Climate Change, Agricultural Risk and the Development of Cooperatives

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Abstract: Cooperatives play an important role in facilitating the transformation of agricultural structure and promoting rural economy for developing countries like China. A growing body of literature has focus on reasons and mechanism of formation of cooperation. However, current studies hold their opinion in a short-run perspective but neglect historical and profound factors. This paper provides a perspective of long-term agricultural risk to illustrate the formation of cooperatives. Using the 1984-2008 county-level crop data, we find that yield fluctuation has negative effects on the number of cooperatives.

Keywords: Climate change; Agricultural risk; Cooperatives

Introduction

Cooperation plays an important role in facilitating the transformation of agricultural structure and promoting rural economy for developing countries like China. It promotes the share of knowledge, information and infrastructure (Fischer et al., 2012), reducing the cost of public in rural area (Song et al., 2014). In addition, it brings the agglomeration effect of factors of production such as labor, energy and land (Huang et al., 2013), and benefits agricultural production of further large-scale mechanization and specialization (Yang et al., 2014). A growing body of literature has focus on reasons and mechanism of formation of cooperation. The main forces include market, government and policies, finance and subsidies, institution and law (Huang and Xu, 2002; Kong et al., 2005). However, current studies hold their opinion in a short-run perspective but neglect historical and profound factors.

This paper provides a perspective of long-term agricultural risk to illustrate the formation of cooperation, which will lead to the different number of agricultural cooperatives in different areas. In China, the agricultural cooperatives are the typical carrier and manifestation of farmers' cooperation. The Chinese government has paid great attention to the development of cooperatives. Series of supportive policies have been introduced to facilitate the development of cooperatives. The law of cooperative, which was enacted in 2006, was revised recently in December 27th, 2017 to ensure the running of cooperative economy in the new situation.

Using the number of cooperatives as a representative of the formation of cooperation, we apply a typical IV strategy to develop whether the perception of long-term agricultural risk can shape the formation of cooperatives and provide an estimation of the causal effect.

Data Source and Variable Construction

The county-level crop data were obtained from the National Bureau of Statistics of China (NBS) for years 1984-2008. This county-specific crop database contains the total production, planted acres and for rice, wheat, corn and other crops. Rice and wheat yields were computed as the total production in a county divided by the total planted acres in that county. From the same source, we obtained agricultural labor, total power of agricultural machinery, fertilizer use and pesticide use for control.

Cooperatives data were obtained from the 2008 China Economic Census. The name, location, start year and capital of cooperatives were included in this database. We selected the cooperatives which established between 1984 to 2008 for observing.

Climate data were calculated by the weather data from the China Meteorological Data Sharing Service System (CMDSSS), which records daily T_{min}, T_{max}, T_{ave}, rainfall, and solar radiation for 820 weather stations in China. Daily extreme weather variables (namely extreme cold, extreme heat and extreme precipitation) are used in this study to represent climate change, which are calculated according to their respective historical average in the same month. For example, an extreme heat day occurs when the daily maximum temperature is higher than the 95% quantile of all the daily maximum temperature observations (T_{max}) in the same month and in the same place from the period 1951-2013, while a place suffered one heatwave if the extreme heat days last for a three days duration or more.

Considering that we want to study the long-term impact of agricultural rick on the development of cooperatives rather than short-term impact, we constructed a new pooled cross-section panel instead of original year-by-year panel data. We divided 25 years (1984-2008) to five periods: 1984-1988, 1989-1993, 1994-1998, 1999-2003 and 2004-2008. We calculated the average rice yield and wheat yield separately for each period and each county. Based on the average yields, mean yields and standard deviation for yields could be calculated to measure the yield fluctuation of a county, which represent agricultural risk in this study.

For the key dependent variable, we used the number of cooperatives to represent the development of cooperatives in a county. Using the same method above, we got the number of cooperatives for every county in every period. And we obtained the time of heatwaves and coldwaves for every county and period through the calculation of daily extreme weather data.

Basic Results

Since that rice and wheat are the two main grain crops in China, the planted acres of these two crops are more than other crops. As a consequence, the yield fluctuation of rice and wheat can better reflect the agricultural natural risk. First, we chose the standard deviation of yields as key independent variable to run the regression. Table 1 and 2 showed the regression results separately for rice and wheat.

