Water Crisis in Pakistan: A Dynamic CGE-Water Model

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Water Crisis in Pakistan: A Dynamic CGE-Water Model

Muhammad Zeshan¹ and Muhammad Shakeel²

Abstract

The demand for freshwater is growing rapidly in Pakistan due to rising agricultural cultivation and its intensification. In addition, the fast growing population in the country (almost 2% per annum) and industrial growth are also adding to the rising water demand in the country. Pakistan is expected to face severe water shortage in near future if suitable policy measures are not taken. Around 95% of the freshwater is used by agriculture in Pakistan while the rest is used by the industry and the private households. Therefore, this paper primarily focuses on the irrigation water and how its shortage is going to affect the economic structure of Pakistan. The irrigation water shortage is expected to increase the price of agricultural land temporarily while a permanent increase is expected in the market price of irrigation water. The irrigation water shortage has a direct and an indirect impact on the production of various crops, which ends up in reducing the crop production. Overall, the resulting GDP losses might reach around 3.11% to 11.07% till 2040 under different water shortage scenarios. Finally, our simulation results show that the welfare losses are expected to be around USD 3.5 to 10.9 billion till 2030.

Key Words: water stress; water scarcity; welfare; agriculture; climate change

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I. Introduction

The sub-continent region especially Pakistan inter alia relies heavily on the irrigation water supplies via man-made or natural sources to fulfill the agriculture sector demand. This is however alarming that acute water shortages in the country are observed in recent years e.g. it has been noted that in 2010, per capita availability of water was around 1,040 cubic meters, which is expected to drop to around 500 cubic meters by 2035 (Ministry of Water Resource, Pakistan, 2018). A water crisis is a situation where the available potable, unpolluted water within a region is less than a region's demand. The water scarcity issues are inter alia derived by the climate change including droughts, floods, pollution as well as overuse of water, increase in population and intensive use of water in agriculture (Alam, 2015). Also, the fresh sources of underground water have not been replenished due to the human, agricultural and industrial wastes (World Bank, 2018). According to the Falkenmark Water Stress Indicator discussed in climate change (2001) report, a country or region is said to experience "water stress" when annual water supplies drop below 1,700 cubic meters per person per year. At levels between 1,700 and 1,000 cubic meters per person per year, periodic or limited water shortages can be expected. When a country is below 1,000 cubic meters per person per year, the country then faces water scarcity.

The current water storage capacity in Pakistan is less than ten percent (about 13.7 million acre feet, MAF onwards) of the total water received (about 145 MAF) every year (Ministry of water resource, Pakistan, 2018). Also, Pakistan has the largest irrigation system of canals and yearly needs 40 MAF but there is an absence of new dams' therein causing 29 MAF waste of water. Therefore, Pakistan is running out of fresh water at an alarming rate, and the country is anticipated to suffer an irrigation water shortage of 31 MAF by 2025. Such a shortfall is devastating for an agriculture-based economy.

Notwithstanding, agriculture sector is inter alia major/noteworthy user of water and related concerns discussed before. The country has a large pool of labor force in the agriculture sector and agricultural output/gross-domestic-product (GDP) has almost 19 percent plus share in aggregate GDP of the country (Economic Survey of Pakistan, 2019-20). Also, the country is an exporter of raw material like cotton and rice as well as of ready-made products like milk packs,

cloths, jackets etc. wherein the dependence on the agriculture sector is pivotal and inevitable for a sustainable trade. Exporting such products provides job opportunities in the local industry, generates economies of scale therein low cost of products as compare to world market prices, raises foreign reserves therein the purchasing power of the domestic currency and overall increases the GDP via multiplier's effect, *ceteris paribus*. There are also forward-backward linkages of the agricultural production leading towards more job creation and output production in the economy as well. The previous discussion clearly implies that water shortages are harmful to the agricultural sector as well as other sectors of the country both directly and indirectly.

