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February 22, 2017

Sarah Dunham
Acting Assistant Administrator for Air and Radiation
Environmental Protection Agency
1200 Pennsylvania Avenue, N.W.
Mail Code 6101A
Washington, DC 20460

RE: Proposed Denial of Petitions for Rulemaking to Change the RFS Point of Obligation: Docket ID No. EPA-OAR–2016–0544

Dear Acting Assistant Administrator Dunham:

I write concerning the economic consequences of moving the Point of Obligation under the Renewable Fuel Standard (RFS).

I am an academic economist with expertise in biofuels, the U.S. fuel system, and methods for analyzing economic data. I am not being paid for our work on the topic of the Point of Obligation, and I do not represent any interested parties in this matter.

This letter summarizes work in five academic papers pertinent to this matter, which have been separately submitted to the docket.[1] This letter summarizes the main findings in these five papers. It also discusses the implication of these findings for the proposal to move the Point of Obligation from refiners and importers to the owner of petroleum fuel immediately prior to its blending with renewable fuel (the owner "just above the rack"). Although I have benefited from extensive discussions with the authors of these five papers about the content of those papers and the Point of Obligation, the views expressed in this letter are mine alone.

As an academic economist, my policy interest in this matter is that the RFS program be structured so that it achieves the goal of blending renewable fuels into the fuel supply with the greatest possible economic efficiency. More specifically, my interest is in whether there are economic inefficiencies under the current RFS system, and in whether there is scope for improving efficiency by moving the Point of Obligation.[2]

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[1] Knittel, Meiselman, and Stock (2016a, 2016b), Pouliot, Smith, and Stock (2017), Lade and Bushnell (2016), and Li and Stock (2017). See the reference list at the end of this letter for the full citations.

[2] I use the term economic efficiency in its standard sense, which is to maximize the net benefits to society of the program. Therefore, our focus is not on economic transfers between producers of petroleum fuel and

As I explain below, from an economist's perspective, the RFS works by providing a financial incentive for producing and using renewable fuels, and a financial disincentive for using petroleum fuels. This financial incentive operates through the RIN system, whereby fuels with high renewable content receive a "RIN subsidy" and fuels with low renewable content pay a "RIN fee". Abstracting from the administrative costs of the program, the question of the economic efficiency of the RFS reduces to the question of whether the net RIN cost is being fully passed on to the producers and end consumers of renewable fuels. For corn kernel ethanol and ethanol blend fractions at or above the E10 blend-wall, the RIN value should be fully passed on to the consumer, to incentivize consumption of higher ethanol blends.

For these reasons, the empirical work in the five papers focuses on quantifying the amount of pass-through of RIN prices to final (pump) fuel prices. To gain additional insights into pass-through and market structure, this work studies fuel transactions at three key points in the supply chain: bulk wholesale transactions at exchange-traded prices; transactions at the rack; and transactions at the retail outlet (at the pump).

Summary of empirical findings of RIN price pass-through. The five academic papers reach the following conclusions:

1. There is complete pass-through in the bulk fuel (exchange-traded) market. The RFS event in bulk markets is that the seller of the fuel into the fuel supply takes on a net RIN obligation. Knittel, Meiselman, and Stock (2016a,b) find that the value of this RIN obligation is fully passed through to the exchange traded price, that is, if RIN prices go up so that the RIN obligation for a gallon of petroleum blendstock increases by 1¢, then the exchange-traded price of that blendstock (for example, the price for New York Harbor RBOB) increases by 1¢, so that the seller of the fuel fully recoups the RIN fee through an increase in the exchange-traded price. More precisely, using updated data through November 2016, Knittel, Meiselman, and Stock (2016b) estimate a RIN price pass-through coefficient of 1.12 (SE = 0.09), which is statistically indistinguishable from complete pass-through (that is, a pass-through coefficient of 1.00).

2. The next RFS event occurs at the rack, when a renewable fuel is blended into the fuel supply; this blending detaches the RIN, which can then be sold. Complete pass-through of the RIN price at the rack corresponds to passing through the market value of this detached D6 RIN. Pouliot, Smith, and Stock (2017) find that there is a great deal of heterogeneity in pass-through at the rack. In the ethanol belt in the Midwest, RIN pass-through coefficients for pass-through of detached D6 RIN prices to E10 prices at the rack at the rack are very nearly 1. The pooled

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biofuels, or among producers of petroleum fuels, except to the extent that those transfers induce *net* costs to society. Similarly, in this work we do not consider what the appropriate volumetric or percentage obligation is; rather, we ask, for a given RFS obligation (for example, the 2017 percentage obligation), is that standard being met as efficiently as possible, in the sense of minimizing the net costs to society of achieving a given standard.

coefficient for major Midwestern cities is 0.88 for branded fuel and 0.99 for unbranded fuel. These estimates are which is statistically indistinguishable from 1: the respective 95% confidence intervals are [0.74, 1.02] and [0.83, 1.16]. In contrast, RIN pass-through to E10 prices on the East coast is incomplete, with an average pass-through coefficients of 0.38 (branded, 95% confidence interval [0.13, 0.63]) and 0.50 (unbranded, 95% confidence interval [0.14, 0.85]). Using a population-weighted average, they estimate a national average pass-through coefficient of RIN prices to E10 of 0.63 for branded fuel (95% confidence interval [0.23, 1.03]) and a 0.92 for unbranded fuel (95% confidence interval [0.70, 1.14]). The population-weighted national average estimates have very wide confidence intervals, with values that include complete pass-through and values that include pass-through coefficients substantially less than one.

