2007. In that year about 120 million m³ of potable water were derived from desalination whereby the production of potable water by purifying natural fresh water decreased by about the same amount (CBS, 2010). The other two water producing activities are left unchanged to guarantee comparability between the scenarios. Accordingly, an updated SAM that accounts for the contribution of the desalination activity to the production of potable water with 120 million m³ and an equivalent reduction in the purification of natural fresh water activity is considered the base SAM for this scenario. Except for slight changes in the allocation of factors and intermediates due to the differences in production structures between the two activities that produce potable water, the SAM has not been further altered.

Also in this scenario the effects of a reduction of natural fresh water availability by 20% are investigated, similar to the first scenario. The difference is that through the introduction of the desalination activity the substitution possibilities are increased significantly, as desalinated water can be used in all sectors.

4 Simulation Results

Generally the reduction of natural fresh water supply in Israel results in higher prices for the natural fresh resource as well as potable water. As a consequence, prices for this production factor and this commodity increase. As relative prices for marginal water commodities fall, they substitute for potable water in those activities allowing for substitution.

Significant differences occur between the non-desal and the desal scenarios. Because there is a higher dependency on natural fresh water in the non-desal scenario and less possibilities of substitution, the implications of a natural fresh water reduction by 20% on the economy are more severe compared to the second scenario (desal), where the desalination is introduced. The price of the natural fresh water resource increases drastically, with both scenarios. However, with 683% the increase in the non-desal scenario it is almost twice as high as in the desal scenario, which shows an increase of 347%. These higher resource prices in both scenarios lead the price of potable water to increase, with the latter being the only activity using natural fresh water (Table 3). This in turn causes the demand for this commodity to decline.

Table 3: Changes in the Israeli water prices in the two scenarios

	average water prices [USD/m³]			change compared to base [%]	
Water quality	base	non-desal	desal	non-desal	desal
potable	0.97	1.43	1.18	47.16	21.11
reclaimed	0.22	0.22	0.22	-0.56	-0.26
brackish	0.27	0.27	0.27	-0.58	-0.27

Source: model results.

Falling relative prices cause the demand for reclaimed and brackish water to increase, resulting in higher production of these commodities (Table 4). However, prices of these two water-commodities drop slightly (Table 3), which might appear counter-intuitive on the first glance. The explanation for this is the general downturn, which the Israeli economy experiences due to the higher potable water prices. The overall production decreases and the gross domestic product (GDP) drops by 0.24% and 0.09% with the non-desal and the desal-scenarios, respectively. Thus, intermediate inputs and production factors other than natural fresh water become cheaper. The study's model assumes that production factors are fully mobile to reflect long-term adjustment. As the water sector is very small compared to the whole economy, it can source more production factors at lower prices and thus the production of brackish water and recycled wastewater becomes cheaper, in spite of an increasing demand.

Generally, the observed effects are less pronounced in the desal scenario compared to the non-desal scenario. In the desal scenario the quantity of desalinated water is almost doubled, therefore less potable water is substituted by marginal water. The price of potable water increases by only 21% and prices of the two marginal water commodities are almost unaffected. This reflects the lower output effect compared to the non-desal scenario, where the potable water price increases by about 47% (Table 3).

Table 4: Changes in the water demand by sectors

		Water demand in base [million m³]		Change compared to base [%]	
User	Water quality	non-desal	desal	non-desal	desal
Agriculture		1129	1129	-3.6	-3.5
thereof	potable	565	565	-50.8	-29.0
	reclaimed	379	379	43.7	22.0
	brackish	185	185	43.4	21.9
Manufacturing	potable	113	113	-27.0	-14.4
Municipalities	potable	712	712	-11.7	-6.2
Export*	potable	100	100	0.0	0.0
Total		2054	2054	-7.5	-4.9
thereof	potable	1490	1490	-26.9	-15.0
	thereof desalinated	0	119	±0.0	98.0
	reclaimed	379	379	43.7	22.0
	brackish	185	185	43.4	21.9

**water diverged to Jordan and the Palestinian Water Authority*
Source: own calculations based on model results.

As described above the production of desalinated water will be almost doubled with the desal scenario, which buffers the reduction of potable water consumption. The latter would decline by -15% with the desal scenario compared to -27% with the non-desal scenario (Table 4).

