U.S. Soybean Quality, Planting Date, and Incompatible Incentives

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Selected Poster prepared for presentation at the 2024 Agricultural & Applied Economics Association Annual Meeting, New Orleans, LA: July 28-30, 2024

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Background

- The US is the second largest soybean producer worldwide. To meet the increasing global demand for soybeans, increasing soybean acres could cause many problems, including environmental concerns.
- Instead of increasing acres, improving soybean quality becomes an alternative solution. However, US farmers do not have incentives to manage soybean quality, even though many of their choices, such as planting date, affect soybean quality.
- Soybean quality determines how much soybean meal (protein) and soybean oil can be made from each bushel.
- Farmers planting date affects yield and quality differently. Early planting leads to higher yield but lower quality soybeans.

Research Question

Research Question:
Theoretically and empirically examine how farmers planting date choices to maximize their yield are not socially optimal for soybean value and estimate how much welfare could be improved if socially optimal planting dates were used.

Data

The soybean quality data we use contains the protein and oil concentration for soybeans from major production counties from 2006 and 2020 (as the percentage of the soybean weight). Planting date is the number of days since the first day of the year.

Table 1: Summary statistics.

	Obs.	Mean	S.D.	Min	Max
planting date	7,200	131.8	6.749	112	162
yield(bushel/acre)	7,200	47.94	9.470	11	80
protein concentration(%)	7,200	34.32	1.238	28.85	40.03
oil concentration(%)	7,200	18.83	0.902	12.80	22.05
Planting Season					
growing degree days$_{10}$	7,200	77.83	39.06	0.380	250.4
precipitation(inches)	7,200	87.70	47.72	1.262	426.0
Growing Season					
growing degree days$_{8,32}$	7,200	1,790	228.5	1,102	2,567
growing degree days$_{34+}$	7,200	1.774	3.116	0	33.00
precipitation(inches)	7,200	484.5	136.1	108.0	1,068

Correspondence

Guang Tian, Ph.D. candidate, UW-Madison. I will be in the job market this year. If you are interested, please contact me at: guang.tian@wisc.edu

Conceptual Framework

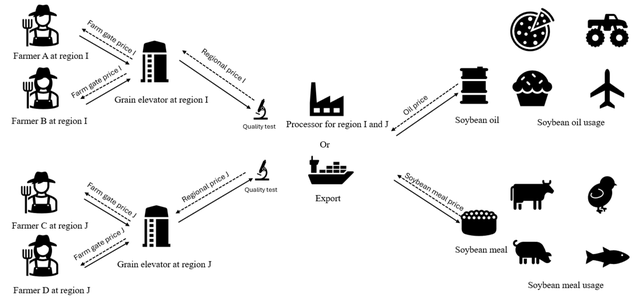

Figure 1: Soybean Value Chain.

Even if quality is important for soybean value, soybean quality tests are not implemented at local elevators and farmers are not incentivized to improve quality. Since there is no price signal for quality, farmers' incentives are to maximize their yields while the soybean industry wants to maximize the value.

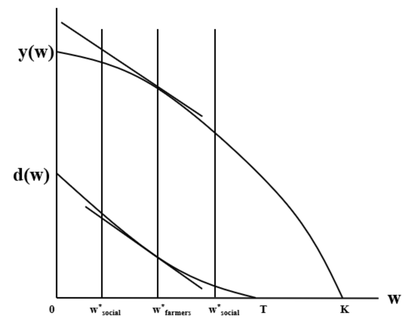

Figure 2: Incompatible Incentives between Farmers and the Society.

