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ORIGINAL PAPER

Water consumption, agriculture value added and carbon dioxide emission in Iran, environmental Kuznets curve hypothesis

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Abstract Agriculture and natural resources have a mutual relationship with each other. The purpose of this study was to evaluate forward and backward relationship between natural resources and agricultural development. The relationship between the consumption of water and agricultural value added per capita income has been studied in order to obtain the forward relationship, and the relationship between carbon dioxide emissions and per capita income of the Iran's agricultural sector has been assessed in order to obtain backward relationship. To test these relationships, the Kuznets theory is used. Therefore, Iran's provinces information from 2001 to 2013 was used and models were estimated by using the panel data and spatial econometric. Results showed that there was an inverted U relationship between per capita income and water consumption and carbon dioxide emissions. Also, spatial estimation showed that both water consumption and carbon dioxide (CO_2) emissions in agricultural sector had a direct relationship with the value of these two variables in the neighboring areas.

Keywords Carbon dioxide emission · Environmental Kuznets curve · Spatial econometric · Water consumption

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Introduction

Agriculture and natural resources have a mutual relationship with each other. First, natural resources are the basis for agricultural activities and provide the required inputs for agriculture. The most important natural input used in agriculture is water. Water plays an important role in the economic development and social welfare, but it also has a vital role in the ecosystem (Duarte et al. 2013), and its limited supply in arid and semiarid regions is a serious challenge for achieving sustainable development. Also, increasing urbanization and economic development in Iran has increased the consumption of those products which have higher water consumption (Statistical Center of Iran Database 2014). Therefore, given the high share of agriculture in consuming water supplies, development of irrigation systems can have a significant role in reducing water consumption and lead to increased productivity of water (Duarte et al. 2011; Najafi Alamdarlo et al. 2016). Reduction in water consumption and growth of agriculture sector can be considered a basis for the realization of Kuznets curve theoretical framework in this sector. This interaction between agriculture and natural resources is the idea behind the formation of the present study.

The relationship between energy consumption and economic growth for the first time is considered by Kraft and Kraft (1978) that direct relationship between them has been confirmed. Energy also has an important role in agricultural products, and increased energy could lead to increase in agricultural value added. On the other hand, agricultural production and its growth have directly correlation with energy consumption. The higher of energy consumption leads to higher agricultural growth. Therefore, energy has a fundamental role in economy and economic growth depends on the quality and quantity of this worthy resource. But the use of energy generates some externality.

Although increase in energy consumption has many benefits for farmers such as increase production, saving time, increase productivity (Ghorbani et al. 2011), it leads to environmental damage and increases greenhouse gases with the further degradation of water resources and an increase in the use of the land (Ozkan et al. 2007 and Nakagawa et al. 2007).

In Iran, the agricultural sector includes 8.4 % in GDP and 21 % in occupation (Central Bank of Iran Database 2014). In Iran's agriculture sector, energy was used in crop production and water extraction. Agricultural sector holds 3.8 % of total energy consumption, but 2.48 % of dioxide emissions in the whole economy is related to agricultural sector (Statistical Center of Iran Database 2014). Therefore, the proportion of carbon dioxide emissions to energy consumption is less than one.

Figure 1 shows the relationship between CO_2 emissions and value added in agricultural sector in the provinces of Iran. With the increase in value added per capita in agriculture, the amount of CO_2 per capita has initially increased, but after sustaining agricultural growth, the amount of CO_2 emissions has been reduced. Figure 2 shows the relationship between value added per capita in agriculture and per capita consumption of water in agriculture sector. In this case, the inverted U relationship between the growth of agriculture and water consumption is evident.

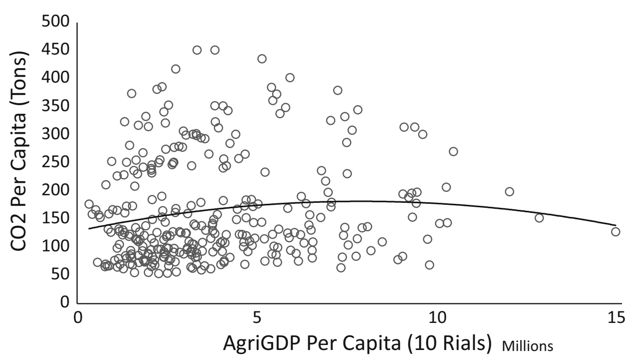

Fig. 1 CO_2 emission per capita and agricultural value added per capita in Iran

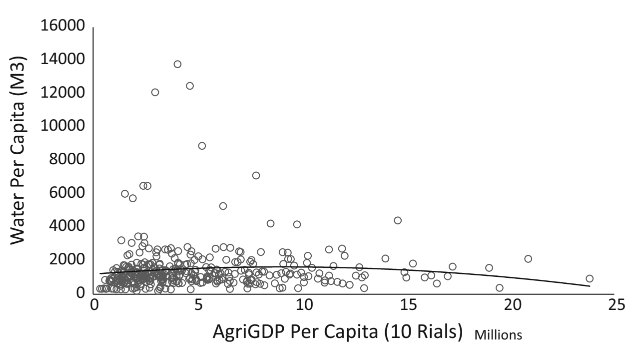

Fig. 2 Water consumption per capita and agricultural value added per capita in Iran

