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RESEARCH ARTICLE

Water consumption and economic growth: evidence for the environmental Kuznets curve

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ABSTRACT

This research investigates the relationship between economic growth and consumption of fresh water in Iran using the environmental Kuznets hypothesis. In this study we used per-capita water consumption and per-capita gross domestic production of 31 provinces of Iran from 2005 to 2018. The results showed the inverted 'U'-shaped relationship between water consumption and economic growth and that the environmental Kuznets hypothesis existed between water withdrawal and economic growth in the agricultural and service sectors, and that the water–production relationship in the industrial sector followed an inverted 'N'-shape. The results can help policymakers with policy implementations related to sectorial water consumption.

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Economic growth; water consumption; environmental Kuznets curve

Introduction

Economic growth is at the core of every economic planning. However, economic growth in most cases has had devastating consequences, especially regarding the environment and natural resources. Most economic activities are closely related to the environment and natural resources and the economic growth of societies depends on them. Over the past decades, extensive unfavourable environmental changes have occurred along with the economic growth of countries, such as resource depletion and reduction of water reserves (Sharzehi & Haqhani, 2008).

Some studies have provided evidence that the relationship between national per capita water withdrawal and per capita income follows an inverted 'U'-shape (e.g., Goklany, 2002), an issue known in the economic literature as the Kuznets curve (KC) hypothesis. However, in Iran, the relationship between economic growth and water consumption in the form of the KC hypothesis has been ignored. In this study we use the KC hypothesis to examine the relationship between economic growth and water consumption in Iran.

As the growth rate for global water consumption continues to outpace the global population growth, governments, international development agencies and leading researchers have pointed to the global water scarcity as a potentially serious economic, health and national security concern (e.g., the United Nations Economic, Scientific and

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Cultural Organization (UNESCO), 2009). The concern for future water scarcity is growing, but measurements of actual water use, and the prediction of future water availability and water consumption rates, have proven difficult to estimate accurately (Gleick, 2003). Part of the difficulty in such estimates is in identifying the role of economic growth as a factor influencing water use.

However, the issue of water management in Iran is more perceptible and vital because Iran is one of the arid and semi-arid regions of the world. Iran has an average annual rainfall of 250 mm, which is less than one-third of the world average of 800 mm, while average evaporation in Iran is 2100 mm, which is three times more than the world average of 700 mm. The inappropriate distribution of rainfall in time and place in the country is such that 70% of the rain falls over 25% of the country, and most of the rainy season does not correspond to irrigation times. Hence, water is a rare commodity in many areas.

Furthermore, the agricultural sector has consumed the most water compared with the other sectors of the economy in all the years under this study (2005–18). On average, 53,994.89 million m^3 of water have been consumed in the agricultural sector during the years under review. Water consumption of the service and industrial sectors during the same period is about 5224.75 and 1082.12 million m^3, respectively.

Meanwhile, the average annual growth of domestic product (GDP) was 3.8% in Iran during the period under this study. According to the official statistics of the Central Bank of Iran, the agricultural sector accounted for 6.6% of Iran's GDP in 2018. The share of each sector, including oil, services, industries and mines, and agriculture in the economic growth in 2018 was 9.8%, 1.9%, 0.6% and 0.2%, respectively. The average growth of value added of the world agricultural sector between 2007 and 2016 was 2.7%. Iran, with a growth rate of 2.4%, ranked 72nd in the world, which is lower than the global average.

Water offers a wide range of productive opportunities, so investing in water for agriculture, hydropower and industry can be a driver of economic growth. Water resource management and development can help protect communities from the destructive effects of water to meet basic human needs and serve as a precondition for economic growth. On the other hand, effective water management has resulted from economic growth, where wider advances in technology and management have led to the superior performance, development and management of water infrastructure and institutions (Grey & Sadoff, 2006).

In addition, economic growth has increased producers' incomes and has encouraged improved good water management systems and infrastructure. Improving water infrastructure reduces water consumption, thereby reducing production costs, and leading to economic growth. Hence, economic growth reduces water consumption both directly and indirectly. Furthermore, in the developed world, 39% of water use is for irrigation, compared with 91% in the developing world (Fallahi et al., 2009). Given that the share of the agricultural sector in economic growth has reduced and the fact that this sector is extremely water intensive, declining share of agriculture in most developed economies has contributed to declining water usage.

A report from World Bank (2008) revealed that investing in water infrastructure, especially in the agricultural sector, has resulted in poverty reduction and economic growth in Sub-Saharan African countries. Gmanee (2016) also argues that there is a causality between economic development and investment in water resources, and investment in the infrastructure for these resource helps create national growth.

