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Policy Shocks and Market-Based Regulations:

Evidence from the Renewable Fuel Standard

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Dynamic Model of RFS Compliance and RIN Prices

In this appendix, we derive the market clearing RIN prices described in the main text of our paper. We derive RIN prices under two mandate structures. First, we consider a market with a single biofuel, a single fossil fuel, and two compliance periods. This model allows us to study the impacts of banking and borrowing restrictions on the relationship between RIN prices across vintage years for the same RIN type. Second, we consider a market with two biofuels, a single fossil fuel, a single compliance period, and a nested mandate. This variant of the model allows us to derive the relationship between RIN prices for different biofuel types due to the nested structure of the RFS mandate.[1]

In the following derivations, we posit a competitive fossil fuel and biofuel industry. We, therefore, derive RIN prices by solving a 'representative' or aggregate firm's problem. In this case, RIN prices are equal to relevant Lagrange multipliers from the policy constraints. In an earlier working paper, we explicitly derive these market clearing RINs prices using a firm-level version of the model where firms face heterogeneous compliance costs and can trade compliance credits (Lade, Lin Lawell, and Smith 2017). The proof is similar to Montgomery (1972) and requires the market for compliance credits to be frictionless and competitive. We refer the reader to this earlier version, and present only the aggregate firm's problem here and just refer to the market clearing RIN prices.

In both iterations of the model, risk-neutral firms make production decisions based on current and expected future market conditions and policy environments. Time is denoted by subscripts t and is discrete. Firms use two types of inputs in the production of fuel Q: (i) a cheap and abundant fossil fuel input q^f and (ii) costly biofuel inputs $\mathbf{q}^b$. Total fuel production in period t is given by:

$$Q_t = q_t^f + \sum_j q_{j,t}^b,$$

where t denotes the period, and j denotes the biofuel. Consumers demand blended fuel and have quasilinear preferences for fuel with aggregate inverse demand $P_t(Q_t;\Theta_t)$. Biofuels and fossil fuels are specified in units so that they are perfect substitutes in production and consumption.[2]

Uncertainty enters model through several avenues. Each day, firms may experience a common price (demand) shock θ_t^p; a cost (supply) shock θ_t^f for fossil fuel; cost (supply) shocks θ_t^b for biofuels; and a policy shock θ_t^α. The tuple of shocks is denoted by $\Theta_t = (\theta_t^p, \theta_t^f, \theta_t^b, \theta_t^\alpha)$. As commonly assumed in stochastic dynamic programming models so that the unobserved shocks can be modeled as a state variable, we assume that firms realize all time t shocks before they make their period t production decisions. However, future values of the shocks remain uncertain and stochastic. We assume every firm knows the distribution of possible future shocks conditional on current state variables and shocks; that firms exhibit rational expectations; and that the distribution of possible future shocks conditional on current state variables and shocks incorporates the possibility of supply and demand shocks due to a variety of factors, including changing market conditions, the possibility that the blend wall becomes binding, and changes in ethanol exports. The firms' aggregate cost functions are assumed to be separable, increasing, and strictly convex such that:

$$C_t(q_t^f, \mathbf{q}_t^b; \Theta_t) = C_t^f(q_t^f; \Theta_t) + \sum_j C_{j,t}^b(q_{j,t}^b; \Theta_t),$$

where $C_t^f(\cdot;\Theta_t)$ is the aggregate cost function for fossil fuel and $C_{j,t}^b(\cdot;\Theta_t)$ is the aggregate cost function for biofuel j, with $C_t^{f'}(\cdot;\Theta_t) > 0$ and $C_t^{f''}(\cdot;\Theta_t) > 0$ for and t. Similar conditions hold for $C_{j,t}^b(\cdot;\Theta_t)$. Firms are risk neutral and therefore maximize expected profit.

We begin with a model of a single fossil fuel and biofuel, but with a mandate that spans two compliance periods. We then consider a model with a single compliance period, but with two biofuels and a nested mandate.

Two Compliance Periods and One Biofuel

Consider a market with one fossil fuel and one biofuel, and suppose there are two compliance periods. Both compliance periods are denoted by superscripts 1 and 2, while subscript t denotes periods in which firms make production decisions. For example, firms may make daily production decisions but are required to meet their compliance obligation under the mandate only once per year. The first compliance period occurs for $t \in [1, T^1]$ with corresponding mandate α^1, while the second compliance period occurs for $t \in [T^1+1, T^2]$ with mandate α^2, which does not necessarily equal α^1. Firms' compliance obligations are due in period $t = T^2 + 1$.

Firms can over- or under-comply with the mandates between compliance period, but are limited in their ability to do so. To enforce these constraints, we first define the amount of banked RINs in each period. The stock of period 1 and 2 compliance credits evolves as follows:

$$\begin{aligned} B_{t+1}^1 &= B_t^1 + \mathbf{1}(t \leq T^1)\left(q_t^b - \alpha^1 q_t^f\right) \\ B_{t+1}^2 &= B_t^2 + \mathbf{1}(t > T^1)\left(q_t^b - \alpha^2 q_t^f\right), \end{aligned}$$

where B_t^1 is the aggregate stock of period 1 compliance credits on day t, B_t^2 is the aggregate stock of period 2 compliance credits on day t, and $\mathbf{1}(\cdot)$ is an indicator function for whether day t is in compliance period 1 or 2. The initial value of the banked credits is zero in both periods ($B_{1,0} = B_{2,0} = 0$), and we allow a forward market for period 2 compliance credits, which means that firms can trade them in period 1 even though none get generated until period 2.[3,4]

The fuel industry faces three constraints on the level of banked RINs, all of which are enforced in period $t = T^2 + 1$. The policy constraint on the total level of biofuel production is given by:

$$B^1_{T^2+1} + B^2_{T^2+1} \geq 0.$$

The constraint states that after the final compliance period, the total amount of biofuel produced over both compliance periods must be greater than or equal to the total renewable volume obligation, given by $\alpha^1 \left(\sum_t^{T^1} q_t^f\right) + \alpha^2 \left(\sum_{T^1+1}^{T^2} q_t^f\right)$. A second constraint specifies that the industry cannot meet more than a proportion γ^1 of its period 1 obligation with credits generated in period 2, a borrowing restriction. We write the restriction as:

$$B^1_{T^1+1} \geq -\gamma^1 \sum_{t=1}^{T^1} \alpha^1 q_t^f.$$

The constraint states that the bank of credits generated in period 1 may be negative, but not too negative. The last constraint is a banking restriction, given by:

$$B^2_{T^2+1} \geq -\gamma^2 \sum_{t=T^1+1}^{T^2} \alpha^2 q_t^f.$$

Similar to the borrowing restriction, the banking constraint states that firms can use no more than a proportion γ^2 of their period 2 obligation with credits generated in period 1. Combining the borrowing and banking constraints with the policy constraint implies that at most one of the periods' banking levels can be negative. Firms may either bank credits from period 1 to make up for a deficit in period 2 or borrow credits from period 2 to make up for a deficit in period 1, but not both. If the aggregate level of period 2 banking is negative, the bank of period 1 credits must be positive in order to make up for the deficit and vice versa.