Environmental Kuznets curve (EKC) is one of the most famous models that focuses on the relationship between environmental quality and economic growth. Kuznets (1955) stated that there is an inverted U-shaped relationship between inequality and per capita income growth, in a way that in early stages of economic growth the inequality in society increases but as economy continues to grow this inequality will decrease. Beckerman (1992) believed that although the environment may suffer damages at the beginning of economic development, the best and perhaps the only way to achieve a clean environment is that countries become rich. These ideas led to extensive research on the effect of economic growth on environmental quality, and a study by Grossman and Krueger (1991) is among these researches. After that study, Panayotou (1993) also examined the relationship between income and environment. After these initial studies, extensive research has been done in the world and Kaika and Zervas (2013a, b) have discussed about these researches. This theory has also been used in several studies to investigate the relationship between economic growth and pressure on natural resources (Kander and Lindmark 2004; Nakicenovic et al. 2000; WWAP 2009; Duarte et al. 2013; Katz 2015).

Kuznets theory can be a useful tool for testing forward and backward relationship between natural resources and agriculture. Therefore, review of the literature in this study consists of two parts. Initially, those studies are mentioned which have used this theory to examine the relationship between water consumption and economic growth (forward relationship), and then those studies are mentioned which have examined the relationship between environmental quality and economic growth (backward relationship).

Fewer studies have examined the relationship between economic growth and pressure on water resources compared to those that have examined the relationship between environmental quality and economic growth. Rock (1998) made the first attempts to examine the relationship between the depletion of water resources and per capita income. Gleick (2003) did not find a clear relationship between water consumption and per capita income. Cole (2004) and Katz (2015) studied the relationship between economic growth and water resources. Other researchers have also examined the relationship between income and water such as Goklany (2002), Bhattarai (2004), Barbier (2004), Jia et al. (2006) and Hemati et al. (2011). Duarte et al. (2013) examined the relationship between water consumption per capita and per capita income according to the environmental Kuznets curve. This research confirmed the inverted U relationship between water consumption and per capita income in the 65 countries. Katz (2015) examined the relationship between water consumption and economic growth using EKC theory.

Given that carbon dioxide emissions by a region affect the amount of carbon dioxide in neighborhood regions, the use of spatial models in the study of this phenomenon has become increasingly popular (Aslanidis 2009). There are four reasons behind the use of spatial method for examining the relationship between the environment and income. First reason is the "pollution haven hypothesis." According to this theory, poor countries produce goods that are usually associated with more pollution. Second, by increasing the distance, the spillover effect of R&D in development countries decreased (Keller 2004). The third reason is the role of industry in creating pollution, and the fourth reason is the policies toward the environmental control by governments that is often imitated from neighboring regions (Fredriksson and Millimet 2002). Accordingly, Murdoch et al. (1997) studied the spatial effects on the pollution emissions in Europe. Rupasingha et al. (2004) studied the environmental Kuznets curve on the subject of toxic pollution and per capita income growth in America. This study confirmed the presence of spatial effects in the Kuznets curve estimation. Maddison (2006) studied the spatial dependence in the environmental Kuznets curve. Auffhammer and Carson (2008) also used spatial econometrics to study this phenomenon in the China's provinces over the 20 years. In this model the spatial effects have been confirmed and investigated the dynamic effects caused by CO_2 emissions. Burnett and Bergstrom (2010) also used spatial dynamic panel to study the relationship between carbon dioxide emissions and economic growth in the states of America. Donfouet et al. (2013) also used dynamic spatial method to estimate the environmental curve in European Union countries. This study results confirmed the existence of EKC, but also reported that emissions in one country have an effect on emissions in the neighboring countries. Germani et al. (2014) used spatial method to study the environmental justice and air pollution in the provinces of Italy. This study has also confirmed the environmental Kuznets relationship.

The purpose of present study was to evaluate forward and backward relationship between natural resources and agricultural development. The relationship between the consumption of fresh water (surface and underground) and agricultural value added per capita income has been studied in order to obtain the forward relationship, and the relationship between carbon dioxide emissions and per capita income of the agricultural sector has been assessed in order to obtain backward relationship.

