Basis Risk and Farmers' Participation in the U.S. Federal Crop Insurance Program: A Conceptual Framework and its Application

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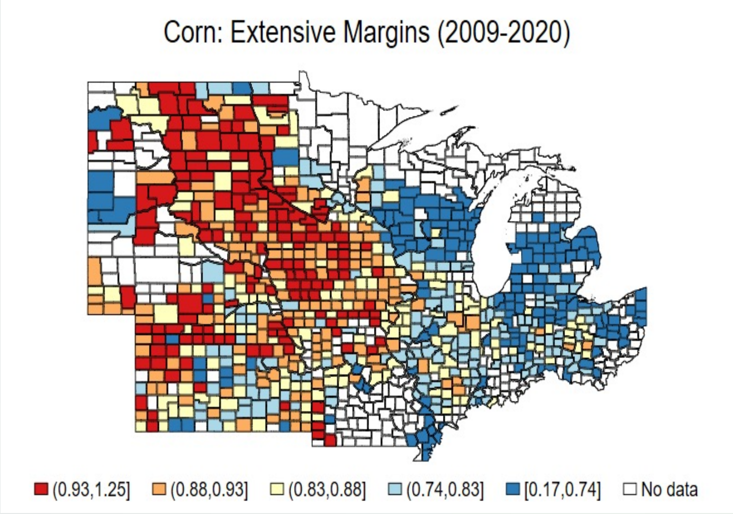
Outline

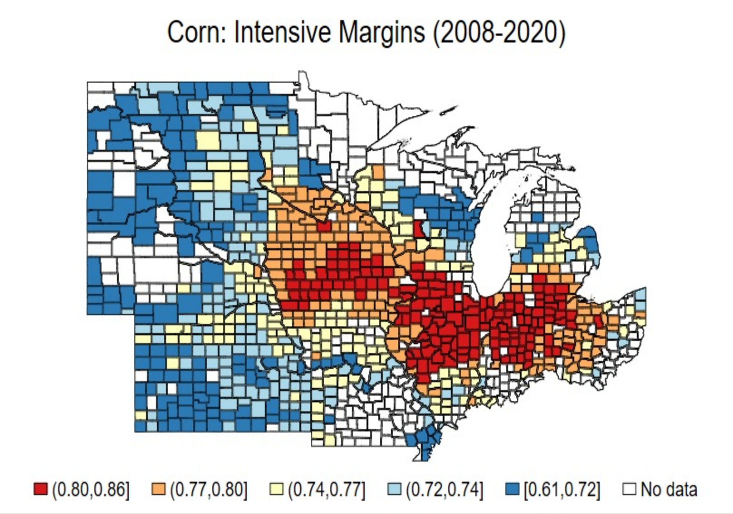
- I. Introduction
- II. Basic Model
- III. Data
- IV. Empirical Results

I. Introduction

❖ *Context*

- Counties outside the main production area have higher ***extensive margins*** participation, however, counties in Corn Belt have higher ***intensive margins***.
    - extensive: insured acres/planted acres; intensive margins: coverage level
- Basis and induced ***mis-matching*** issue are built in the crop insurance contract.





I. Introduction

❖ *Questions*

- Does basis risk take on spatial and geographical variations?
- How does ***basis risk*** (i.e., variation of basis) affect participation?
- Is a difference between Yield and Revenue contracts?

❖ *Purpose*

- Measurements for basis risk.
- Measurements for extensive and intensive margins.
- Estimate effects of basis risk theoretically and empirically.
- Policy Insights.

I. Introduction

❖ *Preview of Results*

- Basis risk has significantly **negative effects** on both margins. This conclusion can be strongly applied to corn, but weakly to soybean.
- Revenue contracts are more ***easily affected*** by basis risk than yield contracts.
- The conclusions still hold when adding State FE or changing model specifications (Linear/Logit).