Given our setup, the representative firm's problem is given by the following Bellman equation:

$$V_t(B_t;\Theta_t) = \max_{q_t^f, q_t^b \geq 0} P_t(Q_t;\Theta_t)Q_t - C_t^f(q_t^f;\Theta_t) - C_t^b(q_t^b;\Theta_t) + \beta \mathbb{E}_t[V_{t+1}(B_{t+1};\Theta_{t+1})]$$

$$\begin{aligned} \text{subject to} \qquad B^1_{T^1+1} &\geq -\gamma^1 \textstyle\sum_{t=1}^{T^1} \alpha^1 q_t^f \\ B^2_{T^2+1} &\geq -\gamma^2 \textstyle\sum_{t=T^1+1}^{T^2} \alpha^2 q_t^f \\ B^1_{T^2+1} + B^2_{T^2+1} &\geq 0 \\ B^1_0 = B^2_0 &= 0. \end{aligned}$$

Interior optimality conditions for q_t^f and q_t^b in the first compliance period ($t \in \{1,...,T^1\}$) are, respectively:

(A.1) $P_t = C_t^{f'}(q_t^f) + \alpha^1 \beta^{(T^2-t)} \mathbb{E}_t[\lambda] + \alpha^1(1-\gamma^1)\beta^{(T^1-t)}\mathbb{E}_t[\Phi^1]$

(A.2) $P_t = C_t^{b'}(q_t^b) - \beta^{(T^2-t)} \mathbb{E}_t[\lambda] - \beta^{(T^1-t)}\mathbb{E}_t[\Phi^1]$,

where λ is the Lagrange multiplier on the policy constraint and Φ_1 is the Lagrange multiplier on the borrowing constraint.

Interior optimality conditions for the second compliance period ($t \in \{T^1+1,...,T^2\}$) are:

(A.3) $P_t = C_t^{f'}(q_t^f) + \alpha^2 \beta^{(T^2-t)} \mathbb{E}_t[\lambda + (1-\gamma^2)\Phi^2]$

(A.4) $P_t = C_t^{b'}(q_t^b) - \beta^{(T^2-t)} \mathbb{E}_t[\lambda + \Phi^2]$, where Φ^2 is the Lagrange multiplier on the banking constraint.

Recall from the main text that, assuming frictionless, competitive trading, on the terminal date $t = T^2$ RIN prices are given by equations (2) and (3), which we re-write below:

$$r^1_{T^2} = \lambda$$
$$r^2_{T^2} = \lambda + \Phi^2.$$

Given rational expectations and risk neutral firms, we can derive the following expressions for RIN prices in all other periods t as:

$$\text{(A.5)} \qquad r^1_t = \begin{cases} \beta^{(T^2-t)}\mathbb{E}_t[\lambda] + \beta^{(T^1-t)}\mathbb{E}_t[\Phi^1] & \text{if } t \leq T^1 \\ \beta^{(T^2-t)}\mathbb{E}_t[\lambda] & \text{if } t > T^1 \end{cases}$$

$$\text{(A.6)} \qquad r^2_t = \beta^{(T^2-t)}\mathbb{E}_t[\lambda + \Phi^2],$$

where r^1_t is the market clearing price of period 1 RINs and r^2_t is the market clearing price of period 2 RINs. Note that by assumption all uncertainty is resolved in period $T_2 + 1$ when compliance for the mandate is due.

We are now able to derive analytic solutions for each RIN price over time in order to show when RIN prices for each compliance period are positive. Consider first the solution on the date $t = T_2$. From equations (A.5) and (A.6), any difference between RIN prices on day $t = T^2$ must be due to the banking constraint binding on the industry ($\Phi^2 > 0$). Using this insight and equation (A.1)-(A.4) we can derive market clear RIN price on day T^2 as a function of the market supply functions and policy parameters. We have three scenarios to consider. First, if none of the policy constraints bind, both Lagrange multipliers are slack, and the credit prices are zero. Second, if the total mandate binds but the banking constraint does not bind ($\Phi^2 = 0$ and $\lambda > 0$), then equations (A.3) and (A.4) implies that the RIN prices are equal and given by:

$$r^1_{T^2} = r^2_{T^2} = \lambda = C^{b'}_{T^2}(q^b_{T^2}) - P_{T^2} = \frac{C^{b'}_{T^2}(q^b_{T^2}) - C^{f'}_{T^2}(q^f_{T^2})}{1+\alpha^2} > 0.$$

Third, if the banking constraint binds ($\Phi^2 > 0$) there are surplus period 1 credits that firms would like to use towards period 2 compliance, but the banking restriction prevents them from doing so fully. These surplus period 1 credits, therefore, have no value on the margin, i.e., $r^1_{T^2} = 0$. From (A.5), this implies that $\lambda = 0$, i.e., the total mandate is not binding. Solving for the period 2 RIN price using equations (A.3) and (A.4) yields:

$$
\begin{aligned}
&r^1_{T^2} = 0 \\
&r^2_{T^2} = \Phi^2 = C^{b'}_{T^2}(q^b_{T^2}) - P_{T^2} = \frac{C^{b'}_{T^2}(q^b_{T^2}) - C^{f'}_{T^2}(q^f_{T^2})}{1+\alpha^2(1-\gamma^2)} > 0.
\end{aligned}
$$

Now, consider the impact of the borrowing constraint on RIN prices. Recall that a binding borrowing constraint implies that there are no period 1 RINs available for trade in period 2 since firms carry forward a negative value of B^1_t into the second compliance period. From equations (A.5) and (A.6), the Lagrange multiplier on the borrowing constraint (Φ^1) only enters our RIN price equations for $t \leq T^1$. On date T^1, the market resolves whether the borrowing constraint binds, so if the constraint is binding, then this is the last day a market exists for both RINs. Using equations (A.1) and (A.2), the period 1 RIN price on day T^1 is given by:

$$
r^1_{T^1} = \beta^{(T^2-T^1)}\mathbb{E}_{T^1}[\lambda] + \Phi^1 = C^{b'}_{T^1}(q^b_{T^1}) - P_{T^1} = \frac{C^{b'}_{T^1}(q^b_{T^1}) - C^{f'}_{T^1}(q^f_{T^1})}{1+\alpha^1} + \frac{\alpha^1\gamma^1}{1+\alpha^1}\Phi^1 > 0.
$$

Using (A.5) and (A.6), and the fact that a binding borrowing constraint means that the banking constraint will not bind ($\Phi^2 = 0$), the difference between RIN prices on day T^1 is therefore:

$$
\begin{aligned}
\Phi^1 &= r^1_{T^1} - r^2_{T^1} \\
&= \left(C^{b'}_{T^1}(q^b_{T^1}) - P_{T^1}\right) - \beta^{(T^2-T^1)}\mathbb{E}_{T^1}\left[\max\left[C^{b'}_{T^2}(q^b_{T^2}) - P_{T^2}, 0\right]\right].
\end{aligned}
$$

