Precautionary Motives in Optimal Corn Seeding Rate Decisions

IOWA STATE UNIVERSITY

Yue Zhao[1]; David Hennessy[1]; Alexander Lindsey[2]

[1]Iowa State University, [2]The Ohio State University

THE OHIO STATE UNIVERSITY

Abstract

We find that farmers' precautionary motives have small impact on optimal corn seeding rates (i.e., the number of seed planted per acre of land), contrary to their significant influence on savings and asset decisions. Our conceptual model shows that precautionary motives increase seeding rates when seeds reduce yield risk and decrease them when seeds increase yield risk. Analysis of Ohio and Illinois field data reveals a U-shaped yield risk response to seeding rates. Simulations indicate a 0.2% seeding rate increase in Ohio and a 0.19% decrease in Illinois due to precautionary motives, while yield insurance reduces optimal seeding rates in both states by up to 2%.

Introduction

When facing production risks, crop producers adjust their input usage to minimize expected costs (Kimball, 1991). This adjustment often results in optimal input levels that differ from those in risk-free scenarios. Seeds are essential but can have negative environmental impacts, particularly when treated with chemicals like neonicotinoids, which harm pollinators. While the U.S. has not banned neonicotinoids, the EPA has restricted their use to protect pollinators. This paper investigates how precautionary motives affect corn producers' optimal seeding rates and explores the resulting environmental impacts, specifically whether these motives lead to increased seed usage.

Conceptual Model

We consider a risk-averse corn producer who, as a price taker, decides on a seeding rate at planting, amid uncertain growing conditions. Using the Just and Pope (1978) production function, we analyze how input levels influence both the expected yield and its risk. Focusing on per-acre analysis, the relationship between corn yield (y) and seeding rate (s) is defined as:

$$(1) \quad y(s,\varphi) = f(s) + \varphi(s)\delta\varepsilon,$$

where $f(s)$ is the mean yield and $\varphi(s)\delta\varepsilon$ represents yield risk. We then consider the risk-averse producer's expected utility (EU) maximization problem:

$$(2) \quad \max_s EU(\pi) = \max_s EU(f(s) + \varphi(s)\delta\varepsilon - ws),$$

where profit (π) has been normalized by output price, w is the ratio of seed cost over output price, and the utility function is increasing and concave. The first-order condition is:

$$(3) \quad f_s - w = -\varphi_s \frac{\delta E(U_\pi \varepsilon)}{E(U_\pi)}.$$

We derive four propositions:

Proposition 1: The existence of yield risk does not affect the optimal seeding rate choice by a risk-neutral producer, but a risk-averse producer applies more (less) seed than a risk-neutral producer whenever planting higher seeding rate decreases (increases) yield risk.

Proposition 2: For a risk-neutral producer, an increase in the ratio of seed cost to output price decreases optimal seeding rate. For a risk-averse producer with DARA utility, if seed is
i) risk-increasing, an increase in the price ratio decreases the optimal seeding rate;
ii) risk-reducing, the response of optimal seeding rate to an increase in the price ratio is not determined.

Proposition 3: Under DARA, when seed is a risk-reducing input then increasing yield risk increases the optimal seeding rate. When seed is a risk-increasing input then increasing yield risk decreases the optimal seeding rate.

Proposition 4: When seed is risk-reducing, a more risk averse decision maker increases her seeding rate. When seed is risk-increasing, a more risk averse decision maker lowers her seeding rate.

Production Function Estimation

We use data from 376 agronomic trials conducted in Ohio and Illinois from 2012 to 2016 to estimate the production function. Figures 1 (a)-(d) display the estimated yield mean and standard deviation responses to plant density (Ohio) and seeding rate (Illinois).

Simulation

We simulate how precautionary motives affect seeding rates adopting a hyperbolic absolute risk aversion (HARA) utility function. In all simulations we consider a typical Midwest corn farm that produces both corn and soybeans at the same time. We assume that the producer owns 2,000 acres out of which 1,000 acres each are planted with corn and soybean. We show simulation results for Ohio and Illinois in Table 1. We then simulate how crop insurance affects seeding rate decisions following methods in Babcock & Hennessy (1996). Results in Table 2 and Table 3, show that adopting yield insurance leads to reduced optimal seeding rates for both risk-neutral and risk-averse producers.

