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Article

The Effects of U.S. Biodiesel Tax Credits and Its Uncertainty on the RIN Prices

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Abstract

The United States' Renewable Fuel Standard (RFS) is a biofuel use mandate that is widely studied for its potential impacts on food prices and greenhouse gas (GHG) impacts. Another policy that affects biomass-based diesel fuel uses is a Biodiesel Tax Credit (BTC) that supports use, but has frequently expired and then been reintroduced with retroactive payments so RFS-BTC interactions are unclear. We investigate the pass-through of the biodiesel-diesel price spread and BTC to the prices of RFS compliance certificates (Renewable Identification Numbers, RINs). The RIN price theoretically depends on the price of fuels, such as biodiesel and diesel, as well as the BTC – if the BTC is in place or expected. Our estimated results shows that market participants' responses to the uncertainty of BTC differ over time and are sensitive to the BTC status. These results raise questions about whether an inconsistently applied BTC in the context of a blend mandate encourages firms' use of biofuel and, if that is the underlying goal, could question the program's effectiveness. Results are relevant to policy makers who create the expire-and-revive BTC, regulators who set RFS targets, market participants, and societal goals regarding GHG emissions and goods' prices.

Keywords

Biodiesel tax credits, Renewable fuel standard, Renewable Identification Numbers

Introduction

The USA biofuel use mandate, the Renewable Fuel Standard (RFS), has long been a topic of scientific and popular interest. On the one hand, the policy's introduction was concurrent with a price surge and the food-versus-fuel debate. The RFS is the longest-lived USA policy intended

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to reduce greenhouse gas (GHG) emissions and scientists have studied the exact rate of GHG reduction from different qualifying fuels. Academic work informs regulations set at the USA Environmental Protection Agency that establish how much biofuel is needed each year and which renewable fuels qualify. Biofuels and the RFS are critically important scientific topics with implications for policy makers, regulators, businesses, and consumers.

The United States policy also includes a biodiesel tax credit (BTC) alongside the RFS. However, the BTC is allowed to expire periodically and then has typically been reintroduced with support retroactively provided on transactions that took place while it was in abeyance. As market participants have faced the expiration and reinstatement of the BTC, they might try to assess the probability that the U.S. Congress would extend or reinstate the BTC by tracking the latest news (Irwin et al., 2020). Consequently, market participants' responses to the uncertainty of BTC might vary over time.

We address two aspects of this issue. First, we explore whether the prices of Renewable Identification Numbers (RIN) that are used to comply with the RFS are influenced not only by the spread between biodiesel and diesel prices but also by the BTC. If the BTC and RFS provide overlapping incentives to use biodiesel, then they might combine in terms of their fuel price impacts or else they might substitute such that the BTC causes an offsetting reduction in the RIN price. Second, we test how market expectations regarding the BTC reinstatement influence the RIN values even when the BTC expired. If the BTC is seen as relatively reliable even when expired, then the BTC is expected to affect prices relatively continuously. If market participants put a high probability that the BTC will not be reinvigorated with retroactive payments, then the BTC price effects will be sensitive to its status. For this experiment, we apply the concept of core RIN price, and test how this price has evolved in the biodiesel market, and then we estimate the biomass-based diesel (D4) RIN pricing model.

We find that market expectations put a 25% chance of BTC restoration on average, and these expectations had different effects on the RIN prices each year. Additionally, we find that the market response to the BTC does not solely depend on the presence of BTC. The estimated pass-through of the spread to the RIN prices is complete or incomplete depending on how we test the BTC dummies. Our work adds to the literature on RFS and BTCs by considering the consequences of the on-and-off nature of BTCs taking the RINs into account. These findings are relevant to lawmakers who want to be sure that the money spent on BTCs has the desired impacts, regulators who might take into account price incentives of BTCs when considering renewable fuel production potential, and market agents whose actions depend on their price expectations.

The purpose of this study is to empirically analyze the impact of the interaction between the BTC and RFS on the RIN prices and to determine the impact of market expectations regarding BTC reinstatement on RIN price formation. Through this research, we aim to reveal how the incentives of BTC and RFS actually affect the market.

