Measuring the Effect of Extreme Weather on Rice Production Efficiency using Zero-inefficiency Stochastic Frontier Model

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Measuring the Effect of Extreme Weather on Rice Production Efficiency using Zero-inefficiency Stochastic Frontier Model

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Introduction

- **Rice production is more vulnerable to climate change than other crops.**
- Rice is important food crop for producers and consumers in Korea
- Rice is more vulnerable to climate change than other crops.

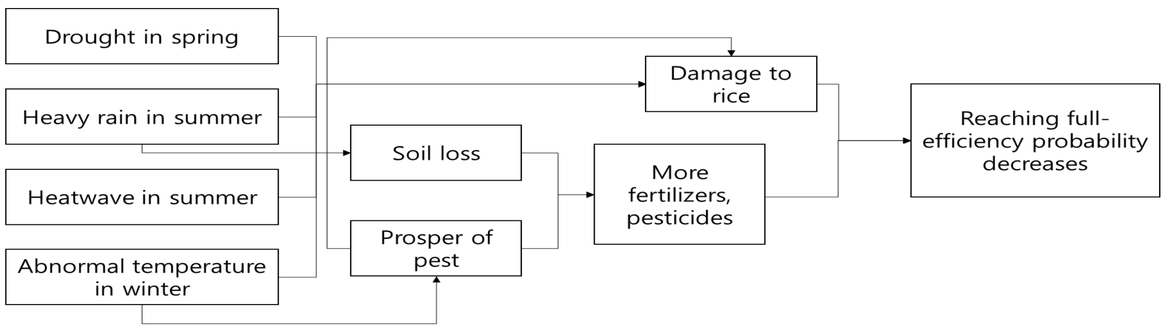
- **Adaptation policies in Korea for rice are not enough.**
- Regional governments do not aware of climate change adaptation polices especially about agriculture production.
- Rice production technology is solidified with high-input production and producers do not use new technologies.

Purpose

- **Investigation of determinants of rice production efficiency considering extreme weather.**
- **Forecasting future efficiency using RCP 8.5 by region**

Methods

• Conceptual framework



• Zero-inefficiency stochastic frontier (Kumbhkar et al., 2013)

- Without inefficiency, cost function is (1) with probability of p, with inefficiency the function is (2) with probability of 1-p.

$$ln\,Cost_i = \beta_0 + \beta_y\,ln\,y_i + \frac{1}{2}\beta_{yy}(lny_i)^2 + \sum_{k=1}^{3}\beta_k ln\,w_{k,i} + \frac{1}{2}\sum_{k=1}^{3}\sum_{l=1}^{3}\beta_{kl}lnw_{k,i}lnw_{l,i} + \sum_{k=1}^{3}\beta_{yk}lny_i lnw_{k,i} + \delta time + v_i \quad (1)$$

$$ln\,Cost_i = \beta_0 + \beta_y\,ln\,y_i + \frac{1}{2}\beta_{yy}(lny_i)^2 + \sum_{k=1}^{3}\beta_k ln\,w_{k,i} + \frac{1}{2}\sum_{k=1}^{3}\sum_{l=1}^{3}\beta_{kl}lnw_{k,i}lnw_{l,i} + \sum_{k=1}^{3}\beta_{yk}lny_i lnw_{k,i} + \delta time + e_i \quad (2)$$

$$e_i = v_i + u_i, \qquad v_i \sim N(0, {\sigma_V}^2),\ u_i \sim N^{+}(0, {\sigma_u}^2)$$

• Finding determinants of production efficiency

- P can be calculated by Bayesian rule (Kumbhakar et al., 2013).
- Using both side censored tobit model, determinants of efficiency can be found.

Categories	Variable	Effects to efficiencies
Hazard	Variance of precipitation in spring	When variance of precipitation gets larger, water supply to rice paddy is instable by drought prohibiting early stage growing
	Variance of precipitation in summer	In monsoon season of summer, heavy rain fall makes rice be washed away from rice paddy
	Minimum temperature of last winter	Larvae of harmful insects can survive when minimum temperature gets higher than before
	Maximum temperature of summer	Weeds and pests are prospering
		Quality of labor is decreasing because of high heat
Sensitivity	Age of owner	Quality of labor can be differed by age
	Acreage of rice paddy	Scale efficiency
	Time	Technology advancement

Data

- **Agriculture Cost Survey (Statistics Korea, 2019)**
- 2009 ~ 2018, 12,322 samples.

