Research on "Growth Drag" of Water Resource on Agricultural Development in China

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Abstract—Based on the “growth drag” conceptual model of Romer, this paper computes the growth drag of water resource on agricultural development through using panel data(1997～2006) of China’s all provinces. The result shows the growth rate of agricultural production value fell 0.1121% per year on average because of the shortage of water resource. The number is seemingly small, but according to calculation, under the drag of water resource, the ratio will be reduced by 2.66% in 2030. Furthermore, it will be 3.74% in 2040 and 4.82% in 2050**.**

Keywords- water resource; agricultural production; growth drag

INTRODUCTION

As is known to all, water is necessary basic element for crop. Without water, there is no agriculture. Since the total quantity of water supply is insufficient, together with industrial and urban increasing demand, the current situation of agricultural water is quite serious in China. During the period of the Tenth Five-Year Plan, irrigation water is shortage of 150 billion m^3, and about 0.26 million hm^2 farmlands suffer from drought, which lead to decrease by 35 billion kg grains per year[1]. Having written an article entitled "Who will feed China", Brown Leicestershire, the director of U.S. World Observation Institute, shocks the world. But, in 1998, he published another article "China's water shortage will shake the world food security" which proved China's most serious resource crisis was not arable land, but water. Based on the future analysis and forecast of China's water demand, Brown pointed out China's agriculture water was facing with fierce competition with urban and industrial water demand. With the depletion of ground water and worsening water pollution, water shortage will greatly threat China's agricultural development, even the food security of the world[2].

Is the situation really serious as the forecast? What is the truth? Scientific answer needs the support of strong evidences, particularly quantitative analysis in line with actual situation. The author, with the conceptual model of David Romer’s "growth drag ", constructs similar model to measure the extent of constraints of China's water resource to agricultural development, so as to provide references for policy-makers and related researchers.

THE DEFINITION OF “GROWTH DRAG”

New growth theory tells us economic development is significantly related to resource and land.

Compared the case of constraints with non-constraints, the growth rate of economy is greatly different, which stems from the "growth drag" of limited resources[3]. Xue Junbo[4], Xie Shuling[5] and Yangyang[6], using special model, respectively assessed the "growth drag" of China's soil and water resources. Though they all translated "growth drag" as "growth tail effect," the meanings are markedly different. According to Xue, "growth tail effect" should be defined as the extent of reduced economic growth rate under resource constraints. While Xie firmly insists on, for any country and region, the process of economic development will inevitably lead to the consumption of resources. Furthermore, initial input will affect the latter growth because of limited resources, which is called "growth tail effect". Based on the above mentioned analysis, Yang Yang believes that "tail effect" generally refers to the lag effect of which will continue to play an important role in the next stage. In fact, the concept should be translated as "damping growth". In terms of land resource, its value equals to the difference of economic growth rate between existed and no-existed constraints.

Clearly, for the connotation of "growth tail effect", Xue and Yang is similar to Roemer's "growth drag", but vastly different from the definition of Xie. The author also agrees with Yang-Yang's view of which "tail effect" is not suitable to describe the "growth drag" of economic development restricted by resource and land. According to Roemer's senior macroeconomics (second edition), it seems more reasonable to translate "growth drag" as "growth resistance". The purpose of this study is to explore the impact of water resource constraints on agricultural production. Referred to Roemer's definition, the "growth resistance" of water resource should mean the growth difference between "there are no water restrictions" and " water restrictions exist" in the process of agricultural development.

MODEL AND METHOD

Assumption Revision

In order to assess the extent of resource constraints on economic growth, Roemer constructed a C-D production function model including natural resource and land, the form is as followed:

$$Y(t)=K(t)^{\alpha}R(t)^{\beta}T(t)^{\gamma}[A(t)L(t)]^{(1-\alpha-\beta-\gamma)}$$

$$\alpha>0,\ \beta>0,\ \gamma>0,\ \alpha+\beta+\gamma<1 \qquad (1)$$

Among them, Y is output, K is capital, R is natural resource, T is land, L is labor, A is knowledge or effective labor. When existing restrictions, $\dot{T}(t)=0$ and $\dot{R}(t)=-bR(t)$ (b>0). When not existing restrictions, $\dot{T}(t)=nT(t)$ and $\dot{R}(t)=nR(t)$ These mean land and resource both grow together with population. The growth drag is:

$$Drag = \frac{\beta b + (\beta + \gamma) n}{1 - \alpha} \tag{2}$$

That is to say, the drag is constantly incremental along with resource share β, land share γ, the utilization of declining resource b, the growth rate of population n and increasing capital share α. In order to see more clearly the influence of water resource to the "growth drag" of China's agriculture, the author will adjust and amend the model in accordance with the facts.