The rest of the paper is organized as follows. Sections 2 and 3 review the policy and relevant literature. Sections 4 and 5 introduce the fundamental D4 RIN pricing model and data we employ. Section 6 presents the empirical methodology. Section 7 provides the empirical results and discusses the results, followed by the conclusions in Section 8.

Backgrounds

The RFS mandates the incorporation of biofuels in the U.S. transportation fuel supply. This policy was first created by the Energy Policy Act of 2005, and it was expanded through the

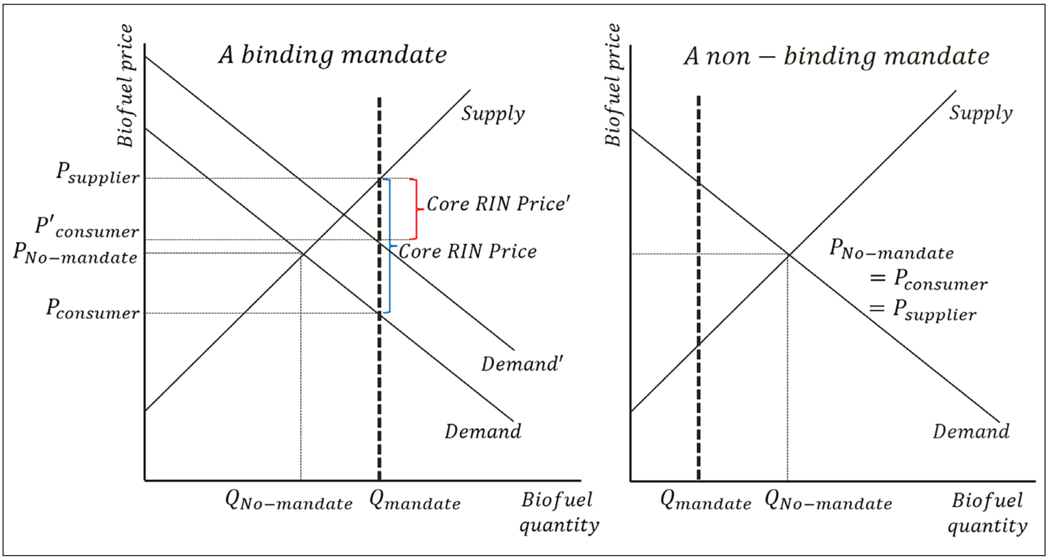

Figure 1. How a mandate may or may not affect a biodiesel wholesale market
Source: A demand shift of a binding mandate case is added based on Thompson et al. (2009, p. 46)

Energy Independence and Security Act of 2007 (EPA, 2020). Each year, the U.S. Environmental Protection Agency (EPA) publishes volume requirements for certain biofuel categories and sets those volumes through annual renewable volume obligations (RVO). RVOs are the volumetric biofuel targets for obligated parties (refiners and importers).

The RINs indicate gallons of biofuel that are produced or imported to be blended for domestic use. RINs are tradable and used by obligated parties to satisfy their compliance requirement. In the presence of a binding mandate, there will be a spread between the price at which biofuel producers are willing to sell to fuel blenders and the price of blended biofuel for producing vehicle fuels (Whistance & Thompson, 2014). The price gap represents the core RIN price. For example, a small price gap and low mandate volumes would cause obligated parties to pay small costs to meet their compliance obligations (Lade & Bushnell, 2019). Figure 1 illustrates the formation of the core RIN price.

The BTC might be another significant factor that influences the core RIN prices. In the United States, fuel blenders have received a BTC of US$1 per gallon of biodiesel when they blend biodiesel into a final fuel, which is expected to contribute to an increase in biodiesel demand. This expansion could lead to higher biodiesel wholesale prices and production. However, if a biodiesel mandate is binding, the BTC might not affect biodiesel wholesale prices but instead reduce the value of the biodiesel RIN. A binding mandate case in Figure 1 shows how a demand shift caused by the implementation of a BTC could affect the market and cause an offsetting impact on RIN price rather than any change in market quantities or fuel prices.

