

Trade Competitiveness Effects of U.S. Ethanol Mandates: An Ex-Post Assessment

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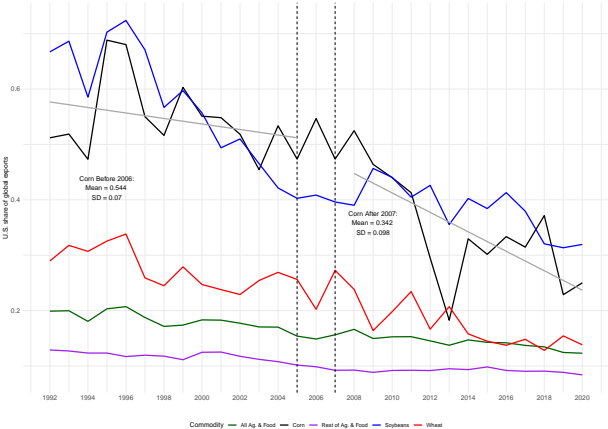
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Introduction

- **2005 Renewable Fuel Standard (RFS) and 2007 Energy Independence and Security Act (RFS2)** fundamentally restructured U.S. corn markets
- Corn for ethanol increased from:
 - 1.6 billion bushels (15% of production) in 2005
 - To 5+ billion bushels (40% of production) by 2011
- One of the largest domestic demand shocks in modern agricultural history
- **What were the implications for U.S. export competitiveness and why should we care?**

Secular decline in US export shares, which seems to accelerate after 2005-2007



US share of global exports of agricultural and food commodities, 1992-2020. Source: Borchert et al. (2022).

Why should we care?

Indirect land use changes (ILUC) from simulation models are used in biofuel regulations:

- The California Air Resource Board utilized the GTAP-BIO model (Hertel et al., 2010) for the Low Carbon Fuel Standard.
- EPA relied on the FAPRI model (Searchinger et al., 2008) for RFS II projections.
- ILUC estimates are highly controversial.
- And they are driven (to a great extent) by ex-ante projections in US export shares (Keeney and Hertel, 2009; Marshall et al., 2011; Khanna, Rajagopal, and Zilberman, 2021; Martin, 2025).

Examine the extent to which earlier projections of changes in US exports of corn, soybeans, and wheat deviate from observed outcomes.

U.S. Ethanol Mandate Assumptions vs. Actual Production
(Billion Gallons)

Searchinger et al.	Hertel et al.	Avg. Prod. 2009-2016
14.8	13.25	13.7

Projected changes in US exports following the 2005-2007 RFS

Crop Group	Searchinger et al. (FAPRI)	Hertel et al. (GTAP-BIO)
Corn	-62%	-17%
Soybeans	-28%	-12%
Wheat	-31%	-15%

Changes in US export shares of each product relative to a non-RFS counterfactual in mid 2010s.

Empirical Strategy

Methodology: Generalized Event Study

Following Schmidheiny and Siegloch (2023), we exploit **continuous variation** in ethanol production intensity (rather than binary treatment indicators):

$$\Phi_{g,t}^{US} = \sum_{\ell=\underline{\ell}}^{\bar{\ell}} \beta_{\ell} E_{g,t}^{\ell} + \mu_g + \theta_t + \varepsilon_{g,t}$$

- **Outcome** ($\Phi_{g,t}$): US Export Share of product g at time t .
- **Treatment** ($E_{g,t}^{\ell}$): Annual change in Ethanol Production (bn gallons). Positive for $g = \text{corn}$ and after 2008, zero otherwise.
- **Lags/Leads**: $\underline{\ell} = 5$ leads, $\bar{\ell} = 9$ lags (allows dynamic adjustment).
- **Interpretation**: $\beta_{\ell} =$ percentage point change in market share per 1 bn gallon increase.

Treated Groups:

- Corn
- Soybeans (Land substitution)
- Wheat (Land substitution)

Control Groups:

- Rice, Pulses
- Fruits, Vegetables, Nuts
- Tobacco, Cocoa, Spices

Assumption: Weakly connected to corn land/feed markets.