Considering the role of sustainable water supplies with respect of agricultural and other sectors, we contribute methodologically by developing a CGE-Water model for Pakistan. Specifically, we develop a dynamic CGE water (Gdyn-W) model, which is a multi-region, multi-sector, recursively dynamic general equilibrium model. Basically, this model links the static GTAP-Water model along with the dynamic GTAP-Energy model (Calzadilla et al. 2011; Golub, 2013).

In 2010, per capita availability of water was around 1,040 cubic meters, which is expected to drop to around 860 cubic meters by 2025 (Ministry of Water Resources, 2018), we call it Scenario 1. Further, Sharif et al. (2016) claim that it might go down to around 500 cubic meters till 2035, labeled as Scenario 2. If any of these scenarios happens, the country would face a transition from a water stressed to a water scarce country. It is important to know that the minimum water requirement is 1,000 cubic meters per capita per year if a country wants to escape water scarcity while it is 1,700 cubic meters per capita per year to escape the water stress condition.

Pakistan's economy primarily depends on irrigated agriculture, and it consumes more than 95 percent of the total fresh water resources in the country, while the remaining balance is consumed by domestic and industrial users (Ministry of Water Resources, 2018). We can figure out how the deteriorating freshwater resources can adversely affect the agriculture in Pakistan. Hence, the water shortage in the country would translate mainly to the production losses of irrigated agriculture in Pakistan. Therefore, the prime objective of the study is to understand the potential gains/losses of the water management considering the scenarios described earlier therein for the sustainable economic development of the country.

The rest of the study is as follows; section 2 discusses major studies and their research findings therein gaps and modeling frameworks used. Section 3 discusses the economic and econometric models of the present study while section 4 discusses the course of simulation analysis. Section 5 presents the simulation results of different scenarios employed, finally, section 6, concludes the research findings.

II. Literature Review

This section highlights the missing links and gaps as well as examines the state of the art modeling frameworks employed in mainstream literature. Notwithstanding, the current literature review will help us to develop our modeling framework and to design our simulation design.

Specifically, a few studies employ either a global dataset to understand the water scarcity issue (e.g. Brauman et al. (2016); Florke et al. (2018); Liu et al. (2017); Chaturvedi et al. (2015)) while others use single country analysis (e.g. Jaeger et al. (2017); Shtull-Trauring & Bernstein (2018); Perez-Blanco et al. (2016); among others)). A part of literature focuses on sectoral/regional aspects (e.g. Alam (2015); Koopman et al. (2015); Njuki and Bravo-Ureta (2019); Chen et al. (2018); among other)). It is nevertheless stated that all of these existing studies highlight different important aspects of water scarcity (Table 1).

Many of the studies link the water scarcity with agriculture in one way or the other. Chen et al. (2012) suggest that water scarcity may be tackled by improving local agricultural practices. Likely, Zou et al. (2015); among others state that water management for increasing efficiency may help reduce the greenhouse gas emissions therein help to reduce the adverse impact of climate change. Using the CGE modeling framework, a few studies assess the issue of water scarcity and the role of agricultural adaptations to mitigate the effects of pollution and water stress in different regions/countries (e.g. Perez-Blanco et al. (2016) and Koopmans et al. (2015); among others). These studies provide novel findings in the regions selected to conserve the rare water resources via different policy options. The present study also attempts to cover the gap of literature in the context of Pakistan considering the paucity of literature on the issue for this region.

S. No.	Author(s)	Time Period	Country/Region	Methodology	Results
1	Njuki and Bravo-Ureta (2019)	1960-2004	48 States of USA	Single-factor Approach	Irrigation productivity increased modestly in various states, driven by technological progress.
2	Chen et al. (2018)	2012	188 Regions Worldwide	Multi-regional Input-output Model	Around one-third of water withdrawal is linked to interregional trade. Improving the local agricultural practices can save water.
3	Florke et al. (2018)	1971-2000	World	WaterGAP3 Model	Nearly 19% of cities, relying on surface-water transfers, might face potential conflict between the urban cities and agricultural sectors.
4	Shtull-Trauring & Bernstein (2018)	2007-2012	Israel	Water-Footprint Analysis	Around 25% of total Blue (irrigation) water ³ used for agriculture production is exported.
5	Jaeger et al. (2017)	2010	USA	Willamette River Basin Model	Key factors behind water scarcity are high cost of transportation, limited storage capacity, and opportunity cost of water.
6	Liu et al. (2017)	2006	World	SIMPLE-G and Water Balance	Rising factor productivity in irrigated sectors is expected to