In this study, we investigate the relationship between economic growth and water consumption in Iran by focusing on the environmental Kuznets hypothesis. Given the scarcity of water resources in Iran, understanding the relationship between water and economic growth in Iran will help water policymakers. For this purpose, we investigate the relationship between growth and water consumption at the macro-level of the economy, as well as the agriculture, industry and services subsectors. The results of this study can help develop improved water policies for different sectors of the economy. The Kuznets relationship between water consumption and economic growth can help decrease the water shortage problem in various sectors, especially in the water scarce provinces.

Literature review

Many studies have focused on the KC hypothesis. For example, in the area of economic growth and air pollution, Fotros et al. (2010) studied the relationship between air pollution and economic growth of the petroleum-exporting countries. The results indicated an increase in the air pollution in the early stages of economic growth in those countries. With increased economic growth and import of less polluting technologies, the environmental quality improved. In addition, Balali et al. (2013) examined the relationship between economic growth and environmental pollution in the oil sector, with an emphasis on price fluctuations in Iran's economy. Their results indicated a bell-shaped relationship exists between the value added of the oil sector and the produced carbon dioxide resulting from its consumption. Hence, the Kuznets hypothesis is confirmed in the energy sector of Iran's economy.

In the field of economic growth and natural resources, Mehrara et al. (2012) investigated the relationship between per capita energy consumption and income for the 13 OPEC member countries during the period 1980–2008 based on the environmental Kuznets hypothesis. The results indicated that the elasticity of per capita energy consumption increased with an increase in per capita income, but with income increasing more and passing a threshold, the income elasticity decreased, confirming the environmental Kuznets hypothesis. In the area of economic growth and water consumption, Goklany (2002) presented a qualitative assessment of water use showing that per capita agricultural water withdrawals in the United States seemed to display an inverted 'U'-shape. Bhattarai (2004) also found an environmental KC for irrigated land for tropical countries. In addition, Jia et al. (2006), Hemati et al. (2011b), Katz (2014) and Gu et al. (2017) confirmed the environment KC hypothesis for industrial water use for several countries.

Distefano and Kelly (2017) developed a multiregional input–output model to investigate the links between water use and economic growth. They found that the most important driver of future water scarcity is economic growth. Gu et al. (2017) studied the relationship between per capita industrial water use and GDP and showed that there is an inverted 'U'-shape curve between per capita industrial water use and GDP from 2002 to 2014 for China, as well as for the eastern coastal and middle Yangtze River regions. Hu et al. (2019) showed that the decoupling state between water consumption and economic growth for primary industry usage was unstable and largely volatile from 1999 to 2015, but showed a good decoupling status for secondary and tertiary industries. Qiao et al.

(2020) remarked that water scarcity still constrains economic growth in Northwest China, and progress in water science and technology is the main power of all water technologies.

Materials, methods and data description

Empirical model

Kuznets first proposed his hypothesis in 1955, examining the relationship between income inequality and economic growth (Kuznets, 1955). He showed economic growth worsens up to a certain level of income, but from that point onwards, income distribution improves along with economic growth (Balali et al., 2013). Since then, many studies have investigated the relationship between economic growth and the environment, which is known as the environmental Kuznets curve (EKC) due to its similarity to the KC hypothesis. The EKC has an ascending segment in which economic growth causes environmental degradation, but it declines after reaching its maximum; that is, economic growth improves the environment (Sharzehi & Haqhani, 2008). Hence, the message of EKC is that economic growth can cause degradation of natural resources and environment in the short run, but high economic growth can be a cure for environmental problems in the long run. Economic growth and increased income can lead to more efficient use of water technologies (e.g., drip irrigation) and better maintenance and protection of water delivery systems, so that less water is wasted.

The general KC model of research is such that the dependent variable (which is often some pollution type) is related to different powers of explanatory variables such as per capita income or GDP. The first and second powers of GDP explain the bell shape of the KC model so that if the first power variable is positive and the second power variable is negative, the bell 'U'-inverted shape is obtained. In line with previous studies on the EKC, we use GDP data, water consumption and equation (1) to investigate the environmental Kuznets hypothesis:

$$Water_{it} = \beta_0 + \beta_1 LNC_{it} + \beta_2 LNC^2{}_{it} + \beta_3 LNC^3{}_{it} + e_{it} \tag{1}$$

where the dependent variable *Water* is the log of water withdrawals; *LNC* is the log of GDP; *e* represents an error term; the subscripts *i* and *t* represent the province and time; and β represents parameters to be estimated. It should be noted that due to the lack of data on water consumption (i.e., freshwater withdrawals, recycling water consumption and repeated use), water withdrawals are considered as a proxy for water consumption.

