POLICY UNCERTAINTY UNDER MARKET-BASED REGULATIONS:
EVIDENCE FROM THE RENEWABLE FUEL STANDARD*

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*Formerly Compliance Costs and RIN Prices under the Renewable Fuel Standard.

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Tradeable credits designed as a cost effective tool for quantity mechanisms.

- Uses include cap and trade (e.g. SO$_2$), resource management (e.g. fishery catch shares), and quotas (e.g. NYC taxicabs).
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Credits derive their value from the belief that underlying policy will be enforced.

- Policy uncertainty will diminish the value of credits.
- Credit markets are an ideal context to quantify effects of policy uncertainty.
We study a relatively new market for tradeable credits: The market for Renewable Identification Numbers (RINs) under the Renewable Fuel Standard (RFS2).

- Every gallon of qualifying renewable fuel is associated with a RIN.
- Obligated parties maintain compliance with RFS2 by turning in a quantity of RINs equal to their prorated share of the mandate.
Research Questions

What determines credit prices for policies with banking/borrowing provisions over multi-year compliance periods?
  ▶ Develop dynamic model with uncertainty.

Have historical RIN markets operated 'rationally' in the traditional economic sense?
  ▶ Test whether historical RIN prices have been predictable.

What have been most important drivers of RIN prices historically?
  ▶ Estimate impact of fuel prices and policy announcements on historical RIN prices.
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Renewable Fuel Standard (RFS2)

▶ Mandates increasing volumes of biofuel through 2022.
▶ Includes sub-mandate structure for 4 categories.
▶ Limited banking and borrowing allowed.
RINs differentiated by biofuel type and year to enforce submandates and borrowing restrictions.
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Dynamic RIN Model: Setup

Competitive industry composed of $N$ firms:

- Firms produce fuel ($Q$) using conventional ($q^c$) and renewable ($q^r$) inputs
- Inputs are perfect substitutes
- Costs are separable and heterogeneous:

$$ C_i(q_i^c, q_i^r) = C_i^c(q_i^c) + C_i^r(q_i^r). $$
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Policy implemented over time:

- Two compliance periods: $\tau \in \{1, 2\}$.
- Production takes place in each time $t$, which is not necessarily same as $\tau$ (e.g., monthly production and yearly compliance).
Policy constraints:

- Over both compliance periods:

\[
\sum_{t=1}^{T_2} (q'_t + c_t) \geq \alpha_1 \sum_{t=1}^{T_1} q_i^c + \alpha_2 \sum_{t=T_1+1}^{T_2} q_t^c
\]

- Over the first compliance period:

\[
B \leq \sum_{t=1}^{T_1} (q'_t + c_t) \leq \overline{B}
\]
When market for credits is perfectly competitive and firms have rational expectations, equilibrium market clearing credit prices are:

\[
rt = \begin{cases} 
\beta(T_2-t)E_t[\lambda T_2] - \beta(T_1-t)E_t[\Phi] & \text{if } t \in [1, T_1 - 1] \\
\beta(T_2-T_1)E_T[\lambda T_2] - \Phi & \text{if } t = T_1 \\
\beta(T_2-t)E_t[\lambda T_2] & \text{if } t \in [T_1 + 1, T_2 - 1] \\
\lambda T_2 & \text{if } t = T_2 
\end{cases}
\]

Note:
- $\Phi$ is LM for banking constraint in $T_1$
- $\lambda T_2$ is LM for RFS2 constraint in $T_2$
Key Insights From Model

▶ With possible exception of $T_1$, RIN prices will follow Hotelling’s rule in expectation.
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- If the banking restriction is expected to bind, it creates an option value for future year vintages.

- RIN prices will adjust instantaneously in each period to incorporate new information from $\Theta$. 

- The RFS2 is equivalent to a revenue-neutral tax on fossil fuels used to subsidize renewable fuels.
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- The RFS2 is equivalent to a revenue-neutral tax on fossil fuels used to subsidize renewable fuels.
We study 2013 conventional RINs, and estimate historical drivers of prices in the market.
Estimating Historical RIN Price Drivers: Major Announcements

<table>
<thead>
<tr>
<th>Event</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>2013 RFS Proposed Rule</td>
<td>1/31/2013</td>
</tr>
<tr>
<td>2013 RFS Final Rule</td>
<td>08/06/2013</td>
</tr>
<tr>
<td>Reuters Article</td>
<td>10/11/2013</td>
</tr>
<tr>
<td>2014 RFS Proposed Rule</td>
<td>11/15/2013</td>
</tr>
</tbody>
</table>

*We focus on effect of 2013 Final Rule because it was first announcement in which the EPA indicated it would deviate from initial volumetric standards specified in 2007.
We estimate two models to identify the effect of policy announcements.