³Blue water represents the primary source of natural water supply (such as groundwater and surface water runoff) while green water is the water from rainfalls.

				Models	boost irrigation water demand while irrigation vulnerability might decrease by inter-basin water transfers.
7	Brauman et al. (2016)	1971-2000	worldwide	WaterGAP3 Model	At least, around 71% of world irrigated area is experiencing periodic water shortage.
8	Perez-Blanco et al. (2016)	2011	Italy	CGE Model	Water charging policy is effective as long as water charges remains under 55 Eurocents/m ³ .
9	Alam (2015)	2013	546 farming households in Bangladesh	Multinomial Logit Regression	Awareness about adverse effects of climatic change is more likely to lead farmers to adaptation strategies.
10	Esteve et al. (2015)	2011	Spain	WEAP Model	Lack of technology is a major factor for inefficient water use by farmers along with decisions made by neighboring farmers.
11	Chouchane et al. (2015)	2005-2011	Tunisia	Water Footprint Assessment	The country is facing severe water scarcity as total blue water used in crop production is around 31% of total renewable blue water.
12	Samian et al. (2015)	148 Farmers, in year 2011	Iran	Factor Analysis Method	Technical, institutional, economic and social factors are mainly responsible for water shortage.

13	Medellín-Azuara et al. (2015)	2012-2014	USA	SWAP & C2VSim Models	Reduced access to groundwater, and uncertain delivery of surface-water during drought reduced crop revenues in the country.
14	Fishman et al. (2015)	1901-2004	India	Sequent Peak Algorithm	Adoption of technologies such as drip and sprinkler irrigation can reduce the extraction of groundwater by two thirds.
15	Zou et al. (2015)	2010	China	Water-saving Irrigation Method	Improved water use efficiency can effectively reduce greenhouse gas emissions.
16	Chaturvedi et al. (2015)	2005	World	GCAM Model	Agrarian regions particularly China and India are expected to experience rising water demands over the next century.
17	Marshall et al. (2015)	2001-2008	USA	CGCM, CSIRO-Mk and MIROC Models	Irrigation water shortage linked to climate change shows different effects on cropland use.
18	Taheripour et al. (2015)	2007	India	CGE Model	Due to water shortage, the welfare losses are expected to increase by \$3.2 billion in 2030.
19	Zhou et al. (2015)	2000-2009	China	OLS	Price mechanism, legally enforceable water rights, and water quotas create incentives for water conservation and improved irrigation efficiency.
20	Koopmans et al. (2015)	2001	87 Regions	GTAP-W	There is considerable room for adaptation measures given that

					total agricultural losses are much lower than the nonagricultural losses.
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112 **III. Research Methodology: Gdyn-W Model**

113 The present study develops a dynamic CGE water (Gdyn-W) model, which is a multi-region,
 114 multi-sector, recursively dynamic model. Basically, this model links the static GTAP-Water model
 115 along with the dynamic GTAP-Energy model (Calzadilla et al. 2011; Golub, 2013). The main
 116 characteristic that distinguishes the dynamic GTAP model from other class of dynamic CGE
 117 models is its disequilibrium approach to portray the capital mobility. It maintains the short-term
 118 and medium-term dissimilarities in the rates of return, which however can be abolished in the
 119 long-term. Hence, this practice allows imperfect capital movement between different regions in
 120 short-term to medium-run while allowing perfect capital mobility in long-term.