Another aspect to be considered is how blenders behaved when the BTC expired. The BTC was established in 2004 by the American Jobs Creation Act of 2004. It has expired at various times since then and been retroactively reinstated through other legislation. From 2010 to 2021, BTC had been in effect at the beginning of the calendar year in 2011, 2013, 2016, and 2020-2021 and had been applied retroactively in other years. This means that the BTC was not in place at the beginning of 2010, 2012, 2014-2015, and 2017-2019. Before Congress decided to retroactively reinstate the BTC, there was a potential but uncertain benefit to blenders. Market participants' responses to the uncertainty about the BTC might have varied from year to year as they faced the expiration and reinstatement of BTC. For example, there was the initial expiration of BTC in 2010 and its first reinstatement in 2011, followed by the BTC expiring for three consecutive years (2017-2019) and then being reinstated in 2020. The market might have reacted differently to these situations relative to one-year suspensions in the program after the first instance.

Literature Review

We do not review here the vast literature on biofuel use and mandates or their potential impacts on GHG emissions and food prices. We focus on the key questions of prices in the context of US policies that we study.

Studies evaluating the pass-through of RIN prices through the fuel supply chain have become increasingly common. One group of studies, focusing on ethanol markets, estimates the pass-through of RIN price to ethanol retail and wholesale prices mostly using panel data sets. Lade and Bushnell (2019) estimate the pass-through rates from RIN price to retail E85 prices using linear ordinary least square (OLS) and cumulative dynamic multiplier (CDM) models and find that the speed of pass-through depends on the local market structure. Li and Stock (2019) estimate an OLS model and find a full pass-through from RIN prices to retail E10 prices but obtain a more heterogeneous pass-through in the case of E85 retail prices. Going beyond ethanol alone, Knittel et al. (2017) estimate OLS and dynamic OLS models handling potential seasonality effects and find a long run pass-through rate of one across wholesale diesel and gasoline prices with considerable variation at the length of periods (daily and weekly levels). Pouliot et al. (2017) also find a complete RIN pass-through using aggregate rack prices across 57 major cities in the United States from their population-weighted and pooled regressions. However, they show the completeness of pass-through might be different depending on fuel types (branded and unbranded fuels) and regions.

Most studies focus on the ethanol markets, so the effects of BTC and its uncertainty are not their primary focus. Irwin and Good (2017) conceptually propose an economic model of D4 RIN pricing that takes into account prices of biodiesel and diesel and the BTC. While Irwin and Good (2017) do not incorporate the option value of RINs, the uncertainty surrounding the BTC, and the nature of bankable compliance permits, Irwin et al. (2020) develop the fundamental D4 RIN price model to improve the limitations. Lade et al. (2018) also present a dynamic model of RIN prices with uncertainty and consider the features of RIN markets such as multiple compliance periods with banking and borrowing and nested biofuel mandates.

A Fundamental D4 RIN Price

The biomass-based diesel RIN, namely D4 RIN, is generated by blending biodiesel with petroleum diesel to create a retail product. Biodiesel typically has higher prices than diesel, so the D4 RIN prices have been positive and often large compared to the fuel prices throughout the life of the mandate. We conceptually employ the static D4 RIN pricing model suggested by Irwin and Good (2017) and Irwin et al. (2020). Considering only an RFS biodiesel volume mandate and setting aside the BTC, the fundamental D4 RIN prices at the time t are given by:

$$P_t^{RIN} = Max\left[\frac{(P_t^{BD} - 0.927 * P_t^{DS})}{1.5}, 0\right], \tag{1}$$

where P_t^{RIN} denotes the D4 RIN price at time t; P_t^{BD} and P_t^{DS} are the biodiesel and diesel wholesale prices, respectively. The value of 0.927 is used to adjust for the energy content difference between biodiesel and diesel; and the value of 1.5 in the denominator denotes the fact that one gallon of biodiesel earns 1.5 D4 RINs. Therefore, equation (1) reflects the assumption that biodiesel and energy-adjusted diesel are perfect substitutes.

