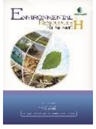

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Impact of water resources sustainability on Technological Gap
Ratio of agricultural sector

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Abstract

Water as a major necessity of sustainable development is essential for agricultural production and food security. Increasing water productivity, especially in agriculture, is one of the key issues for optimum water resource management. The present study applied a Stochastic Metafrontier Model to estimate Technical Efficiency (TE) and Technology Gap Ratio (TGR) of agricultural production from selected countries. The frontier and metafrontier production functions of 27 countries from 2011 to 2016 were used for estimation of the TE. The results showed that the mean of group efficiency ranged from 0.32 to 0.83 and the mean of technology gap ratio based on water crisis indicator in three groups were 0.37, 0.39 and 0.44, respectively. Considering the global water scarcity mainly in arid and semi-arid environments, it is vital to seek appropriate policies directed towards the provision of technology for irrigation infrastructures that would enhance resource use efficiency.

Keywords: Falkenmark indicator, Stochastic Metafrontier, Technical efficiency, Technology gap ratio, Water crisis.

Introduction

Water scarcity is dynamic and complex (Dolan et al., 2021) and is a global leading challenge in the way of sustainable development (Forum, 2015; Nations, 2015). Current global population growth and economic development have increased water demand and exacerbated the problem of water scarcity in many parts of the world (Liu et al., 2017; Falkenmark et al., 1989; Alcamo et al., 2000; Verosmarti et al., 2000). According to a study conducted by International Water Management Institute, a number of 65 countries inhabited by more than seven billion people will face water scarcity by 2050 (Shahroodi and Chizari, 2008). Alan (2002) believes that in 2025, about1.8 billion people will live in regions or countries with water scarcity challenges. It is expected that climate-induced water scarcity and drought will lead to competition between the economic sectors (Mankso et al., 2018). Water resources are unevenly distributed on earth; some countries receive more water and others less (Jafari Shalamzari & Zhang, 2018; Oki, 2006). In 2017, FAO stated that

"While there are sufficient freshwater resources at the global level to enable continued agricultural and industrial, the long-term sustainable use of water resources is of increasing concern."

Since water is essential for agricultural production and food security, increasing water productivity especially in agricultural sector is an important issue for optimal water resource management. Irrigated agriculture uses approximately 70% of the world's freshwater resources (UNDP, 2003). The factors affecting the agricultural management consist of technical, infrastructure, economic and social factors (Iglesias and Carrote, 2015). In recent years, pressurized irrigation systems have been used as one of the ways to increase water use efficiency in the agriculture sector (Ghorbani and Zamanian, 2014). The maximum irrigation efficiency, in the traditional, sprinkler irrigation and drip irrigation methods is around 35%, 70%, and

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95% respectively (Abdolmaleki and Chizari, 2008, p.87). Expanding the use of pressurized irrigation systems will increase crop yield and prevent damage to the environment (Movahedi et al., 2017). According to the Food and Agriculture Organization report in 2009, the total irrigated agricultural lands (million hectares) in Africa, America, Asia, the Middle East, and Iran were 13.7, 44.4, 223.3, 24.4, and 9.1 respectively. In 2009, the share of groundwater resources supply required by the agricultural sector for Africa, America, Asia, the Middle East, and Iran were 18.3, 45.7, 38.5, 46.2, 62.1% respectively. The share of the agricultural sector in Iran from the groundwater resources is quite high (Mohammad Jani & Yazdanian, 2014). According to international studies, the share of agricultural water in the world is about 2700 (billion cubic meters) and it is predicted that this will be doubled by 2050 (Pradhan, 2007). To quote from Noori et al. (2017):

“*Water demand management is one of the most important issues in environmental economics*”.