- **Binning:** Endpoints are binned to capture permanent structural effects (Long-run).
 - A bin is a final category that includes all periods 10 years or more after the RFS.

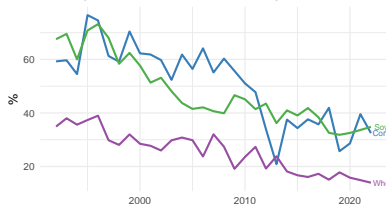
Identification ii

- Allows keeping those observations in the sample and estimate a single coefficient for them (i.e., treatment does not stop suddenly).
- **Parallel Trends:** Tested via pre-treatment leads (β_ℓ for $\ell < 0$).
- **Reference period:** 2005, 2006, 2007 are omitted categories → results are relative to the average 2005-2007 export share.

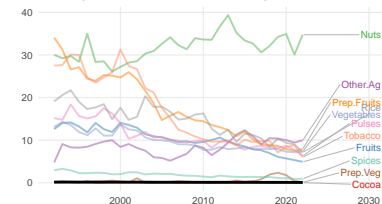
Data

US Export shares $\Phi_{g,t} = X_{g,t} X_{g,t}^W^{-1}$ (1992-2019)

C US Export Shares of Treated Groups



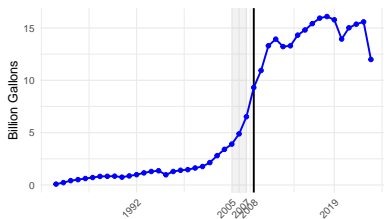
D US Export Share of Control Groups



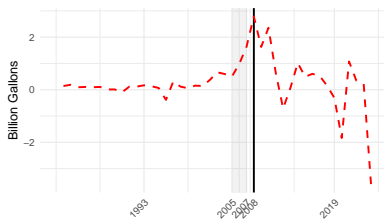
Source: USITC International Trade and Production Database for Estimation (ITPD-E) Release 2.

US ethanol production (1992-2019)

E Ethanol Production in the US



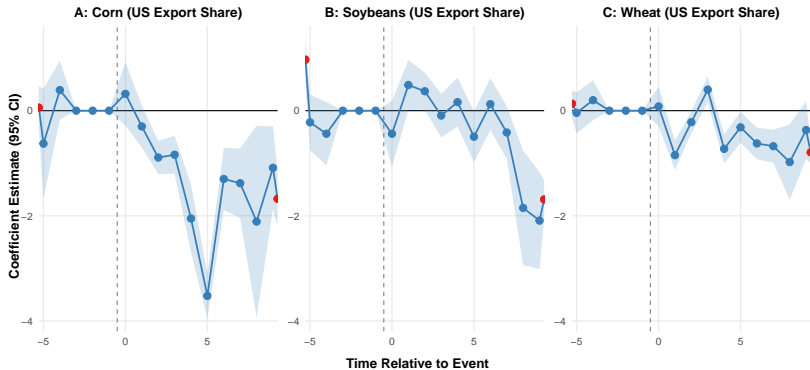
F First Differences: Ethanol Production in the US



Source: USDA Economic Research Service U.S. Bioenergy Statistics.

Results: Model Validation

Impact on Global Export Shares (Φ)

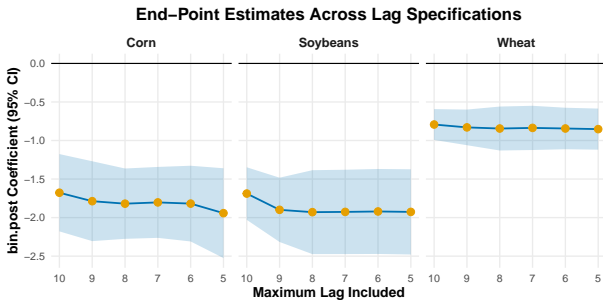


- **Corn:** Immediate, sharp decline. Long-run: **-1.68 pp / bn gal.**
- **Wheat:** Moderate decline. Long-run: **-0.79 pp / bn gal.**
- **Soybeans:** Delayed effect (Lags 6-7). Long-run: **-1.69 pp / bn gal.**