3. The final step in the fuel supply chain is sale to the end consumer at the pump. For retailers who purchase blended fuel at the rack, as is done for essentially all E10 and for much E85, there is no RFS event between the purchase of the fuel at the rack and sale at the pump. Thus the question of pass-through at the pump is a question of whether there is full pass-through of the rack price to the pump price. A large body of empirical literature shows that there is full pass-through for E10 from the rack to the pump, and this finding is confirmed by Li and Stock (2017) using data from Minnesota gas stations. However, there is considerable heterogeneity in pass-through of E85 rack prices to E85 pump prices. The main driver of this heterogeneity appears to be the extent of local competition in the E85 market, that is, whether an E85 retailer has nearby competitors who also offer E85. In regions with high E85 station density, pass-through from rack to pump is nearly complete, however in regions with low E85 station density, rack-to-pump pass-through is less than complete and can be as low as 0.5 (Lade and Bushnell (2016), Li and Stock (2017)).

4. Taken together, these findings provide the following characterization of pass-through to the end retail consumer.

    a. In regions with well-developed retail E85 markets, both higher blends and E100, which can be used for splash-blending of E85, are available at the rack. This competition among higher blends, and the option of splash-blending, leads to full RIN pass-through at the rack. In addition, in areas with competitive retail markets for E85, rack prices are passed through to pump prices of E85. In these regions with local E85 competition and demand for higher blends, there is complete pass-through to final consumers and the RFS is working efficiently. This situation characterizes mature metropolitan markets for higher blends, such as the Twin Cities, Des Moines, and Chicago.

    b. In regions with high demand for higher blends and E100, but low levels of local competition in retail E85, there tends to be complete pass-through at the rack but incomplete pass-through from rack to retail. In such regions, retailers act as a local monopolist in the E85 market. These retailers can charge an additional premium on E85 and can therefore retain some of the rack price discount of E85, relative to E10. Because this discount is largely driven by fluctuations in RIN prices, these markets are characterized by full RIN pass-through to E10 consumers, but not to E85 consumers. In this setting, the RFS is working efficiently in the E10 market, but not in the market for higher blends. This situation would reasonably characterize rural areas and small towns in the Midwest ethanol belt.

c. In regions with little sales of higher blends, there is little or no availability of higher blends or E100 at the rack. Relative to regions with well-developed markets for higher blends, there is less RIN pass-through at the rack (to E10 and E85), and even less RIN pass-through from bulk wholesale to retail because of the lack of local competition. In these regions, the full RIN value is not passed on to consumers of either E10 or E85. This situation would reflect much of the country, including the population centers of the East Coast.[3]

The remainder of this comment is organized as follows. I first review the economics of the RFS and why the pass-through of RIN prices to pump prices of blended gasoline is a measure of the economic efficiency of the RFS. Next, I summarize the five papers in more detail. I conclude with a discussion of the implications of this work for the proposal of moving the Point of Obligation.

Economics of the RFS and the Pass-Through of RIN prices.

The goal of the Renewable Fuel Standard program is to increase the volumes of renewable fuels in the U.S. fuel supply, as laid out in the Energy Independence and Security Act of 2007 and as explained in the preambles of multiple RFS rulemakings. Because the statutory cap of 15 billion gallons of conventional renewable fuels has been hit as of the 2017 final RFS rulemaking, further increasing the volume of renewable fuels in the fuels supply now means increasing the volumes of advanced fuels, in particular second-generation advanced fuels with potential for substantial future growth.

In economic terms, the RFS operates through the RIN system. A petroleum fuel blended incurs the requirement that a RIN bundle (determined by that year's RFS proportional obligation) be retired with the EPA, which serves as a fee on petroleum fuels. RINs can be sold by the owner of renewable fuels when they are blended with petroleum fuel, and the revenue generated by that sale provides a subsidy for the production and consumption of renewable fuels.

In theory, in competitive markets, the RIN subsidy could go to producers of renewable fuels or to end consumers of renewable fuels, or both. Figure 1 (which is Figure 4 in