The World Bank has published a report based on FAO statistics (AQUASTAT 2015) in terms of internal renewable water resources per capita on status of water resources in 177 countries. The report has ranked 177 countries based on renewable water resources per capita, surface, and groundwater. Iran is 69th between 177 countries in terms of per capita renewable water resources. Thus, only 68 countries have more renewable water resources per capita than Iran. In the present study, 27 countries are considered based on their per capita renewable water resources including: China, Germany, Jordan, South Korea, Bulgaria, Romania, Spain, the Netherlands, France, Italy, Japan, Kazakhstan, Turkey, Greece, Iran, Azerbaijan, Belgium, Cyprus, Denmark, Egypt, Jordan, Poland, Ukraine, Kenya, Tunisia, India and Libya. These countries are categorized on the basis of the Falkenmark water crisis indicator (FWCI).

In the present study, considering the importance of water crisis and water resources management, we classified countries using Falkenmark indicator. Then, the frontier and metafrontier agricultural production functions were estimated based on renewable water resources per capita in these countries and the technology gap ratio of the selected countries were compared. The application of a metafrontier function allows the comparison of the technical efficiency of the countries in relation to renewable water resources per capita and water consumption in agricultural sector. Using the metafrontier approach has been found to be more effective in comparing relative technical efficiency levels across countries and assessing the potential to increase efficiency by groups.

In the following section we present literature review and then discuss research methodology followed by a description of the data and variables in the fourth section. The fifth section provides a discussion of empirical results and finally, conclusions and policy implications are highlighted.

Literature review

The matafrontier function was proposed by Hayami (1969) and Hayami and Ruttan (1970). Battese and Rao (2002) introduced an application of the metafrontier function, which allows for the estimation of technical efficiency among different groups. Battese et al. (2004) and O'Donnell et al. (2008) developed this approach by applying a two-step method for estimating the metafrontier function.

Khanal et al. (2018) estimated and compared technical efficiency and Technology gaps of Nepalese farmers in different agro-ecological regions. Bozorg Hadad et al. (2019) introduced an approach for quantifying water depletion and evaluating water shortage crisis in the Middle Eastern countries. Their analysis reveals that Lebanon, Syria, Iraq, and Iran are countries with very negative water scarcity indexes. Chandra and Mukherjee (2018) examined the technical efficiency of Indian agricultural production using the frontier model. In their production function, they considered irrigation lands by canals along with other production inputs and concluded that irrigation facilities were an important factor in increasing the technical efficiency of farmers. Ngoran et al. (2016) examined the use of water resources for sustainable economic growth in sub-Saharan Africa. The results showed that water and labor force are the main factors affecting economic growth in these countries and efficient use of water resources is an important factor in sustainable development. Esfanjari Konari et al. (2015) studied the technological gap ratio between different irrigation methods for wheat crop and showed that the ratio of technological gap for traditional and modern irrigation were 0.88 and 0.96, respectively. Moriera & Bravo (2010) showed that the mean technological gap ratio for Argentina, Chile and Uruguay were 83.8%, 79.6%, and 91.4% respectively.

In regard to agriculture development goals, this study has considered a new evaluation approach to investigate the role of renewable water resources in the technology gap ratio between countries. Water scarcity challenge can influence economic sectors, therefore, adequate investment is necessary in different sectors of water resources to protect groundwater resources as an indispensable assumption for policy makers.

Materials and Methods

Materials

Figure 1 shows the conceptual model of the present study.

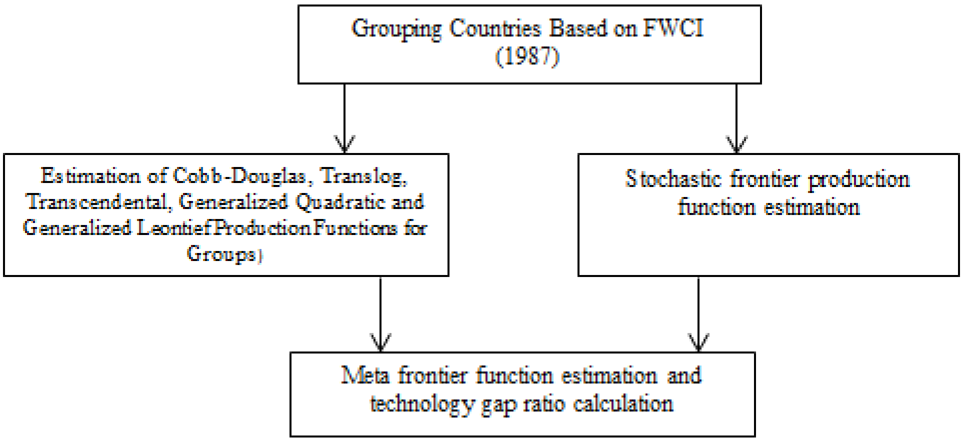

Figure 1. The conceptual model of the present study

Grouping countries based on water crisis indicator

This section introduces the indicators used to assess water crisis.