So, in this paper, it is assumed that the relationship between water consumption, agricultural value added, carbon dioxide emission and agricultural value added has different behavior in Iran provinces. It is also assumed carbon dioxide emission or water consumption in one area impacts on neighboring areas. The contribution of this study to the literature is in using the effects of temporal and spatial relationship between natural resources and agricultural development and then evaluating both forward and backward relationship between them.

Data and case study Amount of CO_2 caused by agricultural activities is an indicator of environmental quality. In this study, the amount of carbon dioxide which is produced by the energy consumption in this sector was used for the calculation of this indicator in each province. For this purpose, the required data were collected from the ministry of agriculture and the environmental protection agency.

The variable of water includes both surface and groundwater. Given that about 90 % of groundwater and 67.5 % of surface water is consumed in the agricultural sector, this sector will have an important role in the management of this scarce resource. The required data were gathered from Iran Water Resources Management Company (IWRM 2014) and Statistical Center of Iran Database (2014). Statistics on the amount of rainfall in each province of the country was gathered from Iran's Meteorological Organization.

Materials and methods

Panel data provide a suitable environment for the development of estimation methods and theoretical results and enable researchers to use cross-sectional time-series data in order to investigate those issues which cannot be studies only in a cross-sectional or a time-series. Panel data approach is a method for combining cross-sectional data and time-series data (Eq. 1) (Baltagi 2009).

$$Y_{it} = \alpha_{it} + \sum_{k=2}^{K} \beta_{kit} X_{it} + \mu_i + \vartheta_{it} \quad (1)$$

Panel data can be estimated using fixed or random effects (Baltagi 2009), but considering the weakness of these two methods in controlling correlation and heterogeneity between instrumental variables and disturbance, using the generalized method of moments (GMM) is recommended (Al-mulali et al. 2015). When data distribution function is not identified, there is no possibility of using the maximum likelihood method; therefore, GMM can be used. Also, to check the probability of explanatory variables endogeneity, the model can be estimated using Arellano–Bover/Blundell–Bond method (Arellano and Bond 1991; Arellano and Bover 1995). This method uses the lag of differential amount of endogenous explanatory variables as Instrument variables. In this method, the validity of the instrumental variables is examined using Sargan test (Arellano and Bond 1991).

In 1988, Anselin for the first time proposed spatial econometric, which included the realities of spatial economics. He stated that conventional econometric methods are not suitable for regional studies, because in the data of regional studies, two phenomena exist: spatial dependence between the observations and the spatial Heteroscedasticity. Therefore, the two models of spatial lag and spatial error are used for assessment in these types of studies (Anselin 2001).

Spatial lag is a phenomenon that occurs in the data samples which contain spatial element, in a way that when there is an observation from a place like i, this observation is dependent on other observations from other places $i \neq j$. For this purpose the contiguity matrix (W) has been obtained. A dynamic model of spatial lag has the following format (Anselin et al. 2008):

$$Y_{it} = \beta_1 Y_{it-1} + \beta_2 X_{it} + \beta_3 WY_{it} + \alpha_i + \varepsilon_{it} \quad (2)$$

In this Eq. 2, i represents the region indicator, t is the time, WY_{it} is the first spatial lag, Y_{it-1} represents the lags of dependent variable, and X_{it} is the other explanatory variables. The above model can be written in a way that would reflect the spatial error model as well. Therefore,

$$\begin{aligned} Y_{it} &= \beta_1 Y_{it-1} + \beta_2 X_{it} + \beta_3 WY_{it} + \alpha_i + \varepsilon_{it} \\ \varepsilon_{it} &= \beta_4 W\varepsilon_{it} + \vartheta_{it} \end{aligned} \quad (3)$$

In this Eq. 3, β_4 is the spatial error parameter that must be estimated. By adding a time lag to spatial variable, the effects of this variable on the dependent variable have been estimated. This model is called "dynamic spatial Durbin model" and is defined as follows (Debarsy et al. 2011):

$$\begin{aligned} Y_{it} &= \beta_1 Y_{it-1} + \beta_2 X_{it} + \beta_3 WY_{it} + \theta WY_{it-1} + \eta_i + \varepsilon_{it} \\ \varepsilon_{it} &= \beta_4 W\varepsilon_{it} + \vartheta_{it} \end{aligned} \quad (4)$$

In this Eq. 4, θ is the parameters that indicate the lagged impact of spatial effects. Dynamic spatial models can be estimated using three methods (Elhorst 2011). The first method is the method of maximum likelihood. Another method is using Markov chain Monte Carlo (MCMC). The third method is based on the instrumental variables or the GMM (generalized method of moments). In this study, the Arellano and Bond method has been used, which is based on instrumental estimations method or GMM (Arellano and Bond 1991; Blundell and Bond 1998).