II. Basic Model

- In the simplest revenue contract, farmers' revenue includes **basis** as a noise source:

$$\underbrace{P_{Dec}^{x} y^{x}}_{\text{Revenue after harvesting}} + \underbrace{\max[\phi F_{Dec,Feb} y^{APH,x} - F_{Dec,Dec} y^{x}, 0]}_{\text{Indemnity from crop insurance}}$$

$$= B_{Dec}^{x} y^{x} + \max[\phi F_{Dec,Feb} y^{APH,x}, F_{Dec,Dec} y^{x}]$$

Noise Source

$$= \begin{cases} B_{Dec}^{x} y^{x} + F_{Dec,Dec} y^{x} & \text{if } y^{x} \geq \phi F_{Dec,Feb}\, y^{APH,x} / F_{Dec,Dec} \\ B_{Dec}^{x} y^{x} + \phi F_{Dec,Feb}\, y^{APH,x} & \text{if } y^{x} < \phi F_{Dec,Feb}\, y^{APH,x} / F_{Dec,Dec} \end{cases}$$

where $B_{Dec}^{x} = P_{Dec}^{x} - F_{Dec,Dec}$ is the local basis at harvest at location **x**;

$\phi \in \{0.5,\ldots,0.9\}$ is coverage level; $F_{Dec,Feb}$ is the Springtime price (expected price before planting) .

II. Basic Model

- As in Feng et al. (2019), supposed $U[\cdot]$ is a standard twice differentiable, increasing, concave utility function, then ***willingness-to-pay*** (WTP) for coverage level ϕ can be implicitly defined as

$$\underbrace{\int_{-\infty}^{\infty}\int_{0}^{\infty}\int_{0}^{\infty} U\{\tilde{R}^{In} - C - WTP(\sigma_B, \phi)\}\, dQ(y \mid B, F)\, dL(B)\, dL(F)}_{\text{With Insurance}}$$

$$= \underbrace{\int_{0}^{\infty}\int_{0}^{\infty} U[Py - C]\, dQ(y \mid p)\, dL(p)}_{\text{Without Insurance}}$$

where $\tilde{R}^{In}$ is revenue with insurance, $WTP(\sigma_B, \phi)$ is WTP for basis risk σ_B , C is production cost, $L(\cdot)$ represents distribution for unconditional basis or futures distribution; $Q(\cdot)$ represents distributions for yield;

II. Basic Model

- **Hypothesis 1:** $dWTP(\sigma_B, \phi) / d\sigma_B < 0$
  - *Note*: WTP decreases when basis risk grows up and coverage level is unchanged.

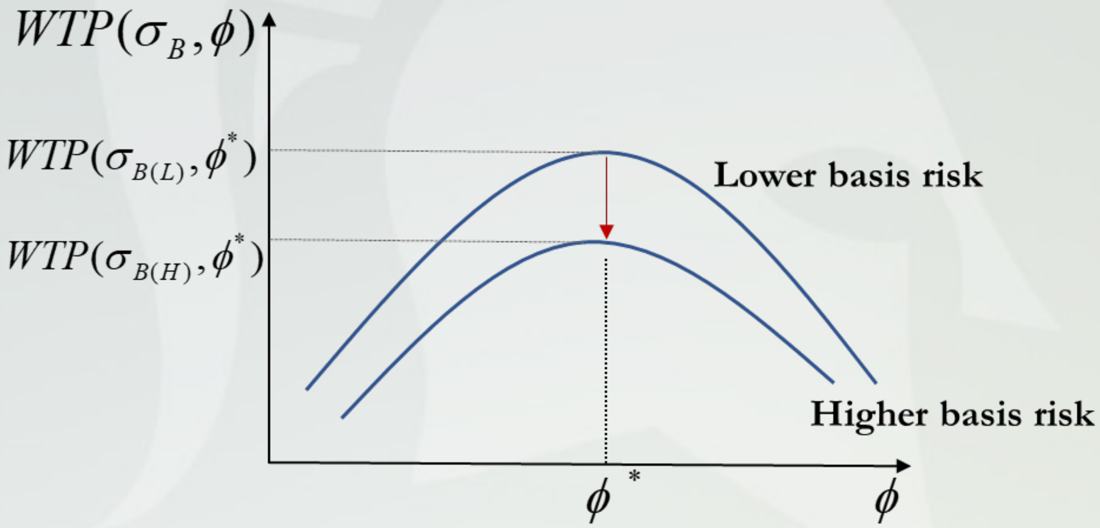


Figure 1. Extensive Margins

II. Basic Model

- **Hypothesis 2:** $d^2WTP(\sigma_B,\phi)/d\phi d\sigma_B < 0$
  - *Note*: Coverage level choice decreases when basis risk grows up.