121

122 The new production structure in Gdyn-W model enables substitution likelihoods between
 123 irrigation water and other key factors of production whereas which is missing in the standard
 124 GTAP model (Hertel, 1997). Hence, it allows substitution likelihood between irrigation water and
 125 irrigable land using a nested CES function at a lower level in, which represent the first nest. The
 126 demand for irrigation water (Wtr) along with irrigable land (Lnd) becomes:

$$127 \quad (1) \quad qfe_{i,j,r} = -afe_{i,j,r} + qlw_{j,r} - ELLW_{j,r} * [pfe_{i,j,r} - afe_{i,j,r} - plw_{j,r}]$$

$$128 \quad i = Lnd, Wtr$$

129 Where the unit cost of the irrigable land-water composite is:

$$130 \quad (2) \quad plw_{j,r} = \sum_{k \in ENDWLW} SLW_{k,j,r} * (pfe_{k,j,r} - afe_{k,j,r})$$

131 In the second (lower) nest, producers also add capital and energy composite using a CES function.

132 The demand for energy and capital composite becomes:

$$133 \quad (3) \quad qfe_{i,j,r} = -afe_{i,j,r} + qke_{j,r} - ELKE_{j,r} * [pfe_{i,j,r} - afe_{i,j,r} - pke_{j,r}]$$

134 $i = \text{Capital}$

135 $(4) \text{ qen}_{j,r} = \text{qke}_{j,r} - \text{ELKE}_{j,r} * (\text{pen}_{j,r} - \text{pke}_{j,r})$

136 Unit cost of the capital-energy composite becomes:

137 $(5) \text{ pke}_{j,r} = \sum_{k \in \text{ENDWC}} \text{SKE}_{k,j,r} * (\text{pfe}_{k,j,r} - \text{afe}_{k,j,r}) + \sum_{k \in \text{EGY}} \text{SKE}_{k,j,r} * (\text{pf}_{k,j,r} - \text{af}_{k,j,r})$

138 At the middle level of nest, producers combine the irrigable land-water composite, rainfed land,

139 pasture land, capital-energy composite, natural resources and labor using a CES function. The

140 demand for pasture land, rainfed land, labor and natural resources becomes:

141 $(6) \text{ qfe}_{i,j,r} = -\text{afe}_{i,j,r} + \text{qvaen}_{j,r} - \text{ESUBVA}_j * [\text{pfe}_{i,j,r} - \text{afe}_{i,j,r} - \text{pvaen}_{j,r}]$

142 Where $i = \text{Rainfed Land, Pasture Land, Natural Resources, Labour}$

143

144 Demand for the irrigable land-water composite becomes:

145 $(7) \text{ qlw}_{j,r} = \text{qvaen}_{j,r} - \text{ESUBVA}_j * (\text{plw}_{j,r} - \text{pvaen}_{j,r})$

146 Demand for the capital-energy composite is:

147 $(8) \text{ qke}_{j,r} = \text{qvaen}_{j,r} - \text{ESUBVA}_j * (\text{pke}_{j,r} - \text{pvaen}_{j,r})$

148 Unit cost of the value-added composite (with energy inputs):

149 $(9) \text{ pvaen}_{j,r} = \sum_{k \in \text{ENDW}} \text{SVAEN}_{k,j,r} * (\text{pfe}_{k,j,r} - \text{afe}_{k,j,r}) + \sum_{k \in \text{EGY}} \text{SVAEN}_{k,j,r} * (\text{pf}_{k,j,r} - \text{af}_{k,j,r})$

150 At the upper level, producers combine the value-added composite with all other inputs using a

151 CES function. Demand for the value-added composite becomes:

152 $(10) \text{ qvaen}_{j,r} = -\text{ava}_{j,r} + \text{qo}_{j,r} - \text{ao}_{j,r} - \text{ESUBT}_j * [\text{pvaen}_{j,r} - \text{ava}_{j,r} - \text{ps}_{j,r} - \text{ao}_{j,r}]$