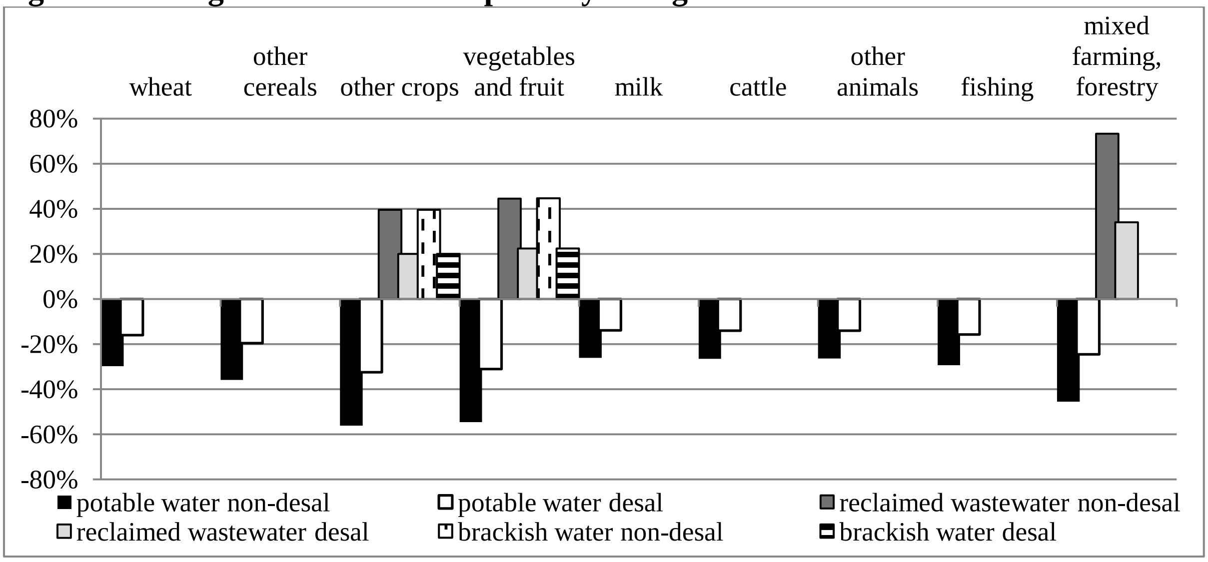
It is important to note that the exports of water, which includes the agreed amounts to be transferred to Jordan and Palestine, are assumed fixed in the model due to political obligations. Therefore, the two scenarios do not show any changes in the amount of water exports.

The use of potable water in all non-agricultural activities, would decline by about 27% and 14% with the non-desal and the desal scenarios, respectively. These activities are characterized by their minor demand for potable water as input, which also can be easily substituted by other factors of production in these activities. Thus total output in most activities of the non-agricultural sector would drop by less than 1% with the two scenarios. However, there are some exceptions, such as some energy and machinery producing activities, which decrease less than other non-agricultural sectors. This is because these activities produce inputs which are required in the wastewater recycling, pumping of brackish water and desalination activities. These water activities which increase under the scenarios analyzed have a different cost-structure compared to the purification of natural fresh water activity (Table 2).

A more moderate reduction of potable water consumption occurs in the municipal sector for both scenarios. This is due to the large share of subsistence demand for water by households, especially of the lower income quintiles which is due to the parameterization of the LES demand system applied. The share of subsistence demand, which is completely inelastic to price changes, reaches 78% in the lowest quintile, while it is 5% in the richest quintile. Therefore, household consumption of potable water is reduced by between 2.5% (poorest quintile) and 9.5% (richest quintile) in the non-desal scenario and by between 1.3% and 5.1%, when desalination is included.