The price gap between biodiesel and energy-adjusted diesel wholesale prices indicates the equilibrium D4 RIN price (Irwin & Good, 2017). Defining the spread ($Spread_t = P_t^{BD} - 0.927 * P_t^{DS}$), the RIN price can be written as $P_t^{RIN} = Max\left[(Spread_t/1.5),\ 0\right]$.

Equation (2) shows how the RIN price is determined when there exists a binding mandate and BTC. Blenders take the BTC of one dollar for a gallon of biodiesel when the BTC is in place. The BTC might contribute to an increase in biodiesel demand, and this expansion might lead to a decrease in RIN prices by the amount of BTC with an assumption that the BTC does not influence the biodiesel wholesale price or diesel price (Irwin & Good, 2017). With a BTC in place, the RIN price is

$$P_t^{RIN} = Max\left[\frac{(Spread_t - BTC_t)}{1.5}, 0\right], \tag{2}$$

where BTC_t is the biodiesel tax credit of one dollar per gallon; Other variables are as defined in equation (1).

Another aspect to consider is how the blenders behaved when the BTC expired. Before the U.S. Congress decides to retroactively reinstate the BTC, there is a potential but uncertain benefit to blenders. The market participants might react differently depending on their belief about the BTC being retroactively reinstated, so the value of RIN will change (Irwin, 2014). Therefore, the rational prices for D4 RINs at time t are expressed as

$$P_t^{RIN} = Max\left[\frac{\{Spread_t - BTC\_on_t - \alpha * (1 - BTC\_on_t)\}}{1.5}, 0\right], \tag{3}$$

where BTC_on_t equals 1 if the BTC is in place at time t or 0 otherwise. Therefore, equation (3) is the same as equation (2) when the BTC is in place, but when the BTC is not in place then RIN prices are a function of spread and alpha (α). This coefficient, α, denotes the expectation that the BTC will be reinstating during intervals when it is inactive, or $E\left[Pr_t(BTC_T = 1 | BTC_t = 0)\right]$. Thus, α measures a market participants' expected probability at time t of whether the BTC will be retroactively reinstated at a certain time T. If we need to take into account the discount rate of RIN prices, specifying the future time of reinstatement, T, will be important. Considering that the reinstatement or extension of the BTC used to be announced at the end of year, market participants might expect that the BTC will be implemented retroactively again at the end of the year. For our discussion, however, we define the T as a next month (t+1). We also assume that market participants believe that BTC will be reintroduced without taking the time value of money into account during our sample period.

Data

We use monthly price data for diesel, biodiesel, and RINs. Each price series consists of 136 observations starting from January 2010 and ending April 2021. The monthly spread, as defined in the previous section, is calculated by using the biodiesel wholesale prices obtained from Economic Research Service (ERS, 2022) of the U.S. Department of Agriculture and the diesel wholesale prices gathered from the U.S. Energy Information Administration (EIA, 2022). Lastly, we use monthly averages of daily D4 RIN prices from the Oil Price Information Service (OPIS, 2021).

The dummy variable, BTC-on, equals one if the BTC was in place at the beginning of the year (2011, 2013, 2016, 2020, and 2021) and zero otherwise (the years in which the BTC was retroactively applied). For example, if $\mathrm{BTC\_on_t}$, the BTC effect reflects just potential benefits to blenders because it was expired at that time. If the U.S. Congress would not retroactively reinstate the policy later, then the real benefit would be zero.

Empirical Methodology

To estimate the D4 RIN pricing model in equation (3), an OLS model is specified as equation (4). We ignore the constraint of maximization of equation (3) since the RIN price is truncated at zero. For example, based on the conceptual model, the D4 RIN prices (P_t^{RIN}) will be positive if the RFS mandate for biodiesel is binding, while the RIN price will be zero in the case of that biodiesel price is lower than the price of energy-adjusted diesel. The RIN prices were always positive for the estimated period (Figure 2). Thus, rescaling the left-hand-side RIN value to ease the comparison, the estimated equation in this approach is

$$y_t = \beta_1 * Spread_t + \beta_2 * BTC\_on_t + \beta_3 * (1 - BTC\_on_t) + \varepsilon_t \qquad (4)$$

where $y_t = 1.5 \times P_t^{RIN}$; BTC_on_t equals 1 if the BTC is in place or 0 otherwise; βs are the coefficients to be estimated; ϵ_t is a white noise error with variance σ^2; and all other variables are as previously defined.