Compared with 1997, total water resource decreases by 352.466 billion m^3 in 2006; agricultural water consumption decreases by 25.547 billion m^3; water share also drops by 7.2 percentage points and irrigation water per acre is approximately reduced 50 m^3. The available water resource of China's agriculture is reducing gradually because of limited water supply as well as increasing water demand from industry and city, which leads to the decline of irrigation water per acre and hinders agricultural production. In order to more accurately reflect the impact, the author will quantitatively calculate the degree of constraint of water resources to the growth of agricultural output.

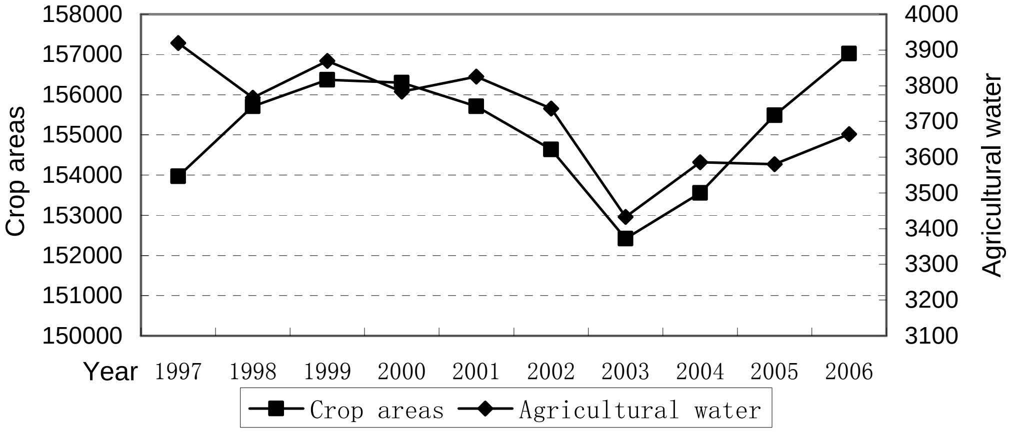

Figure 1 The change trend of China's agricultural water and crop areas (1997 ~ 2006)

Data sources: Statistical Yearbook of China's rural areas（1998～2007）and China's Water Resource Communique(1998~2007), calculated and arranged by the author.

As is shown by Figure 1, from 1997 to 2006, agricultural water doesn’t change at the same proportion as crop areas. Therefore, when analyzing, resource should not be supposed to a fixed constant or the symbol of growth rate is identified as negative or positive beforehand. Based on previous studies, the author makes following revisions to the model. When existing restrictions of water,

$\dot{W}_i(t) = g_{Wi} W_i(t)$. Otherwise, let $\dot{W}_i(t) = g_{Ti} W_i(t)$ .This means the change velocity of agricultural water and crop areas is different. Here, g_{Wi} is the growth rate of agricultural water in i region, g_{Ti} is the growth rate of crop areas in i region.

Model Construction

Now, we still use the form of C-D production function. But the model construction is changed as follows:

$$Y_i(t) = K_i(t)^{\alpha} W_i(t)^{\beta} T_i(t)^{\gamma} [A_i(t) L_i(t)]^{(1-\alpha-\beta-\gamma)} \qquad （3）$$

$Y_i(t)$: Agriculture outputs of i region at the time t ;

$K_i(t)$: Capital investment of i region at the time t ;

$W_i(t)$: Agriculture water inputs of i region at the time t;

$T_i(t)$: Land inputs of i region at the time t;

$L_i(t)$: Labor inputs of i region at the time t;

$A_i(t)$: The effectiveness of knowledge or work of i region at the time t;

α、β、γ: Parameter, and α>0, β>0, γ>0, α+β+γ<1

Taking the logarithm on both sides of the formula (3), we can obtain the following equality:

$$\ln Y_i(t) = \alpha \ln K_i(t) + \beta \ln W_i(t) + \gamma \ln T_i(t) + (1-\alpha-\beta-\gamma)[\ln A_i(t) + \ln L_i(t)] \qquad （4）$$