Despite of the highest reduction of potable water use by the agricultural sector, the total water reduction is relatively small (-3.6% and -3.5% for the non-desal and desal scenarios, respectively). This is explained by potable water in these sectors being partially substituted by marginal water. The effects on water use in the agricultural sector are depicted in Figure 5.

Figure 5: Changes in water consumption by the agricultural sectors

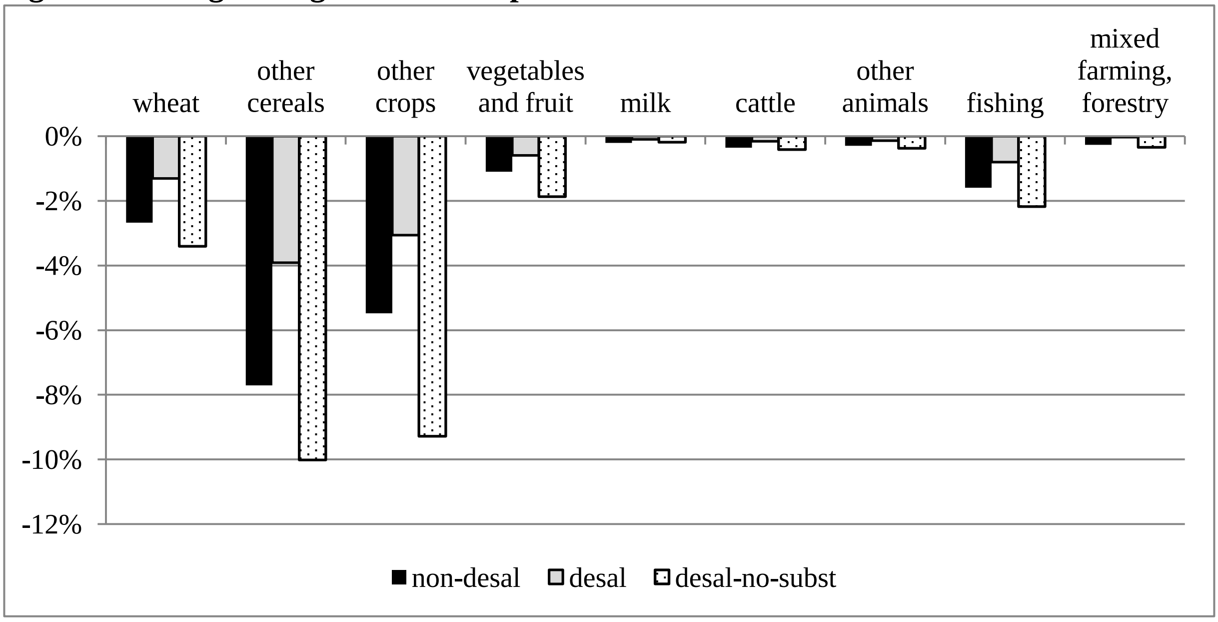


Source: model results.

It can be seen, that the consumption of potable water by all agricultural activities would decline with both scenarios. The reductions are higher in activities which allow for substitution with marginal water (up to 56% in the non-desal scenario). On the other hand the use of brackish water and recycled wastewater in these sectors would increase by up to 45% and 73%, respectively, with the non-desal scenario. In the desal scenario the potable water use would decrease by maximally 35% therefore also the use of marginal water is not increased as much as in the non-desal scenario.

The effects of the reduction and shifts in water supply on agricultural output are shown in Figure 6. To illustrate the sensitivity of the results to the substitution possibilities between the different water commodities, an additional sub-scenario is included in this graph (desal-nosubst). This scenario builds on the desal scenario but assumes no substitutability among the water commodities (σ_{a3} being equal to zero). Figure 6 shows that the output of all agricultural activities is reduced as the cut of potable water supply is not fully compensated by the increased use of water from alternative sources. The comparison of the output over the three scenarios yields, that when increasing substitution possibilities the magnitude of output reduction can be considerably reduced in all agricultural sectors. Allowing for the substitution with marginal water commodities only (non-desal scenario) mitigates on average 22% of the output reduction. When additionally desalination (desal scenario) is included on average 65% of the negative effect is balanced compared to a situation without substitution (differences between the columns in Figure 6).

