The Change of the Weather Risk by Global Warming and the Impact on the Yield of Wheat in Adana, Turkey

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1. Introduction

The researchers of agricultural economics have tried to estimate the impact of weather factors on the yield and the profitability of crops using econometric way. Climate change or global warming changes directly the background of crops. Then, farmers will correspond to the change of the background of crops: for example, changing the date of sowing and changing the amount of fertilizer. Hence, to estimate the impact of climate change on the yield and the profitability of crops, it is important to consider the farmers' responses to climate change. Estimating the reduced form function which assumes the profit maximizing farmers (yield response function, profit function and etc.) is useful to capture the response of farmers to the exogenous factors that affect the growth of crops and the profitability. Kaufmann and Snell (1997) and Sgerson and Dixon (1999) estimated the yield response function and the profit function respectively to quantify the impact of farmers' responses to the climate change on the yield or the profitability of crops.

Global warming affects not only the average weather condition but also the variance. If weather condition becomes risk factors for farmers and the farmers have risk averse utility functions, the change of variance will affect the average productivity of crops through the responses of the farmers to the change of weather risk. Then, the farmer's response to the change of the weather risk by climate change is comprised in the part of the farmers' responses to the climate change. However, the above researches which estimated the reduced form function did not consider the change of the weather risk.

The aim of the report is to conjecture the yield of wheat in Adana under climate change with the consideration of the farmers' responses to the change of the weather risk by global warming. For this purpose, the report introduces the reduced-form yield response function that is derived from the expected utility maximization theory under weather uncertainty. Then, the function is estimated using wheat production data of district in Adana, Turkey.

2. The Model

Assume a farmer who grows wheat on his or her plot. We assume that the production technology has constant returns to scale and multiplicative weather risk. Then, the production function of wheat is expressed as

$$y = Leg\left(x, h\right),$$

where, *y* is production amount of wheat, *L* is the size of plot, *x* is the amount of fertilizer, *h* is a vector of exogenous factors, and *e* is the weather risk which the farmer confronts. Weather risk is assumed to obey the cumulative distribution function *F(e)* between closed interval [*a*, *b*]. Then, if the farmer is risk averse, his or her problem which maximizes the expected utility can be expressed as

$$\max_{x} \int_a^b U\left[pLeg\left(x, h\right) - rLx \right] \mathrm{d}F\left(e\right),$$

where, $U[\cdot]$ is the von Neumann and Morgenstern utility function, *p* is the price of wheat products, and *r* is the price of fertilizer.

Pope and Chavas (1994) proved that, if the technology has multiplicative risk, the cost function $C\left(\bar{q}, r, h\right)$ which minimizes the cost of the subjective expected yield $\bar{q}$ and is coherent with the expected utility theory can be defined. Hence, the above problem which maximize expected utility can be rewritten as

$$\max_{\bar{q}} = \int_a^b U\left[pLe\bar{q} - LC\left(\bar{q}, r, h\right) \right] \mathrm{d}F\left(e\right).$$

In this problem, the farmer chooses the optimal expected yield of wheat which maximizes his or her expected utility. Then, the optimal expected yield is defined by $\bar{q}^*\left(p, r, h, \bar{e}, \sigma^2\right)$, where, $\bar{e}$ is the expected value of the weather risk and σ^2 is the variance of the weather risk[1]. The actual yield that the farmer can gain depends on the realization of the weather risk. The relationship $\bar{e}q = e\bar{q}^*$ consists between the actual yield and the optimal expected yield, because the technology of wheat has multiplicative weather risk. Hence, the reduced-form yield response function of wheat can be expressed as

$$q = \frac{e}{\bar{e}}\bar{q}^*\left(p, r, L, h, \bar{e}, \sigma^2\right).$$

Taking the logarithm of the both side of the equation and assuming the Cobb-Douglas function for the optimal expected yield function, the reduced-form yield response function is rewritten as

$$\begin{aligned} \ln q = \alpha_0 + \alpha_p \ln p + \alpha_r \ln r + \alpha_l \ln L + \\ \beta' \ln h + (\gamma - 1)\ln \bar{e} + \eta \ln \sigma^2 + \ln e. \end{aligned} \quad (1)$$

Estimating this yield response function, we can quantify the effect of farmers' responses to weather risk on the yield of wheat[2].