- **Automated Synoptic Observing System (Korea Meteorological Administration, 2019)**
- Everyday temperature and precipitation from 94 observatories

Results

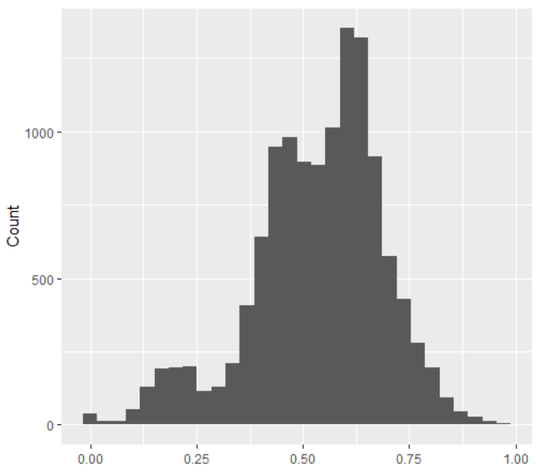
• Estimation Results of production efficiency

<Production Inefficiency by Region>

Region		Average	Maximum
Northern region	Kyunggi	0.0101	0.3638
	Kangwon	0.0086	0.2824
	Chungbuk	0.0085	0.0566
	Chungnam	0.0081	0.4630
Southern region	Jeonbuk	0.0084	0.0303
	Jeonnam	0.0089	0.0238
	Kyungbuk	0.0090	0.0189
	Kyungnam	0.0084	0.0209
Total		0.0089	0.4630

• Determinants of production efficiency

<Distribution of the Probability>



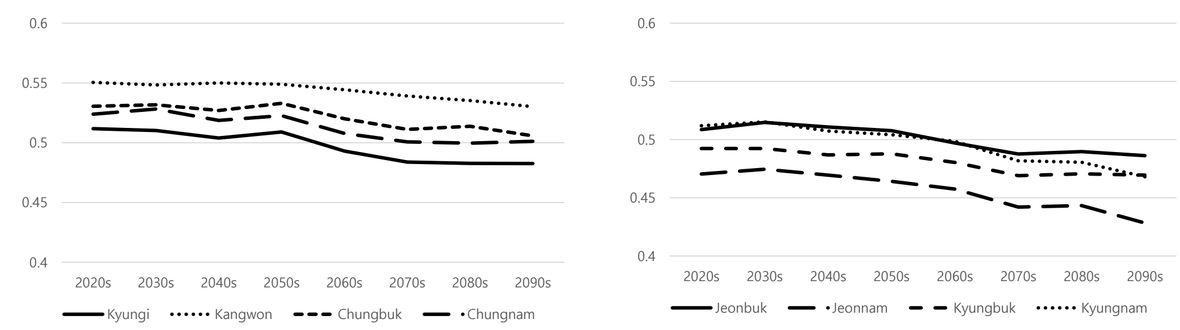
<Determinants of the Probability>

Variables		Marginal effect	Standard error
Hazard	Variance of rain in spring	-0.000024917	0.0000474
	Variance of rain in summer	-0.000033996***	0.000007048
	Maximum temperature in summer	0.020699***	0.002431
	Squared maximum temperature in summer	-0.00026733***	0.00004766
	Minimum temperature in winter	-0.012204***	0.003715
	Squared minimum temperature in winter	-0.00026747***	0.0000912
Vulnerability	Cultivation area	-0.00032777*	0.0001431
	Squared cultivation area	0.0000024715**	0.0000008085
Log-likelihood			5084.42

* means 10 %, ** means 5% and *** means 1% statistically significant.

• Forecasting result of the probability

<Forecasted Probability Changes using RCP 8.5>



Conclusion

- **Efficiency loss due to climate change threats to food security in Korea.**
- Breadbasket of Korea is in southern region and it is forecasted that the region will have more loss.
- Main producing area of rice can be moved to north.

- **Adaptation policy by region and extreme weather is needed.**
- Drought in spring does not have significance because of well developed reservoirs, however soon, their persisting period will be passed.
- To prevent damages from extreme weather, early warning systems, maintenance of irrigation system and disaster insurance is demanding national widely
- By region, Kangwon and Kyunggi needs to prepare of large scale rice production.
- Southern regions recommend to change their rice paddy to dry field for producing other crops.

References

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