Based on the significance and sign of the coefficients of the model presented in equation (1), various relationships between water and production can be observed (Table 1). An EKC is considered to exist if $\beta_1 > 0$, $\beta_2 < 0$ and $\beta_3 = 0$, and both β_1, β_2 are statistically significant. Furthermore, for a meaningful EKC, the estimated turning point (calculated as β_2/β_1) should be within the income range of the sample.

The inverted 'U' relationship between income and water is typically explained in terms of the interaction effects of scale, composition and technique. The scale effect (*S*) states that as the scale of the economy increases, so does water consumption. The composition effect (*C*), however, refers to the fact that as economies develop, there is generally a change in emphasis from agriculture and heavy industry to light manufacturing and

Table 1. Parameters and curve types in the Kuznets curve hypothesis model.

Parameter value	Change in the parameter	Curve connection	Curve types
$1 = \beta2 = \beta3 = 0\beta$	Constant	Without relation to explanatory variable X	Linear
$1 > 0, \beta2 = \beta3 = 0\beta$	Steady increase	Linear function	Straight line
$1 < 0, \beta2 = \beta3 = 0\beta$	Steady decrease	Linear function	Straight line
$1 > 0, \beta2 < 0, \beta3 = 0\beta$	Increase–decrease	Quadratic function	Inverted 'U' curve
$1 < 0, \beta2 > 0, \beta3 = 0\beta$	Decrease–increase	Quadratic function	'U' curve
$1 > 0, \beta2 < 0, \beta3 > 0\beta$	Increase–decrease–increase	Quadratic function	'N' curve
$1 < 0, \beta2 > 0, \beta3 < 0\beta$	Decrease–increase–decrease	Cubic function	Inverted 'N' curve

Source: Hemmati et al. (2011).

services. Since the latter is typically less resource intensive than the former, the composition effect of growth leads to a reduction in water consumption. Finally, as incomes rise, most likely demand for environmental regulations increase. The effect of these regulations leads to a reduction in resource intensity of the production techniques (Cole, 2004).

Data description

In this research, we have included all the 31 provinces of Iran to investigate the relationship between water and production. The data were obtained from the Statistics Center and Central Bank of Iran. Annual GDP data (billions of rials), annual value-added data of agricultural, industrial and services sectors (billions of rials), and water withdrawals (million m^3) ranging from 2005 to 2018, were obtained from the Statistics Center of Iran for the 30 provinces. In the case of annual GDP data and annual value-added data of agricultural, industrial and services sectors, deflationary data at a constant 2011 price were used. Population growth (%)was obtained from the Central Bank of Iran. These variables were converted into their natural logarithms for use. Stata 14 and Excel software were used to perform tests and estimates.

Given the structure of the dataset, the panel-data model was used to estimate the parameters (βs) of equation (1). Combining time series with cross-sectional data provides useful information for estimating econometric models, and based on the results, considerable policymaking inferences can be made. In the panel data model, it is assumed that observations are related to the N-cross-sections and T-periods. Considering the existence of different models for estimating the panel data (i.e., fixed-effects model, random-effects model and pooled-data model), diagnostic tests were used to determine the appropriate model. These tests are examined, and the results are reported in the following sections.

F-*Limer test (selection of combination data type)*

The total data were combined and estimated using the ordinary least squares (OLS) method to obtain the pooling-data model. That is, in the study of cross-sectional and time-series data, when the coefficient of cross-sectional effects and period effects are not statistically significant, all data can be combined and used with OLS regression to estimate the coefficients (Yaffee, 2003). Therefore, the *F*-Limer test is used to choose between panel data and pooled data:

$$H_0 : \alpha 1 = \alpha 2 \ = \ldots = \alpha\, Pooled\ Data$$

$$H_1 : \alpha_i \neq \alpha_j Panel\ Data$$

If $p > 5\%$, the null hypothesis (H_0) cannot be rejected, and the pooled data method should be used. Otherwise, the panel data method will be used (Biabi et al., 2015).

Hausman test

The Hausman test is used to choose between a fixed effects model and a random effects model, and this test is the most common for determining the type of combined data model. The Hausman test is based on the existence or non-correlation between estimated regression errors and independent variables. If there is no connection, the model is a random-effect model, and if this relationship exists, it is a fixed-effect model. In the Hausman test, the hypotheses H_0 and H_1 are defined as follows (Maddala & Wu, 1999):

$$H_0 : b_s = \mathrm{B}_s\, Random\ effects\ method$$

$$H_1 : b_s \neq \mathrm{B}_s\, Fixed\ effects\ method$$

If $p < 5\%$, the null hypothesis (H_0) is rejected, and the fixed-effects method is used. Otherwise, the random-effects method is used (Biabi et al., 2015). In addition, various tests are used to check the heteroscedasticity in the model. For this purpose, the Breusch–Pagan Lagrange multiplier (LM) test was used in this research, and the Wooldridge test was used to check autocorrelation. If the model has autocorrelation and heteroscedasticity, the model should be estimated using the generalized least squares (GLS) method.