Farmer's maximization problem is to choose optimal planting date w. $y(w)$ is potential yield planting at the date w; $d(w)$ is yield losses due to freeze damage.

$$\max_w \ y(w) - d(w) \tag{1}$$

$$F.O.C: \ \frac{dy(w)}{dw} = \frac{dd(w)}{dw} \tag{2}$$

For social optimal planting date, the goal is to maximize the value of soybean.

$$\max_w \ p_p protein(w)(y(w) - d(w)) + p_o oil(w)(y(w) - d(w)) \tag{3}$$

$$\epsilon_{y(w)-d(w)} = -\epsilon_{p_p protein(w)+p_o oil(w)}$$

$$w^*_{farmers} < w^*_{social} \text{ or } w^*_{farmers} > w^*_{social}$$

Compared with social optimal planting date, farmers are planting either too early or too late unless equation (2) holds.

Empirical and Results

Since a farmer's planting decision could be correlated with other decisions, we use weather in planting season to instrument it.

$$y_{it} = \beta_0 + \beta_{pd} \hat{Planting\ Date}_{it} + X\beta + h_r(t) + \theta_i + \varepsilon_{it} \tag{4}$$

$$\hat{Planting\ Date}_{it} = \alpha_0 + \alpha_t T_{it,M_{-j}} + \alpha_p P_{it,M_{-j}} + X\alpha + h_r(t) + \theta_i + \epsilon_{it} \tag{5}$$

y_{it} is yield and components in year t at county i; $PlantingDate$ is coded as the number of days since the first day of year t; X are weather controls in growing seasons; $h_r(t)$ is quadratic regional time trends; θ_i is the county fixed effect. $T_{it,M_{-j}}$ and $P_{it,M_{-j}}$ are average temperature and accumulated precipitation j weeks prior to the county $i's$ historical planting date.

Table 2: Planting date effects on yield and components.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Yield	First stage Protein	Oil	OLS and IV models Yield		Protein		Oil	
				OLS	2SLS	OLS	2SLS	OLS	2SLS
Plating Date				-0.221***	-0.330***	0.00501***	0.0140***	-0.0189***	-0.101***
				(0.00924)	(0.0200)	(0.00185)	(0.00492)	(0.00161)	(0.00966)
Growing degree days$_{10}$(3 weeks prior to plating date)	-0.0181***								
	(0.00346)								
Precipitation(3 weeks prior to plating date)	0.0693***								
	(0.00268)								
Growing degree days$_{10}$(4 weeks prior to plating date)		-0.0342***							
		(0.00246)							
Precipitation(4 weeks prior to plating date)		0.0687***							
		(0.00246)							
Growing degree days$_{10}$(1 week prior to plating date)			0.00253						
			(0.00934)						
Precipitation(1 week prior to plating date)			0.0494***						
			(0.00447)						
Constant	53,030***	58,471***	-134,709***	-11,549	-26,835**	-22,818***	-18,761***	30,177***	15,345***
	(13,549)	(13,852)	(14,662)	(10,765)	(11,113)	(3,065)	(3,108)	(2,314)	(2,953)
Observations	7,200	7,200	7,200	7,200	7,200	7,200	7,200	7,200	7,200
F statistics	77.94	91.41	50.43						
R-squared	0.269	0.284	0.097	0.545	0.534	0.121	0.116	0.138	
0.135 County FE	YES	YES	YES	YES	YES	YES	YES	YES	YES
Growing Season Weather Controls	YES	YES	YES	YES	YES	YES	YES	YES	YES

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

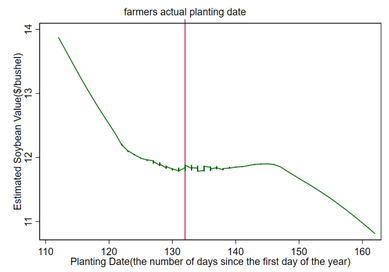

Figure 3: Planting Date and Soybean Value.

Key Results

- Compared with OLS estimation, the absolute value of IV estimators are bigger. For example, OLS estimator shows that one day delay causes about 0.221 bushel yield losses per acre but IV estimates the losses are 0.33 bushel/acre. This is because farmers proactively mitigate yield losses due to delayed planting.
- From figure 3, if farmers can planting earlier, there will be up to $2.5/bushel increment, generating a substantial welfare improvement from adjusting the planting date each year.