Analysis on the Relationship between the Virtual Water and Economic Development in Jing-Jin-Ji Region

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Abstract. Water shortage and irrational allocation have restricted the economic and social development of Jing-Jin-Ji region. 70 percent of water is used for agriculture, while virtual water of agriculture come up to 1854×108m3 which is ten times of the annual water consumption of this area. According to the principle of saving and optimal allocation, the research analyzing the effect of main agricultural products to economic growth, based on calculating ten kinds of virtual water of main agricultural products. The method is fixed effects regression model. The conclusion is as follows: Three products of milk, vegetables, dry and fresh fruit are suitable for production in Jing-Jin-Ji region because of a positive role in development of per capita GDP and low virtual water content; Three products of grain crops, meat and poultry eggs are not suitable for production in Jing-Jin-Ji region because of a negative role in development of per capita GDP and high virtual water content, while a limited amount of grain crops, meat and poultry eggs should be imported to guarantee the regional strategic security; Forest products play an important role in environmental protection and should offer subsidy to producer in spite of a negative role and high virtual water content; cotton belongs to government subsidies product and Oil products and aquatic products could be imported completely.

Introduction

Jing-Jin-Ji region is an urban agglomeration area composed of Beijing, Tianjin and Hebei province. The area of this region reaches 216 thousand square kilometers and the population reaches 100 million. Because of the regional connection, symbiotic resources, complementary economic development and the same strain of water resources, the coordinated development of Jing-Jin-Ji region outline is just enacted in 2015. The aim of outline is to change the imbalance of regional development and resource allocation, to promote the coordinated development of economy, society and resources. Water shortage and uneven allocation have been becoming one of the most serious problems of Jing-Jin-Ji region. According to the statistical yearbook, water supply of Jing-Jin-Ji region was 125×108 m3 in 2013, while water demand was 255×108 m3. The demand-supply gap was 130×108 m3 and year-on-year growth of 172% in 2013. Furthermore, the average of demand-supply gap is 79×108 m3 during the last ten years. Given to the above calculation, water shortage problem of Jing-Jin-Ji region is obvious. Agricultural water demand was 182×108 m3 which is 70% of the whole year supply, while the first industry output value accounted for 4%, Water resources allocation is not reasonable.

According to the Water pollution control plan enacted in 2015, the district such as Hebei province where agricultural water consumption is the major fraction of freshwater consumption should decrease planting area of water intensive crops, and save water by adjusting the agricultural planting structure. Based on previous studies, crop water consumption not only needs to consider the entity water, but also need to account the cost of virtual water. The term ‘virtual water’ was introduced by Tony Allan in the early 1990s. It is defined as the volume of water required to produce agricultural products, which is extended from the concept of embedded water[1]in 1993, then it is defined as the volume of water required to produce a commodity or service in 1996[2]. It is from the production point of view and quantifies virtual water as there all water used in the commodity production. The virtual water of agricultural products in Jing-Jin-Ji region was 1854×108 m3in 2013, which was ten times of agriculture entity water consumption. It is of great importance to control the virtual water for saving water resources of Jing-Jin-Ji region. This research analyzes that main agricultural products virtual water impact on regional economy, basing on accounting main agricultural products virtual water content in Jing-Jin-Ji region..

Review of relationship between Virtual Water and economic development

Virtual water research focused on two main themes so far. One is virtual water content calculation, the other is virtual water trade. The relationshipbetween virtual water and economic development is an important topicbased on the virtual water content calculation. At the beginning, the virtual water calculation object focused on farm crops and livestock products[3-6], that is farm crops productscontent, livestock products content and regional agriculture virtual water total content, whereafter, the virtual water calculation object extended to all the commodity. Tian accounted the China's wood forest products virtual water[7].Economic elements, resources elements and environmental elements are very important influencing factors of virtual water content and virtual water trade[8-11]. Resources elements such as population, plowland number and applying quantity of chemical fertilizer have high matching rate with virtual water. Environmental elements such as soil and water loss have low matching rate with virtual water. Economic elementssuch as GDP have a declining matching rate with virtual water.On the contrary,Virtual water plays an important role on the economic development and adjustment of industrial allocation. Maksud Bekchanov researched the role of virtual water for Uzbekistansustainable economic restructuring by using the input-output method, the conclusion is that developing agro-processing industries and the livestock sector rather than relying on the production of raw agricultural commodities such as cotton, wheat, and rice provides more sustainable economic development in Uzbekistan[12].Research carried on by Samir Suweisfindsthat virtual water controlled demographic growth and population of nations[13]. Zou put forwards the regional virtual water content represents china’s agricultural industry distribution, and optimizing the layout of agricultural production by calculate matching rate betweenthe virtual water contentand regional economic. In conclusion, Virtual water is closely associated with regional economic development, and it is reasonable to promote agricultural planting structure and water resources allocation restructuringby measuring the main agricultural virtual water impact on economic growth.