Falkenmark Indicator (FWCI)

This indicator is calculated based on the annual renewable water resources per capita for all the selected countries. Accordingly, countries with renewable water resources per capita of over 1,700 (cubic meters) have no water limitation. Countries with renewable water resources per capita between 1000 and 1700 (cubic meters) have water stress, and countries with renewable water resources per capita of less than 1000 (cubic meters) per year are countries with water scarcity.

Indicator of United Nation

According to this index, the percentage of exploiting from each country's renewable water resources is considered as an indicator of water crisis. When a country's water exploitation is more than 40 percent of its total renewable water resources, it faces a severe water crisis (Alcamo & Henrich, 2002), and if it is between 20-40 percent, the water crisis is moderate while with 10 to 20% exploitation, the crisis is at a balanced level and for values less than 10%, there is no crisis or low crisis (Mohammadjani and Yazdanian, 2014).

IWMI (International Water Management Institute) indicator

The International Water Management Institute uses the following two indicators simultaneously to study the status of water resources**:**

1) Percentage of current exploitation in relation to total annual water resources.
2) Percentage of future water exploitation in relation to current water exploitation (Babran and Honarbakhsh 2007; Nepomilueva, 2017).

Water Poverty Index (WPI)

The Water Poverty Index (WPI) was originally proposed by Sullivan (2002). This index shows the relationship between (1) available water resources; (2) access to water; (3) capacity for water management; (4) water uses for domestic, food and production purposes and (5) environmental concerns (Damkjaer and Taylor, 2017). These indicators are weighted and integrated into a single measure. Each of these components is standardized and range from 0 to 100 indicating the lowest and highest levels of water poverty (Sullivan et al., 2002).

Estimation of Production Functions

The Stochastic Frontier Analysis (SFA) has been extensively used in the agriculture sector to measure the technical efficiency or TE (Villano et al., 2015). The stochastic metafrontier function has been proposed by Battese and Rao (2002) and Battese et al. (2004). This function enables us to estimate the stochastic group-k frontier in case of having k groups of different countries based on renewable water resources per capita using standard stochastic as shown below: Frontier method (1):

$$Y_{it(k)} = f(X_{it(k)} \cdot \beta_{(k)}) e^{V_{it(k)} - U_{it(k)}} \qquad (1)$$

Where $Y_{it(k)}$ denotes the output of *i*th country at time t for the *k*th group. $X_{it(k)}$ is the input vector used by the *i*th country at time t and the *k*th group and also includes the variables of irrigated land. The unknown parameters that must be estimated for the *k*th group are represented by the vector $\beta_{(k)}$. $V_{it(k)}$ denotes the residual errors based on the assumption that they are independent from each other and have a random distribution $N(0, \delta^2_{v(k)}$. $U_{it(k)}$ is a non-negative random variable and is assumed to have an independent distribution $N(\mu_{it(k)}, \delta^2_{u(k)})$ and measures technical inefficiency (Mariko et al., 2019).

The technical efficiency of the *i*th country at time t and for the *k*th group is obtained by Equation (2). For the *i*th country, the technical efficiency TE^k_{it} is defined as the ratio of the obtained output to the equivalent potential output. The TE is expressed as:

$$TE^k_{it} = \frac{Y_{it}}{e^{X_i \beta^k + V_{it}}} = e^{-U_{it(k)}} \qquad (2)$$

In order to evaluate the performance of each country as a whole, where all technology groups are heterogeneous, a statistic metafrontier function should be used. Based on the models proposed by Battese and Rao (2004) and Battese et al. (2004), the metafrontier production function is generally in the form of Equation (3):

$$Y_{it}{}^* = f(X_{it} \cdot \beta^*) e^{X_{it} \beta^*} \qquad (3)$$

In which Y^*_{it} is the set of frontier production function and β* is unknown parameters of the function and should be estimated. For all values of k, all groups with heterogeneous technology will be $X_{it}\beta^* \geq X_{it}\beta^k$ implying that the frontier function is higher than all the group functions (group Frontier functions). Figure 2 shows the frontier functions for different groups.