Results and discussion

General results

In this study, the panel data method is used to investigate the relationship between water consumption and GDP growth. First, we check the stationarity of the variables. In panel time-series models, if the variables are not stationary, spurious regression problems are created and the observed high R^2 is not due to the true relationship between the variables (Pedroni, 2004). Therefore, the application of the unit root test of the panel data is necessary to ensure the validity of the results.

There are several unit-root tests for panel data which include: Levin et al., 2002), Im et al. (2003), Chow tests (Chow, 1960) and Hadri test (Hadri, 2000). Often these tests are similar, but there are differences in how they work. These tests are classified according to the constraints imposed on the autoregressive process in cross-sections or series (Im et al., 2003). In this study, the stationarity of the variables is studied using the Levin et al. (2002) test. The results of the stationary analysis of the variables are shown in Table 2. The results indicate that all the variables are stationary and, therefore, there is no spurious regression results.

Table 2. Unit root test results for the panel data.

Variable	Level	Condition
Water consumption	−3.66 (0.00)	I(0)
GDP	−11.83 (0.00)	I(0)
GDP^2	−9.9 (0.00)	I(0)
GDP^3	−7.37 (0.00)	I(0)
Population growth	−3.46 (0.00)	I(0)

Note: Numbers in parentheses are *p*-values.
Source: Research findings.

As stated in the methodology section, the *F*-Limer test is used to select the data type (pooled or panel). Based on the obtained results (Table 3), the calculated *F*-statistic is significant at the 1% level. Therefore, the null hypothesis (H_0) is rejected, and the panel data should be used in the regression.

After the *F*-Limer test and selection of the panel data method, the Hausman test was used to determine the fixed or random effects. The results of the Hausman test are expressed in Table 4. Based on the obtained results, the calculated $p > 0.05$ and, therefore, the null hypothesis (random effects) is not rejected, and random effects method is used. As shown in Table 4, in this study the Breusch–Pagan LM test was used to check the heteroscedasticity. The test statistic is 389.38. Given that the calculated value is greater than the critical value, the null hypothesis is rejected. Therefore, heteroscedasticity exists in the dataset. Also, the Wooldridge test was used to check autocorrelation. The value of the obtained statistic is 42.27 (Table 4), which is significant at the 1% level, indicating the existence of autocorrelation. Hence, the GLS method has been used to eliminate heteroscedasticity and autocorrelation.

Table 3. *F*-Limer test results.

Variable	Coefficient	Standard deviation
Constant	8.02	14.57
GDP	−1.85	5.48
GDP^2	0.69***	0.24
GDP^3	−0.01	0.03
Population growth	8.72e°9	4.22e°8
	$F = 131.67$***	$\rho = 0.95$

Note: ***Significant at the 1% level.
Source: Research findings.

Table 4. Results of Hausman, Breusch–Pagan and Wooldridge Tests.

Test	statistics	Prob
Hausman	$Chi^2 = 1.19$	Prob $chi^2 = 0.76$
Breusch–Pagan	LR $chi^2 = 389.38$***	Prob LR = 0.000
Wooldridge	*F* Wooldridge = 42.27**	Prob *F* = 0.000

Note: ***, **Significant at the 1% and 5% levels.
Source: Research findings.

To better understand the following results, the GDP of the provinces of Iran in 2018 (based on 2011 fixed price) is shown in Figure 1. According to the Statistics Center of Iran (Figure 1), the average GDP of the provinces of Iran in 2018 was 236,690 billion rials. Tehran with 1,696,669 billion rials and South Khorasan with 36,075 billion rials had the highest and lowest GDPs in 2018, respectively.

In addition, the water extraction of the provinces of Iran in 2018 is shown in Figure 2. According to Figure 2, the average amount of the provinces' water extraction of Iran in 2018 was 2136 million m^3. Fars with 7990 million m^3 and Ilam with 357 million m^3 had the highest and lowest water extractions in 2018, respectively.

The results of estimating linear, quadratic and cubic relationships between economic growth and water consumption using the GLS model are presented in Table 5. Based on these results, the coefficients of production growth in the linear and cubic relationships are statistically insignificant. Therefore, the existence of a linear and cubic relationship between water consumption and production growth is ignored.