Figure 6: Changes in agricultural output



Source: model results.

5 Conclusions

The scarcity of water in Israel already is a serious problem and is expected to even become more severe in the future. The topic is widely discussed on the policymaking level and it is broadly understood that in the future natural supplies cannot be exploited to the current extent. However, the perceptions differ on the effects this will have on the Israeli economy. This paper tries to quantify these effects.

The findings of the study reveal that a 20% reduction in the natural fresh water resource would lead to a considerable price increase for potable water, even though the production of water from alternative sources would increase. However, the effects on the total economy are less prominent, with the GDP dropping by less than 0.3% in both scenarios due to the relatively small size of the water sector in the Israeli economy, accounting only for about 0.7% of the total output in the base situation. Also, the share of water in the total spending of households is small at an average of about 1% of total expenses (CBS, 2006).

The agricultural sector, which has relatively high demand for water as an intermediate input, would be most affected by the reduction of natural fresh water supply. Due to the good substitution possibilities in this sector, however, the negative effects are partially mitigated, such that output drops are reduced to maximally 4% in the desal scenario and 8% in non-desal scenario. In the industrial and service sectors water is less important as intermediate input and can be substituted by other production factors. Therefore, the effect of the simulation on the output of these sectors is very small.

It has been shown that the substitutability between the different water commodities as well as between water and other production factors has major influence on the size of changes caused by the simulation. The selected elasticity value for the substitution between the different water commodities may be considered high given the fact, that not in all regions in Israel alternative water sources are easily available by now. However, as it is a declared policy aim to reduce the reliance of the agricultural sector on natural fresh water, access to alternative water sources will have to be increased over the next years.

Another aspect which needs to be considered is that the production of desalinated water is energy intensive. This is reflected in the cost structure of the desalination activity by a relatively high share of energy inputs of 40% of the total costs, compared to 30% for producing potable water from natural fresh water. The energy consumption by the desalination activity would strongly increase with the simulation. The value of "coal, oil and gas" consumed by the sector would increase from USD million 9.58 to 34.95 and the value of electricity consumption would rise from USD million 6.38 to 23.27. However, this increase in the demand for energy by the desalination sector represents a very small share in the total of the respective energy sectors accounting to about 1.0% for the "coal, oil and gas" and 0.7% for the electricity sectors. Therefore, the output of the energy sectors is only marginally affected by the increase in the desalination activity. However, as the governmental plans foresee a further increase of seawater desalination to 750 million m^3, which is more than three times higher than as the simulated value in the desal scenario, these effects are expected to become more pronounced in the future.

Finally it has it be considered, that in this paper the production factors are assumed to be mobile between the different sectors, which reflects a long-term perspective. However, in the short run, production factors are less mobile. This would for example reduce the capability of substitution between water commodities, as the production of marginal water commodities as well as potable water from desalination could not be increased so easily. Additionally prices of these alternative water commodities would rise, with increasing demand. In total, the negative effect on the Israeli economy would be stronger in the short run.

6 Outlook

The model presented in this paper is still work in progress and will be further modified to suit the analysis of future developments in the water sector and water-related policies in Israel. The potential for a further increase of reclaimed wastewater use is limited by the quantity of effluents available from households and the marginal costs of wastewater recycling are increasing with the share of total effluents being collected. This will be incorporated in the model by linking household water consumption and the production of recycled wastewater through a supply and a demand function for effluents. In that situation, effluents will then be incorporated in the production function of the wastewater recycling activity as a production factor similar to natural fresh water for the potable water activity.

Further developments could consider the adaptation of the nesting structure by introducing additional levels to allow different rates of substitution between water and factors of production. In addition, this model would be modified in order to better depict water pricing policies such as the block rate pricing and the quota system. The latter is especially relevant for the agricultural sector.

Finally, the use of marginal water commodities could be extended to further sectors, reflecting the production of very high quality reclaimed wastewater and the ongoing research to find further salt tolerant plant species.

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