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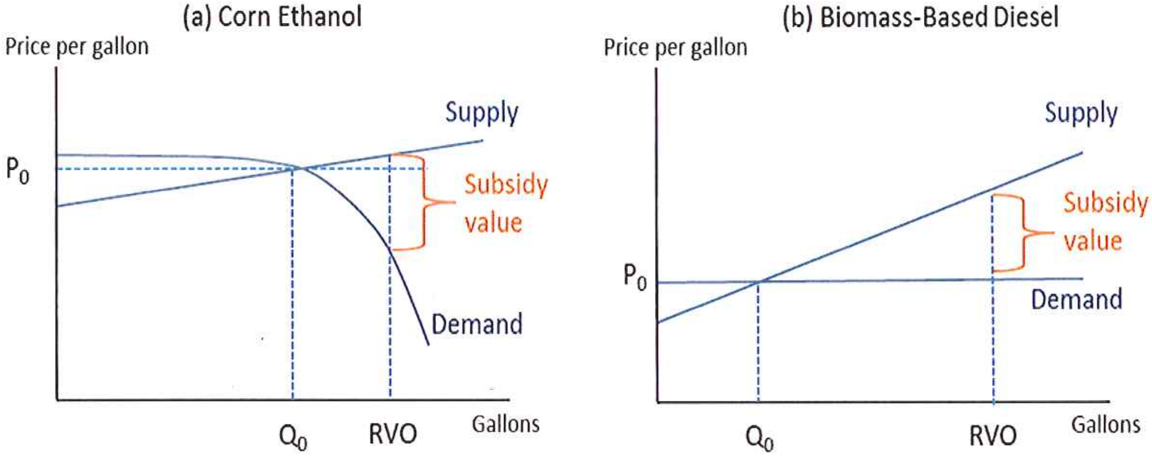
[3] Results for the West coast in Pouliot, Smith, and Stock (2017) are inconclusive because of the highly volatile rack spreads, especially in California, as discussed in that paper.

Knittel, Meiselman, and Stock (2016)) illustrates two different cases: biodiesel and corn ethanol. At current blending ratios, biomass-based diesel is well below any operational blend wall and can be blended smoothly into the diesel supply, so a gallon of biodiesel receives the same market price as petroleum diesel. However, biodiesel is more expensive to produce, so under perfect competition the RIN subsidy accrues to the producer. For corn ethanol, the supply curve is effectively flat in the narrow region at and just above the blend wall, but the demand curve drops steeply because flex fuel vehicle owners require an incentive to purchase ethanol as E85. In this case, under perfect competition the subsidy passes through entirely to the consumer.

Figure 1. Incidence of the RIN subsidy in a competitive market for fuels.



Source: Knittel, Meiselman, and Stock (2017), Figure 4.

This reasoning motivates focusing on pass-through of RIN prices to retail E85 prices for gasoline. Because the supply curve of ethanol is effectively flat in the small range at and above the E10 blend wall, but above the E10 blend wall demand drops off sharply, effectively all of the RIN subsidy should be passed on to consumers. This logic rests on the basic economic principle that a seller of a good in a competitive market sets price equal to marginal cost. In the case of blended gasoline, that price is the price of the wet (physical) fuel, plus any RIN fee or minus any RIN subsidy. A finding that RIN price pass-through is incomplete somewhere along the supply chain is indicative of at least some firms having market power along the supply chain. In that case, end consumers only partially see the RIN subsidy, and instead the RIN value is providing economic rents to producers with market power.

If RIN pass-through is complete, then the RFS program is operating efficiently, in the sense of minimizing the net costs to society of the program, given the fractional obligation.[4] This concept of economic efficiency nets out costs by one obligated party that are a transfer to another party under the RFS. More specifically, some obligated

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[4] This is equivalent to maximizing the net benefits of the program, given a predetermined percentage obligation. Under RFS cost-benefit calculations, the benefits arise from using the renewable fuels. Holding constant the fraction of renewable fuels, maximizing net benefits is equivalent to minimizing net costs.

parties have alleged that they are financially disadvantaged by the current Point of Obligation, relative to other obligated parties; but any disparate effect of the Point of Obligation on obligated parties is not our primary concern because the transfers among obligated parties are netted out.

Summary of main pass-through findings

The five papers summarized here examine RIN pass-through at three steps along the fuel supply chain.

The first (upstream) step is when an importer or refiner (obligated party) sells bulk refined petroleum fuels at the bulk wholesale level for use as a surface transportation fuel. At that point, the obligated party incurs the obligation to retire a RIN bundle with the EPA, where the bundle is determined by the current year's fraction obligation. This step is examined by Knittel, Meiselman, and Stock (2016a,b).

The second (midstream) step occurs when the petroleum fuel is blended with a renewable fuel at a terminal for sale as a blended fuel (E10, E15, or E85). At this stage, the RIN is detached from the renewable fuel, and the owner of the RIN (typically the owner of the renewable fuel just above the rack) can sell the RIN. This step is examined by Pouliot, Smith, and Stock (2017).

The third step (downstream) step is sale to the final consumer at a retail outlet. There is no RFS RIN obligation or generation at this stage. For blended fuels purchased at the rack, as is the case with E10, RIN pass-through is equivalent to full pass-through of rack prices to pump prices. For fuels splash-blended at the rack, or if the fuel is purchased by the retailer above the rack, the retailer can also be the owner of the detached RIN, in which case the second and third steps are in effect merged. Pass-through of RIN prices to final pump prices of higher blends is studied by Lade and Bushnell (2016) and Li and Stock (2017).