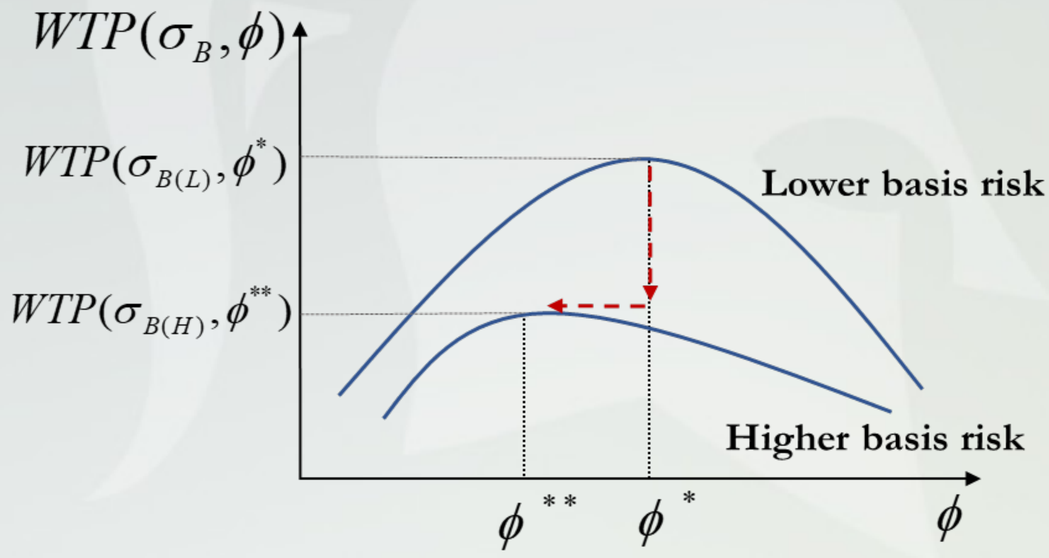


Figure 2. Intensive Margins

II. Basic Model

❖ Summary

- Hypotheses for ***Curvature*** of WTP can be tested by simulation based on Gaussian Copula.
  - o Farm-level yield record (1984-2008)
  - o Elevator-level spot price (2008-2020)

- Basis risk should have **negative** effects on both margins.

III. Data

❖ **Measurement for Basis Risk** (e.g.):

- County-level Basis

$$B^{c}_{Dec,t} = (1/ND) \times [\sum_{n=1}^{N} \sum_{d=1}^{D} B^{c}_{nd,Dec,t}]$$

County-level annual normalized basis

where $B^{c}_{nd,Dec,t} = (P^{c}_{nd,Dec,t} - F_{Dec,Dec,t}) / F_{Dec,Dec,t}$ is the normalized basis at harvesting time (corn Dec/soy Nov) for elevator **n** and trading day **t** in county **c** in year **t**; N is the elevator amounts; D is all trading days in harvesting time.

- County-level Basis Risk

$$Sd(B^{c}_{Dec}) = \sqrt{[1/(T^{c}-1)] \times \sum_{t=1}^{T^{c}} (B^{c}_{Dec,t} - \bar{B}^{c}_{Dec})^{2}}$$

where $\bar{B}^{c}_{Dec} = (1/T^{c}) \times \sum_{t=1}^{T^{c}} B^{c}_{Dec,t}$ represents the long-term average basis at harvesting time in county **c**; T^{c} is the total amount of years for county **c** (unbalanced).

III. Data

- **Measurement of Extensive Margins**
  - **Nominator:**
    - **SOB** (USDA Summary of Business): insured acres for Buy-Up (n1)
  - **Denominator**
    - **NASS** (National Agricultural Statistic Service): planted(d1); harvested(d2); silage(d3)
    - **FSA** (Farm Service Agency): planted(d4); prevented(d5); failed(d6)

Corn/Soy

$$ExPar1 = \frac{n1}{\max(d2, d4) + d5 + d6} \qquad ExPar2 = \frac{n1}{\max[(d4 + d6), d1] + d5}$$