Due to the characteristics of the panel data, unit root test must be used to investigate its stationary (Baltagi 2009). This test is a unit root test for multiple series which is adapted to panel data. A variety of methods for applying unit root test for panel data have been proposed by Im, Pesaran and Shin (IPS) (2003), Maddala and Wu (1999) and Choi (2001), and they have been used in many studies.

The following basic model was used to assess the environmental Kuznets curve (Grossman and Krueger 1991):

$$\mathrm{Log}\left(\frac{E}{\mathrm{POP}}\right)_{it} = \alpha_i + \beta_1 \mathrm{Log}\left(\frac{\mathrm{GDP}}{\mathrm{POP}}\right)_{it} + \beta_2\left(\mathrm{Log}\left(\frac{\mathrm{GDP}}{\mathrm{POP}}\right)\right)^2_{it} + \varepsilon_{it} \quad (5)$$

In this Eq. 5, i represents the regions, t is time, E represents the environmental emissions, Pop is population, GDP is gross domestic product, α_i is the intercept for different regions, and αi is the intercept for different years. These models are often estimated using panel data with fixed or random effects. To confirm the presence of environmental curve, β_1 should be positive and β_2 should be negative. In the event of such circumstances, the return points can be obtained ($\tau = \exp(-\beta_1/2\beta_2)$). This point represents the income level at which the emission is at its maximum level.

According to the EKC literature review, the following model (Eq. 6) was analyzed for the estimation of Kuznets curve in water consumption and CO_2 emissions (Marrero 2010; Burnett and Bergstrom 2010; Donfouet et al. 2013; Auffhammer and Carson 2008):

$$\begin{aligned} \mathrm{Log}\left(\frac{Y}{\mathrm{POP}}\right)_{it} &= \alpha_i + \eta_i + \beta_1 \mathrm{Log}\left(\frac{\mathrm{GDP}}{\mathrm{POP}}\right)_{it} \\ &\quad + \beta_2\left(\mathrm{Log}\left(\frac{\mathrm{GDP}}{\mathrm{POP}}\right)\right)^2_{it} + \beta_3 \mathrm{Log}(X)_{it} \\ &\quad + \beta_4 \mathrm{Log}\left(\frac{Y}{\mathrm{POP}}\right)_{it-1} + \beta_5 \mathrm{Log}\left(\frac{WY}{\mathrm{POP}}\right)_{it} \\ &\quad + \beta_6 \mathrm{Log}\left(\frac{WY}{\mathrm{POP}}\right)_{it-1} + \varepsilon_{it}\varepsilon_{it} = \beta_7 W\varepsilon_{it} + \vartheta_{it} \end{aligned} \quad (6)$$

Given that three types of models have been designed for each category of carbon dioxide emissions and water consumption, a total of six models will be estimated:

Model I (spatial autoregressive model with autoregressive disturbances for CO_2 emission): Y is CO_2 emission per capita and $\beta_3 = \beta_6 = 0$.

Model II (dynamic spatial Durbin model for CO_2 emission): Y is CO_2 emission per capita and $\beta_3 = 0$.

Model III (nonspatial model for CO_2 emission): Y is CO_2 emission per capita and $\beta_3 = \beta_5 = \beta_6 = \beta_7 = 0$.

Model VI (spatial autoregressive model with autoregressive disturbances for water consumption): Y is water consumption per capita, X is precipitation, and $\beta_6 = 0$.

Model V (dynamic spatial Durbin model for water consumption): Y is water consumption per capita and X is precipitation.

Model VI (nonspatial model for water consumption): Y is water consumption per capita, X is precipitation, and $\beta_5 = \beta_6 = \beta_7 = 0$.

Models I, II and III for the period 2001 to 2011 and IV, V and VI for the period 2001 to 2013 were estimated by using STATA software.

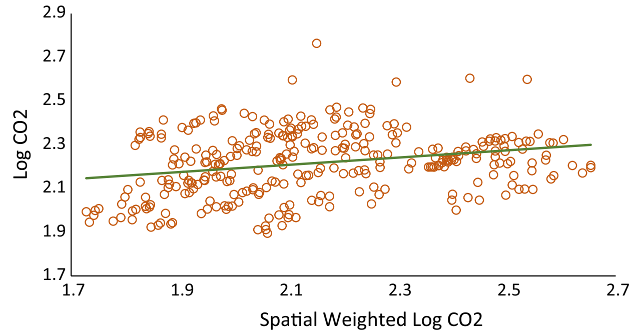

Fig. 3 Relationship between CO_2 emission per capita and spatial variable (logarithmic)