Based on the results (Table 5) in the quadratic form, the coefficients of GDP and GDP^2 are significant at the 5% level. The value of the Wald statistic is 73.45, which is significant at the 1% level and represents the overall significance of the model (Table 5). Based on the results, the growth of production has a positive effect on water withdrawal and considering the negative sign of GDP^2, and it can be concluded that the relationship between water consumption and economic growth in Iran is an inverted 'U'-shape, in which water consumption initially grows as a function of economic growth, but later begins to decline.

These results are consistent with the estimates of income elasticity for industrialized countries, which show that the demand for water is positive (Dalhuisen et al., 2003). The positive income elasticity of water demand means that with increasing income, the use of

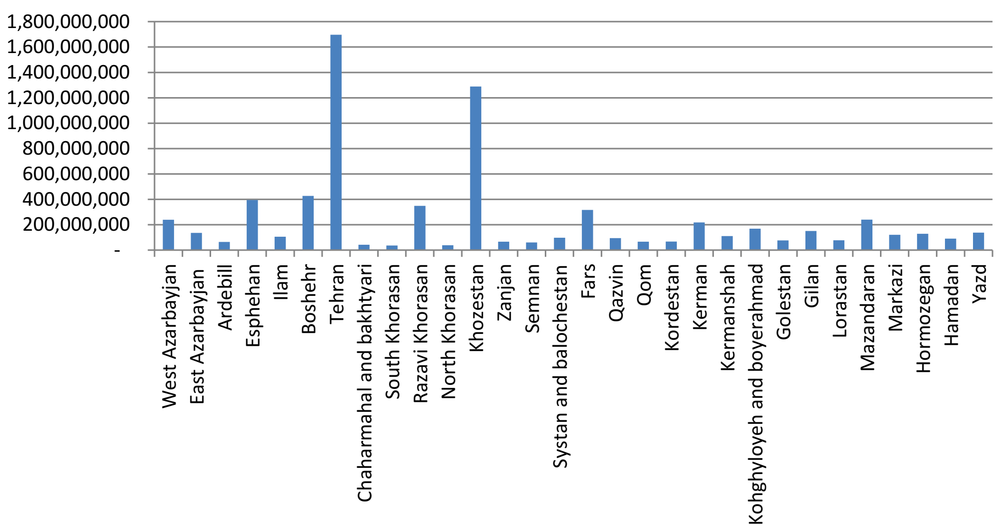

Figure 1. Annual gross domestic product (GDP) data for Iran provinces in 2018 (based on a constant price in 2011).

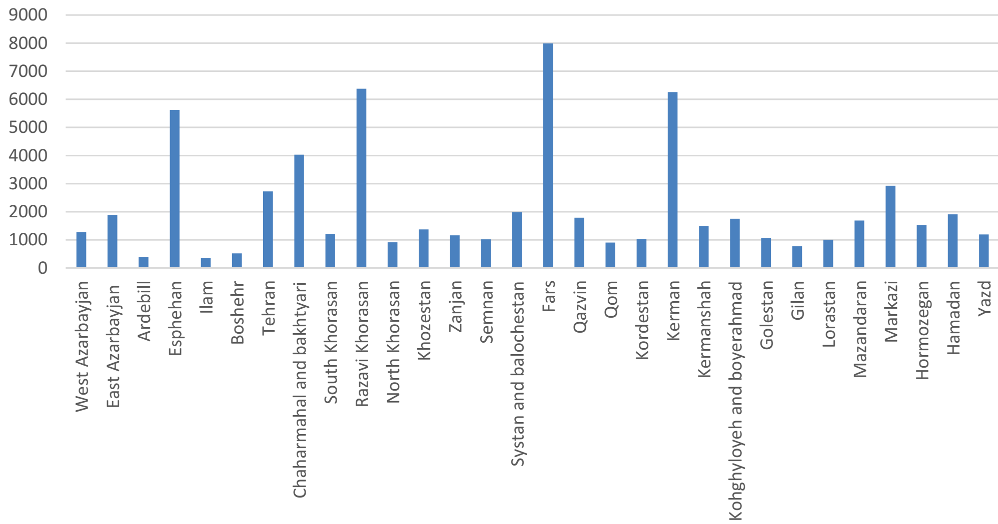

Figure 2. Water extraction data of Iran provinces in 2018 (million m^3).

Table 5. Results of generalized least squares (GLS) model estimation (relationship between water consumption and economic growth).