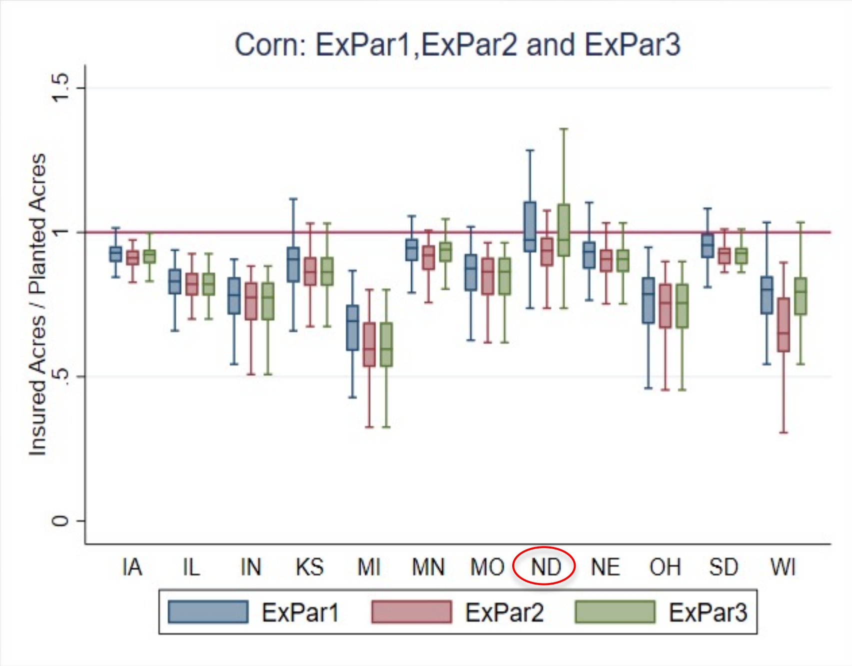
Corn

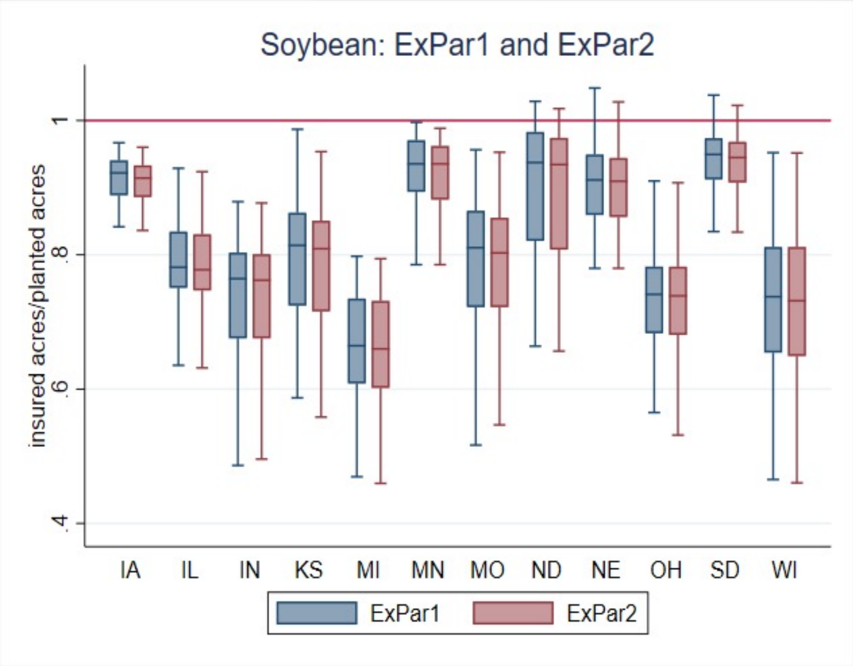
$$ExPar3 = \frac{n1}{\max[(d4 + d6), (d1 - d3)] + d5}$$

III. Data

❖ Measurement of Extensive Margins

- Outliers are excluded.
- red line is the theoretical maximum, i.e., 100%.