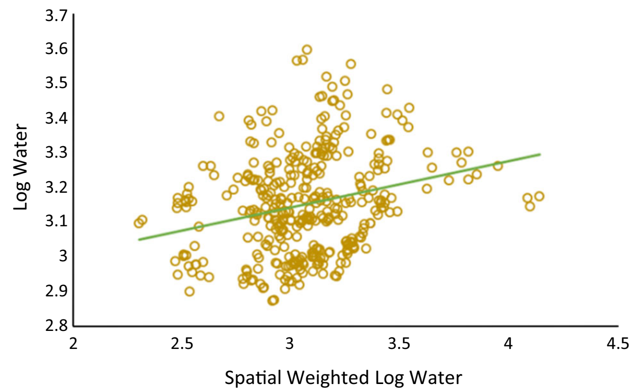

Fig. 4 Relationship between water consumption per capita and spatial variable (logarithmic)

Results and discussion

Maps 1 (A and B in supplementary material) show the spatial distribution of carbon dioxide emissions and water consumption over the course of a decade (2001–2013) in agricultural sector. Central and southern provinces of Iran have the highest agricultural production and pressure on water resources. The spillover effects in the region can be seen in this map.

Contiguity variable: Given that, how to choose a spatial variable is very important in this model. Often, two spatial variables are used in spatial econometric studies: One of them is based on the proximity between the countries (Anselin and Arribas-Bel 2013; Birkelof 2010; Najafi Alamdarlo 2016), and the other one is based on the weight matrix of distance between the countries (Blonigen et al. 2007; Boubacar 2015), but because of the characteristics of carbon dioxide emissions and water consumption in agricultural sector, the first method has been used. In proximity method, according to studies by Costantini et al. (2013) and Germani et al. (2014) the spatial variable (indicator) calculated. On this basis, it is assumed that emissions of carbon dioxide or using groundwater in a province have an effect on the provinces which have a border with it. In this method, provinces that are adjacent to each other gain a weight value of 1 and other provinces gain a weight value of 0. So there is a matrix with 28 rows and 28 columns which contains entries of zero and one. Then this matrix should get standardized, in a way that sum of each row be equal to one. Then, spatial variable is determined according to total CO_2 emissions or total water consumption by the neighboring provinces. Figure 3 shows the relationship between the logarithmic values of CO_2 emissions and spatial variable of CO_2 emissions. Figure 4 shows the relationship between logarithmic values of water consumption and spatial variable of water consumption. As Figs. 3 and 4 show, there is a positive correlation between the amount of carbon dioxide emissions and its spatial value. A positive correlation can also be confirmed in the same way for water consumption.

Before estimating the model, the characteristics of used data and their stationary should be determined. Therefore, the stationary of these variables is examined using IPS (Im–Pesaran–Shin) and LLC (Levin–Lin–Chu) unit root test. Table 1 shows the results of these tests for the logarithmic values of the variables. This table also shows the characteristics of variables, including their mean, minimum, maximum and standard deviation. According to Im–Pesaran–Shin stationary statistics, all variables were stationary.

Three models were used to examine the relationship between carbon dioxide emissions and value added in

Table 1 Panel unit root test and summary statistics

Variable	Summary statistic					Panel unit root				
	Source	Max	Min	SD	Mean	Im–Pesaran–Shin[a]			Levin–Lin–Chu[b]	
						A	B	C	D	E
AGRI GDP per capita (Rials)	Central Bank of Iran	23,822,262.2	333,292.1	2.16	3,741,605.5	−4.621 (0.0000)***	10.70 (1.0000)	19.15 (1.0000)	−1.26 (0.1039)	4.93 (1.0000)
Total water per capita (M3)	Statistical Center of Iran and IWRM	13,783.5	200.7	1.89	1166.8	−4.42 (0.0000)***	−1.43 (0.0761)*	−3.22 (0.0006)***	−5.26 (0.0000)***	−0.76 (0.2234)
Precipitation (mm)	Statistical Center of Iran	882.1	7.4	2.18	153.6	−6.30 (0.0000)***	−6.36 (0.0000)***	−0.24 (0.4061)	−3.29 (0.0005)***	−5.01 (0.0000)***
Spatial variable in water (M3)	Author calculation	3975.9	747.9	1.40	1422.4	−3.68 (0.0001)***	−0.43 (0.3337)	−4.87 (0.0000)***	−4.62 (0.0000)***	0.53 (0.7014)
CO_2 per capita (kg)	Energy balance sheet and author calculation	451.0	53.4	1.69	141.1	−3.34 (0.0004)***	1.55 (0.9391)	3.32 (0.9996)	3.82 (0.9999)	−6.99 (0.0000)***
Spatial variable in CO_2	Energy balance sheet and author calculation	580.3	78.6	1.40	164.7	−1.46 (0.0721)*	5.48 (1.0000)	4.14 (1.0000)	8.056 (1.0000)	−6.59 (0.0000)***