3. Data and Empirical Strategy

As mentioned above, the main aim of this paper is to clear how the farmers adapt to the change of the weather risk and how the adaptation affect the yield of wheat in Adana. For this purpose, the wheat production data at district level in Adana is utilized for the estimation of the yield response function (eq:1). However, some strategies are needed to estimate the yield response function.

The data consists the production data of wheat from 1991 to 2003. The main variety of wheat planted in Adana is spring wheat. But, in the northern part and mountain area of Adana, winter wheat is the main variety. Because of this, it is not appropriate to estimate the yield response function using together the data of the district where the spring wheat is grown and the district where the winter wheat is grown. Then, the districts where winter wheat is grown are eliminated from the estimation[3].

The empirical model introduced above allows only one source of risk. Hence, we need to define the duration when the weather condition is the risk factor for the wheat producing farmers in Adana. The farm survey conducted in 2004 clarified that the weather condition from March to May is the main source of weather risk in Adana (Kusadokoro and Asami (2005)). Then, we assume that the risk source for the wheat farmers in Adana is only the weather condition of March to May.

There are several kind of weather conditions: for example, temperature, precipitation, isolation duration, and etc. Then, it is needed to combine the several weather conditions for estimating the yield function. In this paper, Aridity index developed by Oury (1965) is used for this purpose. Aridity index is defined by

$$W = R / 1.07^T.$$

W is the aridity index, R is the total monthly precipitation (mm), and T is the average monthly temperature (□). Hence, the index quotes higher value, if the precipitation becomes higher and the temperature becomes lower. Then, small value of the index shows that the level of aridity is high. We define the weather risk as the average value of the aridity index of March to May.

The weather risk was defined. Then, the expected value and the variance of weather risk must be calculated to estimate the yield response function. The paper adopts the adaptive expectation approach, that was used by Chavas and Holt (1990) and others, to calculate the expected value and the variance. The expected value and the variance are defined as follows:

$$\bar{e}_t = E\left(e_t\right) = E\left(e_t - e_{t-1}\right) + e_{t-1}, \text{ and}$$

$$\sigma_t = \operatorname{var}\left(e_t\right) = \sum_{j=1}^{3} w_j \left[e_{t-1} - E_{t-1}\left(e_{t-1}\right)\right]^2.$$

w_j shows the weight value: from w_1, the value is

[1] More precisely, the optimal expected yield depends on the more higher moment of weather risk distribution. However, the report eliminates the moments higher than second order for simplification.

[2] I conducted comparative statics of the optimal expecred yield function and analyzed how the risk averse farmers response to the change of weather risk and other exogenous factors (product price, fertilizer price, and etc.) The results are not discussed in the report due to space limitation.

[3] Finally, we used the data of 12 districts for the estimation.

0.5, 0.33, and 0.17, respectively.

Table 1 shows the definition of independent variables that explain the yield of wheat in Adana. Aridity index for November and December are chosen as the other exogenous factors which affect the yield of wheat in Adana. The reason is that the weather condition of this season determines the early growth of wheat. Then, the weather condition of this season may be crucial for the yield of wheat.

4. Result of the Estimation

Table 2 shows the result of the estimation of the yield response function (eq:1). The data used here consist cross sectional and time series data (i.e. panel data). Then, it is needed to test whether there is fixed effect or not. The *F* test rejected the null hypothesis that there is no fixed effect. Hence, fixed effect model and random effect model were estimated and Housman test was conducted to examine which of the models is appropriate. The test chose the fixed effect model.

Firstly, we will see the effect of the weather risk on the yield of wheat. The coefficient of the expected value of the weather risk was positive and statistically enough at 1% level. This means that, if the farmer has the expectation that the aridity index between March to May becomes high (i.e. high precipitation and low temperature), the farmer chooses higher yield. The coefficient of the variance of the weather risk was minus and statistically enough at 5% level. This means that, if the farmer has the expectation that the variability of aridity index between March to May becomes high, the farmer chooses lower yield.