The use of a linear OLS model does not let us test for differences in these relationships at extreme values or relative to certain threshold values. This study is not intended to test any hypothesis about the relationships varying according to the exact level of the variables involved, but a test for other relationships using a nonlinear specification or piecewise model could

Table 1. Descriptive statistics

Parameter	Descriptions	Unit	Mean	Std. dev.	Min	Max
Spread	Biodiesel – 0.927*Diesel	$/gallon	1.63	0.52	0.52	3.27
Diesel	U.S. ultra-low sulfur No.2 diesel spot price[1)]	$/gallon	2.17	0.68	0.84	3.32
Biodiesel	Biodiesel (SME) average wholesale price of IL, IN, and OH (fob)	$/gallon	3.64	0.79	2.55	5.74
RIN	D4 RIN price	$/RIN	0.78	0.33	0.15	1.79
BTC-on	1 if BTC is in place; 0 otherwise	-	0.38	0.49	0	1

[1)] Average of the prices of New York harbor, U.S. Gulf Coast, and Los Angeles, CA.

nevertheless improve fit and our inferences if they proved more appropriate. Moreover, we do not address the risk that the linear model could estimate negative values even though the RIN price is non-negative, but the biodiesel RIN price is much greater than zero throughout the sample period (unlike some other RIN prices) and this risk might be modest.

According to the fundamental RIN pricing model in equation (3), y_t and $Spread_t$ might be the same when the BTC is not in place. Therefore, from the theoretical framework we might expect that the coefficient of $Spread_t$ (β_1) will be positive one if there exists no disturbance. When the BTC is in place, there might be one dollar gap between y_t and $Spread_t$ if all BTC benefits are passed to biodiesel producers. Then, we might expect that the coefficient of $\mathrm{BTC\_on_t}$ (β_2) is negative one. However, β_2 might be between negative one and zero if the BTC benefits are shared by biodiesel producers and blenders. As for the last coefficient, β_3 might be zero if the market believes that the BTC will not be reinstated. However, if some market participants believe that the BTC will be restored, then β_3 would be between negative one and zero, rising with the conviction of that reinstatement will occur.

Figure 2 displays the trend of y_t (red line) and $Spread_t$ (blue line). The periods when BTC are in place (gray) or expired (white) are also noted. There are some time periods that seem to meet the theoretical expectations, yet some other periods, notably such as 2010-2011 and 2019, differ from the expectations.