2012 Drought

- The deepening of coefficients at Lags 5-7 coincides with the historic 2012 North American Drought.
- This weather shock likely amplifies the medium-term estimates.
- Yet, the negative effects persist in the post-treatment binned endpoints (Lags 8-9+).
- Production had normalized by then.
- The mandate seems to have generated a *structural* loss of market share.

Sensitivity Analysis: Lag Structure



Estimates of the long-run effect are stable across different lag specifications (5 to 10 years).

Comparing main projections of changes in US export shares with our estimates

U.S. Ethanol Mandate Assumptions vs. Actual Production
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Change in US export share for each crop: $\hat{\beta}_{\ell=10} \times 13.7$.

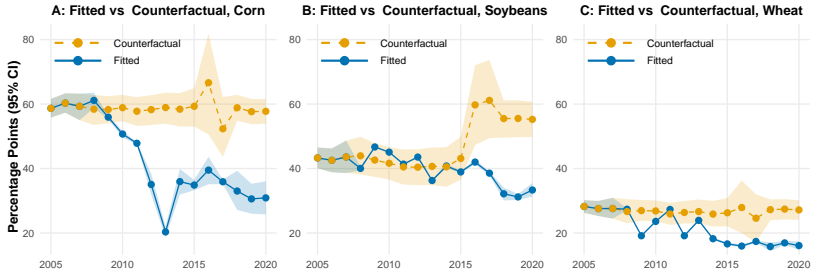
- $\hat{\beta}_{\ell=10} = -1.7$ $[-2.2, -1.3]$ pp for corn
- $\hat{\beta}_{\ell=10} = -1.5$ $[-1.7, -1.2]$ for soybeans
- $\hat{\beta}_{\ell=10} = -0.79$ $[-0.9, -0.7]$ for wheat

Magnitude: FAPRI vs GTAP

Crop Group	Searchinger et al. (FAPRI)	Hertel et al. (GTAP-BIO)	This Study (Ex-Post)
Corn	-62%	-17%	-42.6%
Soybeans	-28%	-12%	-49.2%
Wheat	-31%	-15%	-33.5%

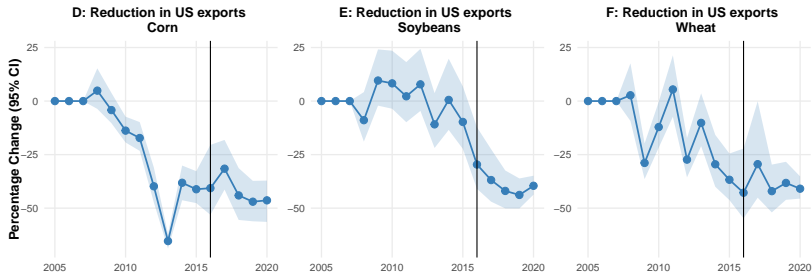
Estimated market responses were closer to the “upper bound” (Searchinger) estimates used in ILUC calculations.

Fitted and counterfactual US export shares from regressions



Counterfactual are predicted values with ethanol volumes set to zero.

Percentage change between non-ethanol counterfactual and fitted (observed) values, on the same year



Predicted market responses were closer to the “upper bound” (Searchinger) estimates used in controversial ILUC calculations.

Conclusions

Implications

- The 2005-2007 RFS generated a structural contraction in the US share of global grain and soybean markets.
- The magnitude of this export displacement aligns with or exceeds the projections of models used for initial regulatory impact assessments.
- The observed equilibrium reflects the combined influence of trade substitutability and supply-side responses, including intensification and extensification.
- Future econometric and modeling work should prioritize estimating and validating these trade and supply responses to accurately capture global land use implications.

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