Next, we will see the effect of the other independent variables on the yield. The coefficient of the price of wheat price was minus and statistically enough at 10%. This result is odd under the world of certainty. However, when there is risk for the production, high price of products means that the variability of profit is also high. Hence, it is possible that the risk averse farmer chooses to decrease the yield when the price of products increases.

5. The Effect of Global Warming

In this section, we simulate the yield of wheat under climate change using the coefficients of the yield response function and pseudo warming data which projected the climate condition of 2070s'.

Generally, the change of risk refers to the situation that only the variability of risk varies with the mean value is held to be constant. Then, for the purpose of quantifying the farmers' response to the change of weather risk, it is appropriate to conduct the sensitivity analysis. However, because global warming affects not only the variance of the weather risk, but also the mean value, the sensitivity analysis cannot say rich suggestion about the effect of global warming on the yield of wheat in Adana. The paper simulates the yield of wheat with the coefficients of weather risk (expectation value and variance) and the yield without the coefficients of weather risk, and then, compares these simulated yields. The former shows the yield that the risk averse farmer can achieve with the farmer' response to the weather risk, and the later shows the yield that the farmer can get, if there is no weather risk.

Table 3 shows the aridity index calculated from pseudo warming data. The result shows that the weather condition of Adana will be parched by global warming. Standard deviation of the weather risk (March to May) decreases by global warming.

Table1 The definition of independent variables

Variables	Definition
WPRICE	Price of wheat products
FPRICE	Price of fertilizer
WAREA	Area for wheat per population in rural area
AR11	Aridity index for November
AR12	Aridity index for December
EAR0305	Expected value of the weather risk
VAR0305	Variance of the weather risk

Table 2 The result of the estimation

	Fixed effect model		
	Coefficient	CF of variation	
WPRICE	-0.607	0.141	***
FPRICE	-0.211	0.14	
WAREA	0.029	0.075	
AR11	-0.02	0.015	
AR12	0.049	0.023	**
EAR0305	1.104	0.055	***
VAR0305	-0.038	0.019	**
Constant	14.876	1.824	***
F test = 7.18 (0.000)1)			
Hausman test = 23.51 (0.001)1)			

*** shows statisticaly enough at 1%,
** at 5%, and * at 10%.
1) The figure in the parentheses shows p valu

Table 3 Aridity index under pseudo warming

		Controll run	Global warming
Nov.	Mean	25.4	14.93
	SD	15.41	10.94
	CV	60.68%	73.24%
Dec.	Mean	103.14	37.72
	SD	83.34	35.21
	CV	80.81%	93.34%
Mar. to May	Mean	50.97	31.92
	SD	25.12	21.37
	CV	49.29%	69.10%

Then, the degree of weather risk the wheat producing farmer in Adana confronts will decrease, but the relative degree will increase.

Table 4 shows the result of the simulation of yield of wheat. (A) shows the estimated yield with the coefficients of weather risk, and (B) shows the estimated yield without the coefficients of weather risk. (C) is the difference of the yield with weather risk and the yield without weather risk. Then, the value reflects the amount of yield that the risk averse farmers lose because of the existence of the weather risk.

The result shows that the yield of wheat will decrease by global warming. The main reason of the decrease is the aridification of Adana region. The effect of the weather risk on the yield will decreases by global warming because of the decrease of the weather risk.

6. Result

The paper quantifies the effect of the farmers' responses to the change of weather risk and simulated the yield of wheat in Adana under global warming. The result shows that the yield of wheat will decrease by global warming, even if we consider the existence of weather risk and the farmers' response to it. It must be noted that the paper did not consider the effect of CO_2 concentration.

7. References

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Table 4 Estimated yield of wheat with pseudo warming

Unit:kg/ha

		Station data	Control run	Global Warming
Estimated yield	with weather risk(A)	3864	4062	3699
	witout weather risk(B)	4610	4931	4444
Effect of Weather risk	Absolute value(C=B-A)	746	869	745
	Proportion(D=100*C/B)	16.18%	17.62%	16.76%