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Weather Impacts the Agricultural Production Efficiency of Wheat: The Importance of Precipitation Shocks

Background

Weather affects the production environment that farmers face and, in some cases, can affect their ability to efficiently convert production inputs into outputs. Despite that the effect of weather shocks on agricultural *production* has been well documented (Donaldson, 1968; Ito and Kurosaki, 2009; Schlenker and Roberts, 2009; Tack, Barkley, and Nalley, 2015), few studies have accounted for the weather as a source of production inefficiency or lower agricultural *productivity*. In a recently published paper, we showed the effects that weather has on the production efficiency of winter wheat farms and discussed some of the implications that climate change could have on the future production efficiency of farms.

Data

This study used data for 540 Kansas winter wheat farms that were in operation between 2008-2016. Kansas winter wheat farms were chosen for two reasons. First, Kansas accounts for approximately 25% of U.S. winter wheat production, making it one of the largest wheat-producing states. Second, the Kansas Farm Management Association (KFMA) collects data on input use and output and then allocates budgets to specific crops, allowing us to directly estimate a production function and thus measuring production efficiency at the farm level.

Methods

Production efficiency is estimated by the Panel Stochastic Frontier Analysis (PSFA) model. The model is preferred over traditionally used ones such as the Data Envelopment Analysis (DEA) and the Stochastic Frontier Analysis (SFA), because (1) it allows us to directly condition technical efficiency on weather variables in a production function, and (2) it allows for the inclusion of farm fixed effects to control for farm-specific heterogeneity. The model used measures winter wheat outputs (e.g. production), inputs (e.g. land, labor, seed, fertilizer, machinery, pesticides, and other input costs associated with winter wheat production) and weather (e.g. precipitation, freezing degree days, low degree days, medium degree days, and high degree days across fall, winter, and spring within the growing season).

Primary Findings

This study had six principal findings:

1. Winter wheat farms had an average technical efficiency of 85% between 2008-2016. The lowest efficiency values occurred in 2013/14 (averaged at 63.8%), a year with an abnormally dry and cold spring.
2. Precipitation has nonlinear effects on technical efficiency, and the optimal level of precipitation is around 200 millimeters in fall and 275 millimeters in

spring.

3. Fall precipitation is the most critical factor that drives the technical efficiency, as it explains approximately 30% of the variation in technical efficiency.
4. Freezing (below 0 degrees Celsius) and high temperatures (above 32 degrees Celsius) in the spring have negative effects on technical efficiency.
5. According to our simulations, the projected increasing variability of precipitation under different climate change scenarios could largely reduce and widen the distribution of technical efficiency among winter wheat farms.
6. Our simulations also suggest that temperature warming will have a minor negative impact on technical efficiency.

Overall, this study suggests that receiving adequate precipitation in the early vegetative stage and the reproductive stage is important to maximize the production efficiency of winter wheat farms in Kansas. For this reason, the projected increasing precipitation variability in Kansas, if realized, could possibly reduce winter wheat production in Kansas.

Policy Implications

This study is among the earliest attempts to identify how weather affects farm-level technical efficiency – a commonly held belief among farmers – and to explore the potential climate change impacts on their production efficiency. These findings generate at least three policy implications:

1. It remains a challenge to sustain efficient winter wheat production given frequent weather shocks. Initial farm endowment and management practices result in winter wheat farms having a large distribution--something that could be enlarged in the future under different climate change scenarios.
2. Extension programs could help enhance farmers' ability to prepare for and react to an abnormal level of precipitation during the growing season.
3. Production practices that enhance a winter wheat's farm resilience to precipitation shocks, such as investing in irrigation equipment and soil conservation practices that leads to increased water retention, could be beneficial to sustaining efficient winter wheat production under different climate change scenarios.

Overall, this initial study is hoped to allow a better understanding of the production challenges that arise from weather shocks. We used a sample of Kansas winter wheat farms. The estimated impacts and derived conclusions may not be broadly applicable to all winter wheat-producing states. We have offered several suggestions for further research. One suggestion was that a similar analysis could be implemented on other regions or other commodities to gain broader understandings of how previously estimated impacts of climate change differ when farmer technical efficiency is used as the variable of interest.

Acknowledgments

For more information on the data, methods, results, or conclusions referenced, refer to Chen, B., Dennis, E.J., and Featherstone, A.M., Weather Impacts the Agricultural Production Efficiency of Wheat: The Importance of Precipitation Shocks. Forthcoming in *Journal of Agricultural and Resource Economics.* (link)

References

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