Local policies, global markets: The effects of biofuel mandates on international agricultural trade and land use

Felipe Grimaldi Avileis

University of Nebraska-Lincoln

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Motivation

- **Desire to reduce GHG emissions from transportation**
  - 28% of US emissions (EPA, 2024)
  - Biofuels are a possible solution
- **Stated Biofuel Policies goals**
  - Provide a lower emissions substitute compared to fossil fuels
  - Support domestic agricultural sector
  - Increase US energy independence
- **Are these policies achieving their goals?**
  - Biofuel policies are set at the country (RFS) or state (LCFS) level, not global, and only regulated feedstocks for fuel use
    - Local policies $\implies$ partial regulation
  - Incomplete regulation leads to inefficient policy outcomes (Fowlie 2009)
  - Especially worrisome for commodities $\rightarrow$ leakage and shuffling are a concern

Research Question

In this work I focus on a central question to the biofuel debate:

- What are the consequences of US biofuel policies on **global** oilseeds **acreage** and vegetable oil **international trade**?

Overview

Why should we care?

- **US biofuel subsidies = US taxpayer money** (Lade and Bushnell 2019)
  - US subsidies can flow to foreign feedstock sources
- **Demand for veg oils for fuel is rapidly growing in the US**
  - RD boom and new 2026-2027 RVO
- **Expansion of foreign oilseed production can be problematic**
  - From 1990-2016, palm oil emitted more CO2 than India (Hsiao 2021)
- **Policy response: Reduce/eliminate subsidies for imported virgin crop oils for fuel use**
  - Border taxes have limited potential to mitigate emissions (Farrokhi and Lashkaripour 2025)
  - No policy response in the food sector

What is happening?

Trade dynamics severely changed since RFS1

- US went from net exporter to **net importer** of vegetable oils

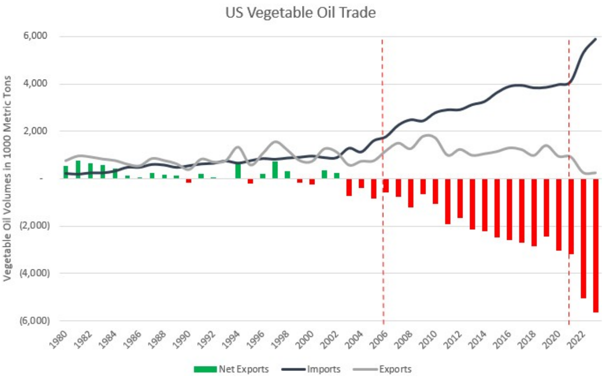


Figure: US Trade Dynamics (GATS, 2024)

Note: The vegetable oils depicted in this figure are soybean oil, canola (rapeseed) oil and palm oil.

Existing Research

Previous Research focused on

- US land use changes and emissions (Lark et al 2022; Chen, Sexton, and Smith, 2025)
- Trade and tax policy in carbon markets (Fowlie 2009; Hsiao 2021; Farrrokhi and Lashkaripour 2025)
- Corn-ethanol markets (Carter, Rausser, and Smith 2017 and Hausman, Auffhammer and Berck 2012)

Contributions

What is new here?

- Oilseeds and vegetable oil market dynamics
- Global farmer decision → how the global farmer reacts to US biofuel shocks
- Trade adaptation under partial regulation
- New exogenous shocks → RVO cost excess premium (Romer and Romer 2004, Gilchrist and Zakrajsek 2012, and Lade, Lawell and Smith 2018)
- Two-Stage Panel Local Projections (Jorda 2023)

Overview

Key findings

- For a 10% increase in RVO prices,
  - oilseed land use **increases** by 0.2% in the US and 0.15% in the RoW → **leakage**
  - US net exports deteriorate, driven by **increasing** imports → **shuffling**.

- Current guardrails are leading to inefficient outcomes

Agenda

- Data
- Empirical Approach
- Results
- Conclusion and Policy Implications

Data

- Data from 2010-2024

- Weekly Soybean Oil futures prices from the CME
  - Nearby and 1st Deferred

- Weekly RIN transaction prices from EPA
  - Tradable compliance credits (D3, D4, D5, and D6)
  - Reflect marginal compliance cost (Whistance and Thompson 2014; Irwin 2017; Lade and Bushnell 2019)

- Two panels → US and RoW
  - 6 US states – Illinois, Iowa, Indiana, Nebraska, Minnesota, and North Dakota
  - 8 countries – Argentina, Brazil, Canada, China, EU-15, Indonesia, India, and Malaysia

Data

RoW Panel

- Yearly Data (2010-2024) for 8 countries
- Acreage, yields, food demand and inventories from FAS/USDA
- Trade flows from the UN Comtrade

US Panel

- Yearly Data (2010-2024) for 6 states
- State-level acreage and yields (NASS/USDA)
- State level imports (US Census Bureau) and exports (FATUS)
- State-level crush shares + total US inventories (USDA/NASS) to construct proxy for state level inventories
- Proxy food demand by combining state population (US Census Bureau) and total US vegetable oil for food use (USDA)

Empirical Approach

The goal of my empirical approach is to isolate the exogenous component of RFS compliance costs (RVO) and estimate impulse response function for US and RoW acreage and vegetable oil trade.