A. Bulk Wholesale

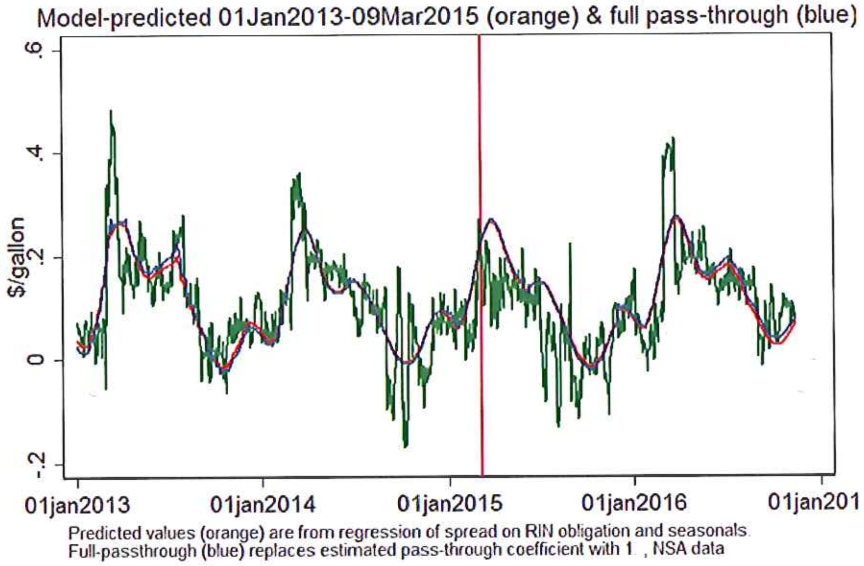
Knittel, Meiselman, and Stock (2016a) use regressions to examine the graphical analysis of Burkholder (2015). The analysis of Knittel, Meiselman, and Stock (2016a) uses data from January 1, 2013 to March 9, 2015. Knittel, Meiselman, and Stock (2016b) update that analysis using data through November 14, 2016.

The strategy of all three papers is the same, which is to compare bulk wholesale prices of pairs of petroleum fuels, where one fuel is obligated under the RFS and one is not. For example, one of the spreads examined in all three papers is the spread between New York Harbor RBOB and Rotterdam EuroBOB. The two fuels are chemically very similar, but because the NYH RBOB is sold into the U.S. fuel supply, it incurs a RIN obligation, whereas the Rotterdam EBOB does not. Under perfect competition, the NYH RBOB price should incorporate the RIN fee, whereas the Rotterdam EuroBOB would not. Thus an increase in RIN prices that increased the RIN bundle on petroleum blendstock by

$0.05/gallon should result in an increase in the NYH RBOB – Rotterdam EuoroBOB spread by $0.05.

Figure 2, which is Figure A (right panel) in Knittel, Meiselman, and Stock (2016b), shows the daily NYH RBOB – Rotterdam EuroBOB spread, Jan. 1, 2013 – November 14, 2016. The solid lines are the predicted values of the spread based solely on RIN prices and seasonals, based on the estimates in Knittel, Meiselman, and Stock (2016a), which use data through March 9, 2015. As suggested by Figure 2, these BOB spread relationships estimated through March 9, 2015 hold up in the post-March 10, 2015 sample.

Figure 2. New York Harbor RBOB – Rotterdam EBOB spread and predicted values


Model-predicted 01Jan2013-09Mar2015 (orange) & full pass-through (blue)

Predicted values (orange) are from regression of spread on RIN obligation and seasonals
Full-passthrough (blue) replaces estimated pass-through coefficient with 1 , NSA data

Knittel, Meiselman, and Stock's (2016b) econometric analysis of five refined product spreads – one fuel obligated, one not – result in a pooled estimate of pass-through coefficients of 1.12 (standard error = 0.09), which is not statistically different the complete pass-through value of this coefficient, 1.0.

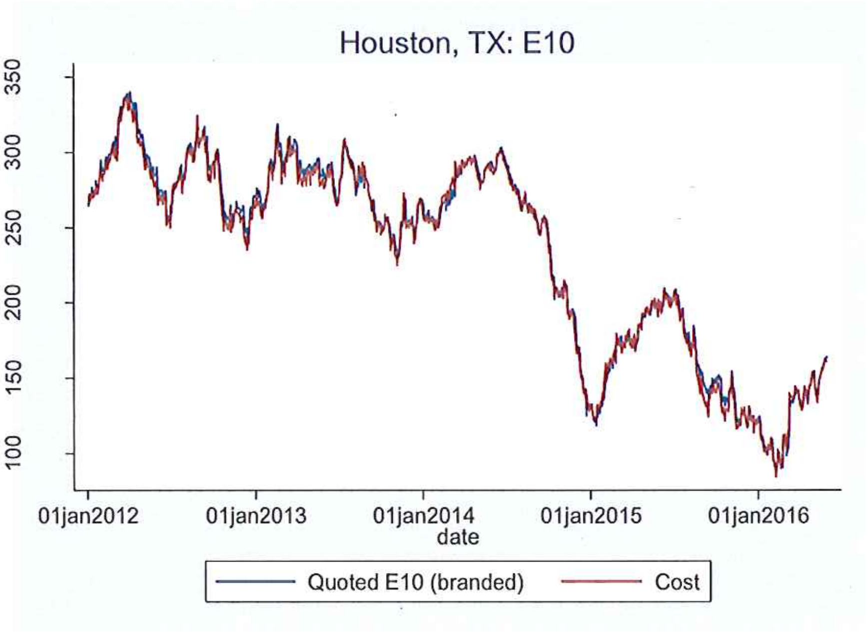
Knittel, Meiselman, and Stock (2016a) also used two crack spreads, using the logic that crude oil is not obligated, but refined gasoline blendstock is. Because the crack spread moves for many reasons in addition to RIN prices, and RIN fee movements are small compared to overall fluctuations in crack spreads, Knittel, Meiselman, and Stock's (2016a) original estimates are noisy. Knittel, Meiselman, and Stock (2016b) show that they are also not robust to extending the sample period. At least one contributing factor in the Los Angeles RBOB – Brent spread was the Exxon-Torrance refinery fire, which produced high crack spreads through the fall of 2015, a period when RIN prices were relatively low. Knittel, Meiselman, and Stock (2016b) conclude that the use of crack spreads to estimate RIN price pass-through is less reliable than the use of refined product spreads.