Thus, the Lagrange multiplier on the borrowing constraint reflects the discounted difference in marginal compliance costs between the costlier first compliance period T^1 and the second compliance period T^2. Using equations (A.1)-(A.4), we can solve further to obtain:

$$\begin{aligned}\Phi^1 &= \frac{C^{b'}_{T^1}(q^b_{T^1}) - C^{f'}_{T^1}(q^f_{T^1})}{1+\alpha^1} + \frac{\alpha^1\gamma^1}{1+\alpha^1}\Phi^1 - r^2_{T^1} \\ &= \frac{C^{b'}_{T^1}(q^b_{T^1}) - C^{f'}_{T^1}(q^f_{T^1})}{1+\alpha^1(1-\gamma^1)} - \frac{1+\alpha^1}{1+\alpha^1(1-\gamma^1)}r^2_{T^1}.\end{aligned}$$

Substituting into the expression for the period 1 RIN price and simplifying yields:

$$r^1_{T^1} = \frac{C^{b'}_{T^1}(q^b_{T^1}) - C^{f'}_{T^1}(q^f_{T^1})}{1+\alpha^1(1-\gamma^1)} - \frac{\alpha^1\gamma^1}{1+\alpha^1(1-\gamma^1)}r^2_{T^1}.$$

In sum, on any day t, we have:

$$\begin{aligned} r^1_t &= \begin{cases} \beta^{(T^2-t)}\mathbb{E}_t\left[r^2_{T^2} - \Phi^2 + \beta^{(T^1-T^2)}\Phi^1\right] & \text{if } t \le T^1 \\ \beta^{(T^2-t)}\mathbb{E}_t[\lambda] & \text{if } t > T^1 \end{cases}, \\ r^2_t &= \beta^{(T^2-t)}\mathbb{E}_t[r^2_{T^2}] = \beta^{(T^2-t)}\mathbb{E}_t\left[\max\left[C^{b'}_{T^2}(q^b_{T^2}) - P_{T^2}, 0\right]\right].\end{aligned}$$

On the last day T^1 of the first compliance period, if the borrowing constraint binds ($\Phi^1 > 0$, $\Phi^2 = 0$) RIN prices are given by:

$$\begin{aligned} r^1_{T^1} &= C^{b'}_{T^1}(q^b_{T^1}) - P_{T^1} \\ &= \frac{C^{b'}_{T^1}(q^b_{T^1}) - C^{f'}_{T^1}(q^f_{T^1})}{1+\alpha^1(1-\gamma^1)} - \frac{\alpha^1\gamma^1}{1+\alpha^1(1-\gamma^1)}r^2_{T^1} > 0 \\ r^2_{T^1} &= \beta^{(T^2-T^1)}\mathbb{E}_{T^1}\left[\max\left[C^{b'}_{T^2}(q^b_{T^2}) - P_{T^2}, 0\right]\right] \\ &= \beta^{(T^2-T^1)}\mathbb{E}_{T^1}\left[\max\left[\frac{C^{b'}_{T^2}(q^b_{T^2}) - C^{f'}_{T^2}(q^f_{T^2})}{1+\alpha^2}, 0\right]\right] < r^2_{T^1}.\end{aligned}$$

On the last day T^2 of the second compliance period, if the banking constraint binds ($\Phi^2 > 0$), then the borrowing constraint does not bind ($\Phi^1 = 0$) and RIN prices are given by:

$$\begin{aligned} r^1_{T^2} &= 0 \\ r^2_{T^2} &= C^{b'}_{T^2}(q^b_{T^2}) - P_{T^2} = \frac{C^{b'}_{T^2}(q^b_{T^2}) - C^{f'}_{T^2}(q^f_{T^2})}{1+\alpha^2(1-\gamma^2)} > 0.\end{aligned}$$

Single Compliance Period and Two Biofuels

Now suppose firms produce two types of biofuels $q^b_{j,t}$, where we differentiate the fuels using subscript $j \in 1,2$. RIN prices for each fuel type are denoted by $r_{j,t}$. For simplicity, assume that there is only one compliance period for $t \in [1,T]$. Suppose firms face two policy constraints: (i) a mandate on total biofuel production with blend requirement α_1; and (ii) a sub-mandate for $q^b_{2,t}$ with blend mandate α_2.[5] The policy constraints are given by:

$$\sum_{t=1}^{T}\left(q^b_{1,t}+q^b_{2,t}\right) \geq \alpha_1 \sum_{t=1}^{T} q^f_t$$

$$\sum_{t=1}^{T}\left(q^b_{2,t}+w_{i,2,t}\right) \geq \alpha_2 \sum_{t=1}^{T} q^f_{i,t}.$$

We write the constraints in a more compact form by defining the number of banked credits for each mandate, $B_{1,t}$ and $B_{2,t}$, as:

$$B_{1,t+1} = B_{1,t} + q^b_{1,t} + q^b_{2,t} - \alpha_1 q^f_t$$
$$B_{2,t+1} = B_{2,t} + q^b_{2,t} - \alpha_2 q^f_t.$$

Given this definition, we can write the policy constraints as:

$$B_{1,T+1} \geq 0$$

$$B_{2,T+1} \geq 0.$$

As before, firms will trade compliance credits until they equalize their compliance costs to the market clearing RIN prices. In this case, market clearing RIN prices are:

(A.7) $r_{1,t} = \beta^{(T-t)}\mathbb{E}_t[\lambda_1]$

(A.8) $r_{2,t} = \beta^{(T-t)}\left(\mathbb{E}_t[\lambda_1]+\mathbb{E}_t[\lambda_2]\right)$

It therefore follows that RIN prices in the final period T are given by:

$$r_{1,T} = \lambda_1$$
$$r_{2,T} = \lambda_1 + \lambda_2 = r_{1,T} + \lambda_2,$$

where λ_j is the Lagrange multiplier for policy constraint j in the aggregate firm's problem.

