A Causal Analysis of the Effect of Conservation Tillage on U.S. Corn and Soybean Yield and Profitability

Bowen Chen[1], Benjamin M. Gramig[1], Seong D. Yun [2]

[1]University of Illinois at Urbana-Champaign

[2]Mississippi State University

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What is Conservation Tillage (CT)?

Traditional definition: CT has >30% residue cover (including no-till); conventional tillage has <30% residue cover.

Conservation tillage (CT)

- Minimal soil disturbance.
- Environmental benefits are well-known.
  - ◇ Reduced soil loss and nutrient runoff
  - ◇ Reduced greenhouse gas emissions, increased carbon sequestration
  - ◇ Improved soil health;
- Overall economic impacts important for farmer adoption.
  - ◇ Mixed findings from field trials: heterogeneous yield effects;
- Focus of this study: CT effect on crop yields and production costs.

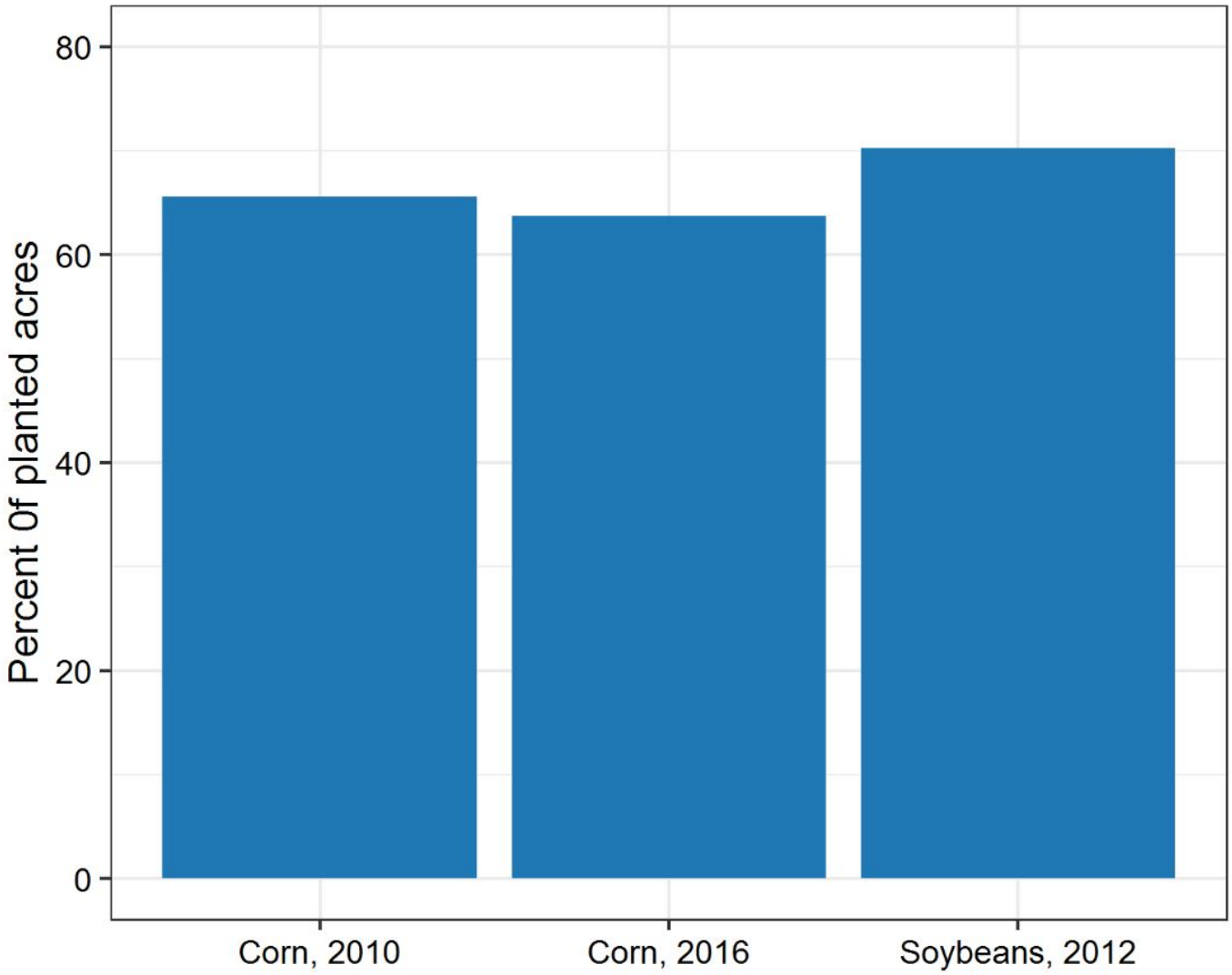
Mechanisms

- CT effects on crop yields:
  - ◇ Positive $(+)$: greater water and nutrient use efficiencies;
  - ◇ Negative $(-)$: waterlogging and poor crop establishment; restricted root growth due to surface soil compaction; increased incidence of pests and weeds.
- CT effects on costs:
  - ◇ Positive $(+)$: saves fuel, labor and machinery use;
  - ◇ Negative $(-)$: might increase usage of fertilizer and/or herbicide.

Primary data source: Agricultural Resource Management Survey (ARMS) from USDA-ERS

- Phase II survey
  - ◇ CT: tillage management practices that result in a Soil Tillage Intensity Rating (STIR) of less than or equal to 80 (Claassen et al., 2018);