153 Demand for remaining inputs becomes:

$$\begin{aligned}
& qf_{i,j,r} = D_NEGY_{i,j,r} * D_VFA_{i,j,r} * [-af_{i,j,r} + qo_{j,r} - ao_{j,r} - ESUBT_j * [pf_{i,j,r} - af_{i,j,r} - ps_{j,r}]] \\
& + D_ELY_{i,j,r} * D_VFA_{i,j,r} * [-af_{i,j,r} + qen_{j,r} - ELELY_{j,r} * [pf_{i,j,r} - af_{i,j,r} - pen_{j,r}]] \\
154 \quad (11) \quad & + D_COAL_{i,j,r} * D_VFA_{i,j,r} * [-af_{i,j,r} + qnel_{j,r} - ELCO_{j,r} * [pf_{i,j,r} - af_{i,j,r} - pnel_{j,r}]] \\
& + D_OFF_{i,j,r} * D_VFA_{i,j,r} * [-af_{i,j,r} + qncoal_{j,r} - ELFU_{j,r} * [pf_{i,j,r} - af_{i,j,r} - pncoal_{j,r}]]
\end{aligned}$$

155

156 Lastly, unit cost of output becomes:

$$\begin{aligned}
157 \quad (12) \quad & ps_{j,r} + ao_{j,r} = \sum_{i \in ENDW} STC_{i,j,r} * [pfe_{i,j,r} - afe_{i,j,r} - ava_{j,r}] \\
& + \sum_{k \in TRAD} STC_{k,j,r} * [pf_{k,j,r} - af_{k,j,r}] + profitslack_{j,r}
\end{aligned}$$

158

159 Where:

- $qfe_{i,j,r}$ demand for endowment i for use in industry j in region r
 $qlw_{j,r}$ composite "irrigable land + water" in industry j of region r
 $qke_{j,r}$ composite "capital + energy" in industry j of region r
 $qen_{j,r}$ composite energy (electricity + non - electricity) in industry j of region r
161 $qvaen_{j,r}$ value - added in industry j of region r
 $qo_{i,r}$ industry output of commodity i in region r
 $qf_{i,j,r}$ demand for commodity i for use by j in region r
162 $qnel_{j,r}$ composite non - electric good in industry j of region r
 $qncoal_{j,r}$ composite non - coal energy good in industry j of region r
 $pfe_{i,j,r}$ firms' price for endowment commodity i in industry j of region r
163 $plw_{j,r}$ firms' price of "irrigable land + water" composite in industry j of region r
 $pke_{j,r}$ firms' price of "capital + energy" composite in industry j of region r
 $pen_{j,r}$ price of energy (elec. + non - elec.) composite in industry j of region r
164 $pf_{i,j,r}$ firms' price for commodity i for use by industry j in region r
 $pvaen_{j,r}$ firms' price of value - added in industry j of region r

- $ps_{i,r}$ supply price of commodity i in region r
165 $pnel_{j,r}$ price of non - electric composite in industry j of region r
 $pncol_{j,r}$ price of non - coal composite in industry j of region r

 $afe_{i,j,r}$ primary factor i augmenting technical change by industry j of region r
 $af_{i,j,r}$ composite intermediate input i augmenting technical change by j of r
166 $ava_{i,r}$ value added augmenting technical change in sector i of region r
 $ao_{j,r}$ output augmenting technical change in sector j of region r

 $ELLW_{j,r}$ elasticity of substitution between irrigable land and water in j
167 $ELKE_{j,r}$ elasticity of substitution between capital and the composite energy good in j
 $ESUBVA_j$ elasticity of substitution in production of value - added in j

 $ESUBT_j$ elasticity of substitution among composite intermediate inputs in production
 $ELCO_{j,r}$ elasticity of substitution between coal and the composite
168 $ELEY_{j,r}$ elasticity of subs. between electricity and the composite non - electric good in j
 $ELFU_{j,r}$ elasticity of substitution between remaining fossil fuels in j