As before, we can solve for the RIN prices as a function of prices, marginal costs, and policy parameters by solving the representative firm's Bellman equation:

$$V_t(B_{1,t}, B_{2,t}; \Theta_t) = \max_{q_t^f, q_{1,t}^b, q_{2,t}^b \geq 0} P_t(Q_t; \Theta_t) Q_t - C_t^f(q_t^f; \Theta_t) - \sum_j C_{j,t}^b(q_{j,t}^b; \Theta_t)$$
$$+ \beta \mathbb{E}_t V_{t+1}(B_{1,t+1}, B_{2,t+1}; \Theta_{t+1})$$

$$\text{subject to} \quad B_{1,t+1} = B_{1,t} + q_{1,t}^b + q_{2,t}^b - \alpha_1 q_t^f$$
$$B_{2,t+1} = B_{2,t} + q_{2,t}^b - \alpha_2 q_t^f$$
$$B_{1,T+1} \geq 0, B_{2,T+1} \geq 0,$$
$$B_{1,1} = 0, B_{2,1} = 0.$$

The optimality conditions are:

$$q_t^f \geq 0 \quad \perp \quad P_t - C_t^{f'}(q_t^f) - \beta^{(T-t)} \left(\alpha_1 \mathbb{E}_t[\lambda_1] + \alpha_2 \mathbb{E}_t[\lambda_2]\right) \leq 0$$
$$q_{1,t}^b \geq 0 \quad \perp \quad P_t - C_{1,t}^{b'}(q_{1,t}^b) + \beta^{(T-t)} \mathbb{E}_t[\lambda_1] \leq 0$$
$$q_{2,t}^b \geq 0 \quad \perp \quad P_t - C_{2,t}^{b'}(q_{2,t}^b) + \beta^{(T-t)} \left(\mathbb{E}_t[\lambda_1] + \mathbb{E}_t[\lambda_2]\right) \leq 0$$

$$B_{1,T+1}\lambda_1 = 0, \quad B_{2,T+1}\lambda_2 = 0.$$

Combining the optimality conditions with the market clearing RIN price equations, we can show that in the final period T RIN prices are given by:

$$r_{1,T} = \max\left[C_{1,T}^{b'}(q_{1,T}^b) - P_T, 0\right]$$
$$r_{2,T} = \max\left[C_{2,T}^{b'}(q_{2,T}^b) - P_T, 0\right]$$
$$\lambda_2 = \max\left[C_{2,T}^{b'}(q_{2,T}^b) - \max\left[C_{1,T}^{b'}(q_{1,T}^b), P_T\right], 0\right].$$

Furthermore, from equations (A.7) and (A.8) we can show:

$$r_{1,t} = \beta^{(T-t)}\mathbb{E}_t[\lambda_1] = \beta^{(T-t)}\mathbb{E}_t[r_{1,T}],$$
$$r_{2,t} = \beta^{(T-t)}\mathbb{E}_t[\lambda_1+\lambda_2] = \beta^{(T-t)}\mathbb{E}_t[r_{1,T}+\lambda_2].$$

Robustness Checks

RIN Abnormal Returns

In this section of the appendix, we consider alternative specifications to test the robustness of our RIN event study results. First, we consider alternative specifications of our normal return variables, controlling for prices of commodities that more directly impact ethanol and biodiesel production costs. Second, we consider alternative time periods for our main regression. Last, we specify all variables in levels instead of logs.

Table B.1 presents our results using alternative controls for RIN normal returns. We specify normal returns for conventional and advanced RINs as a function of futures prices of reformulated gasoline (RBOB), yellow No. 2 corn, No. 11 sugar, soybean oil, and Henry Hub natural gas. For biodiesel RINs, we use prices of July futures contracts for New York Harbor ultra low sulfur diesel (ULSD) instead of RBOB futures prices. We download all prices for July 2014 contracts from Quandl. As before, all normal return estimates are imprecisely estimated, but have the expected sign and are similar to the results are similar to those in Table 5. For example, a 1% increase in RBOB and ULSD futures have similar effects on RIN prices as WTI prices do. Soybean oil futures continue to have the largest impact on conventional and biodiesel RINs, while sugar futures have the largest positive impact on advanced RINs. Importantly, all abnormal return estimates are nearly identical to those used in the main analysis.

Table B.2 presents results using the same specification as in Table 5 for two alternative time periods. In columns (1), (3), and (5) we take advantage of our full RIN price history and estimate our model using data from January 2011 through May 2014.[6] The specification has the benefit of allowing us to have a longer period over which to estimate normal returns. However, if the relationship between RINs and energy futures changed over the period, the coefficients may be biased. Columns (2), (4), and (6) estimate regressions for a shorter period, using data from January 2013 through May 2014. We estimate the regression to address the concern that pre-2013 RIN prices had a different relationship with energy futures prices than post-2013 RINs.

Normal return estimates for the longer time series remain noisy and reflect energy futures prices having a lower impact on RIN prices. WTI, ethanol, and soybean oil futures have a much smaller impact on all RIN prices, and for conventional RINs we estimate that an increase in WTI prices increases RIN prices. The results are consistent with pre-2013 RIN prices reflecting a non-binding mandate. When we use post-2013 data only, the point estimates are similar to those estimated in Table 5. The coefficient on soybean oil futures increases for all three RIN series, consistent with biodiesel being the marginal fuel over the period.[7] As before, normal return estimates are not sensitive to either specification and remain around the same magnitude and significance as our main results.

Table B.3 present our results when we specify all variables in levels (cents/gallon). As before, the normal return estimates are noisy but consistent with our theoretical model. The point estimates suggest that a \$1.00/gal increase in WTI futures decreases RINs prices by \$0.06/gal to \$0.09/gal depending on the specification and RIN series. An increase in ethanol futures prices does not have a statistically significant effect on any series, while biodiesel continues to have a statistically significant impact on conventional and biodiesel RIN prices. Abnormal return estimates show significant impacts of the announcements on the same days as before. To compare the returns with those in Table 5, we can divide the estimates from Table B.3 by the RIN price on each day of the respective event. For example, on the day the 2013 Final Rule was released conventional, advanced and biodiesel RIN prices were \$0.91, \$0.97, and \$1.04, respectively. Thus, the abnormal return estimates in columns (2), (4) and (6) correspond to a 12.9%, 12.9%, and 6.4% decrease, respectively, very close to our main results. Table B.4 presents our estimates of the change in the value of the 2013 RVO when we estimate the panel version of the levels specification. Results are very similar to those in Table 6.

Commodity Market Abnormal Returns

To explore whether the commodities market results are driven by our selection of July 2014 future contracts, we conduct additional event studies for all eleven futures contracts that were trading at the time of the events for each commodity.[8] Tables B.5 and B.6 present the abnormal return and SQ critical value estimates for the event day and subsequent trading day. Consistent with our findings in the paper, we observe no systematic significant abnormal returns in WTI, ethanol, or No. 11 sugar futures contracts. We only find significant abnormal returns in soybean oil and corn futures contracts. All soybean oil contracts experienced abnormal losses between 1.3% and 1.7% following the release of the 2013 final rule, 1.9%-2.3% following the leaked 2014 rule, and 1.0%-1.7% following the 2014 proposed rule. Similar to our main results, corn markets experienced 1.5%-2.6% losses following the 2014 proposed rule.

Extended Event Study Results

Our work focuses on the events surrounding the EPA's original proposed cuts to the total biofuel mandates. The last event included in our main results was the 2014 Proposed Rule. That rule was not finalized for two years as the EPA took a prolonged period to consider the future of the RFS mandates after initially proposing the cuts in 2013. History appears to have repeated itself in 2015 as the EPA released new rules for 2014 and beyond. Here, we consider three additional 'policy shocks' that occurred in 2015 and 2016. The first is the long-delayed 2014-2016 Proposed Rule in May 2015. The rules were slightly altered and finalized in November 2015. Our last event is the 2017 Proposed Rules, released in June 2016. The timing of the three events are shown in Figure B.1 along with the price of 2015 vintage RINs. The first two events correspond again with sharp changes in RINs prices, while the release of the 2017 Proposed Rules corresponds with a small, but notable, increase in RINs prices.