Data sources

According to China statistical yearbook classification, the main agricultural products in Jing-Jin-Ji region are farm products, forestry products, husbandry products and fishing products. Farm products include grain (such as rice, winter wheat, corn, beans and tubers), cotton, oil plants, vegetable and fruit. Husbandry products include pork, beef, mutton, poultry meat, egg and milk. Fishing products mainly include fresh-water fish. Forestry products include afforestation of barren hills and culture of seedling. Given to the different planting conditions, Hebei province additionally includesmillet, Chinese sorghum, tobacco and hemp.

There are two types of virtual water calculation method. One is calculation according to separate products[15], the other is according to different kinds of products[16].Both of them are Life cyclecalculation method and are based on the Penman-Monteith Method developed by FAO. The Penman-Monteith Method is used to calculate agricultural products virtual waterper unit mass. Main agricultural products virtual water equal to agricultural products virtual waterper unit massmultiply by agricultural products production. The data of agricultural products production is from China Statistical Yearbook (1995-2014), Beijing Statistical Yearbook (1995-2014),Tianjin Statistical Yearbook (1995-2014) and Hebei Statistical Yearbook (1995-2014). The data of agricultural products virtual water per unit mass is from previous studies. Sun[8] and Ma[18]figure out main agricultural products virtual waterper unit mass of China. Hoekstra A Y[19] figure out livestock products of China. Tian[7]figure out wood forest products virtual water. Finally, we obtain main agricultural products virtual waterper unit mass of Jing-Jin-Ji region(Tab.1). The data we get above is in line with the panel data form, so panel data model is applicable.

Tab.1 Main agricultural products virtual waterper unit mass of Jing-Jin-Ji region

Unit:m3/kg

industry	products	Beijing	Tianjin	Hebei
Farm products	winter wheat	1.23	1.25	1.065
	rice	1.4	1.19	2.185
	corn	0.84	0.85	0.817
	millet	--	--	0.93
	Chinese sorghum	--	--	1.343
	beans	2.24	3.73	1.08
	tubers	0.7	1.07	1.2
	cotton	5.22	4.4	5.5
	oil plants	1.5	1.5	2.2
	tobacco	--	--	2.76
	hemp	--	--	2.185
	vegetable	0.24	0.13	0.1
	fruit	0.55	1.38	1.5
husbandry products	pork	3.7	3.6	3.6
	beef	19.99	19.99	19.99
	mutton	18.01	18.01	18.01
	poultry meat	2.7	3.11	--
	egg	8.65	8.65	8.65
	milk	2.2	2.2	2.2
Fishing products	fresh-water fish	3.11	3.11	3.11
Forestry products	afforestation (m^3/hm^2)	85865.1	85865.1	85865.1

Notice: Beijing and Tianjin do not product millet, Chinese sorghum, tobacco and hemp.

Model construction and test

Model construction

Panel data model usually include fixed-effect model, random-effect model and mixed-effects model. The general expressions for the three model is as follows.

$$\ln Y_{it} = C + \beta_{it} \sum \ln X_{it} \quad (1)$$

Where Y_{it} is dependent variables, this study selects GDP per capita. X_{it} is independent variables, these are ten agricultural products virtual water in Jing-Jin-Ji region. "i" is sectional data, and this study include Beijing, Tianjin and Hebei. "t" is time-series data from 1994 to 2013. C is constant. β_{it} is regression coefficient vector.

Unit Root Test

Tab.2 Unit root test results

	Madfuller test					Hadrilm test	
	lag phase	difference order	MADF	critical value (5%)	stationarity	difference order	stationarity
Y	1	2	123.411	49.619	stationary	2	stationary
X1	1	1	56.797	45.195	stationary	1	stationary
X2	1	1	53.249	45.195	stationary	1	stationary
X3	1	1	52.654	45.195	stationary	1	stationary
X4	1	2	146.125	49.619	stationary	2	stationary
X5	1	1	48.547	45.195	stationary	2	stationary
X6	1	1	78.018	45.195	stationary	1	stationary
X7	1	0	88.321	41.700	stationary	2	stationary
X8	1	2	71.858	49.619	stationary	2	stationary
X9	1	0	43.348	41.700	stationary	1	stationary
X10	1	2	118.394	49.619	stationary	1	stationary

This study adopts Madfuller test and Hadrilm test to test stationarity of time series data.①Madfuller test:H0 is all 3 time series in the panel are I(1) processes, if you reject the null hypothesis that at least one sequence is smooth. ②Hadrilm test: H0 is all 3 time series in the panel are smooth, if you reject the null hypothesis thatat least one sequence is not smooth.

In the Madfuller test, all the lag time series is 1. At least one sequence of X7 and X9 is smooth in original data sequence, and at least one sequence of X1, X2, X3, X5 and X6is smooth in lag time 2. In the Hadrilm r test, at least one sequence of X1, X2, X3, X6, X9 and X10 is not smooth in lag time 1, and at least one sequence of Y, X4, X5, X7 and X8 is not smooth in lag time 2. Combining with two kinds of results, Time series of X1-X10 are stationary under the condition of difference order(Tab.2).