B. At the rack

The RFS event at the rack is the detachment of the RIN from the blended renewable fuel, at which point the RIN can be retired or sold. Thus, the marginal cost of fuel at the rack is the sum of two components: the upstream cost of the bulk fuel (e.g. RBOB exchange price and Ethanol exchange price), and the value of the detached RIN.

Pouliot, Smith, and Stock (2017) use daily data from OPIS on rack prices of blended gasoline and pure ethanol to estimate pass-through at the rack. They find evidence of complete pass-through of the wet fuels component of the marginal cost. This finding is illustrated in Figure 3, which shows the OPIS city average rack price of E10 in Houston and the wet-fuel cost of E10 based on bulk fuel market prices. The two prices move essentially one-for-one.

Figure 3. Houston average E10 rack price and the cost of the constituent fuels based on bulk exchange prices.



In contrast to full pass-through of wet fuel prices, Pouliot, Smith, and Stock (2017) find heterogeneous pass-through of RIN prices to blended fuel prices which, on average, is incomplete:

1. Using the 20 major cities in their data set, they estimate a population-weighted national average pass-through of 0.63 for branded fuel; however, this coefficient is imprecisely estimated, with a 95% confidence interval of [0.23, 1.03], which includes complete pass-through.

2. There is considerable heterogeneity in pass-through. This is illustrated in Figure 4 (also Figure 4 in their paper), which shows estimated pass-through coefficients at the rack for different groups of racks.

    a. In the Gulf and Midwest – the ethanol belt – pass-through at the rack is complete or nearly so, with an average branded pass-through in the Midwest of 0.86 (95% CI [0.63, 1.09]).

    b. In the East, RIN pass-through is incomplete, with an average pass-through coefficient of 0.38 (95% CI [0.13, 0.63]).

    c. Pass-through in the West is also estimated to be incomplete, but for Western racks the pass-through coefficient is very imprecisely estimated. This imprecision is due to the high volatility and persistence of Western rack spreads, for which RIN values are only a small part of the rack spreads.

    d. Pass-through is greater for unbranded E10 than for branded E10, and it is greater when there are multiple suppliers of higher blends (including E85) at the rack (Figure 4, lower panel). For branded fuels, pass-through of E10 is statistically indistinguishable from 1 if the number of suppliers of E100 plus the number of suppliers of branded higher blends at the rack exceeds 5. As Figure 5 shows, the racks in the Pouliot, Smith, and Stock data for which there is high availability of blended fuels or E100 at the rack are in the Gulf and Midwest.

Figure 4. Average RIN pass-through coefficients from bulk wholesale prices to rack prices for E10 (bars denote 95% confidence intervals)