To understand the reasons for the jumps, we update the proposed mandate volumes from before in Table B.7, extending them to include the new rules. The 2014-2016 Proposed Rule increased the proposed 2014 mandates across the board, increasing the total biofuel mandates by 700 mgals over the November 2013 proposal. However, the proposals fell short of industry expectations at the time, leading to the sharp decline seen at the time of the release (Irwin and Good 2015). The Final Rule, released six months later, increased the 2014 mandates by an additional 350 mgals, over a billion gallons more than the proposed cuts from November 2013. The market responded to the volumes immediately as RINs prices increased sharply at its release. RINs prices trended up slightly from November through the following June. When the 2017 Proposed Rules were released, RINs prices exhibited a small but sharp increase.

We again turn to our event study framework to investigate the influence of other potential factors in driving the observed RIN price movements over this period, and to quantify the impacts of the new announcements on the value of the 2015 RVO. Table presents our results. Consistent with the observed RIN prices from the figures, we find large and statistically significant abnormal returns in RINs prices around each event. RINs experienced a large, negative shock following the release of the 2014-2016 Proposed Rule and positive shocks following the 2014-2016 Final Rule and 2017 Proposed Rule.

Table B.9 presents the estimated impacts of the announcements on the 2015 RVO. The 2014-2016 Proposed Rules led to a $3 billion loss in the value of the 2015 RVO. The losses were largely offset by the release of the 2014-2016 Final Rule, where we estimate a $4.3 billion increase in the value of the RVO over five days. The 2017 Proposed Rule was followed by a smaller but significant $480 million increase in the 2015 RVO.

Notes

[1]We have also considered a variant of the model that allows for both multiple compliance periods and nested biofuel mandates. In this case, analytical solutions are difficult to derive given the number of potential cases we consider with binding and non-binding banking/borrowing constraints and nested mandates. We focus here on the two simpler cases to concentrate on the intuition behind the effects of banking/borrowing constraints and nested mandates.

[2]For example, we can accommodate relevant energy content differences across fuels by specifying them in energy-equivalent units such as gasoline gallon equivalents (GGE).

[3]The initial stock of banked RINs does not necessarily have to equal to zero so long as it is equal to a fixed, known value and taken as given by firms. However, since RINs are attached to biofuel produced in a particular compliance period it is natural to specify the initial value as zero.

[4]Firms regularly trade forward contracts for RINs. For example, OPIS began reporting 2013 RINs in August of 2012, four months before firms could generate the RINs.

[5]We use subscripts for the mandates here to differentiate them from our previous model where we used superscripts to denote compliance period.

[6]We construct the longer RIN time series by taking the average of all RIN prices that trade on a particular date. We estimate similar coefficients if we use the front-year RIN price series in all estimates. Oil, ethanol, and soybean oil futures continuous contracts were downloaded from Quandl and are constructed using the front-month contract in all periods.

[7]The coefficient on soybean oil futures in the advanced RINs regressions doubles when we consider only post-2013 data. This result, as well as the result from Table B.1 that sugar futures have the largest impact on advanced RINs when we consider the entire 2013 advanced RIN series, help in part to explain our result that soybean oil futures prices do not have a large impact on advanced RINs. In particular, the results would be consistent with advanced RINs reflecting sugarcane ethanol costs before 2013 and soybean oil prices post-2013 when biodiesel became the marginal biofuel. However, this explanation is speculative, and we are unable to explain this result fully.

[8]We observe No. 11 sugar futures contracts for March, May, July, and October for.

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Table B.1. RIN Event Study Results
(Dependent Variable: Log Differenced 2013 RIN Prices)

		Conventional RINs		Advanced RINs		Biodiesel RINs	
		(1)	(2)	(3)	(4)	(5)	(6)
Normal Returns							
RBOB Futures		-0.237	-0.235	-0.451	-0.402	–	–
		(0.328)	(0.322)	(0.343)	(0.350)	–	–
ULSD Futures		–	–	–	–	-0.323	-0.325
		–	–	–	–	(0.411)	(0.397)
Corn Futures		0.145	0.138	0.190	0.152	0.123	0.084
		(0.172)	(0.163)	(0.216)	(0.212)	(0.199)	(0.197)
Sugar Futures		0.220	0.221	0.349	0.307	0.384	0.395
		(0.278)	(0.284)	(0.268)	(0.290)	(0.250)	(0.261)
Soybean Oil Futures		0.448	0.451	0.125	0.177	0.617	0.628
		(0.335)	(0.332)	(0.405)	(0.402)	(0.410)	(0.411)
Natural Gas Futures		0.038	0.071	0.135	0.160	0.054	0.068
		(0.191)	(0.201)	(0.199)	(0.210)	(0.179)	(0.184)
Abnormal Returns							
2013 Final Rule:	Day 0	-0.135**	-0.11**	-0.135**	-0.120**	-0.062*	-0.057*
	Day 1	-0.148**	-0.134**	-0.139**	-0.127**	-0.142**	-0.141**
	Day 2	-0.196***	-0.176***	-0.158**	-0.137**	-0.181**	-0.167**
	Day 3	0.022	0.040	0.039	0.049	0.048	0.053*
	Day 4	0.047	0.057	0.042	0.045	0.027	0.033
Leaked 2014 Rule:	Day 0	-0.151**	-0.136**	-0.028	0.000	-0.056*	-0.041
	Day 1	0.088**	0.095**	0.146***	0.166***	0.049	0.064*
	Day 2	0.053	0.070*	0.001	0.030	-0.009	0.006
	Day 3	0.002	0.014	-0.022	0.004	-0.029	-0.017
	Day 4	-0.059*	-0.039	-0.060	-0.022	-0.047*	-0.023
2014 Proposed Rule:	Day 0	-0.043	-0.035	-0.037	-0.039	-0.048*	-0.053*
	Day 1	-0.189***	-0.188***	-0.123**	-0.131**	-0.216***	-0.222***
	Day 2	0.059	0.070*	-0.025	-0.023	-0.000	-0.005
	Day 3	-0.008	-0.004	-0.002	-0.006	0.038	0.029
	Day 4	0.022	0.035	-0.022	-0.016	-0.056*	-0.053*
SQ 10% Lower Bound		-0.059	-0.051	-0.052	-0.053	-0.045	-0.043
SQ 10% Upper Bound		0.061	0.059	0.055	0.056	0.051	0.052
SQ 5% Lower Bound		-0.077	-0.076	-0.100	-0.091	-0.068	-0.065
SQ 5% Upper Bound		0.088	0.089	0.074	0.079	0.080	0.078
SQ 1% Lower Bound		-0.176	-0.165	-0.253	-0.235	-0.209	-0.215
SQ 1% Upper Bound		0.182	0.169	0.138	0.133	0.135	0.137
Observations		445	445	445	445	445	445
Time Controls		No	Yes	No	Yes	No	Yes

Notes: Normal return standard errors in parentheses are Newey-West errors with 5 lags. Inference for abnormal returns are based on sample quantile critical values given at the bottom of the table (Gelbach, Helland, and Klick 2013). *, **, and *** denote significance at the 10%, 5%, and 1% confidence levels, respectively.