Table 1. Regression Result: Impacts of Rice Yield Fluctuation on the Development of Cooperatives (Key Independent Variable: Standard Deviation of Rice Yield)

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	Cooperatives		ln(Cooperatives)		Cooperatives	
StDRice	-1.8413**	-1.7344***	-0.2244**	-0.2493***	-2.6131**	-3.4456**
	(0.8753)	(0.6291)	(0.0883)	(0.0911)	(1.2415)	(1.7114)
average agricultural labor					0.0000	0.0000
					(0.0000)	(0.0000)
average power of agricultural machinery					0.0000***	0.0000**
					(0.0000)	(0.0000)
average fertilizer use					-0.0001***	-0.0000
					(0.0001)	(0.0000)
average pesticide use					0.0014	-0.0009
					(0.0011)	(0.0012)
Observations	6,905	6,905	2,481	2,481	2,058	2,058
Province control	Yes	No	Yes	No	Yes	No
City control	No	Yes	No	Yes	No	Yes

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 2. Regression Result: Impacts of Wheat Yield Fluctuation on the Development of Cooperatives (Key Independent Variable: Standard Deviation of Wheat Yield)

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	Cooperatives		ln(Cooperatives)		Cooperatives	
StDWheat	-3.6203**	-4.3845***	-0.5846***	-0.8281***	-6.4939***	-8.4816***
	(1.4244)	(0.9920)	(0.1425)	(0.1510)	(2.3825)	(2.3196)
average agricultural labor					0.0000	0.0000
					(0.0000)	(0.0000)
average power of agricultural machinery					0.0000	0.0000*
					(0.0000)	(0.0000)
average fertilizer use					-0.0001	-0.0000
					(0.0000)	(0.0001)
average pesticide use					0.0031**	0.0014
					(0.0013)	(0.0015)
Observations	8,595	8,595	2,884	2,884	2,447	2,447
Province control	Yes	No	Yes	No	Yes	No
City control	No	Yes	No	Yes	No	Yes

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

As shown in Table 1 and 2, we could find that yield fluctuation has negative effects on the number of cooperatives. Column (1) and (2) show the basic result of impact. More specifically, a 1 standard deviation increase of rice yield fluctuation would decrease the number of cooperatives by 1.84 and a 1 standard deviation increase of wheat yield fluctuation would decrease the number of cooperatives by 3.62. Column (5) and (6) show the result with control variables. The negative effects are still robust after adding the control variables. Column (4) and (4) are sub-sample regressions. We eliminated the counties which did not have new established cooperatives in a period through calculating the Napierian Logarithm of the number of cooperatives. The sub-sample regression result still showed robust. What's more, comparing Table 1 and 2, we could find that the coefficient of standard deviation of wheat yield is almost twice over that of rice yield, which indicated that counties planting wheat had lager negative effects on the development of cooperatives than counties planting rice when facing high agricultural risk.

Next, we changed the key independent variable to test the robustness of result. We calculated the distance between real yield and average yield in a period and then add up the distance for every period and every county. Table 3 and 4 showed the result.

Table 3. Regression Result: Impacts of Rice Yield Fluctuation on the Development of Cooperatives (Key Independent Variable: Mean Rice Yield)

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	Cooperatives		ln(Cooperatives)		Cooperatives	
MeanRice	-0.4084**	-0.3914***	-0.0503**	-0.0560***	-0.5719**	-0.7716*
	(0.1936)	(0.1456)	(0.0199)	(0.0203)	(0.2796)	(0.3984)
average agricultural labor					0.0000	0.0000
					(0.0000)	(0.0000)
average power of agricultural machinery					0.0000***	0.0000**
					(0.0000)	(0.0000)
average fertilizer use					-0.0001***	-0.0000
					(0.0001)	(0.0000)
average pesticide use					0.0014	-0.0009
					(0.0011)	(0.0012)
Observations	6,905	6,905	2,481	2,481	2,058	2,058
Province control	Yes	No	Yes	No	Yes	No

City control	No	Yes	No	Yes	No	Yes

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 4. Regression Result: Impacts of Wheat Yield Fluctuation on the Development of Cooperatives (Key Independent Variable: Mean Wheat Yield)

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	Cooperatives		ln(Cooperatives)		Cooperatives	
MeanWheat	-0.8356**	-1.0090***	-0.1359***	-0.1889***	-1.5021***	-1.9376***
	(0.3368)	(0.2242)	(0.0352)	(0.0350)	(0.5430)	(0.5388)
average agricultural labor					0.0000	0.0000
					(0.0000)	(0.0000)
average power of agricultural machinery					0.0000	0.0000*
					(0.0000)	(0.0000)
average fertilizer use					-0.0001	-0.0000
					(0.0000)	(0.0001)
average pesticide use					0.0031**	0.0014
					(0.0013)	(0.0015)
Observations	8,595	8,595	2,884	2,884	2,447	2,447
Province control	Yes	No	Yes	No	Yes	No
City control	No	Yes	No	Yes	No	Yes

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Column (1) and (2) showed the basic result. The higher yield fluctuation would lead to the lower level of development of cooperatives. Column (3) and (4) showed the sub-sample regression result and column (5) and (6) showed the controlled regression result. The results are still robust and show the same characteristic as that in Table 1 and 2.