	Variable	Coefficient	Standard deviation
Linear relationship	Fixed	3.18***	0.12
	GDP	−0.02	0.02
	Population growth	$7.66e^{-08}$***	$1.04e^{-08}$
	Prob chi^2 = 0.00	Wald chi^2 = 56.75**	
Second-degree relationship	Fixed	0.08	1.43
	GDP	0.78**	0.37
	GDP^2	−0.05**	0.03
	Population growth	$8.48e^{-08}$***	$1.03e^{-08}$
	Wald chi^2 = 73.45**	Prob chi^2 = 0.00	
Third-degree relationship	Fixed	−5.31	15.39
	GDP	2.86	5.92
	GDP^2	−0.32	0.76
	GDP^3	0.01	0.03
	Population growth	$8.47e^{-08}$	$1.01e^{-08}$
	Wald chi^2 = 83.95***	Prob chi^2 = 0.00	

Note: ***, **, *Significant at the 1%, 5% and 10% levels.
Source: Research findings.

water resources increases. Theories of structural growth patterns also indicate that water consumption increases in the direction of the development of concentrated agriculture and then, with the economy shifting from agriculture to industry, and eventually towards less water-focused sectors, such as the service sector, water consumption reduces.

The results of this study confirm and have the same interpretation, indicating the existence of an EKC between water consumption and economic growth. In Hemati et al. (2011a), Jia et al. (2006), Bhattarai (2004) and Goklany (2002), the relationship between per capita water consumption and economic growth has also followed an inverted ‘U’-shape. Based on the results in Table 5, the maximum point and the changing direction of relationship between water consumption and economic growth is at the production level of 63,095 billion rials. Therefore, according to the production level of different provinces over the studied years, except for South Khorasan, Chaharmahal and Bakhtyari, North Khorasan and Semnan, provinces of Iran in 2018 were at a production level above the threshold (Figure 1). In other words, they were in the descending part of the KC and production growth was possible with reduction in water consumption. South Khorasan, Chaharmahal and Bakhtyari, North Khorasan and Semnan provinces has not yet reached that desired threshold, and if production increases in this province, water usage will increase.

The agricultural sector

The results of the survey on the relationship between water use and economic growth in the agriculture sector are shown in Table 6. Based on these results, the relationship between water use and economic growth in Iran's agricultural sector follows the Kuznets hypothesis. In other words, the results showed that there was an inverted 'U'-shape relationship between water consumption and the growth of the agriculture sector. The coefficients GDP and GDP^2 were significant at the 5% level, and the environmental Kuznets hypothesis exists in the agricultural sector.

Based on the results in Table 6, the maximum point and the changing direction of relationship between water consumption and production in the agriculture sector is at the production level of 75,857 billion rials. Hence, according to the production level of different provinces over the studied years, production in the provinces of Khorasan Razavi, Khuzestan, Fars, Kerman and Mazandaran in 2018 was above the threshold level. In other words, they were in the descending part of the KC and increasing production in the agricultural sector in these provinces is accompanied by a reduction in water consumption.

According to the Iran Chamber of Commerce, Industries, Mines and Agriculture (ICCIMA) (2018), water productivity in the agricultural sector of these provinces in Iran are more than other provinces. Production in the agricultural sector in other provinces of

Table 6. Results of generalized least squares (GLS) model estimation (relationship between water consumption and economic growth in the agriculture sector).

	Variable	Coefficient	Standard deviation
Linear relationship	Fixed	3.48***	1.23
	GDP	2.07	1.64
	Population growth	$0.95e^{-08}$***	$0.18e^{-08}$
	Prob chi^2 = 0.00	Wald chi^2 = 56.75**	
Second-degree relationship	Fixed	−36.28	15.45
	GDP	10.24**	4.34
	GDP^2	−0.65**	0.30
	Population growth	$4.32e^{-08}$***	$1.60e^{-08}$
	Wald chi^2 = 33.79**	Prob chi^2 = 0.00	
Third-degree relationship	Fixed	−75.08	284.89
	GDP	26.85	121.07
	GDP^2	−3.02	17.10
	GDP^3	0.11	0.80
	Population growth	$4.23e^{-08}$***	$1.64e^{-08}$
	Wald chi^2 = 34.62***	Prob chi^2 = 0.00	

Note: ***, **, *Significant at the 1%, 5% and 10% levels.
Source: Research findings.

Iran has not yet reached that desired threshold and increasing production increases water usage. The process of investing in irrigation equipment in the agricultural sector in Iran also confirms these results.

According to the Ministry of Agriculture Jihad statistics, Fars, Khorasan Razavi, Khuzestan, Kerman and Mazandaran provinces have the most investment in the development of new irrigation systems. This has led to more savings in water consumption and has also made the development of agricultural products possible. Among different types of modern irrigation systems, Khorasan Razavi and Kerman provinces have the most investment in low-pressure irrigation systems. Most of the investment of irrigation facilities in Khuzestan, Fars and Mazandaran provinces have been related to the development of drip irrigation systems. Also, the trend of value added in the agricultural sector in different provinces shows that the mentioned provinces have the highest value added in the agricultural sector of Iran.