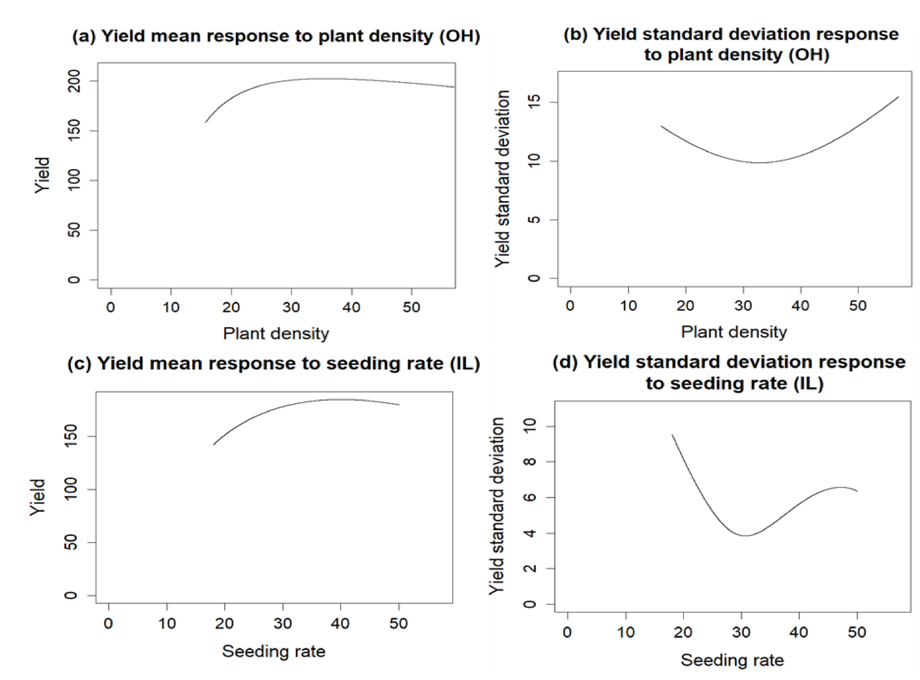

Figure 1. Production

Table 1. Impacts of Precautionary Motives on Optimal Seeding Rates for Ohio and Illinois under Expected Utility Theory

	Weather risks	Weather & soybean production profit risks		Weather risks	Weather & soybean production profit risks
	Ohio			Illinois	
w/p	0.7	0.7	w/p	0.76	0.76
$\bar{\pi}$ ($)	728,211	729,352	$\bar{\pi}$ ($)	557,428	556,236
m	122,049	150,726	m	71,870	150,905
$\theta_1(In=\bar{\pi}/3)$	0.21	0.26	$\theta_1(In=\bar{\pi}/3)$	0.14	0.29
$\theta_2(In=2\times\bar{\pi}/3)$	0.15	0.18	$\theta_2(In=2\times\bar{\pi}/3)$	0.1	0.21
$\theta_3(In=\bar{\pi})$	0.11	0.14	$\theta_3(In=\bar{\pi})$	0.08	0.17
h^{rn}	29.383	29.383	s^{rn}	34.235	34.235
h^{ra}	29.433	29.434	s^{ra}	34.175	34.169
Δh	0.05	0.059	Δs	-0.06	-0.066
Δh(%)	0.17%	0.20%	Δs(%)	-0.18%	-0.19%
y^{rn}	200.52	200.52	y^{rn}	182.75	182.75
y^{ra}	200.56	200.56	y^{ra}	182.71	182.70
ΔY (%)	0.020%	0.020%	ΔY (%)	-0.022%	-0.027%