  - ◇ STIR calculated based on machinery operations;
  - ◇ Field-specific data on crop yields and production costs;
  - ◇ Production cost is the sum of operating costs (e.g., seed, fertilizer) and allocated overhead costs (e.g., hired labor)
- Phase III survey
  - ◇ Household and farm-level characteristics (e.g., education, age)
- Corn: 2010 and 2016; Soybeans: **2012** (a drought year).
- Rain-fed, non-organic fields, and **non-erodible lands** only.

CT adoption rates (similar to the ERS reports)



Additional publicly available data sources

- Historical and contemporaneous weather data
  - ◇ Source: PRISM database (Oregon State University);
  - ◇ Used to construct weather and climate variables;
- Soil data
  - ◇ Source: the gSSURGO database (USDA-NRCS);
- Weather and soil data are from spatially-weighted county-level variables based on county FIPS codes from ARMS
- Number of observations: 1820 (corn), 1278 (soybeans).

Identification strategy

- Bias-corrected matching estimator (Abadie and Imbens, 2011).
  - ◇ Treatment variable: CT adoption = 1 if STIR $\leq$ 80, and 0 otherwise
  - ◇ Outcome variables: logged yields; logged production costs;
  - ◇ Use both Propensity Score (PS) and Mahalanobis Distance (MD) matching;
  - ◇ Linear regression is used to adjust for remaining matching discrepancy;
  - ◇ ARMS Sampling weights are incorporated into the analyses.
- Estimate Average Treatment effect on the Treated (ATT), and Average Treatment effect on the Untreated (ATU).