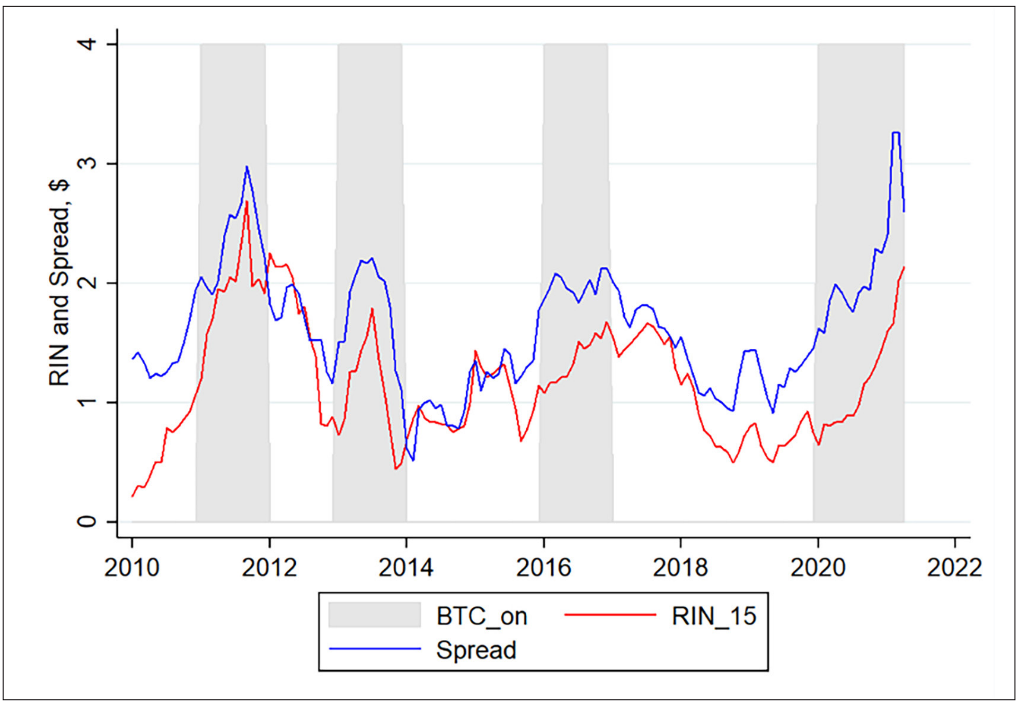

Figure 2. Monthly RIN (times 1.5) prices and spreads between biodiesel and energy adjusted diesel prices

Empirical Results and Discussions

Stationarity Tests

We test the RIN price and spread for stationarity using the ADF (Augmented Dickey–Fuller) test. The optimal lag length is determined using the Akaike Information Criterion (AIC). The null hypothesis (non-stationarity) of the ADF test is rejected in both prices at the 10% significance level when the test equations include an intercept. These results suggest that the spread and RIN price are stationary in levels. However, we cannot confirm the same results if adding the trend term in the test equations.

As a robustness check, we conduct the Kwiatkowski–Phillips–Schmidt–Shin (KPSS) test which has an opposite null hypothesis (stationarity) to that of the ADF test. The KPSS tests support the conclusions that both RIN price and spread are stationary in levels.

We find that evidence mostly supports stationarity of these data and consequently proceed with regression analysis, as described in the next section.

The Estimation Results

We estimate equation (4) and the results are shown in Table 3. The models (1) and (2) in the OLS estimates offer alternative approaches to testing the BTC dummy variables. The first model provides results based on dummy variables indicating whether the BTC was in place, while the second model uses a set of year dummies associated with the presence or absence of the BTC. As stated earlier when defining variables, the BTC dummy takes a value of one if the credit was in place at the start of the year and is otherwise zero, so the value is zero in years when the credit is applied retroactively.

Looking at the results of the model (1), we find that the estimated coefficient of spread (β_1) is 0.956 and statistically significant at the 1% level. The result of Wald test, which cannot reject the null hypothesis of $\beta_1 = 1$, indicates a complete pass-through of spread to the value of D4 RIN. The estimated β_2 is -0.612 so the BTC lowers the RIN price by $0.612 per gallon when the BTC is in place. The absolute value of β_2 is less than one.[1] This difference might imply that the market power of biodiesel producers is stronger than that of blenders. When the BTC is not in place, it appears that the effect of the BTC expiration is a decrease in the RIN price of 0.251 dollars per gallon. The estimated value of -0.251 indicates that the market participants believe that the BTC will be retroactively reinstated with a 25.1% chance, while Irwin et al. (2020) show the estimated probabilities between 9.8-14.6% from their linear models.

Moving to the model (2), the coefficient of spread (β_1) is estimated to be 0.825, which

Table 2. Unit root test results

Variable	Model	ADF	KPSS
Spread	Intercept	-2.580*	0.117
	Intercept and trend	-2.549	0.116
1.5*RIN	Intercept	-2.575*	0.155
	Intercept and trend	-2.630	0.072

Note: The values show test statistics, and * denotes the rejection of the null hypothesis at a 10% significance level.

indicates an incomplete pass-through of spread to the RIN prices according to the Wald test that reject the null hypothesis of β_1=1. In addition, we find that the annual dummies vary. To the extent that the annual dummies reflect BTC impacts, we would conclude that the BTC had different effects on the value of RINs in each year. Under the assumption that BTC impacts dominate annual dummies, the market reacted as if the BTC was in effect in 2010 and 2019 even though the BTC was not in place in those two years. Conversely, even though the BTC was in place in 2011 and 2016, the annual dummy coefficients might imply that the BTC had no effect on the RIN prices.