Two-Stage Approach:

- First, I estimate the excess return of RVO costs (Romer and Romer, 2004; Gilchrist and Zakrajšek, 2012)
  - Isolate the exogenous abnormal returns from fundamental driven returns in RVO costs (Lade, Lawell, and Smith, 2018)
- Second, I estimate FE Panel Local Projection models (Jorda, 2005; Jorda, 2023)
  - Estimate relevant IRFs

Empirical Approach

What is the RVO price? The total cost imposed on obligated parties to comply with the RFS mandate.

The **RVO price per gallon** is the sum of the required shares (s_i) multiplied by the price of the RIN credit (p_i) for each fuel category:

$$\textbf{RVO} = \sum_i s_i \, p_{RIN_i} \quad \text{for } i \in \{D3, D4, D5, D6\}$$

- **RVO is the aggregated cost of the RIN percentages per gallon of transportation fuel** (Platts, 2025).

Empirical Approach

- From a fundamental perspective, the RVO (i.e., combination of RINs) price should reflect the **cost differential** between the biofuel and the conventional fuel it displaces. (Whistance & Thompson, 2014; Irwin, 2014)

The Fundamental Price (Expected RVO)

$$\textbf{Expected RVO} = \sum_i s_i * (C_{\text{Biofuel}_i} - C_{\text{Conventional Fuel }_i})$$

$\implies$ This cost differential is the price component explained by **market fundamentals** (e.g., Biodiesel-Diesel, Ethanol-Gasoline).

Empirical Approach - First Stage

I decompose the observed RVO Price (P_t^{RVO}) into a predicted, fundamental component ($\hat{P}_t^{RVO}$) and the unanticipated Abnormal RVO Premium (ARP_t). (Gilchrist & Zakrajšek, 2012)

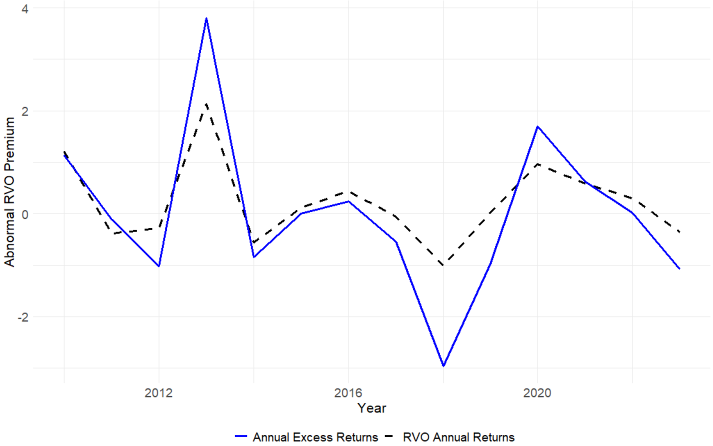
$$P_t^{RVO} = \hat{P}_t^{RVO} + \text{ARP}_t$$

Where the predicted component is estimated following Lade, Lawell, and Smith (2018):

$$\Delta \ln(P_t^{RVO}) = \underbrace{\alpha + \sum_{k=0}^{4} \beta_k \Delta \ln(P_{t-k}^{\text{FS}}) + \sum_{j=1}^{4} \delta_j \Delta \ln(P_{t-j}^{RVO})}_{\substack{\text{Fundamental} \\ \text{Response}}} + \varepsilon_t$$

Empirical Approach - First Stage

The ARP_t is the estimated residual component (ε_t) and orthogonal to market fundamentals.



Empirical Approach - Second Stage

Panel Local Projections (Jorda, 2005; Jorda, 2023)

$$\Delta y_{i,t+h} = \alpha_i + \gamma_h \cdot \mathrm{ARP}_{i,t} + \lambda_h \cdot \Delta \ln(\mathrm{food})_{i,t} + \sum_{l=1}^{2} \Delta \mathbf{X}_{i,t-l} \cdot \beta_{h,l} + u_{i,t+h}$$

Where:

- $\mathbf{y_{i,t+h}}$: Cumulative log-change in the outcome variable (Acreage, Exports) for unit i between t and $t+h$.
- $\gamma_{\mathbf{h}}$: The IRF coefficient of interest
- $\mathrm{ARP}_{\mathbf{i,t}}$: The annual Abnormal RVO Premium
- $\alpha_{\mathbf{i}}$: Country-specific fixed-effects
- $\mathbf{X}_{i,t-l}$: Vector of controls and lagged outcome variables .