The observed output for the *i*th country at *t*th time period defined by the stochastic frontier for the *j*th group in equation (1) is alternatively expressed in terms of the metafrontier function of Equation (4) by:

$$Y_{it} = e^{-U_{it(k)}} \times \frac{e^{X_{it} \beta_k}}{e^{X_{it} \beta^*}} \times e^{X_{it} \beta^* + V_{it(k)}} \qquad (4)$$

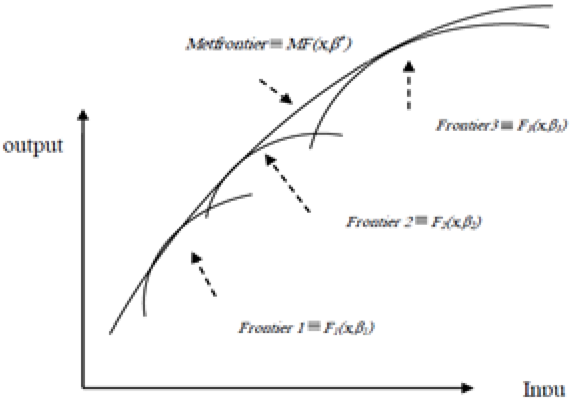

Figure 2. The metafrontier pattern at different levels of technology
Adopted from Battese et al. (2004)

The first term on the right-hand side of Equation (4) is technical efficiency of the *i*th country at time t in the *k*th group. The second term on the right-hand side of Equation (4) shows the technology gap ratio based on the water crisis (WC-TGR) and can be calculated using Equation5 as below:

$$\mathrm{WC-TGR}_{it} = \frac{e^{X_{it}\beta_k}}{e^{X_{it}\beta^*}} \qquad (5)$$

$X_{it(k)}$: The inputs vector of production (by the *i*th country at time t for the *k*th group).
$\beta_{(k)}$: The unknown parameters to be estimated for the *k*th group.

The technology gap ratio is the *k*th group frontier production function output related to the potential output from the metafrontier production function and is between 0 and 1 (Battese, 2004). Higher ratio indicates less gap in the technology (Onumah et al., 2013). A value of one means that the group frontier is the same as the metafrontier. A TGR of less than one means that the group frontier is inferior to the metafrontier (Lin, 2011).

Data

The analysis is based on data obtained from FAOSTAT system of statistics used for dissemination of statistics compiled by the Food and Agricultural Organization, Iran Water Resources Management, Iran Statistics Center, and the World Bank. Panel data of 27 countries from 2011 to 2016 was used in the present study.

The 27 countries considered in this study included China, Germany, Jordan, South Korea, Bulgaria, Romania, Spain, the Netherlands, France, Italy, Japan, Kazakhstan, Turkey, Greece, Iran, Azerbaijan, Belgium, Cyprus, Denmark, Egypt, Jordan, Poland, and Ukraine, Kenya, Tunisia, India and Libya.

Results and Discussion

This section describes the results of the categorizing countries based on the Falkenmark water crisis indicator (renewable water resources per capita in 2017). The results are shown in Table1.