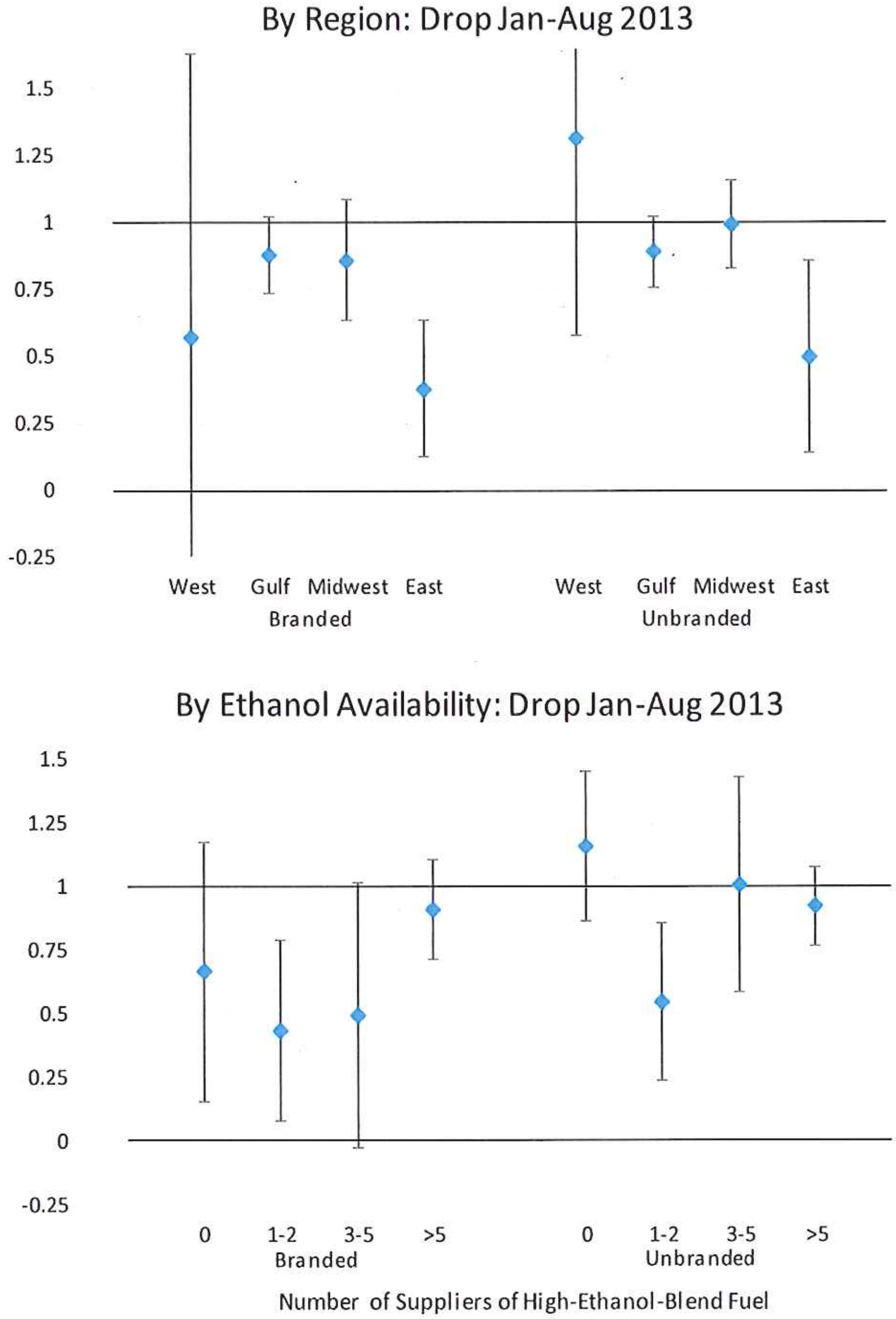


Figure 5. Racks in Pouliot, Smith and Stock data set, by number of suppliers offering blended higher blends and/or E100 at the rack (major cities only)

The data set in Pouliot, Smith, and Stock is comprised of 216 active terminals. As Table 1 shows, of these terminals, 24% offer higher blends. This fraction likely overstates the fraction of terminals nationally that offer higher blends, because the terminal sampling scheme in Pouliot, Smith, and Stock intentionally oversamples terminals in the ethanol belt. Still, it is instructive to look at the terminals offering higher blends by the owner's obligation status under the RFS, and by whether the terminal is RIN long or RIN short.[5] As shown in Table 1, no higher blends were offered at terminals owned by RIN long obligated parties. Among terminals operated by RIN short obligated parties, 17% offered higher blends. The category of terminal most likely to offer higher blends is terminals owned by non-obligated parties (42%).

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[5] RIN long/RIN short terminal owner classifications are from Ronald Minsk, Comments about EPA Proposed Denial of Petition, February 22, 2017, Table 3.

Table 1. Availability of higher blends at terminals by rack owner status in Pouliot, Smith and Stock terminal data

Terminal Owner Classification	Number of terminals	Number offering high-blend fuels	Percent offering higher blends
RIN Long	48	0	0%
RIN Short	35	6	17%
Not obligated	84	35	42%
Obligation unknown	49	10	20%
Total	216	51	24%

Notes: A terminal is classified as having higher blends if, for at least 250 days a year during January 9, 2013 – May 31, 2016, at least one rack supplier offered from E60 up to E100. To be included in this count, E10 must have been offered for at least 250 days a year by at least one rack supplier during this period. The sample of terminals in Pouliot, Smith, and Stock oversamples the ethanol belt so the totals and percentages are not nationally representative. Among the terminals owners used to construct Table 1 here, the classifications are: RIN long: BP Oil, Chevron, Shell/Motiva, Exxon Mobil; RIN short: Citgo, Marathon, Phillips, Valero, Western; Not obligated: Buckeye, Kinder Morgan, Magellan, Nustar, Transmont; Obligation unkown: Flint Hills, Sopus, SPMT, Tesoro, Calumet, CARBO, Global, Sinclair, other (22 entities that own a single terminal in the data set).

C. At the pump

Lade and Bushnell (2016) and Li and Stock (2017) examine RIN price pass-through to pump prices for higher blends. Lade and Bushnell (2106) use weekly observations on E85 retail prices at 450 retail stations in Minnesota, Iowa, and Illinois; for their wet fuel costs, they use exchange-traded bulk fuel prices. Li and Stock (2017) use monthly data on 274 retail stations in Minnesota on E85 and E10 retail prices; for their wet fuel costs, they use rack prices of blended fuels. Lade and Smith's data set heavily represents urban stations, whereas Li and Stock's data has a large number of rural stations.