From the results of negative β_3 in model (1) and negative coefficients of 2010 and 2019 dummies in the model (2), we might conclude that, at least in the OLS estimation, there were market beliefs that the BTC would be retroactively reinstated in some years. The OLS estimates of model (2) also suggest that the market has not reacted according to the implementation of BTC but has reacted according to their expectations on the BTC. This finding is in line with the argument of Busse et al. (2012) that price responses do not necessarily correspond to changes in policy implementation when the policy timing or status is uncertain.

The estimated results under the constraint of β_1=1 are presented on the right side of Table 3. In the case of model (1), the restriction on β_1 might be appropriate since the null hypothesis (β_1=1) was not rejected. Under the constraint, the effects of BTC and expectations about BTC reinstatement are generally greater than that of unrestricted cases.

Discussions

The results of incomplete pass-through from the OLS estimates with year dummies are worth a discussion. The BTC is likely to affect biodiesel prices, as suggested by both the conceptual model and industry information. For instance, biodiesel producers and blenders might make a precontract to share potential benefits of a possibly reinstated BTC when the BTC was expired. Then, biodiesel producers sell biodiesel to blenders at partly discounted prices, and producers will still receive a share the benefits of the BTC from blenders if the BTC is retroactively reinstated. Irwin et al. (2020) present another explanation, namely that blenders purchased RINs over the mandated volumes of a year when the BTC is present to meet their mandate for the next year if they believe that the BTC will not be extended. This situation might increase biodiesel prices when the BTC is present if the expiration date is near.

Another possible reason for the incomplete pass-through is that biodiesel and diesel might be complements rather than substitutes. The fundamental D4 RIN price model assumes that petroleum diesel and biodiesel are effectively perfect substitutes. This assumption may hold if the RFS is either not binding or binding at a lower level of use. However, if the RFS mandate is at a higher level, biodiesel might function as a complement to diesel, as blenders are required to mix the mandated amount of biodiesel regardless of higher biodiesel prices. Irwin et al. (2020) note that the EPA, which sets annual targets, considers whether the BTC is in place when determining the RVO. Therefore, if the EPA sets an ambitious mandate volume with the BTC in place, biodiesel and diesel might be complements in that year.

This study demonstrates the impact of BTC uncertainty on market participants' decision-making, indicating that such uncertainty can distort the market. Enhancing policy consistency and predictability through institutional improvements could contribute to both expanding biofuel production and achieving market stability. Of course, this study does not address all of the many related topics. For example, the biodiesel market outcomes and policies in one country can be related to markets and policies for these products in other countries, as well as with inputs,

Table 3. The estimated results of the OLS model

Dependent: y_t Restriction	Model (1) none	Model (2) none	Model (1) β_1=1	Model (2) β_1=1
β_1	0.956*** (0.095)	0.825*** (0.089)	-	-
β_2	-0.612*** (0.190)	-	-0.703*** (0.040)	-
Year.2011	-	-0.015 (0.227)	-	-0.432*** (0.066)
Year.2013	-	-0.412** (0.163)	-	-0.731*** (0.046)
Year.2016	-	-0.268 (0.187)	-	-0.616*** (0.058)
Year.2020	-	-0.588*** (0.174)	-	-0.924*** (0.039)
Year.2021	-	-0.523** (0.317)	-	-1.027*** (0.226)
β_3	-0.251** (0.128)	-	-0.309*** (0.037)	-
Year.2010	-	-0.543*** (0.144)	-	-0.790*** (0.064)
Year.2012	-	0.285* (0.202)	-	-0.004 (0.105)
Year.2014	-	0.107 (0.092)	-	-0.049 (0.046)
Year.2015	-	0.032 (0.140)	-	-0.200** (0.080)
Year.2017	-	0.091 (0.156)	-	-0.212*** (0.045)
Year.2018	-	-0.163 (0.111)	-	-0.368*** (0.052)
Year.2019	-	-0.324*** (0.113)	-	-0.544*** (0.025)
Obs.	136	136	136	136
R-sq	0.937	0.971	0.711	0.872
H_0: $\beta_1 = 1$	0.21 [0.648]	3.86* [0.052]	-	-
H_0: $\beta_2 = -1$	4.20** [0.042]	-	55.79** [0.000]	-
H_0: 011=2013=2016=2020=2021	-	13.04*** [0.000]	-	12.61*** [0.000]
H_0: 2010=2012=2014=2015=2017=2018=2019	-	35.90*** [0.000]	-	27.88*** [0.000]