Table 1. Results of grouping countries according to Falkenmark indicator

Group	Countries	Falkenmark indicator
1	Cyprus, Egypt, Jordan, Denmark, Tunisia, Kenya and Libya	With water scarcity
2	India, Poland, Iran, Belgium, Pakistan and South Korea	With water stress
3	China, France, Italy, Japan, Kazakhstan, Germany, Romania, Spain, Turkey, the Netherlands, Armenia, Bulgaria, Ukraine and Azerbaijan.	Without water stress

Source: FAO, 2017

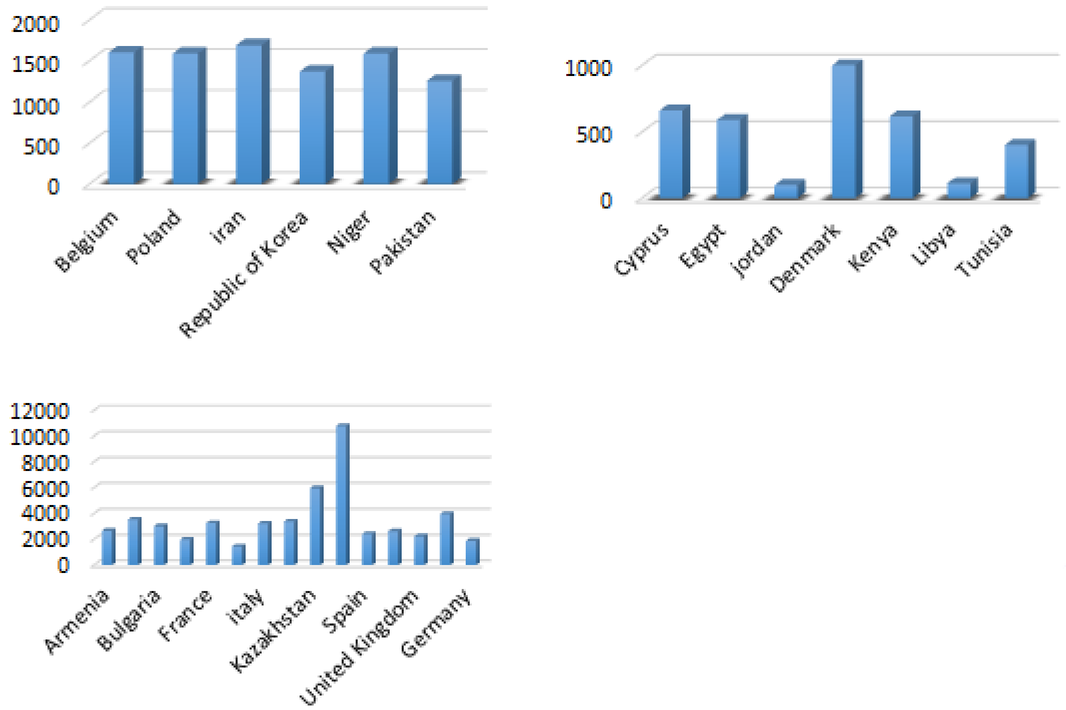

Figure 1. Classification of the Countries based on FWCI indicator (1989).

Figure 3 shows the renewable water resources per capita of Iran in 2017 which was compared to other countries. As the distribution of water in the world is very heterogeneous and this is also the case for the renewable water resources per capita of the studied countries, in the group of non-water stress countries, the highest and lowest renewable water resources per capita belong to Romania and the lowest to India. Among the group of countries with water stress, the highest renewable water resources per capita belongs to Iran and the lowest to Pakistan. In the group of water scarcity countries, Denmark has the highest renewable water resources per capita and Jordan shows the lowest.

Hypotheses Testing

The results of testing different hypotheses are presented for the three groups of countries. First, five production functions were estimated using a regression method and then generalized likelihood-ratio test was used to select the appropriate form (Equation 6) (Coelli et al., 1998).

$$LR = -2(Ln\left(\frac{L(H_0)}{L(H_1)}\right) = -2[Ln(L(H_0) - Ln(H_1) \quad (6)$$

$L(H_0)$ and $L(H_1)$ are the value of likelihood ratio function in H_0 and H_1. If the calculated statistic value exceeds the critical value of the chi-square, the flexible functions will be selected (Table 2).

Using likelihood-ratio test, the Cobb–Douglas was tested against the translog, leontief, generalized quadratic and transcendental function to determine its adequacy for representation of the data. The results showed that among functions, translog function was suitable as it considers the significance of the LR statistic and the significance of the coefficients.