 $SLW_{i,j,r}$ share of i in the composite good "irrigable land + water"
 $SKE_{i,j,r}$ share of i in second level composite good "capital + energy"
169 $SVAEN_{i,j,r}$ share of i in first level composite good "value added + energy"
 $STC_{i,j,r}$ share of i in total costs of j in r

profitslack $_{j,r}$ slack variable in the zero profit equation
170 $D_VFA_{i,j,r}$ dummy variable for identifying zero expenditures in VFA
 $D_NEGY_{i,j,r}$ dummy variable for intermediate demand : 1 = non - energy; energy = 0

 $D_ELY_{i,j,r}$ dummy variable for intermediate demand : 1 = electricity; others = 0
171 $D_COAL_{i,j,r}$ dummy variable for intermediate demand : 1 = coal; others = 0
 $D_OFF_{i,j,r}$ dummy variable for intermediate demand : 1 = oil, gas, petr. products; others = 0

172
173 IV. Simulation Design:

The demand for water is growing rapidly overtime in Pakistan due to rising agricultural cultivation and its intensification. In addition, the fast growing population in Pakistan (almost 2% per annum) and industrial growth are also adding to the rising water demand in the country. Pakistan is expected to face severe water shortage if suitable policy measures are not taken. In 2010, per capita availability of water was around 1,040 cubic meters, which is expected to drop to around 860 cubic meters by 2025 (Ministry of Water Resources, 2018), we call it Scenario 1. Further, Sharif et al. (2016) claim that it might go down to around 500 cubic meters till 2035, labeled as Scenario 2. If any of the scenarios happens, the country would face a transition from a water stressed to a water scarce country. It is important to know that the minimum water requirement is 1,000 cubic meters per capita per year if a country wants to escape water scarcity.

Pakistan's economy primarily depends on irrigated agriculture, and it consumes more than 95 percent of the total fresh water resources in the country, while the remaining balance is consumed by domestic and industrial users (Ministry of Water Resources, 2018). We can figure out how the deteriorating freshwater resources can adversely affect the agriculture in Pakistan. Hence, the water shortage in the country would translate mainly to the production losses of irrigated agriculture in Pakistan.

Average annual flow of rivers, stocks of groundwater and rainfall have important implications for the agriculture in Pakistan. Average annual flow of western rivers is almost 143 MAF in Pakistan. After incorporating the contribution from and reduction in the eastern and western rivers, and Makran and Kharan basins, the remaining available water is around 145 MAF in the Indus Basin Irrigation System (IBIS). Further, around 50 MAF of ground water and 30 MAF of the rainwater is available in the country per year (Sharif et al., 2016). As discussed above, let's assume the Scenario 1 (or Scenario 2) is translated into all the available fresh water resource in Pakistan including the IBIS, groundwater and rainfall. It would reduce the freshwater supply of the Indus Basin from 145 MAF to 120 (or 69.7) MAF where as groundwater stock reduces from 34 to 29.6 (or 24) MAF and the rainfall water reduces from 30 MAF to 26 (or 14.4) MAF.

V. Simulation Results

Given that Pakistan is a small open economy, water crisis in the country would have a negligible impact on the rest of the world. Hence, we report results for Pakistan only. In this section, Variable1 & Variable2 represent the simulation results for Scenario 1 & Scenario 2, respectively. In our model, the agricultural land and overall freshwater both are dependent on surface and ground water for irrigation purpose.⁴The simulation results reveal that increase in agricultural land price is temporary under both scenarios (1&2). For instance, agricultural land price increases by 4.5% and 5.5% under the Scenario 1 and Scenario 2, respectively in 2020 (Figure 1). However, this change starts reversing in 2025 in Scenario 1 and the same follows under Scenario 2 in 2035. Overall agricultural land price reduces by around 2.5% and 11.5% in 2040, under the scenario 1 and scenario 2 respectively, indicating that the previous rise in agricultural land price was not permanent.