Standard errors in parentheses for the coefficients, and p-values in square brackets for the Wald tests.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

competing products, and complementary goods, suggesting scope for additional analysis to relate BTC impacts more broadly. However, for our focus on these specific prices as indicators of how these policies interact with market decisions, the scope provides the basis for certain conclusions.

Conclusion

The US RFS, or biofuel mandates, are the country's main existing GHG policy and have been a subject of scientific and popular interest for its potential role in the food-versus-fuel debate. The concurrent BTC supporting biodiesel use has been allowed to expire and then been reintroduced with benefits retroactively awarded for transactions during the time the BTC was in abeyance. While basic economics might lead to the expectation that these two policies' overlap can cause BTC status to and RIN prices to interact strongly, the reality is complicated by market elasticities and final incidence common among subsidy problems and, in this case, the on-and-off nature of the BTC leads to complicated questions about what sort of effect to expect when the BTC has expired but might be presumed to resume. The questions of industry expectations and BTC impacts are fundamental to assessing how this program works relative to the intended targets of lawmakers who design it, and these effects also matter to RFS regulators who must set targets and market agents who receive BTCs or trade with others that do.

We outline a D4 RIN pricing model and show the empirical results of OLS method. We confirm that the existence of BTC is not sufficient to explain the RIN pricing model. Market participants might track news and respond to the market conditions according to their expectations before policymakers announce that the BTC will be retroactively reinstated.

According to the OLS estimates, market participants believe that the BTC will be retroactively reinstated with a 25.1% chance on average. However, the market expectations on the BTC reinstatement have different effects on the RIN prices in each year. If the annual dummies are dominated by the impact of BTC, then the OLS estimates with annual dummies suggest the following conclusions. In the years of 2010 and 2019, when the BTC was not in place, the market reacted as if the BTC was in effect. Conversely, even though the BTC was in place in 2011 and 2016, the effects of BTC on the RIN prices did not appear. These results support the view that the market has been responding to market conditions according to their expectations before policymakers announce that the BTC will be retroactively reinstated. Market responses to the BTC do not coincide precisely with the implementation of the BTC. We also confirm that the pass-through from the fuel price spread to the D4 RIN values might be incomplete. The coefficient of the variable representing this price spread is 0.812 and this value is significantly smaller than one.

The incomplete price pass-through might result from imperfections of the biofuel market, or rational decision making under uncertainty. If the incomplete pass-through is caused by imperfect competition, then this could be evidence of some ineffectiveness of the policy (Pouliot et al., 2017). In addition, the uncertainty of the BTC subsidies might discourage entry of new biofuel producers into the market. This result raises a question whether the BTC is an efficient instrument to achieve the policy goal of biofuel expansion. Alternatively, the D4 RIN price model assumption that biodiesel and diesel are substitutes might be questioned. The substitute relationship might not hold in practice or only partially hold during the sample period. Sensitivity analysis raises questions about how well the analysis presented here relates to a different indicator of the spread that is often referenced in trade journals. This question of incomplete pass-through remains a topic for future research.

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Conflicting interests

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Notes

1. The null hypothesis of $\beta_2 =-1$ is rejected (p-value=0.042 and F=4.20) in model (1).

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