The pooled stochastic frontier is estimated to test differences in group frontiers. The generalized likelihood ratio test statistic for the null hypothesis as the group frontiers was LR=-330.34 and with respect to the degree of freedom, the null hypothesis claiming that the regional frontiers are the same was rejected. The coefficient γ in the three groups was also significant at the 10% level in the translog function. The estimation of γ parameter by maximum likelihood method for the first group is 18.48, for the second group is 34.82, and for the third group is 162.37 that is consistent with the concept of being more than zero.

Table 2. Testing Hypotheses for frontier Production Functions.

Null Hypothesis	Test Statistic			Critical Value($\chi_{0.10}$)			Decision		
	Group1	Group2	Group3	Group1	Group2	Group3	Group1	Group2	Group3
Cobb-Douglas $H_0: \gamma = 0$	134.83	203.84	228.83	2.7(1)	2.7(1)	2.7(1)	Reject H0	Reject H0	Reject H0
Translog $H_0: \gamma = 0$	18.48	34.82	162.37	2.7(1)	2.7(1)	2.7(1)	Reject H0	Reject H0	Reject H0
Generalized quadratic $H_0: \gamma = 0$	0.32	13.10	70.89	2.7(1)	2.7(1)	2.7(1)	accept H0	Reject H0	Reject H0
Leontief $H_0: \gamma = 0$	0.25	112.78	8.38	2.7(1)	2.7(1)	2.7(1)	accept H0	Reject H0	Reject H0
Transcendental $H_0: \gamma = 0$	2.96	657.29	47.41	2.7(1)	2.7(1)	2.7(1)	Reject H0	Reject H0	Reject H0
H_0: Cobb-Douglas Vs. Translog	69.38	-30.96	181.16	22.3(15)	22.3(15)	22.3(15)	Accept Translog	Accept Translog	Accept Translog
H_0: Cobb-Douglas Vs. Transcendental	2168.02	-1082.72	-7160.38	9.24(5)	9.24(5)	9.24(5)	Accept Transcendental	Accept Transcendental	Accept Transcendental
H_0: Cobb-Douglas Vs. Leontief	-1990.56	-1536.04	-7105.46	16(10)	16(10)	16(10)	Accept Leontief	Accept Leontief	Accept Leontief
H_0: Cobb-Douglas Vs. Generalized quadratic	-1942.84	-1411.94	-7079.52	22.3(15)	22.3(15)	22.3(15)	Accept Generalized quadratic	Accept Generalized quadratic	Accept Generalized quadratic
H_0: Translog Vs. Leontief	2059.94	1505.08	7286.62	9.24(5)	9.24(5)	9.24(5)	Accept Translog	Accept Translog	Accept Translog
H_0: Translog Vs. Transcendental	2171.96	1051.76	7341.54	16(10)	16(10)	16(10)	Accept Translog	Accept Translog	Accept Translog
H_0: Leontief Vs. Transcendental	112.02	-453.32	54.92	9.24(5)	9.24(5)	9.24(5)	Accept Transcendental	Accept Transcendental	Accept Transcendental
H_0: Leontief Vs. Generalized quadratic	47.72	124.1	25.94	9.24(5)	9.24(5)	9.24(5)	Accept Generalized quadratic	Accept Generalized quadratic	Accept Generalized quadratic
H_0 Generalized Quadratic Vs. Transcendental	159.74	-329.22	80.86	16(10)	16(10)	16(10)	Accept Generalized quadratic	Accept Generalized quadratic	Accept Generalized quadratic
$H_0: LR_{Pooled} = \sum_{i=1}^{3} LR$	-330.34			28.4(20)			Reject H0		

Source: Research findings

Model Specification

The proposed model consists of two steps including:

1. Estimate the group stochastic frontier function.
1) Estimate the stochastic metafrontier by pooling the data

Majority of studies have used Cobb-Douglas and Translog production functions to estimate group frontier production functions. In the present study, five production functions were compared using a regression method, and an appropriate production function for the database was obtained. Therefore, the group frontier translog function of countries under study is as follows:

$$\mathrm{LN}(Y_{it}) = \beta_0 + \sum_{j=1}^{S} \beta_j LN(X_{ijt}) + \sum_{j=1}^{S} \sum_{F=1}^{S} \beta_{jf} LN(X_{jit}) LN(X_{Kit}) + V_{it} - U_{it} \quad (7)$$

