7D-2

Farm Characteristics and the Impact of Temperature Rise: Evidence from Corn Yields in US

By Yi-Chun Ko*, Shinsuke Uchida**, and Akira Hibiki***

l. Introduction and Objectives

There is a consensus that extreme heat can reduce crop yields and directly affect future food supplies. (e.g., Schlenker and Roberts 2009 *PNAS*, Burke and Emerick 2016 *AEJ Policy*, Chen et al. 2016 *JEEM*, Kawasaki and Uchida 2016 *AJAE*, Aragón et al. 2021 *AEJ Policy*). A number of practices and techniques are available to farmers which mitigate yield loss from extreme hot temperatures, such as heat-tolerant cultivar adoption and water management. The degree to which farmers adopt them, however, depends on farm characteristics. This study specifically examines how farmer's age structure and irrigated cropland influence crop yields under heat stress. Aging at an early stage positively impacts production as farmers accumulate more experiences and knowledge from learning-by-doing, while it gradually lowers cognitive and physical skills and consequently reduces productivity (Tauer 1984 *North Central J. of Agri. Econ.*, Eggertson et al. 2019 *AER Insights*). Irrigation technology can enhance efficient water management to control a resilient environment to heat stress by cooling the canopy temperature, thereby alleviating the negative hot temperature effects (Troy et al. 2015 *Environ. Res. Lett.*). In contrast, farms without irrigation systems may be vulnerable to heat stress.

2. Methodology and Data

We construct the following baseline model to explore the effect of farmer's age and irrigated cropland on the relationship between temperatures and corn yields using the US county-level panel data in 1978-2017. We use growing degree days (GDD) which measures the cumulative heat that crops receive during the growing season. We use GDD below the temperature threshold (T) and GDD above T.[1]

$$\log(\mathrm{Y}_{it}) = \beta_1 \mathrm{GDD}_{\le T\,it} + \beta_2\left(\mathrm{GDD}_{\le T\,it} \times \mathrm{X}_{it}\right) + \beta_3 \mathrm{GDD}_{>T\,it} + \beta_4\left(\mathrm{GDD}_{>T\,it} \times \mathrm{X}_{it}\right)$$

$$+\mathbf{Z}_{it}\gamma + \mathrm{C}_i + \lambda_{st} + \varepsilon_{it} \qquad (1),$$

where Y_{it} is corn yield in county i in year t, $\mathrm{GDD}_{\le T\,it}$ is GDD below T, $\mathrm{GDD}_{>T\,it}$ is GDD above T, X_{it} represents the farm characteristics measured by the share of farmers under 45 years old and the share of farmers over 65 years old, or the share of acres irrigated, a vector $\mathbf{Z}_{it}$ includes the sum of daily precipitation over the growing season and their quadratic terms as well as farmer characteristics, the county fixed effects C_i account for county-specific factors such as geological conditions, the state-by-year fixed effects λ_{st} account for technological change and policy interventions in state s, and ε_{it} is the error term.

* Asian Growth Research Institute
** Corresponding author: Graduate School of Economics, Nagoya City University, 〒467-8501 Yamanohata 1, Mizuho-cho, Mizuho-ku, Nagoya, Aichi, Japan (E-mail: suchida@econ.nagoya-cu.ac.jp);
*** Graduate School of Economics and Management, Tohoku University

[1] GDD below T is bounded from the lower threshold set as 0°C. Each GDD is computed as follows. For example, if T = 19 and a set of daily temperatures during the growing season is -1, 15, 18, 21, and 24, GDD below T is equal to 0, 15, 18, 19, and 19, and GDD above T is equal to 0, 0, 0, 2, and 5.

Agricultural data on corn acreage and yields and weather data on temperatures and precipitation are drawn from Schlenker and Roberts (2009 *PNAS*).[2] Besides, we collect farm characteristics data (age, corn areas irrigated, number of corn farms, etc.) from quinquennial Agricultural Censuses.

3. Results and Conclusion

Table 1 presents the effect of farmer's age and irrigated cropland on the temperature-yield relationship. We find in column (1) that the negative hot temperature effects increase by 0.0021% and 0.0037% with 1% increase in the share of younger farmers (below age 45) and older farmers (above age 65), respectively, although this aging effect is not statistically significant for younger farmers. Column (2) and (3) show that these negative age effects are less pronounced in irrigated areas but very strong in rainfed areas. In other words, irrigation can mitigate the negative age effects on crop yields under heat stress.

From these findings, we have some policy implications. Firstly, aging in agricultural sectors in US is likely to increase the negative hot temperature effects, and thus a policy to assist younger farmers in learning appropriate knowledge and skills about heat stress management will be useful to increment resilience under higher-temperature environment in the future. Secondly, irrigation can not only be effective in reducing the negative hot temperature effects on crop yields, but also help inexperienced and elderly farmers mitigate the yield loss from extreme hot temperatures.[3]

Table 1. Main results of the effects of age and irrigation

	All areas (1)	Irrigated areas (2)	Rainfed areas (3)
GDD above *T*	-0.0039***	-0.0044***	-0.0020*
	(0.0006)	(0.0007)	(0.0011)
GDD above *T* × age < 45	-0.0021	-0.0010	-0.0067***
	(0.0013)	(0.0014)	(0.0022)
GDD above *T* × age > 65	-0.0037**	-0.0021	-0.0084***
	(0.0015)	(0.0016)	(0.0024)
age < 45	-2.1445***	-1.7425***	-3.6843***
	(0.4616)	(0.5000)	(0.7434)
age > 65	-1.1164*	-0.5406	-2.7795***
	(0.5863)	(0.6320)	(0.8863)
Observations	49,967	49,967	49,967
Fixed effects	Cty, State-Yr	Cty, State-Yr	Cty, State-Yr
Control var.	Yes	Yes	Yes
Adjusted R^2	0.8721	0.8725	0.8725
F statistic	79.77	44.68	44.68

Notes: ***, **, and * denote 1 percent, 5 percent, and 10 percent significant levels, respectively. Data are for US counties east of the 100th meridian, 1978–2017. Standard errors clustered at the county level are reported in parentheses. Regressions are weighted by the 1978–2017 average corn area. *T*: threshold temperature; 28°C. age (< 45 and > 65) unit: 0–1 (e.g., 0.1 means 10 percent). We assign counties with no irrigation use in 1978–2017 as rainfed areas, and irrigated areas otherwise (col.2-3 from the same regression).

[2] The agricultural data used in Schlenker and Roberts (2009) is from United States Department of Agriculture (USDA). The USDA's National Agricultural Statistics Service provides annual data on corn areas and yields at the county level. The weather data is the 4 km-grid cell data from satellite on total precipitation and maximum and minimum temperatures that are aggregated to the county-day level by averaging daily values at grid cells in each crop-growing county.

[3] We also find that the share of irrigated corn acres reduces the yield loss from extreme hot temperatures (Result not shown here due to space limit), which is consistent with the previous studies examining the similar irrigation effect on wheat yields (Zaveri and Lobell 2019 *Nat. Commun.*).