Table B.2. RIN Event Study Results
(Dependent Variable: Log Differenced 2013 RIN Prices)

		Conventional RINs		Advanced RINs		Biodiesel RINs	
		(1)	(2)	(3)	(4)	(5)	(6)
Normal Returns							
Oil Futures		0.138	-0.697	-0.027	-0.135	-0.021	-0.278
		(0.195)	(0.481)	(0.154)	(0.428)	(0.136)	(0.343)
Ethanol Futures		0.014	0.068	0.004	0.048	0.009	0.106
		(0.073)	(0.249)	(0.054)	(0.255)	(0.040)	(0.254)
Soybean Oil Futures		0.224	0.911**	0.058	0.527	0.343	0.764*
		(0.309)	(0.416)	(0.242)	(0.492)	(0.238)	(0.454)
Abnormal Returns							
2013 Final Rule:	Day 0	-0.115**	-0.128**	-0.113**	-0.118**	-0.059*	-0.059*
	Day 1	-0.127**	-0.136**	-0.129**	-0.127**	-0.151**	-0.133**
	Day 2	-0.178***	-0.186***	-0.150***	-0.139**	-0.154**	-0.173**
	Day 3	0.039	0.040	0.045	0.038	0.034	0.057
	Day 4	0.055*	0.048	0.074**	0.038	0.034	0.032
Leaked 2014 Rule:	Day 0	-0.133**	-0.104**	-0.025	0.016	-0.045*	-0.022
	Day 1	0.111**	0.118**	0.205***	0.175***	0.051*	0.077*
	Day 2	0.080*	0.077*	0.021	0.033	0.010	0.011
	Day 3	0.024	0.031	-0.025	0.002	-0.023	-0.004
	Day 4	-0.025	-0.025	-0.009	-0.008	0.013	-0.013
2014 Proposed Rule:	Day 0	-0.032	-0.043	-0.051	-0.036	-0.041*	-0.054*
	Day 1	-0.202***	-0.206***	-0.104**	-0.129**	-0.175***	-0.224***
	Day 2	0.062*	0.054	-0.014	-0.016	-0.014	-0.003
	Day 3	0.030	-0.022	-0.026	-0.008	0.036*	0.027
	Day 4	0.042	0.014	0.018	-0.025	-0.045*	-0.059*
Sample		1/3/11-5/15/14	1/2/13-5/15/14	1/3/11-5/15/14	1/2/13-5/15/14	1/3/11-5/15/14	1/2/13-5/15/14
SQ 10% Lower Bound		-0.054	-0.059	-0.038	-0.054	-0.033	-0.043
SQ 10% Upper Bound		0.052	0.066	0.048	0.066	0.034	0.058
SQ 5% Lower Bound		-0.073	-0.081	-0.070	-0.102	-0.060	-0.073
SQ 5% Upper Bound		0.094	0.096	0.068	0.081	0.061	0.079
SQ 1% Lower Bound		-0.152	-0.174	-0.144	-0.252	-0.172	-0.220
SQ 1% Upper Bound		0.205	0.164	0.116	0.127	0.126	0.130
Observations		594	344	594	344	594	344
Time Controls		Yes	Yes	Yes	Yes	Yes	Yes

Notes: Normal return standard errors in parentheses are Newey-West errors with 5 lags. Inference for abnormal returns are based on sample quantile critical values given at the bottom of the table (Gelbach, Helland, and Klick 2013). *, **, and *** denote significance at the 10%, 5%, and 1% confidence levels, respectively.

Table B.3. RIN Event Study Results
(Dependent Variable: Differenced 2013 RIN Prices ¢/gal)

		Conventional RINs		Advanced RINs		Biodiesel RINs	
		(1)	(2)	(3)	(4)	(5)	(6)
Normal Returns							
Oil Futures		-0.08	-0.08	-0.06	-0.06	-0.08	-0.09
		(0.07)	(0.07)	(0.07)	(0.07)	(0.10)	(0.10)
Ethanol Futures		0.05	0.04	0.04	0.03	0.06	0.04
		(0.05)	(0.06)	(0.06)	(0.06)	(0.07)	(0.06)
Soybean Oil Futures		0.10**	0.11**	0.06	0.07	0.13**	0.14**
		(0.05)	(0.04)	(0.05)	(0.05)	(0.06)	(0.07)
Abnormal Returns							
2013 Final Rule:	Day 0	-12.76***	-11.79***	-13.53***	-12.53***	-6.91**	-6.64**
	Day 1	-11.87***	-11.21***	-11.90***	-11.03**	-13.26***	-13.05**
	Day 2	-13.80***	-12.79***	-12.17***	-10.67**	-15.05***	-13.93***
	Day 3	1.89	2.72*	2.86	3.74*	4.21*	4.62*
	Day 4	3.70*	4.12*	3.62*	3.74*	2.76	2.88
Leaked 2014 Rule:	Day 0	-4.23**	-3.32*	-0.69	0.75	-2.51	-1.59
	Day 1	2.70*	3.14*	6.87**	7.51**	2.91	3.51*
	Day 2	1.39	2.36	-0.35	1.05	-0.93	-0.23
	Day 3	-0.17	0.51	-1.32	-0.06	-1.58	-0.90
	Day 4	-2.00	-0.99	-2.66	-0.72	-2.45	-0.91
2014 Proposed Rule:	Day 0	-0.73	-0.36	-0.82	-0.59	-1.10	-1.19
	Day 1	-3.89**	-3.96**	-3.10*	-3.60*	-5.58**	-5.99**
	Day 2	1.12	1.56	-0.55	-0.31	0.14	-0.18
	Day 3	-0.65	-0.44	-0.39	-0.26	0.49	0.21
	Day 4	-0.22	0.27	-0.96	-0.27	-2.00	-1.44
SQ 10% Lower Bound		-2.45	-2.43	-2.73	-2.89	-3.05	-3.01
SQ 10% Upper Bound		2.39	2.67	3.10	3.20	3.02	2.95
SQ 5% Lower Bound		-3.72	-3.63	-5.38	-4.90	-5.02	-4.90
SQ 5% Upper Bound		4.87	4.66	4.35	4.47	5.21	5.59
SQ 1% Lower Bound		-8.89	-9.16	-11.18	-11.55	-13.24	-13.08
SQ 1% Upper Bound		8.38	8.13	8.93	8.90	9.60	9.56
Observations		445	445	445	445	445	445
Time Controls		No	Yes	No	Yes	No	Yes

Notes: Normal return standard errors in parentheses are Newey-West errors with 5 lags. Inference for abnormal returns are based on sample quantile critical values given at the bottom of the table (Gelbach, Helland, and Klick 2013). *, **, and *** denote significance at the 10%, 5%, and 1% confidence levels, respectively.