Resources: research finding

E: common AR; included panel mean; not included time trend

D: common AR; included panel mean; included time trend

C: common AR; not included panel mean; not included time trend

B: panel-specific AR; included panel mean; not included time trend

A: panel-specific AR; included panel mean; included time trend

The number in parentheses indicates the *P* value, and ***, **, * are significant at 1, 5 and 10 % level

The stationary test was conducted for logarithmic value

[a] Z-t-tilde-bar statistic reported

[b] Adjusted t^* statistic reported

Table 2 Estimation results for agricultural value added per capita and CO_2 emission per capita GMM

	Spatial model I		Spatial model II		Nonspatial model III	
	Coefficient	*P* value	Coefficient	*P* value	Coefficient	*P* value
Constant	−13.73***	(0.0000)	−13.61***	(0.0000)	−13.74***	(0.0000)
LCO_2 (−1)	0.503***	(0.0000)	0.312***	(0.0000)	0.56***	(0.0000)
Lagrijp	4.36***	(0.0000)	4.31***	(0.0000)	4.4***	(0.0000)
Lagrijp2	−0.33***	(0.0000)	−0.32***	(0.0000)	−0.33***	(0.0000)
Spatial lag	0.13***	(0.0000)	0.12***	(0.0000)		
Spatial lag (−1)			0.21***	(0.0000)		
Spatial error	0.22*	(0.054)	−0.343***	(0.007)		
Turning point (Rials)	4,711,196		5,424,691		4,920,617	
Wald χ^2	2177.51***	(0.0000)	2189.95***	(0.0000)	3358.7***	(0.0000)
Sargan test	26.92	(0.9801)	27.3	(0.9772)	27.85	(0.9725)
Number of observations	252		252		252	
Number of groups	28		28		28	

Resources: research finding

***, **, * are significant at 1, 5 and 10 % level

agricultural sector in each province of Iran. The results of each of these three models, estimated using GMM (Arellano and Bond 1991) method, are shown in Table 2. Significance of Wald test results for all three models confirms the validity of the models, and insignificance of Sargan test results indicates that the instrumental variables were chosen correctly for model estimation.

Environmental curve was confirmed in all three models. In fact, it means that with the continued growth of the agricultural sector, the emissions will first increase and then will decrease. The results of models I and II also indicate that the spatial lag and spatial error effects existed in this equation. Therefore, the amount of emissions in one province was directly affected by the emissions in neighboring provinces. Also the significance of spatial lag variable with one lag reflects the fact that carbon dioxide emissions in an area can also affect the emissions in other areas with one period lag. On the other hand, the significance of the effect of lag-dependent variable means that CO_2 emissions have also been dependent on the emissions of the previous year. Since the coefficient of lag-dependent variable was higher than the coefficient of spatial lag variable, it can be said that the effect of time in carbon dioxide emissions in the agricultural sector has been higher than the effect of spatial. So the overflows of emissions from contiguity regions are less effective than the spillovers in the same region resulted by passage of time (emissions from previous years).

Also, considering the overflow point, it can be stated that at the end of the study period (2013), more than 84 % of the provinces have passed the return point, but if the average per capita income has been considered, only 14 % of the areas have crossed that threshold.

According to results of model I, it can be expressed that the environmental Kuznets curve in conjunction with carbon dioxide emission and agricultural value added in Iran has been confirmed, but this assumption is not true for all provinces in Iran and there are provinces which are far from the point of return. One of the reasons is the heterogeneity of agricultural development in Iran, since the agricultural infrastructure is not uniform in all areas and, in some areas, energy productivity is low and leads to greater amount of environmental pollutants. On the other hand, implementation of the liberalization of energy prices in Iran leads to decrease the energy consumption in agricultural sector. As a result, carbon dioxide emission is reduced.

Three models were also used to examine the relationship between income and water. The Wald statistic value confirmed the validity of the model, and insignificance of Sargan test results indicated that the instrumental variables were chosen correctly. Results of the estimation of these three models are shown in Table 3.

In all these models, given the positive coefficient of value-added variable and the negative value of its second degree, Kuznets theory regarding water use and growth of the agricultural sector in Iran is confirmed. So with the

Table 3 Estimation results for agricultural value added per capita and water consumption per capita (GMM)