Further deducing, we can get:

$$g_{Yi} = \alpha g_{Ki} + \beta g_{Wi} + \gamma g_{Ti} + (1-\alpha-\beta-\gamma)(g_i + g_{Li}) \qquad （5）$$

Among them, g_{Yi} , g_{Ki} , g_{Wi} , g_{Ti} , g_{Li} and g_i respectively represent the growth rate of $Y_i(t)$、$K_i(t)$、$W_i(t)$、$T_i(t)$、$L_i(t)$、$A_i(t)$. According to Roemer, if locating in a balanced growth path, g_{Yi} is certainly equal to g_{Ki} . Put it into the type (5) and solve the equation.

$$g_{Yi}^{bgp} = \frac{(1-\alpha-\beta-\gamma)(g_i + g_{Li}) + \gamma g_{Ti} + \beta g_{Wi}}{1-\alpha} \qquad （6）$$

g_{Yi}^{bgp} : growth rate of agricultural output in a balanced growth path.

It also means the growth rate of agricultural output per acre is:

$$g_{(Y/T)i}^{bgp} = g_{Yi}^{bgp} - g_{Ti}^{bgp} = \frac{(1-\alpha-\beta-\gamma)(g_i + g_{Li}) + \beta g_{Wi} - (1-\gamma) g_{Ti}}{1-\alpha} \qquad (7)$$

After deducing the growth rate $g_{(Y/T)i}^{bgp}$, with the same method, we study the situation of no-existing constraints and get the following output growth rate per acre.

$$\tilde{g}_{(Y/T)i}^{bgp} = \frac{(1-\alpha-\beta-\gamma)(g_i + g_{Li}) + (\gamma+\beta-1) g_{Ti}}{1-\alpha} \qquad (8)$$

Therefore, during the process of agriculture development, the "growth drag" of water resource is:

$$Drag = \tilde{g}_{(Y/T)i}^{bgp} - g_{(Y/T)i}^{bgp} = \frac{\beta (g_{Ti} - g_{Wi})}{1-\alpha} \qquad (9)$$

From the equality (9), we can see the "growth drag" will ascend along with increasing capital output elasticity(α), output elasticity of water resource (β) and crop areas. This indicates: although capital, land and water resource are main input elements of agricultural production, agricultural sustainable development can not excessively depend on them. Thus, the only way to reduce "growth drag" is to promote technological progress which raises itself status in agricultural production.

In addition, under CD production function, the substitution elasticity of production elements is a fixed constant 1. In fact, the elasticity may not be equal to 1. When it is less than 1, as growing scarcity elements, the contribution share of input to output will increase and become more important. On the contrary, the share will drop[7].

MEASURES OF “GROWTH DRAG”

Data Description

The research's goal is to measure the constraint extent of water resource shortage on agricultural production. Considering available data, we adopt panel data set of China's all provinces and autonomous regions from 1997 to 2006. All data are derived from "Statistical Yearbook of China's Rural Areas" and "Communique of China's Water Resources". The output variable, $Y_i(t)$, is reflected with agricultural output. As numerical value is from current year's price, we will take 1996 as the base year and adjust $Y_i(t)$ according to comparable price. Referring to past research literatures[8], the article uses employment figure of agriculture, forestry, animal husbandry and fishery as $L_i(t)$. $K_i(t)$

is measured by the total power data of agricultural machinery. With regard to $W_i(t)$, because output data mainly aim at narrow planting agriculture, here, we adopt irrigation water data. On average, it accounts for 90%[9] of total agricultural water. Therefore, for the data of published Yearbook, the author converts them through multiplying by 90%. In addition, the missing data are polished by differential technique.

Quantitative Analysis

According to the formula (9), $\alpha$and β, parameters of C-D production function model, are basis of quantitative estimating the "growth drag". The paragraph first carries on the parameter estimation to multiple regression model of formula (4) through using the software STATA10.0. Table 1 shows the results of parameter estimation. As can be seen, the value of χ^2 is of 4.79 on Hausman test, which indicates the estimation results of fixed effects (FE) and random effects (RE) model differ just slightly according to the panel data set. Moreover, the results of F-test and Breusch-Pagan LM random effects test also show the above two methods are superior to ordinary least squares (OLS), more than 96% in goodness of fit. However, further tests display there exist first order autocorrelation, relevant section and heteroscedasticity in both fixed effect model and random effects model.