We also run the regression for different periods. As shown in Table 5 and 6, the result suggested that there was no significant relationship between yield fluctuation and the development of cooperatives for every independent period. It indicated that the impacts of agricultural risk are not restricted to any isolate period. In reverse, the impacts could be long-term and profound.

Table 5. Regression Result: Impacts of Yield Fluctuation on the Development of Cooperatives for Different Periods (Key Independent Variable: Standard Deviation of Yield)

	(1)	(2)	(3)	(4)	(5)
VARIABLES	PERIOD1	PERIOD2	PERIOD3	PERIOD4	PERIOD5
Panel A: Rice					
StDRice	-0.1759*	0.0435	-0.1163	-0.0319	0.2889
	(0.1061)	(0.1810)	(0.1743)	(0.4552)	(2.3230)
Observations	1,381	1,381	1,381	1,381	1,381
R-squared	0.3621	0.4338	0.2368	0.4287	0.5635
Panel B: Wheat					
StDWheat	0.3352	0.0596	-0.7652	-0.6857	-0.0357
	(0.4963)	(0.1776)	(0.7042)	(1.1312)	(2.4179)
Observations	1,719	1,719	1,719	1,719	1,719
R-squared	0.3491	0.4300	0.2170	0.4700	0.5217

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 6. Regression Result: Impacts of Yield Fluctuation on the Development of Cooperatives for Different Periods (Key Independent Variable: Mean Yield)

	(1)	(2)	(3)	(4)	(5)
VARIABLES	PERIOD1	PERIOD2	PERIOD3	PERIOD4	PERIOD5
Panel A: Rice					
MeanRice	-0.0461*	0.0044	-0.0323	-0.0153	0.1168
	(0.0249)	(0.0370)	(0.0361)	(0.1141)	(0.5355)
Observations	1,381	1,381	1,381	1,381	1,381
R-squared	0.3621	0.4338	0.2368	0.4287	0.5635
Panel B: Wheat					
MeanWheat	0.0818	0.0233	-0.1598	-0.1884	0.0077
	(0.1058)	(0.0446)	(0.1460)	(0.2732)	(0.5414)
Observations	1,719	1,719	1,719	1,719	1,719
R-squared	0.3491	0.4300	0.2170	0.4701	0.5217

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Considering the endogeneity problem of omitted variables, we run the second-stage regression using the climate change as instrument variables, which was defined as the time of extreme weather. The data of extreme weather was separated to four seasons. According to the growth period of rice and wheat, the extreme weather in summer and autumn would affect the rice yield and the extreme weather in spring and winter would affect the yield of wheat. Table 7 showed the instrument variables result.

Table 7. Two-Stage Regression Result: Impacts of Yield Fluctuation on the Development of Cooperatives (Instrument Variables: Extreme Weather: Heatwave & Coldwave)

	(1)	(2)	(3)	(4)
VARIABLES	Cooperatives	Cooperatives	Cooperatives	Cooperatives
StDRice	-27.7255**			
	(12.2452)			
MeanRice		-7.1927**		
		(3.1565)		
StDWheat			-166.0679***	
			(46.7448)	
MeanWheat				-38.2309***
				(11.0729)
Control	Yes	Yes	Yes	Yes
Fixed Effect	Yes	Yes	Yes	Yes
Observations	1,696	1,696	2,034	2,034
R-squared	-0.0270	-0.0608	-1.7691	-1.7584
Number of county_code	848	848	1,017	1,017

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Column (1) and (2) showed the IV results for rice and column (3) and (4) showed the results of wheat. Though the sample size was narrowed since the data attrition of control variables, the coefficients were significant and robust. Using climate change as instrument variable, the yield fluctuation has negative impacts on the development of cooperatives for both two crops. It was consistent with the OLS results. So, we could draw a conclusion that high yield fluctuation, which means high agricultural natural risk, would decrease the development of cooperatives in most counties of China. But comparing the coefficients of rice and wheat, we could find that the negative impacts in counties planting wheat were lager than counties planting rice.