Theoretical Implications and Empirical Findings

If current regulations and guardrails are working, then

- RVOs shocks would only (or mainly) increase US acreage
- US net exports deteriorates by lower exports

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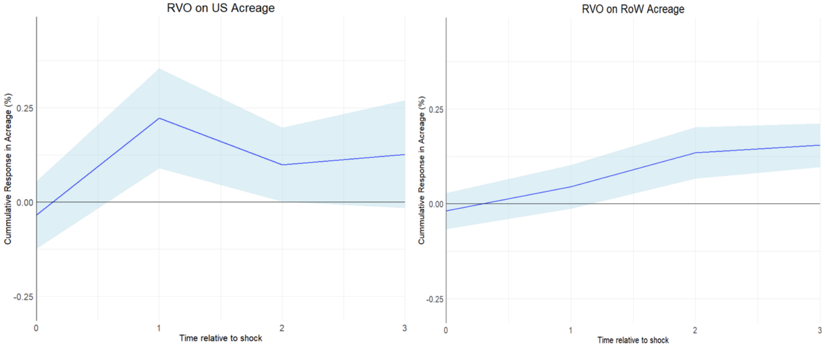
- US net exports deteriorates by lower exports

However I find that for a 10% increase in RVO prices

- US acreage increases in the short-run by 0.2%, but long-run effect is small.
- RoW acreage takes longer to respond (2 years after shock), but increases by 0.15% in the long-run
- US net exports of vegetable oil deteriorates, driven by increases in **imports**

Results

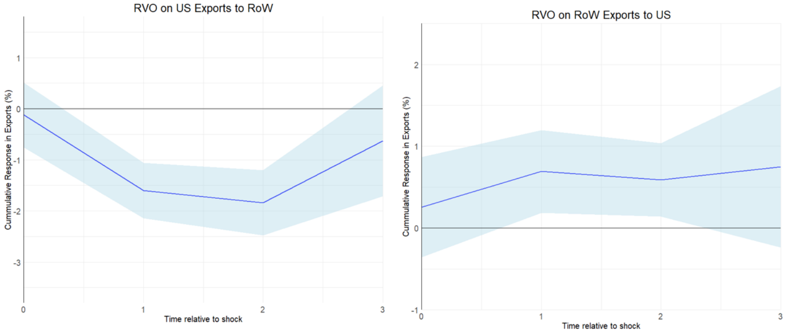
Global acreage response to biofuel demand shocks



*Note:*The figures display the impulse response functions of a 10% RIN price increase on US and RoW acreage. Horizon 0 denotes the horizon contemporaneous to the shock. Standard errors are Driscoll-Kraay at the 90% confidence interval.

Results

US and ROW trade response to biofuel demand shocks



Note: The figures display the impulse response functions of a 10% RIN price increase on US and RoW vegetable oil trade. Horizon 0 denotes the horizon contemporaneous to the shock. Standard errors are Driscoll-Kraay at the 90% confidence interval.

The Impact of US biofuel policies

The RFS drives significant responses across global markets

Example: The RVO price surge between 2020 and 2021. I find this event resulted in:

- **Global Land Use Change:**
  - **US:** 2.7 million acres converted to oilseeds in the US. (3.3%)
  - **RoW:** 2.4 million new acres permanently converted to soybeans in Brazil and 500 thousand new permanent acres of palm trees in Indonesia and Malaysia. (2.5%)
- **Trade Deterioration:** US farmer sector lost local and global market share
  - US net exports of vegetable oils significantly deteriorated by over **500 thousand MT**.
  - Driven by a significant increase of 830 thousand MT in imports. (2.7%)

The Impact of US biofuel policies

Conclusions

- **Incomplete regulation leads to inefficient outcomes** (Fowlie 2009; Hsiao 2021; Farrokhi and Lashkaripour 2025)
  - Unregulated food sector and foreign countries
  - Global carbon club could be a solution
- **Low trade barriers and fungibility** of vegetable oils adds to the problem $\rightarrow$ shuffling between fuel and food
- **US crushing sector has been responding to the additional demand**, but that takes time (Janzen, 2025)
  - Long term policy clarity could accelerate crush sector response and reduce leakage $\Longrightarrow$ real options effect (Dixit and Pyndick, 1994)