Table B.4. Change in Value of the 2013 Renewable Volume Obligation - Levels Specification

		Change in 2013 RVO	Lower Bound	Upper Bound
2013 Final Rule:	Event Day	-2.05***	-2.14	-1.95
	3 Day	-6.315***	-6.56	-6.06
	5 Day	-5.365***	-5.77	-4.94
Leaked 2014 Rule:	Event Day	-0.635***	-0.78	-0.47
	3 Day	0.06	-0.22	0.33
	5 Day	-0.36	-0.81	0.09
2014 Proposed Rule:	Event Day	-0.13**	-0.25	-0.01
	3 Day	-0.64***	-0.94	-0.33
	5 Day	-0.80***	-1.27	-0.33

Notes: The table presents the change in the value of the 2013 Renewable Volume Obligation (RVO) due to each event. Lower and upper bounds represent 95% confidence intervals. *, **, and *** denote significance at the 10%, 5%, and 1% confidence levels, respectively.

Table B.5. Commodity Market Abnormal Returns: All Traded Contracts

		2013 Final Rule		Leaked 2014 Rule		2014 Proposed Rule	
	Contract	Day 0	Day 1	Day 0	Day 1	Day 0	Day 1
WTI Crude	December-13	-0.009	-0.006	-0.009	0.004	0.002	-0.003
	March-14	-0.009	-0.004	-0.005	0.002	-0.000	-0.005
	May-14	-0.008	-0.003	-0.006	0.001	-0.002	-0.007
	July-14	-0.008	-0.003	-0.005	0.001	-0.003	-0.008
	September-14	-0.007	-0.002	-0.004	0.001	-0.003	-0.008
	December-14	-0.007	-0.001	-0.002	0.001	-0.003	-0.007
	March-15	-0.007	-0.000	-0.001	0.000	-0.002	-0.007
	May-15	-0.006	0.000	-0.001	-0.000	-0.002	-0.007
	July-15	-0.006	0.001	-0.001	-0.001	-0.001	-0.006
	September-15	-0.005	0.002	-0.000	-0.001	-0.001	-0.006
	December-15	-0.005	0.002	0.000	-0.001	-0.000	-0.006
Ethanol	December-13	0.013	-0.007	-0.012	0.006	-0.017**	-0.001
	March-14	0.005	-0.008	-0.012	0.005	-0.008	-0.013*
	May-14	0.005	-0.007	-0.012	-0.000	-0.009	-0.014*
	July-14	0.005	-0.008	-0.011	0.000	-0.008	0.002
	September-14	0.004	-0.008	-0.011	0.001	-0.008	0.003
	December-14	0.004	-0.009	-0.010	0.000	-0.007	0.003
	March-15	0.005	-0.009	-0.011	0.000	-0.007	0.003
	May-15	0.005	-0.009	-0.011	0.000	-0.007	0.003
	July-15	0.005	-0.009	-0.011	0.000	-0.007	0.003
	September-15	0.005	-0.008	-0.011	0.000	-0.007	0.003
	December-15	0.005	-0.008	-0.010	-0.001	-0.007	0.002

Notes: SQ test critical values for each contract is given in Table 7. All specifications include flexible time controls. *, **, and *** denote significance at the 10%, 5%, and 1% confidence levels, respectively.

Table B.6. Commodity Market Abnormal Returns: All Traded Contracts

		2013 Final Rule		Leaked 2014 Rule		2014 Proposed Rule	
	Contract	Day 0	Day 1	Day 0	Day 1	Day 0	Day 1
Soybean Oil	December-13	-0.017**	-0.016**	-0.023***	0.003	-0.010*	-0.006
	March-14	-0.016**	-0.015**	-0.022***	0.003	-0.010*	-0.005
	May-14	-0.015**	-0.013*	-0.021***	0.004	-0.011*	-0.004
	July-14	-0.014**	-0.013*	-0.021***	0.004	-0.012*	-0.004
	September-14	-0.013*	-0.013*	-0.020***	0.004	-0.012*	-0.005
	December-14	-0.014**	-0.013*	-0.018**	0.006	-0.015**	-0.004
	March-15	-0.013*	-0.009	-0.019***	0.003	-0.016**	-0.006
	May-15	-0.013*	-0.006	-0.019***	0.003	-0.016**	-0.004
	July-15	-0.014**	-0.006	-0.019***	0.009	-0.015**	-0.003
	September-15	-0.013*	-0.001	-0.021***	0.003	-0.017**	-0.003
	December-15	-0.014**	-0.002	-0.019***	0.000	-0.009	-0.007
Corn	December-13	-0.004	-0.004	-0.009	0.008	-0.009	-0.026**
	March-14	-0.003	-0.003	-0.008	0.008	-0.013	-0.023**
	May-14	-0.003	-0.001	-0.009	0.008	-0.014	-0.023**
	July-14	-0.004	-0.003	-0.009	0.007	-0.014	-0.022**
	September-14	-0.003	-0.003	-0.008	0.006	-0.014	-0.021**
	December-14	-0.001	-0.003	-0.008	0.007	-0.013	-0.020**
	March-15	-0.002	-0.002	-0.007	0.004	-0.013	-0.020**
	May-15	-0.002	-0.001	-0.006	0.003	-0.014	-0.019*
	July-15	-0.001	-0.001	-0.005	0.005	-0.014	-0.017*
	September-15	-0.002	-0.001	-0.002	0.003	-0.014	-0.018*
	December-15	0.004	-0.004	-0.004	0.010	-0.014	-0.015*
Sugar	March-14	0.001	0.016*	0.010	0.006	-0.005	0.014*
	May-14	0.002	0.017**	0.010	0.006	-0.003	0.011*
	July-14	0.001	0.016*	0.009	0.006	-0.001	0.010
	September-14	0.000	0.015*	0.008	0.005	0.002	0.009
	March-15	-0.000	0.013*	0.007	0.005	0.003	0.009
	May-15	0.000	0.013*	0.006	0.004	0.003	0.008
	July-15	0.000	0.014*	0.004	0.004	0.004	0.007
	September-15	0.002	0.015*	0.003	0.004	0.004	0.007

Notes: SQ test critical values for each contract is given in Table 7. All specifications include flexible time controls. *, **, and *** denote significance at the 10%, 5%, and 1% confidence levels, respectively.