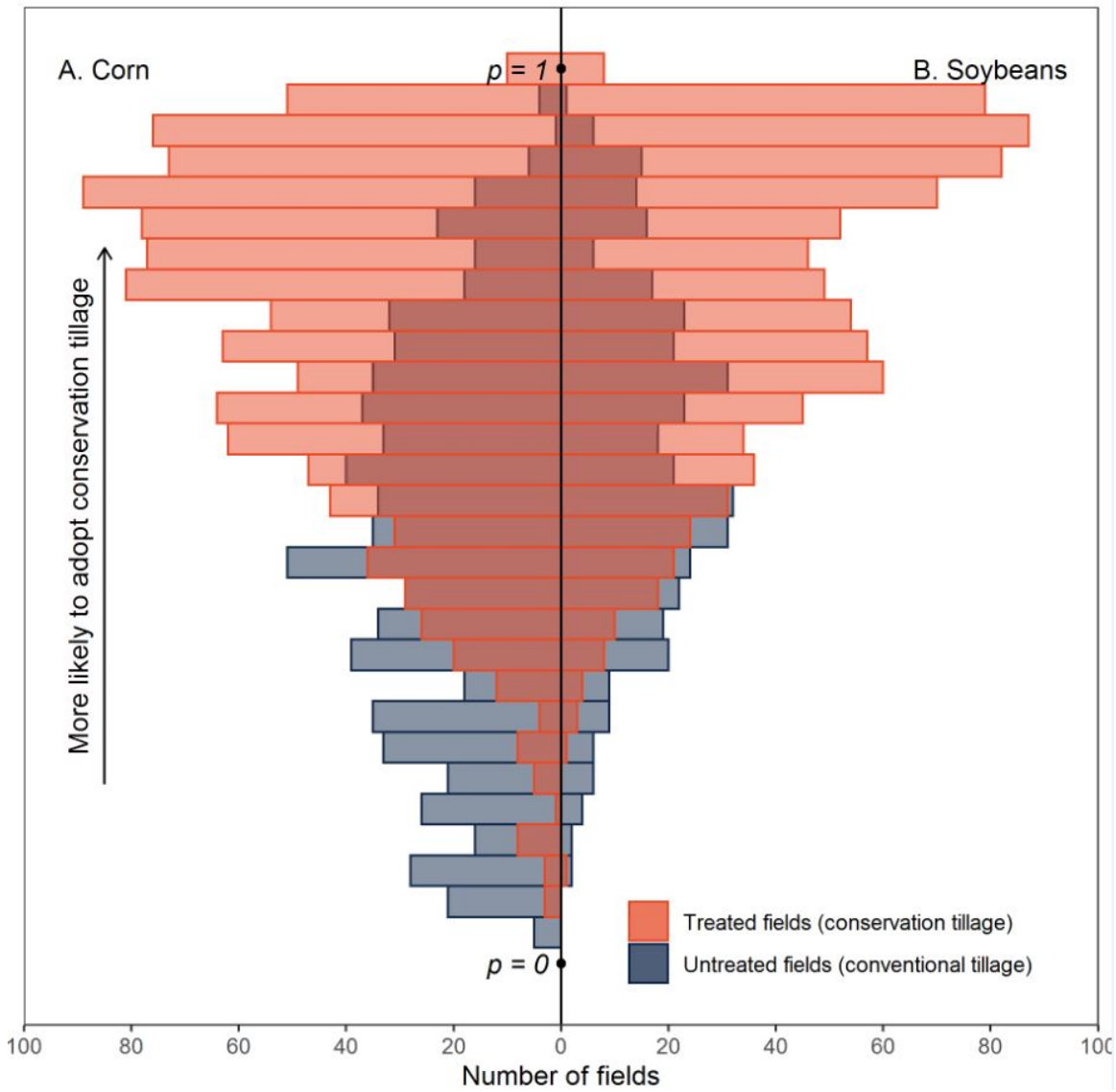
Key assumptions and empirical strategy

- **Selection on observables**: conditional on the observed covariates, treatment is as-good-as randomly assigned.
  - ◇ Include a large set of variables as covariates (see next slide);
  - ◇ Restrict matching within the same states and years.
- **Common support**: sufficient overlap in the distribution of covariates between the treated and untreated units.
  - ◇ Sensitivity analyses through data pruning;
  - ◇ Track covariate balance along with data pruning;
  - ◇ Covariate balance measured by Standardized Mean Difference (SMD);
  - ◇ Matching frontier (King et al., 2017).
- **Stable unit treatment value assumption**: no spillover effect
  - ◇ Not a serious concern (matched farms are not neighbors).