Where Y_{it} is the value of agricultural yields (constant price 2004-2006, thousand-dollar) for country i-th and at time t, X_1 is the irrigated agricultural land (thousand-hectare), X_2, capital stock in agriculture (million- value of local currency at constant price in 2010), X_3, energy consumption in agriculture (Terajoule), X_4, employment in agriculture (thousand-people), X_5, fertilizer consumption in agriculture per hectare (kg), and X_6 is the amount of water applied in the agricultural sector (cubic meters). It should be noted that the variables of this study were selected based on the studies of Chandra and Mukherjee (2018); Khanal et al. (2018); Negoran et al. (2016), and Nimak and Sango (2006).

Table 3 shows the results of the estimates of the group stochastic, frontier and metafrontier model. It should be noted that variables of agricultural production per capita and stock per capita in agriculture have been used for better results.

Table 3. Parameter Estimates of the group stochastic frontier and metafrontier functions.

Variables	Frontier function Group1	Frontier function Group2	Frontier function Group3	Pooled Function	Metafrontier
Constant	4.83*	2.66	-5.32*	9.39*	-2.26
Ln(agri-irrigation)	-0.57**	1.72**	-1.28*	-0.31	14.40
Ln(capital)	-1.24*	28.20*	-3.81*	-0.65	26.29
Ln(fertilizer)	0.23**	4.54*	0.95**	-0.27*	-21.17
Ln(Energy)	-0.16	-5.10*	2.73*	-0.12	-5.44
Ln(Water)	0.02*	-0.35*	-0.06*	-0.01*	0.82
Ln(agri-irrigation*capital)	1.44*	-3.06*	1.03*	0.41**	4.74
Ln(agri-irrigation*fertilizer)	0.38	-0.27	0.16	0.11	-2.69
Ln(agri-irrigation*Energy)	-0.25	0.19	-0.42*	0.01	-1.96
Ln(agri-irrigation*Water)	-0.25*	0.03*	-0.003	-0.003	-0.14
Ln(capital*fertilizer)	-0.12	-5.70*	-0.39	-0.12*	-0.24
Ln(capital*energy)	-0.05	-0.65	0.08	0.10	-0.73
Ln(capital*water)	-0.009*	0.19*	-0.01	-0.003	-0.05
Ln(Energy*fertilizer)	-0.24*	-0.11	-0.24*	-0.04	5.96
Ln(fertilizer *Water)	0.07*	0.05*	0.004	0.001	-0.22
Ln(Energy*water)	0.12*	0.004	0.002	-0.002	0.07
Ln(agri-irrigation)^2	0.46	-0.17*	0.44*	-0.01	0.59
Ln(capital)^2	-0.18*	-1.71	2.22*	0.07	-5.29
Ln(fertilizer)^2	-0.14	-0.15	-0.04	-0.007	0.61
Ln(Energy)^2	0.009	0.49*	-0.11*	0.004	-0.37
Ln(Water)^2	0.001	-0.003*	0.004*	0.002**	0.003
Variance Parameters					
σ^2	0.03	0.17	0.28	0.90	-
γ	0.56	0.99	0.98	0.98	-
μ	0.29	-0.83	1.05	1.88	-
η	0.12	0.03	-0.01	0.0007	-
Log-L	18.33	62.13	71.39	-22.52	-

Note: *,** represent statistical significance level respectively at 5% and 10%.
Source: Research findings

Estimates of technical efficiencies and WC-TGR are presented in Table 4. For the first group (countries with water scarcity), the mean group, pooled and metafrontier technical efficiency for the period 2011-2016 are 0.65, 0.35, and 0.25 respectively.

Based on the TE estimate, an average country in the first group could expand its output by about 35% with a given input combination in order to become fully efficient as opposed to 17% in the second group and 68% in the third group. In other words, the countries in this group can increase their production by an average of 35% by filling their technical gap with the best country in their group.