Taking into account the differences in the two data sets, the two papers reach similar conclusions:

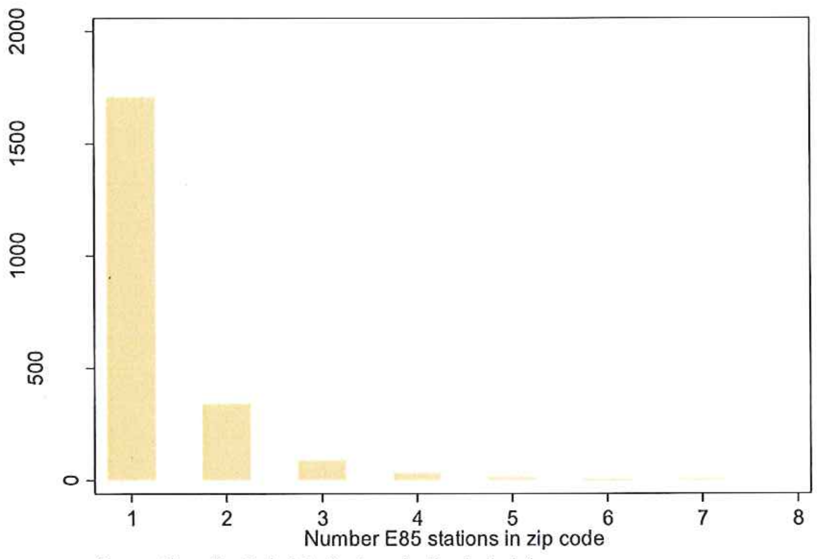
1. There is a high degree of pass-through of blended fuel prices at the rack, to pump prices, in areas that have a high density of retail stations that sell E85. Lade and Bushnell estimate RIN pass-through along the full supply chain of 1.08 (standard error = 0.18). When Li and Stock restrict their data to the Twin Cities (specifically, Hennepin and Ramsey counties in Minnesota), they estimate RIN pass-through along the full supply chain of 0.80 (standard error = 0.05). Despite the seemingly large differences in estimated pass-through, these estimates are not statistically different from each other.

2. Both papers find that the degree of pass-through depends on the amount of local competition among E85 retailers. One illustration of this finding is Li and Stock's estimate of pass-through in the Twin Cities vs. outside of the Twin Cities. Their estimate of RIN pass-through along the full supply chain outside the Twin Cities is 0.31 (standard error = 0.05). They attribute this low pass-through rate mainly to pass-through of approximately half from blended rack prices to retail prices of higher blends (specifically, E85-E10 spreads at the rack to E85-E10 spreads at the pump), combined with partial RIN pass-through of 0.74 (standard error = 0.06) at the rack outside the Twin Cities.

Combining these results at the three steps along the supply chain leads to the summary provided in the first section of this letter. In particular, these results indicate that, in well-developed markets for higher blends, RIN pass-through at the rack is effectively complete and RIN (and wet fuel cost) pass-through from rack to pump is effectively complete. In these areas, consumers are on average receiving the full RIN subsidy and the RFS is economically efficient in the sense defined above.

This said, most E85 stations nationally are not in competitive E85 retail markets. Figure 6 is a histogram of the number of E85 stations by zip code, using stations in the Alternative Fuel Data Center Web site (accessed February 20, 2017). Of the approximately 43,000 zip codes in the United States, 1707 have one E85 station, 340 have two E85 stations, and only 131 have three or more E85 stations; the rest have no E85 stations.

Figure 6. Histogram of number of E85 retail stations in a zip code, national data



Source: Alternative Fuels Data Center and authors' calculations

Implications for the Point of Obligation

We now turn to a discussion of these results for the proposal to move the Point of Obligation under the RFS from refineries and importers when they sell petroleum fuel into the fuel supply, to the owners of the fuel at the upstream terminal gate ("just above the rack").

Ability of RIN-short entities to recoup RIN costs.

One source of concern is over the distributional effects of the RIN system in the gasoline supply chain. Recall that the RIN price is a tax on gasoline and a subsidy to ethanol. By its construction, the RIN system creates a transfer and has a distributional effect. The issue is whether some market participants benefit and others are hurt from the RIN system in a manner other than that intended. In particular, one argument is that refineries who are RIN short must purchase RINs to show compliance with the RFS and thus the RIN system lowers their profits. The most RIN-short refiners are so-called merchant refiners who do not blend any ethanol with gasoline. The flip side of the argument is that pure blenders and refiners who are RIN long profit from the RIN system because they can sell their extra RINs to create a revenue stream.

One conclusion from the analysis in Knittel, Meiselman, and Stock (2016a,b) is that RIN-short obligated parties, such as merchant refiners, recoup the cost of their RIN obligations in the bulk market on average. Because this occurs through exchange-traded and bulk wholesale prices, which go up one-for-one with the increase in the value of the RIN obligation as RIN prices change, this recouping of costs is not necessarily transparent to market participants. In particular, this recouping of costs does not appear as a balance sheet revenue item, in the way that the cost of RIN purchases appears as a balance sheet cost. This said, the combination of fluctuations in RIN prices and mismatches in timing of RIN obligation and purchases can expose obligated parties to balance sheet uncertainty even if they recoup RIN prices on average.