The industrial sector

Table 7 shows the results of the study of the relationship between water consumption and economic growth in the industrial sector. Based on these results, the coefficients of production growth in linear and quadratic relationships are statistically insignificant. In the third equation, the coefficients of production growth and its second and third powers are significant at the 1% level. Considering the negative sign of the coefficients of production growth and its third power, and positive sign of the second-power coefficient of the production growth, it can be stated that there an inverted 'N'-type relationship exists between water consumption and production growth in the industrial sector. That is, in the early stages of the growth path of the industrial sector, water consumption decreases and with further growth of this sector, water consumption increase, but with the continued growth of the industrial sector, water consumption decreases. Therefore, the water–production relationship

Table 7. Results of generalized least squares (GLS) model estimation (relationship between water consumption and economic growth in the industrial sector).

	Variable	Coefficient	Standard deviation
Linear relationship	Fixed	0.63***	0.99
	GDP	0.45	0.52
	Population growth	$4.66e^{-08}$***	$1.66e^{-08}$
	Prob chi^2 = 0.39	Wald chi^2 = 0.74	
Second-degree relationship	Fixed	1.28	2.28
	GDP	−0.51	2.67
	GDP^2	0.30	0.78
	Population growth	$5.49e^{-08}$***	$1.83e^{-08}$
	Wald chi^2 = 1.10	Prob chi^2 = 0.58	
Third-degree relationship	Fixed	15.85***	5.61
	GDP	−21.08***	7.48
	GDP^2	16.23***	5.69
	GDP^3	−1.26***	0.45
	Population growth	1.55^{-07}***	$3.98e^{-08}$
	Wald chi^2 = 14.65***	Prob chi^2 = 0.002	

Note: ***, **, *Significant at the 1%, 5% and 10% levels.
Source: Research findings.

Table 8. Results of generalized least squares (GLS) model estimation (relationship between water consumption and economic growth in the service sector).

	Variable	Coefficient	Standard deviation
Linear relationship	Fixed	0.81	1.28
	GDP	0.26	0.16
	Population growth	$5.95e^{-08}$	$1.26e^{-07}$
	Prob chi^2 = 13.56***	Wald chi^2 = 0.000	
Second-degree relationship	Fixed	−9.93	6.17
	GDP	2.95*	1.52
	GDP^2	−0.17*	0.10
	Population growth	$1.06e^{-08}$***	$1.24e^{-07}$
	Wald chi^2 = 4.52**	Prob chi^2 = 0.02	
Third-degree relationship	Fixed	32.32	5.61
	GDP	−13.52	58.81
	GDP^2	1.88	22.48
	GDP^3	−0.09	0.12
	Population growth	-7.56^{-09}	$1.25e^{-07}$
	Wald chi^2 = 3.22***	Prob chi^2 = 0.005	

Note: ***, **, *Significant at the 1%, 5% and 10% levels.
Source: Research findings.

in the industrial sector has two threshold levels or a critical point. The first threshold level is at the minimum point and the second threshold level is at the maximum point of the function.

The minimum and maximum points of the water–production relationship in the industrial sector are at the production level of 5099 and 79,894 billion rials, respectively. Therefore, according to the production level of different provinces over the studied years, production in the provinces of East Azerbaijan, Isfahan, Bushehr, Tehran, Khorasan Razavi, Khuzestan, Fars, Kerman and Kohgiluyeh and Boyer-Ahmad, Markazi and Yazd are at the production level above the second threshold. That is, they are in the descending part of the KC and increasing production in the industrial sector of these provinces is accompanied by a reduction in water consumption. The results of this study are consistent with the results of Katz (2014) who showed there was 'N'-type relationship between water consumption and economic growth in the industrial sector of the United States as well as Organisation for Economic Co-operation and Development (OECD) countries.

The service sector

The results of the relationship between water use and economic growth in the service sector are shown in Table 8. According to the results, the Kuznets hypothesis holds in the service sector. The relationship between water consumption and growth of the service sector follows the inverse 'U'-shape curve. The maximum point and the change in the water–production relationship is at the level of 474,241 billion rials. Accordingly, production in the service sector of Tehran province is more than the threshold for other provinces. An increase of production in Tehran's service sector is accompanied by a reduction in water consumption, while production in the service sector of other provinces has not reached the desired level and an increase in production in these provinces leads to an increase in water usage.