	Spatial model IV		Spatial model V		Nonspatial model VI	
	Coefficient	*P* value	Coefficient	*P* value	Coefficient	*P* value
Constant	-6.27^{***}	(0.0000)	-7.00^{***}	(0.0000)	-5.88^{***}	(0.0000)
Ltw (−1)	0.286^{***}	(0.0000)	0.279^{***}	(0.0000)	0.296^{***}	(0.0000)
Lagrijp	2.96^{***}	(0.0000)	3.01^{***}	(0.0000)	2.48^{***}	(0.0000)
Lagrijp2	-0.206^{***}	(0.0000)	-0.23^{***}	(0.0000)	-0.19^{***}	(0.0000)
Lper	-0.02^{*}	(0.070)	−0.14	(0.217)	-0.02^{**}	(0.031)
Spatial lag	-0.082^{*}	(0.016)	−0.026	(0.405)		
Spatial lag (−1)			-0.157^{***}	(0.0000)		
Spatial error	0.48^{***}	(0.000)	0.617^{***}	(0.0000)		
Turning point (Rials)	3,312,239		3,495,250		3,387,958	
Wald χ^2	4080.36^{***}	(0.0000)	2956.34^{***}	(0.0000)	5444.92^{***}	(0.0000)
Sargan test	26.95	(1.0000)	25.42	(1.0000)	26.49	(1.0000)
Number of observations	308		308		308	
Number of groups	28		28		28	

Resources: research finding

***, **, * are significant at 1, 5 and 10 % level

continued growth of the agricultural sector, the water consumption has been first increased, but as this trend continues, the water consumption has been decreased. In these models (IV, V and VI), precipitation had a negative effect on the amount of water consumption per capita, because in those years which had higher precipitation, agriculture sector used the rain water to provide for its needs. In model IV, the value of lagged water consumption coefficient was higher than spatial lag coefficient. So it can be said that, in case of water consumption, farmers were more likely to follow the pattern which they previously acted upon, and their consumption was less dependent on the amount of water consumption in the neighboring provinces. However, with increased consumption of water in a region, the availability of water to adjacent regions was reduced. The reason behind this relation can be the shared water basins between these areas. The per capita income at the return point (Chen 2010) shows that if the per capita income at the end of the period (2013) has been considered, 27 provinces have passed the turning point. But if the average income of the period (2001–2013) has been considered, 82 % of provinces have passed the turning point. Although it should be noted that better status of provinces in the water consumption model compared with carbon dioxide emissions model, can be due to water shortages and droughts.

Proof inverted U-shaped relationship, between water consumption and agricultural value added in Iran, confirms that agricultural growth leads to decrease in consumption and withdrawals from surface water and groundwater. This finding suggests an important reality that continuous agricultural growth and crossing the water crisis are not in the opposite directions and, with a comprehensive program of sustainable development, both water resources will be protected and agricultural growth will be continued.

Table 4 shows the estimation of unit root test for the residuals of the models. Estimation results show that according to IPS (A) statistics, all residuals are stationary at 1 % level. The stationary of these remaining suggests that there is no spurious regression, and that the coefficients obtained in all models are reliable.

Figure 5 shows the relationship between logarithmic values of agricultural per capita value added and the average CO_2 emissions per capita in each province. Figure 6 shows the relationship between logarithmic values of agricultural per capita and per capita consumption of water in this sector. These two figures show the status of each province compared to another. The results of these two graphs show that in the case of CO_2 emissions, fewer provinces have crossed the threshold, but in the case of relationship between water and agricultural development, more provinces have crossed the threshold. Accordingly, it can be stated that in the category of per capita consumption of water, EKC theory has happened with a larger dimension.

Table 4 Unit root test for residuals in six models

Summary statistic	Panel unit root				
	Im–Pesaran–Shin[a]			Levin–Lin–Chu[b]	
Variable	A	B	C	D	E
Model I	−2.66 (0.0038)***	−1.97 (0.0242)**	−2.28 (0.0110)**	−3.45 (0.0003)***	−3.4 (0.0003)***
Model II	−1.98 (0.0234)**	−1.34 (0.0899)*	−1.47 (0.0710)*	−1.87 (0.0303)**	−2.89 (0.0019)***
Model III	−2.31 (0.0103)**	−1.98 (0.0237)**	−3.52 (0.0000)***	−5.03 (0.0000)***	−4.1 (0.0000)***
Model VI	−6.75 (0.0000)***	−4.76 (0.0000)***	−2.31 (0.0102)**	−6.82 (0.0000)***	−5.09 (0.0000)***
Model V	−6.51 (0.0000)***	−4.31 (0.0000)***	−2.59 (0.0047)***	−6.92 (0.0000)***	−5.002 (0.0000)***
Model IV	−6.72 (0.0000)***	−4.5 (0.0000)***	−2.25 (0.0123)**	−6.66 (0.0000)***	−4.83 (0.0000)***

Resources: research finding

E: common AR; included panel mean; not included time trend

D: common AR; included panel mean; included time trend

C: common AR; not included panel mean; not included time trend

B: panel-specific AR; included panel mean; not included time trend

A: panel-specific AR; included panel mean; included time trend

The number in parentheses indicates the *P* value, and ***, **, * are significant at 1, 5 and 10 % level

