Impact of Growing-Season Meteorology on Japonica Rice Productivity in Northeastern China

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Abstract. Meteorological factors have major impact on crop productivity in the world. Many researchers have evaluated the possible impact of climate change on crop yields using models. Here we use a 1980–2015panel dataset from China Agricultural Cost and Return Yearbook to investigate the meteorological impact on Chinese Japonica rice yield growth. We find that average temperature has significantly positive effect on rice yields; while maximum temperature and minimum temperature have negative effect on rice yield. Physicalinputs and time trend (technological progress) into the crop yield have an accurate estimation on crop yields. Means including irrigation or drainage could use during growing season.

Keyword: Meteorology, Japonica rice yield, Model, Northeastern China

Introduction

Climate changing have an important impact on crop yield in the world. The linkage between crop yield and climate variability has been mentioned in numerous researches using statistical models (YouL., etc., 2009; Xu S., etc., 2013; G Leng&M Huang., 2017; Wan E., 2017).With the increase of the income level of Chinese residents, more and more people choose japonica rice as the staple food. In order to discuss the effects of material input and climate on the yield of Japonica rice, this paper studies the japonica rice.

Data and method

We use time series and provincial data from 1980 to 2015 for 3 major japonica rice producing provinces in Northeastern China and the corresponding climate data such as temperature, rainfall, and solar radiation during the growing season of this period. Japonica rice input and output data are from China Agricultural Cost and Return Yearbook (1980–2015) published by China's Price Bureau.

Both Japonica rice yield and physical inputs demonstrate huge variations among the 108 observations. For example, the mean yield is about 454.3kg/mu while the rice could be as low as 165.7kg/mu (minimum), or as high as 632.0kg/mu (maximum).

Table 1 the basic statistics of the dataset.

Variable	unit	Mean	Std. Dev.	Min	Max
yield	kg/mu	454.3	83.7	165.7	632.0
seed	yuan/mu	17.0	10.0	4.1	45.4
fertilizer	yuan/mu	63.7	45.4	3.7	176.3
pesticide	yuan/mu	14.6	12.4	1.1	100.2
machinery	yuan/mu	57.1	69.6	1.2	247.3
others	yuan/mu	92.6	87.6	7.8	596.8
labor	yuan/mu	135.3	127.4	14.4	537.2
rainfall	mm	21871.5	12802.0	2260.5	49620.2
sunshine	hour	7.4	0.5	6.2	8.6
tempave	℃	15.9	3.7	8.4	20.8
tempmax	℃	21.9	3.4	14.2	26.5
tempmin	℃	10.5	4.1	3.1	15.5

The provincial climate parameters are averages of all the metrological stations within the provinces. Some basic statistics for rainfall, sunshine, average temperature, maximum temperature and minimum temperature are shown in Table 1.

We hypothesize the crop yield as a function of crop inputs, technology, land quality, and climate factors. The initial explanatory variables for the yield equation include inputs such as land, chemical fertilizer, seeds, pesticide, machinery, irrigation and other physical inputs; regional production specialization; climate variables such asprecipitation and solar radiation, average temperature, maximum temperature and minimum temperature; regional dummyvariables. In this study, the labor cost does not include in the model, for we hypothesize the labor manage the rice well. The physical inputs are measured in expenses per unit-harvested area. We includedseed, chemical fertilizer, pesticide, machinery individually and combined all the rest of inputs into an aggregated category of‘‘others’’. In the model, we hypothesize the regional production specialization variable is based on Heilongjiang Province, which is used to reflect the environment factors such assoil quality and others. Finally, a time trend is used to represent the factor due to technological change during this period (1980-2015).Finally, a Cobb–Douglas form of rice yield function is specified as follows:

$$\text{Ln Yield}= \alpha_0 + \alpha_t + \sum_{j=1}^{3} \beta_j \, lnX_{jit} + lnClimate_{it} + \sum_{I=1}^{2} \gamma_I D_I + \varepsilon_{it} \quad (1)$$