Actually, the results of negative impacts were unexpected. We further considered whether there were U-relationship between yield fluctuation and the development of cooperatives. We added the quadratic term of key independent variables into regression and Table 8 and 9 showed the results.

Table 8. Regression Result: Impacts of Rice Yield Fluctuation on the Development of Cooperatives (Adding quadratic term)

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	Cooperatives		ln(Cooperatives)		Cooperatives	
Panel A						
StDRice	-4.0423*	-3.5291**	-0.5734***	-0.4717**	-4.9236*	-6.1913*
	(2.1271)	(1.4277)	(0.2194)	(0.2035)	(2.5251)	(3.3206)
$StDRice^2$	1.3452	1.0861*	0.2175**	0.1423	1.2019	1.3764
	(0.8916)	(0.6198)	(0.0938)	(0.0948)	(0.8502)	(0.9611)
Control	No	No	No	No	Yes	Yes
Province control	Yes	No	Yes	No	Yes	No
City control	No	Yes	No	Yes	No	Yes
Observations	6,905	6,905	2,481	2,481	2,058	2,058
Panel B						
MeanRice	-0.9780**	-0.8519**	-0.1295***	-0.1086**	-1.1712*	-1.4864*
	(0.4868)	(0.3368)	(0.0469)	(0.0443)	(0.6140)	(0.8177)
$MeanRice^2$	0.0804*	0.0645*	0.0111**	0.0076*	0.0751	0.0878
	(0.0478)	(0.0333)	(0.0044)	(0.0046)	(0.0529)	(0.0619)
Control	No	No	No	No	Yes	Yes
Province control	Yes	No	Yes	No	Yes	No
City control	No	Yes	No	Yes	No	Yes
Observations	6,905	6,905	2,481	2,481	2,058	2,058

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 9. Regression Result: Impacts of Wheat Yield Fluctuation on the Development of Cooperatives (Adding quadratic term)

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	Cooperatives		ln(Cooperatives)		Cooperatives	
Panel A						
StDWheat	-11.4290***	-12.6502***	-1.6453***	-2.1760***	-12.4695***	-18.1312***
	(3.9142)	(2.4990)	(0.3897)	(0.4340)	(3.9037)	(4.7180)
$StDWheat^2$	9.8249***	10.3492***	1.2999***	1.6619***	6.7461**	10.8104***
	(3.4316)	(2.3236)	(0.3910)	(0.5080)	(2.7293)	(3.7283)
Control	No	No	No	No	Yes	Yes
Province control	Yes	No	Yes	No	Yes	No
City control	No	Yes	No	Yes	No	Yes
Observations	8,595	8,595	2,884	2,884	2,447	2,447
Panel B						
MeanWheat	-2.6158***	-2.8990***	-0.3856***	-0.5188***	-2.7670***	-4.0913***
	(0.8704)	(0.5642)	(0.0839)	(0.0916)	(0.8612)	(1.0649)
$MeanWheat^2$	0.5182***	0.5480***	0.0709***	0.0943***	0.3336**	0.5647***
	(0.1743)	(0.1199)	(0.0184)	(0.0239)	(0.1340)	(0.1957)
Control	No	No	No	No	Yes	Yes
Province control	Yes	No	Yes	No	Yes	No
City control	No	Yes	No	Yes	No	Yes
Observations	8,595	8,595	2,884	2,884	2,447	2,447

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

In Table 8, we could find that the coefficients of quadratic term ($StDRice^2$ and $MeanRice^2$) were not stably significant but there was still a trend of U-relationship between rice yield fluctuation and the development of cooperatives. And we could find a significant U-relationship in Table 9 for wheat yield fluctuation. It showed that the impacts of yield fluctuation were not simply negative but varied with the degree of agricultural risk. In the condition of low yield fluctuation, the impacts on the development of cooperatives were negative. On the other hand, in the condition of high yield fluctuation, the impacts were positive and farmers would seek for cooperation.

Conclusion

In this paper, we basically found that the yield fluctuation has negative impacts on the development of cooperatives for both two crops. Using climate change as instrument variable, we came to the same conclusion. With further consideration, we found that impacts were not linear but a U-relationship. Under the condition of low-middle level yield fluctuation, the increase of yield fluctuation would reduce the development of cooperatives. However, in the condition of middle-high level yield fluctuation, the increase of yield fluctuation would promote the development of cooperatives to face the high agricultural risk.