III. Data

Table 1. Definition of Main Variables

Variable	Description	Data Source
Participation		
ExPar	= Insured Acres / Total Acres	NASS, FSA, SOB
InPar	Acreage-weighted average coverage level	SOB
Basis		
Sd(B)	Normalized Basis Risk (2008-2020)	Bids Data
EleAmt	Elevator Amount	Bids Data
AveYear	Average Years of Elevator Records	Bids Data
Distance	Distance to Cook County	NBER
Land Quality		
LCC	= Acres (Class I-II) / Acres (Class I-VIII)	NRI
Weather Determinant		
G	Growing Degree Days (1989-2019)	NOAA
S	Stress Degree Days (1989-2019)	NOAA
P	Precipitation (1989-2019)	NOAA

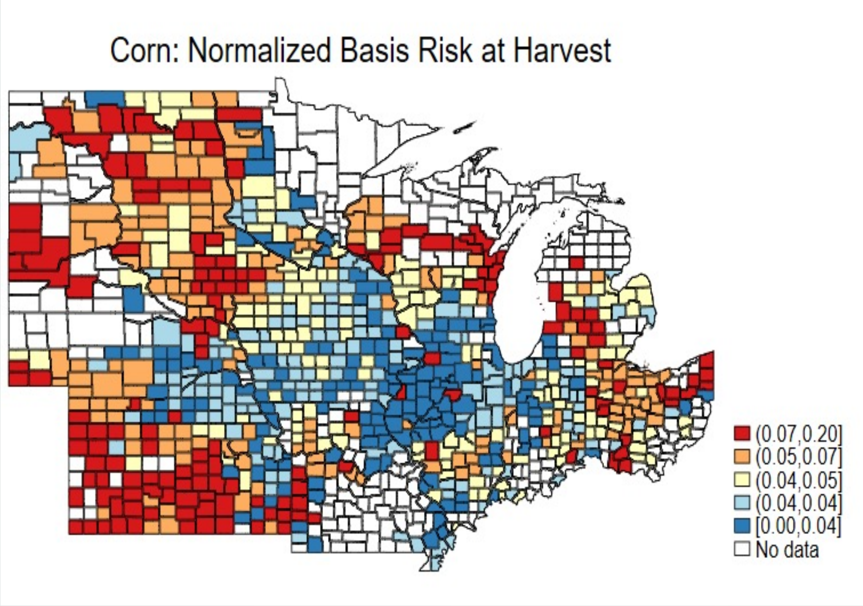
Dependent Variable

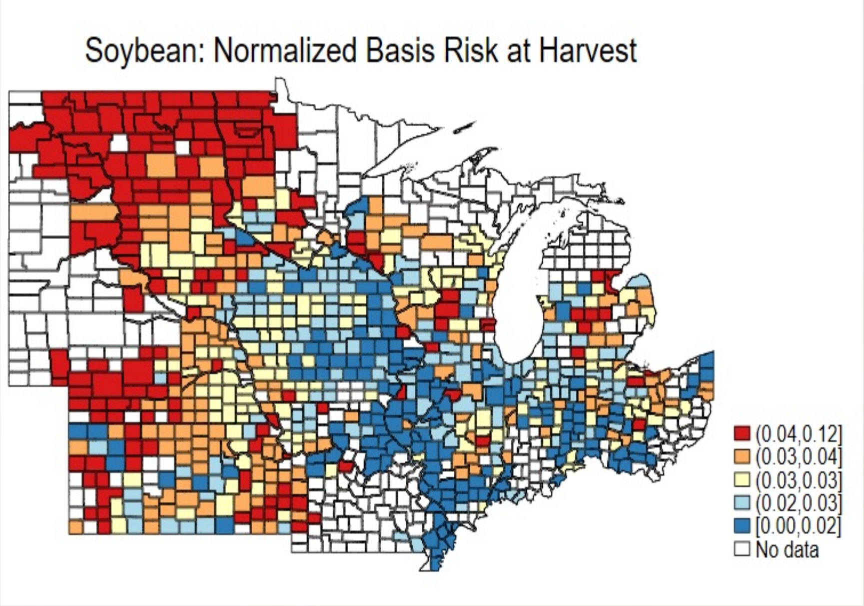
Normalized Basis = Basis/Futures price

III. Data

❖ Geographical Distributions of Basis Risk

- Basis risk increases when moving away from the main production area (IL, IA, IN).
- Patterns for corn and soybean are consistent.