WhereLn is natural log, t = 1, 2. . .36 denotes observations from the years 1980 to 2015. Yield_itrefers to rice yield for Chinese provincei at time t (the time trend from 1980 to 2015); Xrepresents the conventional inputs per hectare of sown ricearea including seeds, fertilizer, pesticide, machinery, and other inputs such as irrigation, manure, and animal power. All other inputs are represented by real expenses per hectare of sownrice area (see Table 1 for more); Climate is the climate variables including temperature, rainfall and solar radiation duration.

Results

We find that meteorological impact is significant on rice yields during its growth seasons (Table 2):

Material input In the material inputs, the seed perimeter is 0.126, which means that the seed is positively significant for rice yield, while other input including irrigation is negatively significant, which means other material inputs more.

Meteorological factors We find the significantly negative relationships between rice yield and rainfall while significantly positive relationship between rice yield and sunshine (solar radiation). However, the average temperature has a significantly positive effect while maximum and minimum temperature has a significantly negative effect on rice yield. The significance for rainfall is at 5%level, reflecting the negative influence of rainfall on rice productivity, while sunshine has positive influence on it. Average temperature has 1% significance level. As reflects the significantly positive impact of rice growing season temperatures on rice yield in China, while maximum temperature and minimum temperature have significantly negative impact on rice yield in Northeastern China.

Time trendwe find that there is significant effect of rice yield from time series, which shows technological progress.

Region difference The based region is Heilongjiang Province, Jilin has no significance while Liaoning significantly has lower rice yield.

Table 2 Estimated Japonica rice yield function in Northeastern China, 1980-2015.

Explanatory variables	definition	Coef.	t-value	P>t	
lnseed	Logarithm of seed cost	0.126	1.86	0.067	*
lnfert	Logarithm of fertilizer cost	0.076	1.08	0.282	
lnpestcide	Logarithm of pesticide cost	-0.017	-0.22	0.828	
lnmachinery	Logarithm of machinery cost	-0.152	-1.63	0.105	
lnothers	Logarithm of irrigation, etc.	-0.112	-1.86	0.066	*
lnrf	Logarithm of rainfall	-0.848	-2.49	0.015	**
lnss	Logarithm of sunshine	2.890	1.99	0.049	**
lnta	Logarithm of average temperature	49.240	4.24	0.000	***
lnth	Logarithm of maximum temperature	-50.934	-5.08	0.000	***
lntl	Logarithm of minimum temperature	-5.237	-1.94	0.055	*
t	Trend based on 1980	0.050	7.06	0.000	***
Based region	Heilongjiang	-	-	-	
_Iregion_2	Jilin	-0.955	-1.34	0.183	
_Iregion_3	Liaoning	-2.641	-2.87	0.005	***
_cons	constant	42.947	5.14	0.000	***
	Number of obs=108				
	F(13,94)=13.07				
	R-squared=0.5946				

Note:Dependent variable = Ln(rice yield).

* 0.10 level of statistical significance.

** 0.05 level of statistical significance.

*** 0.01 level of statistical significance.

Conclusions

Generally, during the total rice growth season, the rainfall is not significant, and sunshine is negative and but significant, Average temperature is positive, but maximum and minimum temperature is negative for rice growth.

Considering the rice growing,

- The rice in jointing stage need less rainfall, but in the stage transferring and filling stage, the rice need more rainfall. Generally, the Japonica rice in Northeastern China has more rainfall during the growing season; The sunshine has the positive effect as rainfall in the rice growth seasons; For the temperature, averagely, the higher average temperature is better for rice growing, while the maximum and minimum temperature is not better for the rice yield;
- During the rice growth season, some means are need to use, for example, water irrigation or draining.
- Technology is an import factor for rice yield increasing, though the coefficient of time trend variable is low.
- Region difference is from soil quality and other environments.

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