I Using dates of announcements:

\[ \beta(L)r_t = \alpha + \Phi(L)E_t + \gamma Z_t + \lambda_j A_t + \epsilon_t, \quad t = 1, \ldots, T \]

II Using Bai-Perron break-point estimator with breaks in conditional mean:

\[ \beta(L)r_t = \alpha_j + \Phi(L)E_t + \gamma Z_t + \epsilon_t, \quad t = T_{j-1} + 1, \ldots, T_j \]

- \( E_t \) are futures prices for WTI, ethanol & soybean oil.
- All variables converted to approximate cents/gal and everything estimated in levels.
- Up to 2 lags for \( r_t \) used and contemporaneous through second lag of all energy prices used.
### Long-Run Effects & Counter-Factual RIN Prices Using Announcement Dates

<table>
<thead>
<tr>
<th>2013 Final Rule</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>-107.58*</td>
<td>-91.88**</td>
<td>-71.12**</td>
<td>-62.52***</td>
</tr>
<tr>
<td></td>
<td>(58.35)</td>
<td>(36.04)</td>
<td>(29.17)</td>
<td>(16.95)</td>
</tr>
</tbody>
</table>

![Graph showing RIN Price over time with vertical lines indicating announcement dates.](image-url)
**Long-Run Effects & Counter-Factual RIN Prices Using B-P Break Dates**

<table>
<thead>
<tr>
<th>B-P Break</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>-173.84**</td>
<td>-142.84***</td>
<td>-204.30</td>
<td>-125.78*</td>
</tr>
<tr>
<td></td>
<td>(70.05)</td>
<td>(51.41)</td>
<td>(142.92)</td>
<td>(67.02)</td>
</tr>
</tbody>
</table>

Policy Uncertainty under Market-Based Regulations:

![Graph showing RIN Price changes over time with significant breaks indicated.](image-url)
Through our dynamic model, we show expected future costs affect current RIN prices.
SUMMARY

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- Using forecasting exercise (results not shown here), we show the random walk forecast predicted by our model is among top forecasts, and the result strengthens over time.
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EPA announcements have been primary driver of historic RIN prices.

- No corresponding movement in commodity futures prices following announcements (preliminary).
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May imply high marginal cost of moving beyond 10% ethanol-gasoline blend, but below 10% mandate is not very costly.
The decrease in RIN prices after 2013 Final Rule amount to a $17.7-$28.8 billion loss in the value of the subsidy (tax) to the renewable (fossil) fuel industry.
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EPA has demonstrated it has time inconsistent preferences.

- Calls into question efficacy of quantity-based instruments in this setting.
- Creates large option value to waiting for renewable fuel companies due to policy uncertainty.
- Efficiency may increase by putting price collars on credit prices or altering program to be equivalent (revenue-neutral) tax-subsidy scheme.
Thank you!
RINs differentiated by biofuel type and year to enforce submandates and borrowing restrictions.
If define ‘banked’ RINs as state variable such that

\[ B_{t+1} = B_t + q_t^r + c_t - \alpha_T q_t^c, \quad t = 1, \ldots, T_2 + 1, \]

with \( B_0 = 0 \), we can rewrite the constraints as:

- Over both compliance periods:
  \[ B_{T_2+1} \geq 0. \]

- Over the first compliance period:
  \[ \underline{B} \leq B_{T_1+1} \leq \bar{B}. \]
Dynamic RIN Model: Firm Problem

Firms solve problem:

\[ V_t(B_t; \Theta_t) = \max_{q^c_t, q^r_t \geq 0, c_t} \left( P_t - C^c_t(q^c) - C^r_t(q^r) - r_t c_t + \beta E_t V_{t+1}(B_{t+1}; \Theta_{t+1}) \right) \]

subject to

\[ B_{t+1} = B_t + q^r_t + c_t - \alpha c_t \]

\[ B \leq B_{T1+1} \leq B \]

\[ B_{T2+1} \geq 0 \]

\[ B_1 = 0. \]

for \( t \in [1, T_2] \).
Dynamic RIN Model: Firm Problem

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V_t(B_t; \Theta_t) = \max_{q^c_t, q^r_t \geq 0, c_t} \quad P_t - C_t^c (q^c_t) - C_t^r (q^r_t) - r_t c_t + \beta \mathbb{E}_t V_{t+1}(B_{t+1}; \Theta_{t+1})
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\underline{B} \leq B_{T_1+1} \leq \overline{B}
\]

\[
B_{T_2+1} \geq 0
\]

\[
B_1 = 0.
\]

for \( t \in [1, T_2] \).

Notes:

- Restrictions bind in \( T_2 \) and \( T_1 \) only.
- Problem solved recursively.