[a] Z-t-tilde-bar statistic reported

[b] Adjusted *t** statistic reported

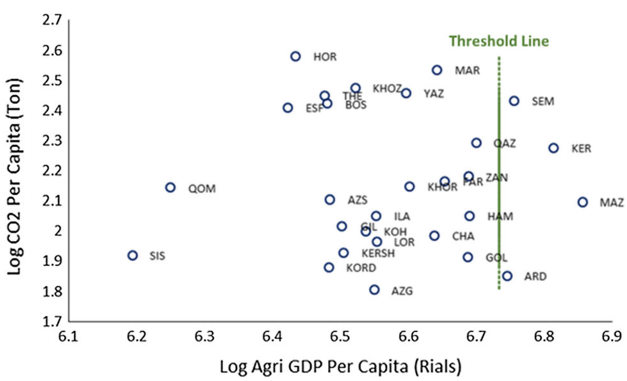

Fig. 5 Logarithmic value of CO_2 emission and agricultural value added per capita by provinces

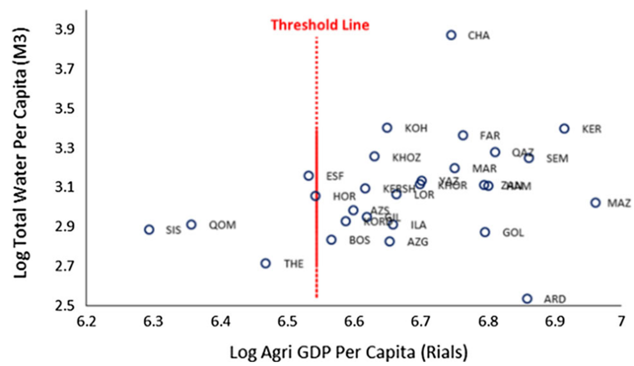

Fig. 6 Logarithmic value of water consumption and agricultural value added per capita by provinces

Conclusion

Agricultural growth can be considered the basis for economic development, but its growth will have a significant impact on development orientation. Due to close relationship between agriculture and natural resources, this sector not only affects the natural resources but also is affected by it. Therefore, developmental programs should be designed, developed and implemented in a way that the highest agricultural value added will be created with a minimal use of natural resources. Confirmation of spatial effects on carbon dioxide emissions and water consumption means that a comprehensive policy must be adopted for water resource management and pollutants control, which prevents from negative impacts of one area to other areas.

In this study, forward and backward relationships have been used to examine the relationship between economic growth and the use of natural resources in Iran in the time period of 2001–2013. Kuznets theory was used to examine the forward relationship, in which the relationship between per capita consumption of water in agriculture and the per capita value added in this sector was examined. In case of backward relationship, the relationship between carbon dioxide emissions per capita caused by the agricultural sector and per capita value added in this sector was examined. Few studies have considered the use of a model that can show the effects of both time and space simultaneously (Burnett and Bergstrom 2010). Results of estimation in both models showed that there was an inverted U relationship between per capita income and water consumption and carbon dioxide emissions (Vaseghi and Esmaeili 2010; Molaei et al. 2010; Mirshojaeian Hosseini and Rahbar 2011; Shahbazi et al. 2015), but this curve happened more aggressively for water consumption. On the other hand, spatial estimation showed that both water consumption and CO_2 emissions in agricultural sector had a direct relationship with the value of these two variables in the neighboring areas. Therefore, the effect of spillover in CO_2 emissions and water consumption in the agricultural sector is confirmed. Using dynamic model estimation indicated that the extent of carbon dioxide emissions and water consumption depended more on the values of these variables in the past periods (previous years), rather than their values in adjacent areas. So the impact of time was greater than the impact of spatial. In the category of relationship between water consumption and per capita income, more regions have passed the threshold and are in the downward section of Kuznets curve, but in CO_2 emissions category, many provinces have not yet reached the threshold point. This can be due to the higher value of agricultural per capita income in the return point of CO_2–income curve compared with the same parameter in water–income curve. The ratio of this parameter in these two curves is 1.55.

Given that the spatial effect in the water consumption and CO_2 emissions is approved, the estimation of models which investigate the environmental Kuznets curve should be tested by this method. Given the higher value of income in the return point of CO_2–income curve, many regions in Iran have not yet reached this point (Fig. 5); as a result the development and investment in new energy sectors and environmental pollutants control are more important.

Since the environmental Kuznets curve can be applied to both water consumption and CO_2 emissions in agricultural sector, development and growth of agriculture in the country can lead to controlled CO_2 emissions and water consumption in this sector. Overall, in order to sustain this growth, the continued investment in increasing productivity of energy and water inputs in agricultural sector is recommended.

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