On the other hand, the impact of freshwater shortage is permanent on its market price. For instance, initially water prices increase by 15.5% and 30% in 2020 under Scenario 1 and Scenario 2, respectively. As the Scenario 1 implements the water shortage up to 2025, the water price starts reducing in the later years. The overall increase in water price is just 14.3% compared to its highest rise (23.3%) in 2025. Under Scenario 2, initially water prices increase by 30% in 2020, and the cumulative increase in water price is the highest in 2035 (63.2%). As the Scenario 2 implements water shortage up to 2035, the water price starts reducing in the succeeding years and the cumulative increase in water price is just (45.9%), which is 17.3% low compared to its peak price in 2035.

⁴ The rainfall water is adjusted between the surface water and underground water.

Figure 1: Impact of Water Shortage on Irrigated Land and Irrigation Water Prices (Cumulative %)

Own Calculations

The freshwater shortage has direct and indirect impact on crop production. The indirect effect originates from the rising price of agricultural land and water, it ends up in reducing the production of all the crops under analysis at the national level. From our simulation results; production of wheat, vegetables and fruits is affected the most in Scenario 1 while situation become severe under Scenario 2 till 2030. Further, rice and wheat are the most affected crops in later years till 2040.

Own Calculations

The previous section highlights how the water shortage in a country causes production losses, and such information leads to develop an investor's expectation. Investors in a country are interested in the information set that helps them to foresee the future developments in the country. If such developments seem positive, the expected rate of return would be high in future resulting in rising level of investment in the country. In contrast, any negative development in a country would be alarming for investors as the expected rate of return on their investment would fall. Water shortage in a country is a negative development, and it ends up in reducing the expected rate of return. Particularly for an agrarian economy, implications of water shortage are huge as such economy has the strong backward and forward linkages that depend on agriculture.

From our simulation results, we find that the expected rate of return starts falling down under both of our scenarios (Scenarios 1-2). However, the expected rate of return reduces almost more than double under the Scenario 2 compared to the Scenario 1 till 2025. Later on, there is a slight decrease in the expected rate of return under Scenario 1 but it decreases enormously under the Scenario 2. The decrease in the expected rate of return is more than ten times under the Scenario 2 compared to the Scenario 1 in 2035. This gap starts reducing as there is no water constraint afterwards. We find that expected rate of return is just 5.6 times higher in Scenario 2 compared to the Scenario 1.

The changes in expected rate of return are translated into the changes in investment level. In our model, level of investment in firms is determined by domestic as well as foreign residents. Equity investment in a region is made through investment firms, where firms raise capital to purchase capital goods. Our simulation results reveal that the investment level reduces by 2.5% and 5.0% under the Scenario 1 and Scenario 2 in 2025, respectively. The reduction in investment level is almost double under the latter scenario compared to the former scenario. Further, the gap keeps increasing as it reached around 4.2 times in 2035, however it slightly reduces to 3.7 times till 2040.

Finally, it is important to discuss the Gross Domestic Product (GDP) and the change in overall economic welfare level in the country as these indicators specify the macroeconomic stability of a country. The analysis of GDP indicates the change in overall productive capacity of a country. Our simulation results show that the GDP begins to reduce under both of the scenarios, and the losses are higher under the scenario 2 compared to the scenario 1. The simulation results indicate that the GDP losses might increase by 3.11% and 11.07% in 2040 under the scenario 1 and scenario 2, respectively.

Figure 3: Impact of Water Shortage on Rate of Return, Equity Investment and Real GDP (Cumulative %)

Own Calculations

In our model, economic (equivalent) welfare is derived from the national income allocated between private and government consumption while the rest of it is saved (Hertel 1997). In this setting, a representative household is benefitted from her own current consumption expenditure. She is also benefitted from current savings as this increases her future household consumption. Lastly, she is benefitted from the current government expenditures on public goods and services. Hence, national income is distributed between total private consumption, total government consumption and the rest is saved to maximize utility level by a representative household. A change in policy translates into the change in disposable income of its residents. It translates into change in prices, hence the purchasing power of consumer also changes.