Model test

This study adopts Wald F test, B-Ptest and Hausman test to distinguish the difference of fixed-effect model, random-effect model and mixed-effects model. ①Wald F test: H0 is bit= b0, if you reject the null hypothesis that we should adopt fixed-effect model; ②B-P test: H0 is bit= 0, if you reject the null hypothesis that we should adopt random-effect model; ③Hausman test: H0 is COV（Xit，bit ）=0, if you reject the null hypothesis that we should adopt fixed-effect model. According to the test results, this study adopts the fixed-effect model to estimate the panel data(Tab.3).

Tab. 3 Statistical tests

test	detection value	Pvalue	Preferred
Wald test	24.31	0.0000	fixed-effect model
B-P test	894.88	0.0000	random-effect model
Hausman test	49.46	0.0000	fixed-effect model

Regression analysis of fixed-effect model

According to descriptive statistics, the virtual water content of egg, afforestation, grain and meat are highest, and the annual virtual water content are more than 100 billion cubic meters. The annual virtual water content of fruit is 41billion cubic meters. The annual virtual water content of vegetable and milk are more than 20 billion cubic meters. The annual virtual water content of fresh-water fish is 18 billion cubic meters. The annual virtual water content of cotton and oil plants are 18 billion cubic meters. The distribution of ten agricultural products virtual water content reflect water resources allocation situation and crops industry layout in Jing-Jin-Ji region. Additionally, it is controversial to make water resources policy just rely on virtual water content[20], so this research also analyzes the effect of main agricultural products to economic growth as the basis of agricultural planting restructuring.

Regression analysis shows R^2 = 0.9642. All the X1- X8 are through the t value test within the 95% confidence interval. X10 passes the t value test the 90% confidence interval. X9 do not pass the t value test.In addition, thatF test is significant shows equation simulation effect is good. The regression equation we get is as follows(Tab.4).

$$LnY = 10.9 - 0.34LnX1 - 0.16LnX2 - 0.76LnX3 + 0.97LnX4 + 0.18LnX5 - 0.33LnX6 - 0.39LnX7 + 0.49LnX8 - 0.97LnX10 \quad (2)$$

Vegetable, milk and fruit have a positive effect on Per Capita GDP, where vegetable has the strongest positive effect, and milk and fruit are subsequent. Virtual water of vegetable each additional unit, the per capita GDP growth rate was 97%. Virtual water of milk and fruit each additional unit, the per capita GDP growth rate was 49% and 18% separately. Grain, cotton, oil plants, meat, egg and afforestation have a negative effect on Per Capita GDP, where oil plants has the strongest negative effect, and egg, grain and meat are subsequent. Virtual water of oil plants each additional unit, the per capita GDP growth rate was -75%.Virtual water of egg, grain and meat each additional unit, the per capita GDP growth rate was -38%, -34%and -33%. Besides that, cotton and afforestation also have limited negative effect on Per Capita GDP, and virtual water of cotton and afforestation each additional unit, the per capita GDP growth rate was -16%and -9%respectively.

Tab.4 Regression result

LnY	coefficient	t	P value
LnX1	-0.34	2.86	0.006
LnX2	-0.16	5.43	0.000
LnX3	-0.76	-6.70	0.000
LnX4	0.97	3.87	0.000
LnX5	0.19	3.63	0.001
LnX6	-0.33	-2.54	0.015
LnX7	-0.39	-3.38	0.001
LnX8	0.49	5.72	0.000
LnX9	-0.06	-0.62	0.535
LnX10	-0.97	-1.69	0.097
_cons	10.89	13.77	0.000
	R^2（within）=0.9642		
	F=24.31 Prob>F = 0.0000		

Conclusions

The present situation and restructuring direction of agricultural planting structure in Jing-Jin-Ji region is as follows.

(1) Vegetable, milk and fruit are suitable for production in Jing-Jin-Ji region. Because of the positive effect on Per Capita GDP and less of virtual water, three products not only is beneficial to improve the level of GDP per capita, but also save water resources.

(2) Because of the negative effect on Per Capita GDP and cost of virtual water, three products of grain, meat and egg are not suitable for production in Jing-Jin-Ji region. Given to be closely related to residents, three products have important strategic security status. It necessary to limitedly reduce the local production and increase imports from the surrounding area and international trade, while maintaining regional safety.

(3) Forestry products play an important role to protect the ecological environment, though it has a week negative effect on Per Capita GDP and cost of virtual water. So the restructuring direction of forestry products is to increase subsidies for forestry industry, to increase economic forest tree planting proportion for improving the income of planter, to increase the coniferous forest planting proportion for saving water.

(4) Cotton virtual water is less, but has a week negative effect on Per Capita GDP. So the restructuring direction of cotton is to develop cotton processing industries for increasing the income of peasants.
(5) Because of the heaviest negative effect on Per Capita GDP and be difficult to improve the economic benefit by large-scale production, oil plants could completely import from Shandong peninsula and Liaodong peninsula.
(6) Fishing products have no significant impact on the economy, combining with the current situation that the river is dying up and wetland is shrinking. So the restructuring direction of fishing products is to reduce the local production and increase imports from the surrounding area.

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