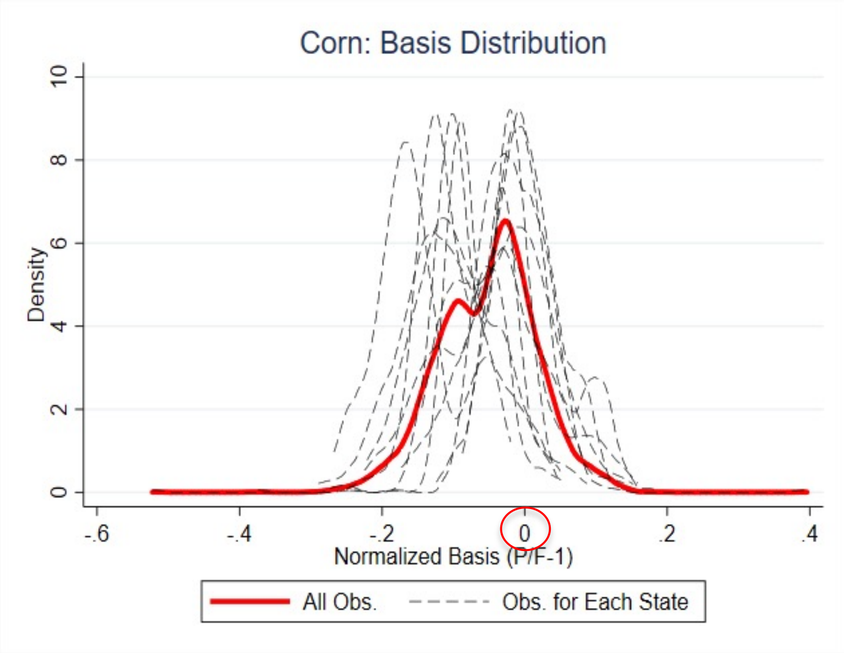


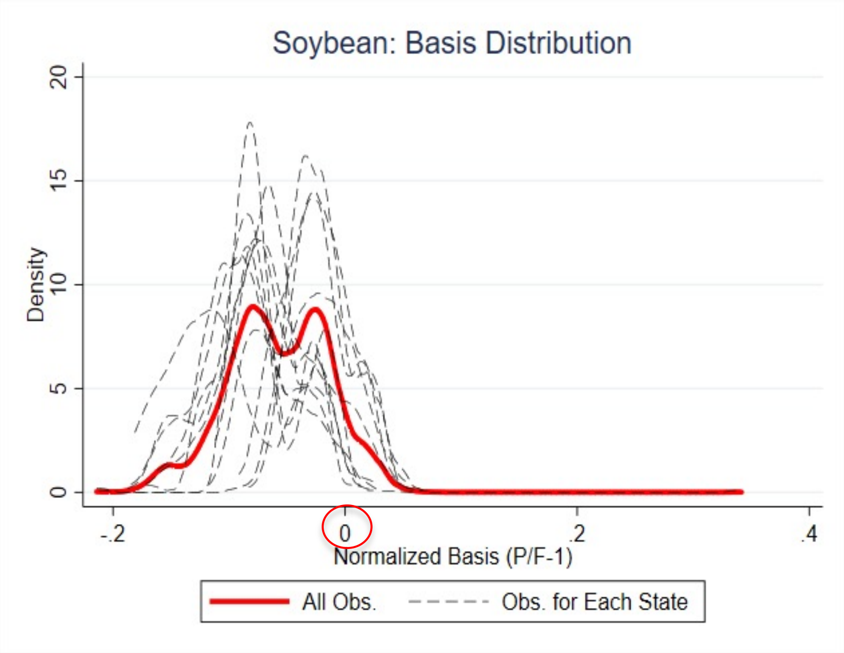


III. Data

❖ Kernel Density Estimation (KDE) for Basis Risk

- Red solid curve: distribution for all 12 states
- Grey dashed curves: each state.





IV. Empirical Results

❖ Model Specification: Fractional Probit

$$E[ExPar \mid Sd(B^c_{Dec}), \mathbf{Z}^c, \eta^c] = \Phi(\gamma Sd(B^c_{Dec}) + \mathbf{Z}^c\boldsymbol{\beta} + \eta^c)$$

where $\mathbf{Z}^c = \{LCC, EleAmt, AveYear, Tmiles, G, S, P\}$, $Sd(B^c_{Dec})$ is the basis risk in county **c**, which is the main variable of interest; η^c is the unobserved heterogeneity.