Table 2. Impacts of Yield Insurance on Optimal Seeding Rate Choices for Ohio

Risk neutrality			
Percentage of mean yield	0	75%	85%
Yield coverage level (bushel/acre)	0	150	170
Seeding rate (1,000 seeds/acre)	29.383	29.297 (-0.29%)	29.056 (-1.11%)
Seeding rate change (1,000 seeds/acre)	NA	-0.086	-0.327
m^{in} ($\$/1,000\,acre$)	150,726	149,508	141,158
$\bar{\pi}^{in}$ ($\$/1,000\,acre$)	729,352	729,874	733,159
y^{in} ($bushel/acre$)	200.52	200.46	200.28
Risk aversion: $\theta_1\left(In=\frac{1}{3}\bar{\pi}\right)=0.27$, $\theta_2\left(In=\frac{2}{3}\bar{\pi}\right)=0.17$, $\theta_3(In=\bar{\pi})=0.13$, $\bar{\pi}=729{,}352$, $m=150{,}726$, $a=0.001$, $b=170$, $\gamma=-1$			
Percentage of mean yield	0	75%	85%
Yield coverage level (bushel/acre)	0	150	170
Seeding rate (1,000 seeds/acre)	29.434	29.274 (-0.54%)	28.882 (-1.88%)
Seeding rate change (1,000 seeds/acre)	NA	-0.16	-0.552
m^{in} ($\$/1,000\,acre$)	150,726	149,508	141,088
$\bar{\pi}^{in}$ ($\$/1,000\,acre$)	729,352	729,874	733,148
y^{in} ($bushel/acre$)	200.56	200.44	200.15

Table 3. Impacts of Yield Insurance on Optimal Seeding Rate Choices for Illinois

Risk neutrality			
Percentage of mean yield	0	75%	85%
Yield coverage level (bushel/acre)	0	137	155
Seeding rate (1,000 seeds/acre)	34.235	34.231 (-0.01%)	34.134 (-0.3%)
Seeding rate change (1,000 seeds/acre)	NA	-0.004	-0.101
m^{in} ($\$/1,000\,acre$)	93,848	150,885	149,093
$\bar{\pi}^{in}$ ($\$/1,000\,acre$)	557,830	556,246	557,148
y^{in} ($bushel/acre$)	182.75	182.75	182.67
Risk aversion: $\theta_1\left(In=\frac{1}{3}\bar{\pi}\right)=0.34$, $\theta_2\left(In=\frac{2}{3}\bar{\pi}\right)=0.29$, $\theta_3(In=\bar{\pi})=0.25$, $\bar{\pi}=557{,}985$, $m=221{,}872$, $a=0.001$, $b=170$, $\gamma=-1$			
Percentage of mean yield	0	75%	85%
Yield coverage level (bushel/acre)	0	137	155
Seeding rate (1,000 seeds/acre)	34.169	34.161 (-0.20%)	33.999 (-0.50%)
Seeding rate change (1,000 seeds/acre)	NA	-0.008	-0.17
m^{in} ($\$/1,000\,acre$)	150,905	150,876	149,062
$\bar{\pi}^{in}$ ($\$/1,000\,acre$)	556,236	556,244	557,142
y^{in} ($bushel/acre$)	182.70	182.70	182.57

Discussion

We find that precautionary motives can lead to either over-application or under-application of seeds, depending on the production technology and market prices of seed and grain. The ambiguity in precautionary motives' impacts on seeding rate is attributed to a U-shaped response curve of yield variability to seeding rate. We conduct empirical and simulation analysis based on agronomic field experiment data collected from Ohio and Illinois during 2012-2016. Results show that, unlike the significant effects of precautionary motives on saving, asset holding, and portfolio decisions identified in the literature, precautionary motives have only a minor influence on farmers' seeding rate decisions. The small impacts result from limited marginal effects of seeding rate on corn yield risks. The finding is in some regards unsurprising. Low seeding rates create the risk of unused natural resources while high seeding rates create risk from over-crowding a fields natural resources, especially under drought conditions. Yield risk from high application rates for other inputs may not be as large because the input not used by the plant may be washed into the environment.

Considering the negative environmental impacts of seeds mainly induced by neonicotinoids seed treatment, our results suggest that efforts to reduce corn farmers' excess seed use by altering their precautionary motives may not yield substantial environmental benefits. Consequently, adopting integrated pest management practices is recommended to mitigate the adverse environmental outcomes associated with neonicotinoid use. Moreover, our analysis indicates that yield insurance has significant reduction effects on seeding rate among both risk-neutral and risk-averse producers. Whether crop insurance induces overall reduction in seed usage is an empirical issue and needs to consider its impacts in the extensive margin.

References

1. Just, Richard E., and Rulon D. Pope. 1978. "Stochastic Specification of Production Functions and Economic Implications." *Journal of Econometrics* 7(1): 67-86.
2. Babcock, Bruce A., and David A. Hennessy. 1996. "Input Demand under Yield and Revenue Insurance." *American Journal of Agricultural Economics* 78(2): 416-427.

Contact

YueZhao
Email: yzhao19@iastate.edu
Website: https://yuezhao-isu.weebly.com/