Table 1 Estimation results of fixed effects and random effects model

Independent variable	Coefficient fixed effects model	 random effects model
lnT	0.8748***(0.0346)	0.8650***(0.0327)
lnL	0.0577(0.071875)	-0.0169(0.0437)
lnK	0.1503***(0.0225)	0.1289*** (0.0199)
lnW	0.1378***(0.0454)	0.1116*** (0.03558)
constant	-1.9029***(0.5124)	-1.0781*** (0.2226)
Goodness-of-fit: Within	0.7693	0.7680
Between	0.9697	0.9690
Overall	0.9662	0.9657
Sample number	310	310
F test：u_i=0	F(30, 275)＝71.46	
Breusch-Pagan LM: Random effects test		χ^2＝1047.38
Wooldridge Autocorrelation test	F= 15.380	LM=289.41
Breusch-Pagan LM: Independent testing	χ^2=738.326	
Wald Heteroscedasticity test	χ^2=7428.07	
Hausman test	χ^2= 4.79, Prob>χ^2= 0.3094	

Note： ① Agricultural output value is seen as dependent variable

② *indicates a 10% significant level, ** indicates a 5% significant level and *** indicates a 1% significant level. Standard errors in parentheses

When the model exists heteroscedasticity or serial correlation, the estimator is still unbiased and consistent, but not effectiveness under same variance. Therefore, it is necessary to re-estimate the model by using feasible generalized least squares (FGLS) of a relax assumption. In table 2, all parameters are statistical significant within the level of 10%. Wald test also makes the same view clear.

Table 2 Estimation results of FGLS existed in heteroscedasticity and first-order autocorrelation

Independent variable	Coefficient	Standard error
lnT	0.7181***	0.0467
lnL	0.0417*	0.0564
lnK	0.1137**	0.0447
lnW	0.1031**	0.0460
Constant	-0.6468***	0.1348
Variable number	310	
Wald test	χ^2=3180.76	Prob>χ^2＝0.000

Note: ① Agricultural output value is seen as dependent variable

② *indicates a 10% significant level, ** indicates a 5% significant level and *** indicates a 1%.

Calculation Results

For average change rate of variables, we use the following formula:

$$a(1+n)^t = b \qquad (10)$$

Here, a is initial (1997) variable value; b is terminal (2006) variable value; t, the period of growth, is 9 and n represents average growth rate. According to the above conclusions, α is 0.1137 and β is 0.1031. Then through the formula (9), we can obtain the "growth drag"(0.001121) of water resources to China's agriculture. In other words, owing to the shortage of water resource, China's agriculture is greatly affected and productivity is dropping. In addition, water resource can’t be up at the same proportion with crop areas, which makes the growth rate of agricultural output reduced 0.1121% per year on average. This also proves that China's agricultural water consumption is of depletion. In the long run, the issue should be closely concerned.

The previous quantitative analysis show, due to insufficient supply of water resource, the average output growth rate of China’s agriculture is continuously decreasing from 1997 to 2006. The numerical value does not seem large, but, according to the projection, by 2030, China’s agricultural output growth rate per acre will lower 2.66% than the current because of the "growth drag", lower 3.74% by 2040 and 4.82 % by 2050. Therefore, water resource will play an important role on China’s agricultural production, and will cause greater influence to agricultural sustainable development.

CONCLUSIONS

Water, as a renewable resource, exists “growth drag” in agricultural production. Our findings show the “growth drag” has slowed down the output growth rate of lands, limiting the grain yield. In addition, fierce competition from industry and city, together with climate warming and water pollution, also makes useable water resource be greatly reduced, which will further intensify the harm degree of “growth drag”. Thus, from a long-term perspective, if it can not be effectively controlled, gradually accumulated, it is bound to cause serious damage to China's agricultural production.

In addition, from the formula (9), we can see the "growth drag" is positively related with output elasticity α of capital, output elasticity β of water resource and grow rate of crop areas, which indicates the "drag" can be reduced through α and β. Its intrinsic economy meaning is that we can achieve our aim through lowering the role of capital, land and water resource of agricultural production. That is to say, agricultural development can’t overly depend on capital, land and water resource. But it does not mean wasting water resources randomly. The appearance of "growth drag" is just because water resource is relatively shortage and can’t grow at the same proportion with land. Therefore, we must try to reform the current use patterns of agricultural water, rely on technological progress, protect and use water resource rationally, adopt advanced water-saving technology and measures to improve water-using efficiency. Only by doing so can we alleviate increasingly serious water-using pressure and maintain sustainable growth of national economy without increasing or even decreasing gross water.

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