- **Reason** for the Specification
  - Both extensive and intensive margins are fractional.
  - Endogeneity issue: county-specific ending stock; farmers' expectation for the supply and demand in the market.

IV. Empirical Results

❖ Strategy for Endogeneity: Control Function

Suppose $\mathbf{Z}^{\mathbf{c}} = \{\mathbf{Z}_1^{\mathbf{c}}, \mathbf{Z}_2^{\mathbf{c}}\}$ where $\mathbf{Z}_1^{\mathbf{c}} = \{G, S, P\}$ represents a vector for **instrumental** variables; $\mathbf{Z}_2^{\mathbf{c}} = \{LCC, EleAmt, AveYear, TMiles\}$ is a vector for **control** variables.

- A two-step procedure
  - Step 1: $Sd(B_{Dec}^c) = \alpha_0 + \sum_{l \in \mathbf{Z}_1^{\mathbf{c}}} \alpha_l Z_{1,l}^c + \sum_{m \in \mathbf{Z}_2^{\mathbf{c}}} \alpha_m Z_{2,m}^c + v_1^c$
  - Step 2: $E[ExPar^c \mid Sd(B_{Dec}^c), \mathbf{Z}_2^{\mathbf{c}}] = \Phi(\beta_0 + \beta_1 Sd(B_{Dec}^c) + \mathbf{Z}_2^{\mathbf{c}}\boldsymbol{\beta} + \gamma \hat{v}_1^c)$

where $\hat{v}_1^c$ denotes predicted residuals from Step I (see more in Wooldridge(2015)).

- Results Report
  - **semi-elasticity**(= dy/d(lnx)) are employed since both rates are scaled 0 to 1.
  - explanation: a 1% increase of a covariate increases participation rates by how much (a percentage scale)

IV. Empirical Results

Table 2. Semi-Elasticity of Basis Risk for Extensive Margins

Estimation Method	Pooled Fractional Probit			CF Fractional Probit		
Dependent Variable	(1) ExPar1	(2) ExPar2	(3) ExPar3	(4) ExPar1	(5) ExPar2	(6) ExPar3
Corn						
Normalized Basis Risk	-0.016	-0.04***	-0.03**	-0.19***	-0.32***	-0.26***
Elevator Amount	0.02***	0.03***	0.02***	0.02***	0.02***	0.02***
Elevator-year Records	-0.01	-0.01	-0.01	-0.02*	-0.02**	-0.03**
Distance from Chicago	0.13***	0.16***	0.15***	0.12***	0.16***	0.13***
p-value of residual	—	—	—	0.06	0.004	0.01
Soybean						
Normalized Basis Risk	-0.07	-0.07*	—	-0.25	-0.27	—
Elevator Amount	0.02***	0.02***	—	0.04***	0.04***	—
Elevator-year Records	0.02*	0.02**	—	0.03**	0.03**	—
Distance from Chicago	0.15***	0.15***	—	0.07***	0.06***	—
p-value of residual	—	—	—	0.42	0.39	—

Note: *** p<0.01, ** p<0.05, * p<0.1

IV. Empirical Results

Table 3. Semi-Elasticity of Basis Risk for Intensive Margins

Estimation Method	Pooled Fractional Probit		CF Fractional Probit	
Contract Type	(1) Yield	(2) Revenue	(3) Yield	(4) Revenue
Corn				
Normalized Basis Risk	-0.01*	-0.01***	0.007	-0.05***
Elevator Amount	0.01***	0.006***	0.01*	0.01**
Elevator-year Records	0.004	0.004*	0.005	0.002
Distance from Chicago	-0.05***	-0.04***	-0.05***	-0.04***
p-value of residual	—	—	0.49	0.006
Soybean				
Normalized Basis Risk	0.0003	0.002	-0.03	0.02*
Elevator Amount	0.008	0.006***	0.01	0.008***
Elevator-year Records	0.008	0.006**	0.002	0.01*
Distance from Chicago	-0.05***	-0.03***	-0.05***	-0.05***
p-value of residual	—	—	0.77	0.29

Note: *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Thanks!