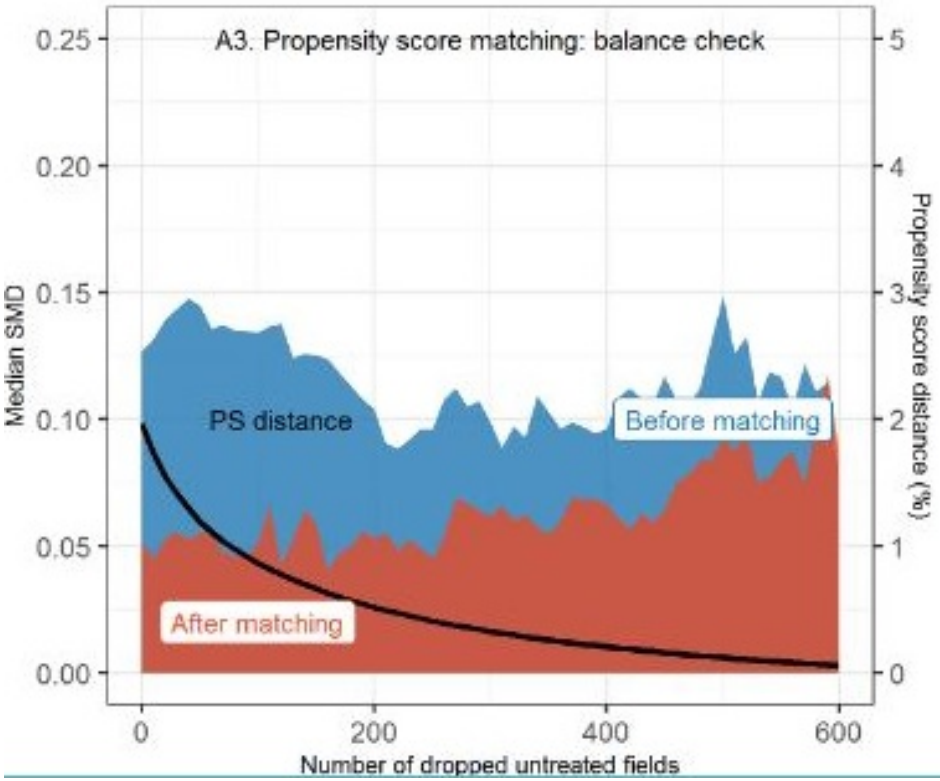
Covariates included

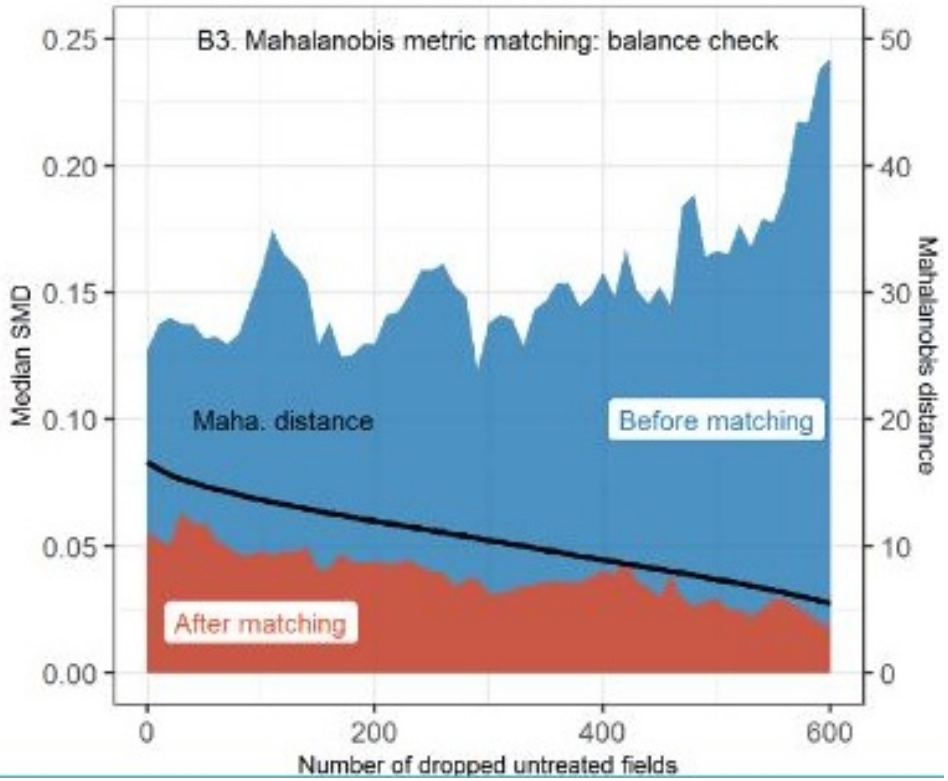
- **County soil characteristics**: wetland adjacency (field-level), available water capacity, k-factor, soil PH, organic matter;
- **County weather and climate conditions**: growing degree days, precipitation, spring wetness, historical temperature, historical precipitation, dry years, drought risks (Wallander et al., 2013);
- **Household and farm characteristics**: education, farming experience, farm size, land tenure, and corn-soy ratio;
- **Farm management practices and gov't programs**: Herbicide-tolerant seeds, crop rotation, cover crop, federal crop insurance participation; conservation payments, nutrient management, pest management, seeding rate, planting dates.
- There are 30 covariates in total.