Conclusions and suggestions

The importance of the environment and its degradation process has attracted many researchers' attention in recent years. Most scientific attention has focused on whether economic growth improves the environment. However, at the international level, few studies have examined the relationship between economic growth and water consumption at the provincial or national levels. In Iran, so far, the issue of economic growth and water consumption has not been studied. This research fills that gap, investigating the relationship between water consumption and national production by analysing the GLS method with a panel data. For this purpose, data on water withdrawals and gross production in 30 provinces of Iran were collected and analysed for the 2005–18 period.

Based on the results, it can be argued that there is an inverted 'U'-shape relationship between water consumption and economic growth in which water consumption initially increases as a function of economic growth, but later begins to decline. Gleick (2003) found little correlation between national economic growth and water consumption, while some studies show a positive correlation between wealth and domestic water consumption (Bhattarai, 2004; Dalhuisen et al., 2003; Portnov & Isaac, 2008; Rock, 1998). The study by Gu et al. (2017) supports the EKC hypothesis in China as well as the eastern coastal and middle Yangtze River regions. Hu et al. (2019) indicated that the largest cumulative effects on water consumption are economic development and technology, which are positive and negative drivers of water consumption.

Seemingly, at the beginning of the economic growth path, increased production requires more water resources. With an increase in income and investment, improved infrastructure, and more use of new advanced technologies and methods of water saving in production, consumption of water will reduce. In addition, the relationship between water–production in the three sectors of Iran's economy (i.e., agriculture, industrial and services) shows that in the agriculture and services sectors, Kuznets hypothesis between water withdrawal and economic growth exists.

Based on these results, production in the agriculture sector of provinces of Khorasan Razavi, Khuzestan, Fars, Kerman and Mazandaran is at a higher level than the threshold, and production growth in these provinces is accompanied by a reduction in water withdrawal. According to the Ministry of Agriculture Statistics of Iran, these provinces have the most investment in irrigation systems and have a higher share of the value added in Iran's agricultural sector, which indicates a higher growth of the agricultural sector in these provinces. In other words, the growth of the agricultural sector in these provinces has led to investment in irrigation infrastructure and a reduction in water consumption.

As per capita income increases, farmers are shifting to new ways of irrigation and improved technologies, which reduces water consumption. With reduction in water consumption, water resources will not be considered as an obstacle to agriculture growth and allow for the creation and development of new agricultural lands. In other words, the improved technologies and reduction in water consumption in the agricultural sectors of these provinces can offset the increased water consumption required by new agricultural lands.

In the service sector, production is higher than the calculated threshold only in Tehran province. The water–production relationship in this sector follows an inverted 'U'-shape relationship. Therefore, the impact of economic growth on water usage affects the scarcity of water resources, and attention to water consumption and investment in water infrastructure is essential, especially in the provinces that the threshold of production is lower than the calculated thresholds in this study. To design the growth path of the sectors and apply water-related policies, the results of this research can benefit policymakers.

Overall, the development and progress of each region should be consistent with the existing capacities of that region in the field of agriculture, industry and services, so that in the low-rainfall regions, more attention is paid to the service sector, including tourism and programming companies. In Khorasan Razavi, Khuzestan, Fars, Kerman and Mazandaran provinces, because these provinces are at a higher level in terms of agricultural development, it is possible to increase the production level of crops with the same amount of available water by increasing the efficiency of other production inputs (i.e., better management of water consumption).

Production in the provinces of East Azerbaijan, Isfahan, Bushehr, Tehran, Khorasan Razavi, Khuzestan, Fars, Kerman and Kohgiluyeh and Boyer-Ahmad, Markazi, and Yazd are at a production level above the second threshold. So, given the limited water resources in other provinces, policymakers must make policies that will prevent further development of water-intensive industries in these areas. In addition, by limiting water used in industry in low rainfall areas, people will be directly and indirectly safe from the negative consequences of those industries. Water savings can be achieved in the industrial sector through a combination of changing behaviour, modifying and/or replacing equipment with water-saving equipment to reduce overall water consumption and increase internal reuse as well. Raw exports of water products should be prevented to pave the way for development and progress of the country.

In this study, we had limitations such as the lack of historical provincial characteristics (especially arable land area, local culture), and the lack of economically accurate water intake data. Thus, further studies are needed to address all these limitations. Finally, it should be noted that while the focus of this article was on Iran, the problems and consequences discussed are not unique to Iran. In fact, the water management system in Iran, despite its major shortcomings, is much more advanced and successful than most countries in the Middle East and many developing countries. Most countries in the region lag behind Iran in their development stages. Hence, according to the KC hypothesis, they can increase their economic growth to the threshold of KC by increasing investment in the infrastructure and their irrigation systems.

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