Our simulation results indicate that water shortage reduces the level of welfare in Pakistan under both of our scenarios. Initial impact of water shortage is somewhat similar under both the scenarios till 2020, which however starts to increase greatly in later years. We find that the welfare loss is around USD 3.5 billion and 10.9 billion in 2030 under the scenario 1 and scenario 2, respectively. The gap between the two scenarios increase greatly as the welfare losses increase by 12.6 billion and 44.5 billion under the scenario 1 and scenario 2, respectively.

Figure 4: Impact of Water Shortage on Welfare Level (Cumulative Change in Million USD)

Own Calculations

VI. Conclusion

The present study develops a dynamic CGE-Water model to simulation the different water stress scenarios in Pakistan. In both scenarios, the research findings show that expected rate of return, investment and domestic production all decrease significantly especially after 2020. These results imply that concerted endeavors are required for a viable water management policy in the country. From the simulation results; production of wheat, vegetables and fruits is affected the most in Scenario 1 while situation become severe under Scenario 2 till 2030. Further, rice and wheat are the most affected crops in later years till 2040.

The results also indicate that water shortage reduces the level of welfare in Pakistan under both of our scenarios. Initial impact of water shortage is somewhat similar under both scenarios till 2020, which however starts to increase greatly in later years. We find that the welfare loss is

324 around USD 3.5 billion and 10.9 billion in 2030 under the Scenario 1 and Scenario 2, respectively.
325 The gap between the two scenarios increase greatly as the welfare losses increase by 12.6 billion
326 and 44.5 billion under the Scenario 1 and Scenario 2, respectively.

327 The research findings nevertheless imply for the provision of water conservation methods as well
328 as adaptation measures to be indigenized in agriculture and industrial sectors. Also, there should
329 be defined ownership and legislation for licensing of groundwater and increase the groundwater
330 recharge for urban and rural areas under legal framework. Without such measures, the country
331 might face a severe economic and health crisis considering the contemporary water shortages in
332 the country.

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APPENDIX

Table A1

Sectoral Aggregation

S. N.	Sectors	57 Sector of GTAP Database Version 9
1	Rice	Paddy rice
2	Wheat	Wheat
3	Cereal crops	Cereal grains nec
4	Vegetables and fruits	Vegetables, fruit, nuts
5	Oilseeds	Oilseeds
6	Sugarcane	Sugar cane, sugar beet
7	Other Agriculture	Plant-based fibers; Crops nec; Raw milk; Wool, silk-worm cocoons
8	Animals	Bovine cattle, sheep and goats, horses; Animal products nec
9	Forestry	Forestry
10	Fishing	Fishing
11	Coal	Coal
12	Oil	Oil
13	Gas	Gas; Gas manufacture, distribution
14	Meat	Bovine meat products; Meat products nec
15	Processed food	Vegetable oils and fats; Dairy products; Processed rice; Sugar; Food products nec; Beverages and tobacco products
16	Other industry	Textiles; Wearing apparel; Leather products; Wood products; Paper products, publishing; Manufactures nec; Machinery and equipment nec; Electronic equipment; Transport equipment nec;
17	Oil products	Metal products; Motor vehicles and parts
18	Energy-intensive industry	Petroleum, coal products
19	Electricity	Minerals nec; Chemical, rubber, plastic products; Mineral products nec; Ferrous metals; Metals nec
20	Water	Electricity
21	Market services	Water
22	Non-market services	Construction; Trade; Transport nec; Water transport; Air transport; Dwellings; Defense; Education; Health; Recreational and other services; Business services nec; Insurance; Financial services nec; Communication
		Public administration

Figures

Figure 1

Impact of Water Shortage on Irrigated Land and Irrigation Water Prices (Cumulative %)

Figure 2

Impact of Water Shortage on Crop Production (Cumulative%)

Figure 3

Impact of Water Shortage on Rate of Return, Equity Investment and Real GDP (Cumulative %)

Figure 4

Impact of Water Shortage on Welfare Level (Cumulative Change in Million USD)