Propensity scores vary by crop and treatment status

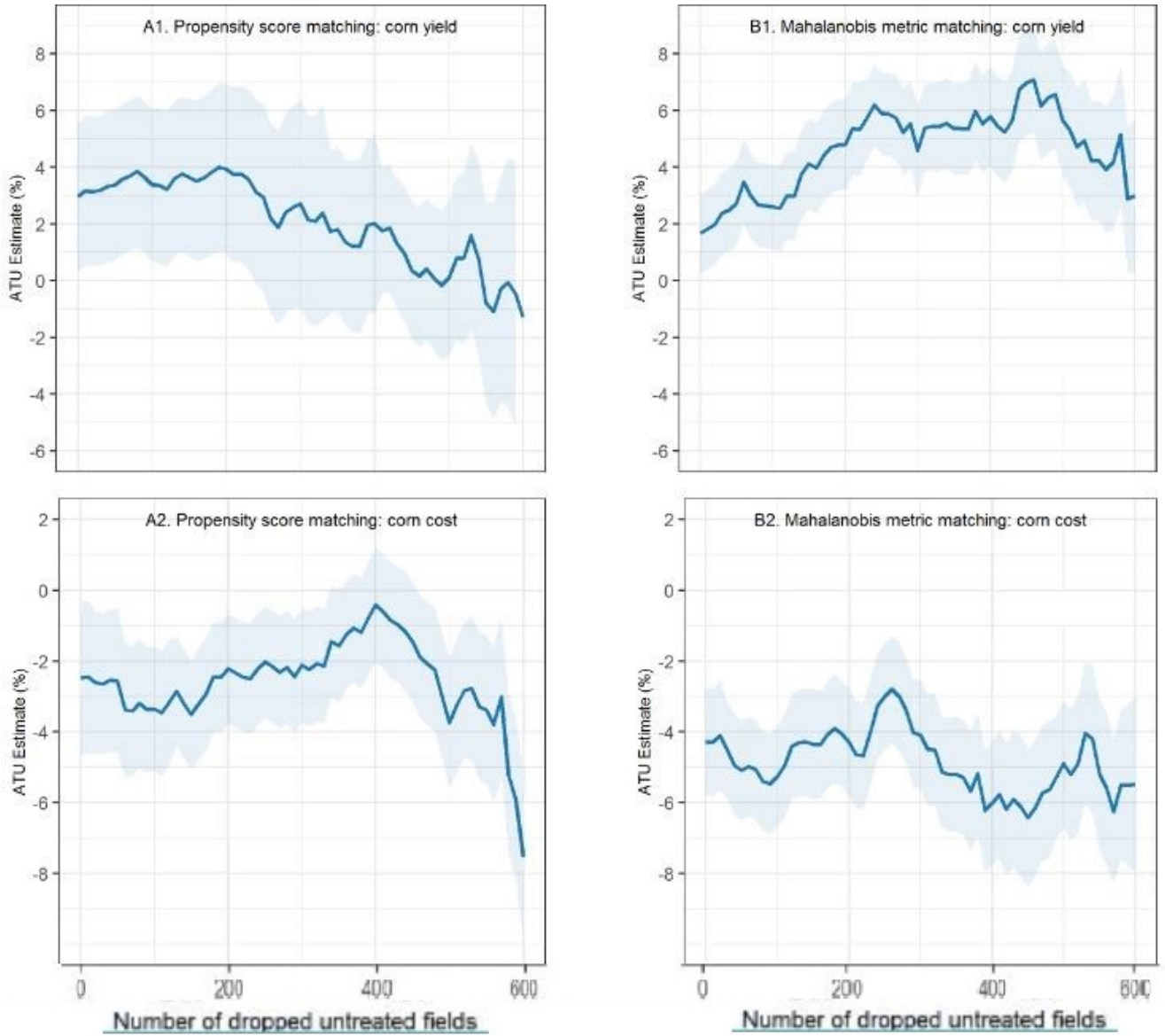


ATU for corn: balance check

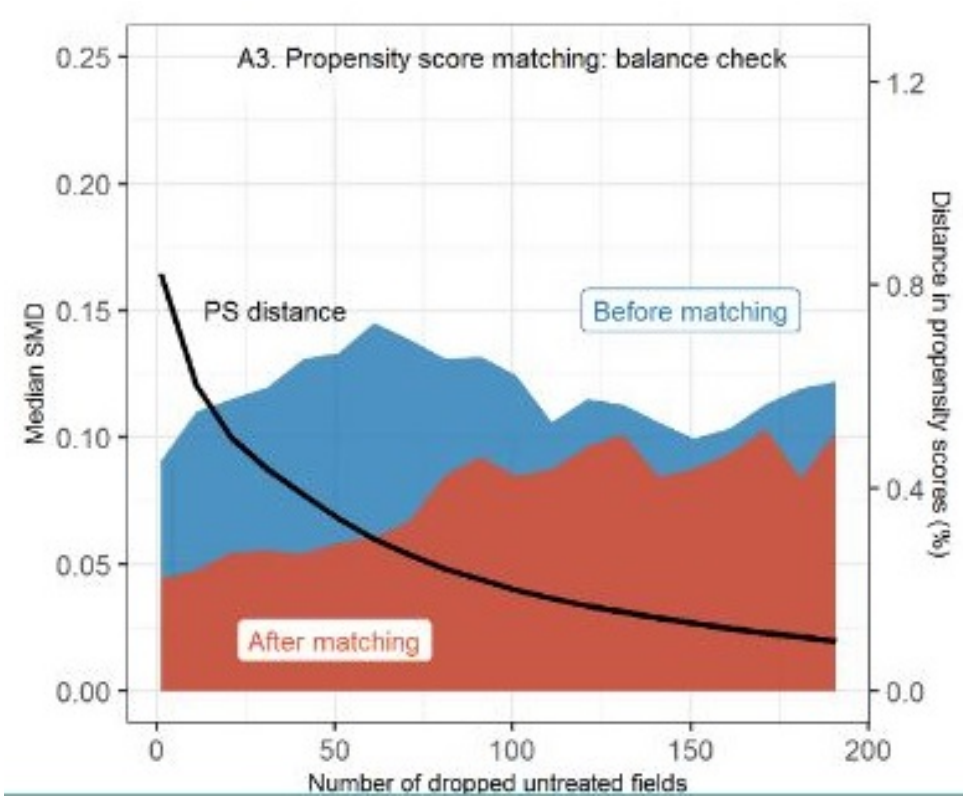


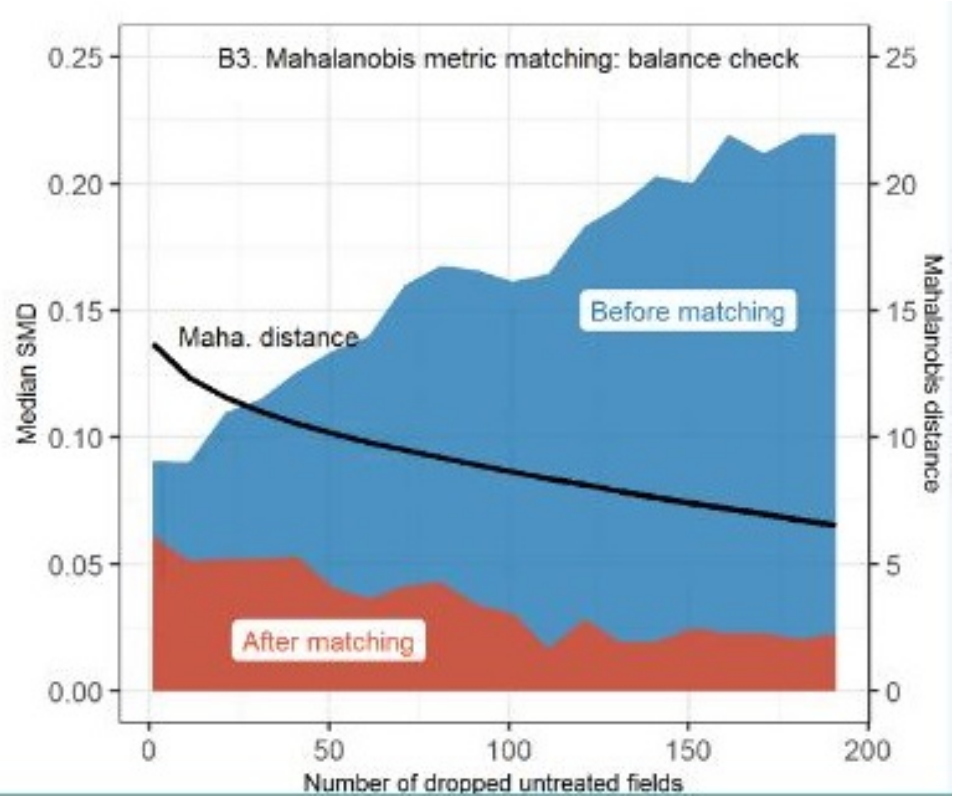


ATU for corn: estimation results

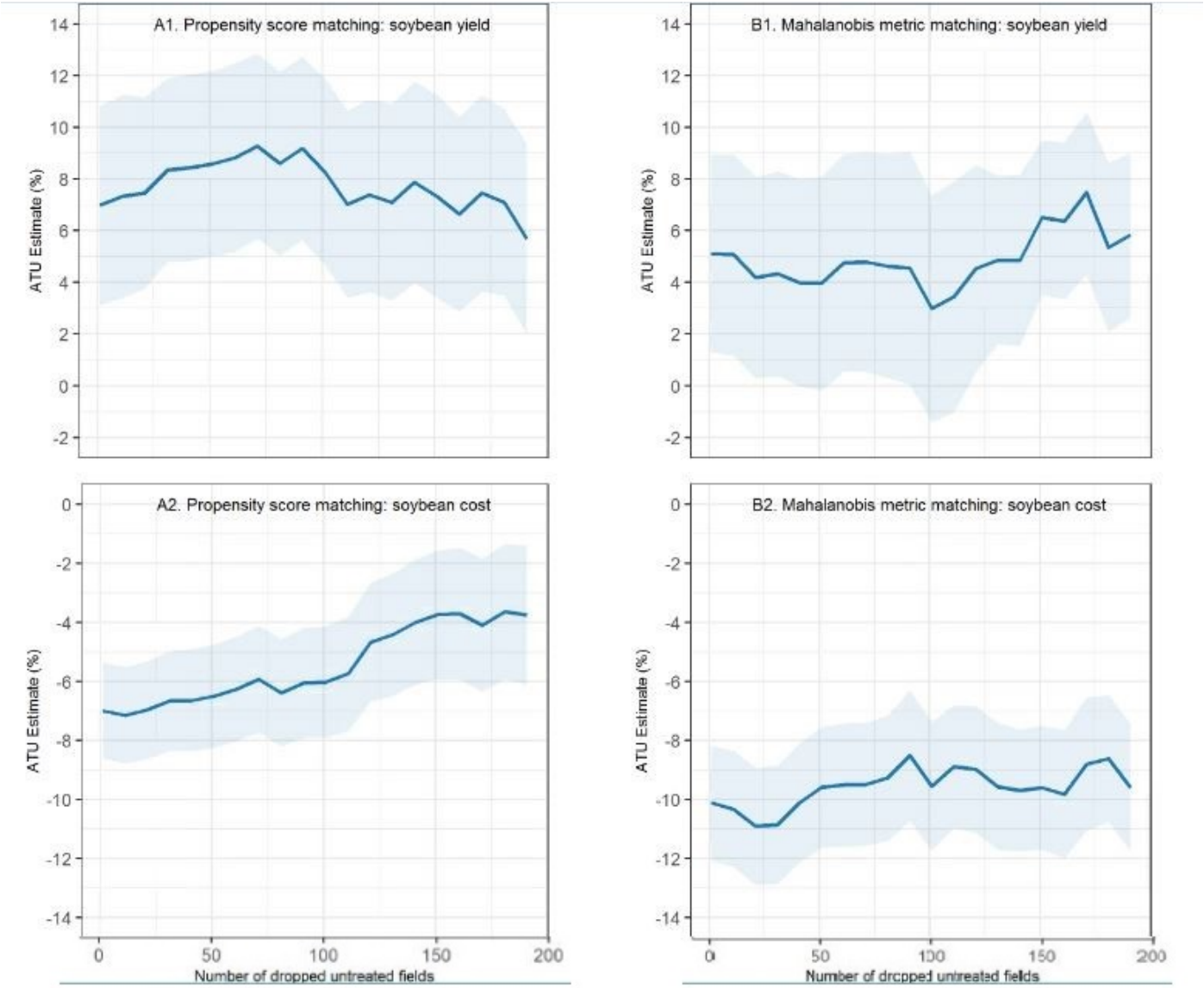


ATU for soybeans: balance check

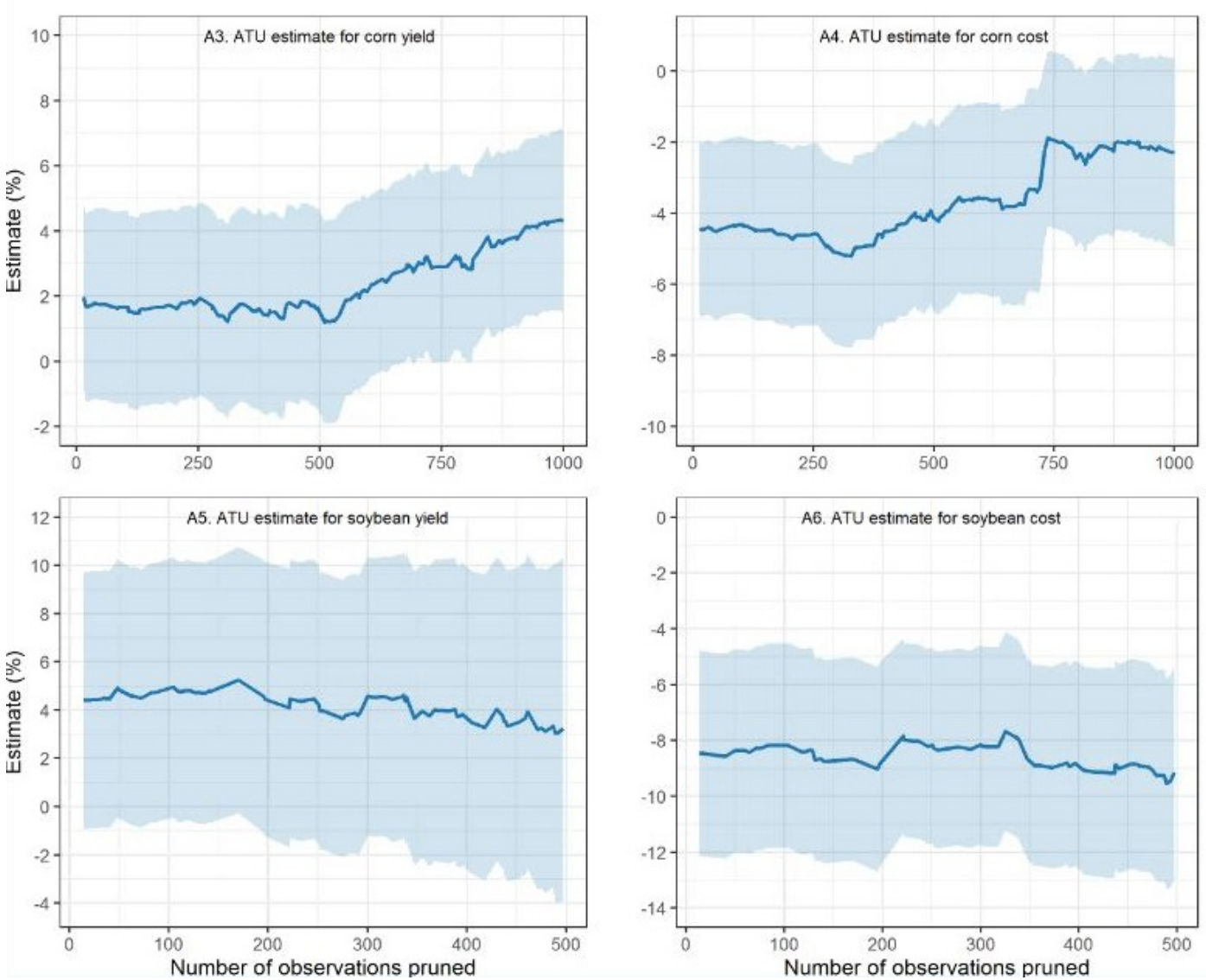




ATU for soybeans: estimation results



Results from the matching frontier (King et al., 2017)



Summary of key findings