Table B.7. Statutory vs. Proposed Mandates: 2013-2017

	2013(M)	2013(F)	2014(M)	2014(P1)	2014(P2)	2014(F)	2015(M)	2015(P)	2015(F)	2016(M)	2016(P)	2016(F)	2017(M)	2017(P)
Cellulosic Biofuel	1	0.006	1.75	0.017	0.033	0.033	3	0.106	0.123	4.25	0.206	0.23	5.5	0.312
Biomass-Based Diesel	>1.5	1.28	>1.5	1.28	1.63	1.63	>1.5	1.7	1.73	>1.5	1.8	1.9	>1.5	2
Advanced Biofuel	2.75	2.75	3.75	2.2	2.68	2.67	5.5	2.9	2.88	7.25	3.4	3.61	9	4
Total Biofuel	16.55	16.55	18.15	15.21	15.93	16.28	20.5	16.3	16.93	22.25	17.4	18.11	24	18.8

Notes: The table compares volumes from the statutory mandates passed under EISA to volumes from various proposed and final rules. Statutory mandates are denoted by (M); 2013(F) denotes volumes from the 2013 Final Rule; 2014(P1) are volumes from the 2014 Proposed Rule; 2014(P2), 2015(P), and 2016(P) are volumes from the 2014-2016 Proposed Rule; and 2017(P) are volumes from the 2017 Proposed Rule. All volumes are specified ethanol-equivalent volumes except for biomass-based diesel which is physical gallons. (Sources: Environmental Protection Agency (2010, 2013a,b, 2015a,b, 2016))

Table B.8. Extended RIN Event Study
(Dependent Variable: Log Differenced 2015 RIN Prices)

		Conventional RINs		Advanced RINs		Biodiesel RINs	
		(1)	(2)	(3)	(4)	(5)	(6)
Oil Futures		0.057	0.068	-0.003	0.016	-0.013	-0.002
		(0.046)	(0.047)	(0.072)	(0.071)	(0.045)	(0.047)
Ethanol Futures		-0.089	-0.076	-0.210*	-0.213*	-0.117	-0.103
		(0.122)	(0.114)	(0.125)	(0.119)	(0.105)	(0.097)
Soybean Oil Futures		0.045	0.039	0.036	0.010	0.121	0.094
		(0.092)	(0.098)	(0.145)	(0.150)	(0.110)	(0.108)
2014-2016 Proposed Rule:	Day 0	-0.122***	-0.113***	-0.033*	-0.036**	0.062**	0.064***
	Day 1	-0.124***	-0.129***	-0.085***	-0.087***	-0.032**	-0.028*
	Day 2	-0.133***	-0.141***	-0.045**	-0.047**	-0.014	-0.015
	Day 3	-0.058**	-0.059**	0.047**	0.054**	-0.026*	-0.019
	Day 4	0.037*	0.036*	0.028*	0.027*	-0.010	-0.010
2014-2016 Final Rule:	Day 0	0.218***	0.212***	0.096***	0.085***	0.093***	0.084***
	Day 1	0.451***	0.442***	0.171***	0.165***	0.193***	0.185***
	Day 2	-0.004	-0.005	-0.014	-0.012	-0.015	-0.016
	Day 3	-0.043**	-0.045**	0.001	-0.004	-0.018	-0.025*
	Day 4	-0.072**	-0.074**	-0.065**	-0.069**	-0.076***	-0.078***
2017 Proposed Rule:	Day 0	0.071***	0.077***	0.072***	0.075***	0.060**	0.059**
	Day 1	0.030*	0.036*	0.012	0.007	0.017	0.012
	Day 2	-0.030*	-0.024*	-0.028*	-0.033*	-0.026*	-0.029*
	Day 3	-0.016	-0.014	-0.015	-0.022	-0.015	-0.018
	Day 4	-0.017	-0.017	-0.014	-0.021	-0.013	-0.021
SQ 10% Lower Bound		-0.024	-0.023	-0.026	-0.024	-0.023	-0.022
SQ 10% Upper Bound		0.025	0.026	0.027	0.027	0.024	0.022
SQ 5% Lower Bound		-0.038	-0.036	-0.038	-0.035	-0.032	-0.030
SQ 5% Upper Bound		0.038	0.039	0.041	0.039	0.037	0.037
SQ 1% Lower Bound		-0.111	-0.097	-0.084	-0.080	-0.066	-0.060
SQ 1% Upper Bound		0.056	0.072	0.074	0.068	0.064	0.060
Observations		421	421	421	421	421	421
Time Controls		No	Yes	No	Yes	No	Yes

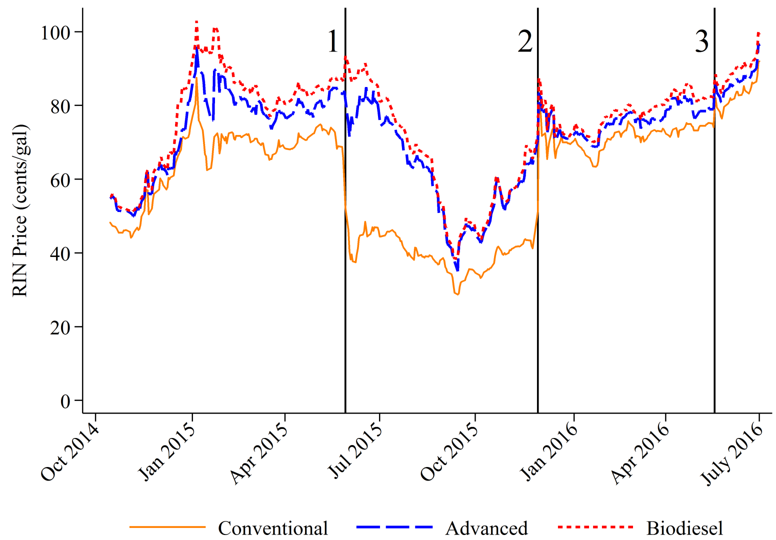
Notes: Futures contracts are for July 2016 contracts. Normal return standard errors in parentheses are Newey-West errors with 5 lags. Inference for abnormal returns are based on sample quantile critical values given at the bottom of the table (Gelbach, Helland, and Klick 2013). *, **, and *** denote significance at the 10%, 5%, and 1% confidence levels, respectively.

Table B.9. Change in Value of the 2015 Renewable Volume Obligation

		Change in 2015 RVO	Lower Bound	Upper Bound
2014-2016 Proposed Rule:	Event Day	-0.82***	-0.87	-0.77
	3 Day	-2.89***	-2.96	-2.81
	5 Day	-3.04***	-3.15	-2.92
2014-2016 Final Rule:	Event Day	1.75***	1.71	1.80
	3 Day	5.31***	5.20	5.42
	5 Day	4.32***	4.14	4.50
2017 Proposed Rule:	Event Day	0.94***	0.89	1.00
	3 Day	0.92***	0.76	1.08
	5 Day	0.48***	0.26	0.71

Notes: The table presents the change in the value of the 2015 Renewable Volume Obligation (RVO) due to each listed event. Lower and upper bounds represent 95% confidence intervals. *, **, and *** denote significance at the 10%, 5%, and 1% confidence levels, respectively.

Figure B.1. 2015 Vintage RIN Prices



Notes: The figure graphs daily prices for 2015 vintage conventional (orange), advanced (blue), and biodiesel (red) RINs from 10/15/2014-6/30/2016. The figure indicates the timing of three additional policy announcements. Event 1 is the release of the 2014-2016 Proposed Rule, 2 is the release of the 2014-2016 Final Rule, and 3 is the release of the 2017 Proposed Rule.