Table 4 shows the efficiency differences for the selected countries separately based on the metafrontier results. On average, the second group are more technically efficient (34%) compared to the first group (0.25%) and the third group (0.13%). It should be noted that the mean technical efficiency of all three groups is not comparable. Comparison of the mean technology gap ratio of the three groups of countries shows that the technology gap ratio in the third group countries is higher than that of the second group and the country frontiers of this group are closer to the frontiers of the metafrontier function. The results showed that by shifting production technology level to top technology, one could increase the production of the third group countries to 56%, the second group countries to 61% and the first group countries to 63%.

Table 4. Technical Efficiency and WC-TGR Estimates

Group	Year		Mean	Min	Max
Group1	2011-2016	TE-Group	0.65	0.33	0.96
		TE-meta	0.25	0.05	0.76
		TE-Pooled	0.35	0.03	0.95
		WC-TGR	0.37	0.08	1
Group2	2011-2016	TE-Group	0.83	0.27	0.98
		TE-meta	0.34	0.05	0.88
		TE-Pooled	0.13	0.04	0.67
		WC-TGR	0.39	0.19	1
Group3	2011-2016	TE-Group	0.32	0.09	0.98
		TE-meta	0.13	0.01	0.66
		TE-Pooled	0.10	0.08	0.61
		WC-TGR	0.44	0.14	1

Source: Research Findings

Table 5 presents the results of the calculation of technical efficiency and technology gap ratio for Iran. According to the results of Table 6, the technical efficiency of Iran in the group of countries with water stress is from 0.85 to 0.87; Iran’s metafrontier function efficiency ranges from 0.55 to 0.77, and its technology gap ratio fluctuates from 0.62 to 0.90. For Iran, the mean technical efficiency, metafrontier function, efficiency and technology gap ratio for the whole period were 0.86, 0.65 and 0.75 respectively. Therefore, if the level of production technology is transferred to the state of the metafrontier technology, production in the agricultural sector of Iran can be increased by 25%.

Table 6. Technical Efficiency and Technology Gap Ratio Estimates of Iran

Year	TE	TE-meta	WC-TGR
2011	0.85	0.66	0.77
2012	0.86	0.77	0.90
2013	0.86	0.59	0.69
2014	0.87	0.55	0.64
2015	0.87	0.54	0.62
2016	0.87	0.56	0.64
Mean 2011-2016	0.86	0.65	0.75

Source: Research Findings

Conclusion and Recommendations

The present study examined the technical efficiency and the technology gap ratio of the agricultural sector of some countries selected based on their water crisis index. The results showed that the technology gap ratio in countries without water stress is higher than the other groups. Thus, renewable water resources per capita in the agricultural sector play important role in the development of the countries.

Due to the problem of water scarcity and droughts of varying severity, pressurized irrigation systems can be the best strategy to tackle water shortages and achieve the goals of increasing production and ensuring food security. Calculation of mean technical efficiency, cover function, efficiency and technology gap ratio for Iran in the group of countries with water stress placed the country higher than the average of the whole group. Based on the results of this study, the following recommendations are offered:

- Countries with less renewable water resources could improve their performance through a better management using the available technologies and resources. With the advancement of innovation through irrigation infrastructures in the agricultural sector, agricultural production can be increased and this can lead to a reduction in the technology gap ratio of countries.
- The agricultural policies should emphasize both the efficiency improvement and technology advancement. In this regard, significant promotion of water productivity in agriculture, reduction of per capita water consumption in different sectors, and promotion of water security of renewable sources of appropriate quantity and quality are important. Using efficient water management strategies is the key for increasing water productivity. In addition to evaluating product management strategies, improving irrigation systems can lead to efficient and sustainable agricultural water management. Therefore, making the right policies for agriculture and implementing efficient farming consultation plans for future economic growth in countries with water scarcity is essential.
- Promoting irrigation management, including knowledge of the farmers and the relevant organizations, to increase timely and reliable water and sustainable water productivity are solutions for managing water resources. Improving the efficient use of water resources in agriculture reduces production costs in this sector and positively interacts with other sectors through backward and forward relations.

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