- Likely positive selection into treatment (CT adoption);
- CT has positive effects on corn (+3%) and soybean yields (+6%) among the untreated;
- CT can reduce production costs for corn (-5%) and soybean (-9%) among the untreated;
- Overall, CT is a cost-reducing practice that does not have a negative impact on yield
- Further notes/caveats/considerations:
  - ◇ Soybean data are in 2012 (a drought year).
  - ◇ Might capture the long-term effects (13 years = mean reported number of years since adopted CT among the treated).

Effects of CT on profits

Table 1: Corn and soybeans production costs and returns per planted acre with conventional tillage in the central Corn Belt

	Observed			Counterfactual			Price
	Yield (bu/acre)	Cost ($/acre)	Profit ($/acre)	Yield (Bu/acre)	Cost ($/acre)	Profit ($/acre)	($/bu)
Corn, 2010	162	605	116	166	575	168	4.46
Corn, 2016	196	730	-77.8	202	694	-21.7	3.32
Soybeans, 2012	45.3	527	121	48	479	207	14.3

Notes: Observed production costs and yields are weighted averages among the fields using conventional tillage in Iowa, Indiana, and Illinois. Counterfactual values are calculated from the observed values and the ATU estimates, representing yields and production costs if CT had been used on these fields instead of conventional tillage. ATU estimates used here are +3% for corn yields, -5% for corn production costs, +6% for soybean yields, and -9% for soybean production costs.

Thank you!

Any questions, comments or suggestions are welcomed.