This logic and empirical evidence also implies that moving the point of obligation downstream will not affect the bottom line of merchant refiners that sell primarily into the bulk refined product market. The reason is that because they would no longer bear a RIN obligation, competition in the bulk wholesale fuels market would drive down the exchange-traded prices so that they still equaled marginal cost; that is, the crack spread would be reduced by the amount that the per-gallon RIN obligation is reduced. The reduction of compliance costs for a currently RIN-short obligated party would be offset one-for-one by the decline in the price it can charge for its BOB.

Will moving the Point of Obligation increase sales of higher blends at the rack and at retail?

An argument put forth by petitioners is that, under the current system, RIN-long obligated parties that own or control a terminal currently have a disincentive to detach more ethanol RINs from sales of higher blends, because doing so would drive down the value of the RINs that they currently own or that they generate through blending more E10 than they refine (as blendstock). For example, consider a RIN-long obligated party that purchases from merchant refiners at bulk exchange prices, then blends that petroleum fuel along with blendstock from its own refineries, and detaches the associated RINs.

Because this RIN-long obligated party makes money from selling RINs, actions that reduce RIN prices, in particular selling E85 at racks at its terminal, are not in its interest. According to this argument, moving the Point of Obligation to the owner of the fuel just above the rack would make all obligated parties RIN short. Thus the formerly RIN-long obligated party would now have the incentive to sell higher blends at the rack to meet its obligation (and to drive down RIN prices) instead of having an incentive not to do so.

I consider this to be the key argument concerning moving the Point of Obligation, and I make the following observations on this argument.

(1) For this argument to be valid, RIN-long parties (a) must have the ability to control which fuels are provided at the rack and (b) must have market power at the rack. Absent these two conditions, a retail chain could splash-blend E100 and E10 if the E10 were available, and with perfect competition, the RIN value would be passed on to the retailer (through the E100 price at the rack). Knowledge of the industry and the results in Pouliot, Smith, and Stock suggest that conditions (a) and (b) hold.

   (a) My understanding is that many terminals, especially those on the West and East Coasts are owned by obligated parties or their subsidiaries. In addition, even at racks owned by non-obligated parties, decisions to make investments for provision of E100 or higher blends require support of the fuel providers currently using the terminal. Thus, a RIN-long obligated party can exercise control of fuels provided at its own terminals and even at terminals owned by a third party.

   (b) Our findings of incomplete pass-through at the rack on the East and West coasts aligns with only a few, or no, higher blends being offered at those terminals. Not providing higher blends or E100, or rack and storage space to retailers who buy above the rack, eliminates what Pouliot, Smith, and Stock finds to be an important channel for RIN pass-through, which is RIN price arbitrage at the rack.

   (c) Table 1 above shows that, of the 46 terminals in the Pouliot, Smith, and Stock data set that are owned by obligated parties, none offer higher blends or E100 at the rack.

(2) This argument also requires that it be in the self-interest of a RIN-long party that own or control a rack not to provide higher blends at its rack. I believe that this condition plausibly holds in this market, either for parties that hold an existing stock of RINs or for RIN-long parties that exercise market power at the rack. I first lay out the our reasoning in the case that there are negligible investment costs associated with providing higher blends at a rack, then consider the case that there are investment costs. Throughout, I suppose that the RIN-long party either owns or controls the terminal, and that the party is RIN-long because it blends more fuel into E10 than it refines.

   (a) First suppose that there are no investment costs, that the party holds no existing carry-over RIN inventory, and has local market power at the rack so that it is able to pass-through only a fraction of the RIN value. Then two considerations are in play when this obligated party considers offering higher blends at its rack. On the one hand, the additional RIN generated by selling a higher blend will have market value, and because the party has local market power at the rack, it will be able to retain part of that RIN value. On the other hand, increasing the number of RINs in the system by blending E85 will decrease the price of D6 RINs, which decreases the party's profits on the fraction of the RIN value it is able to retain on its RINs generated through its normal E10 operations. If RIN values depended only weakly on the number of RINs detached, the first of these effects (generating a RIN from selling E85) would dominate; however, for volumes above the blend wall, RIN prices depend strongly on the amount of RINs available. Thus, for these RIN-long parties, if their net RIN detachment is sufficiently large, and their pass-through rate is sufficiently low, it will be in their own self-interest not to generate additional RINs by offering E85 at their rack. Moreover, it is not in their self-interest to allow others to splash-blend at the rack (that is, not offer E100 at the rack) or to lease space to parties who would purchase E10 and E100 above the rack and splash blend.

(b) The argument in (2)(a) is strengthened if the RIN-long obligated party has a carryforward inventory of RINs, because generating an additional RIN from higher blend sales devalues that additional stock.

(c) The argument in (2)(a) is strengthened if there are substantial investment costs that must be paid to offer higher blends and/or E100 at the rack. The magnitude of these investment costs is portrayed differently by different market participants. Our understanding is that, at some terminals, they may be as modest as a software upgrade. At other terminals, they might require additional piping, a blender upgrade, a new blending manifold, or possibly even new ethanol tank capacity. Overall, my impression is that these costs are fairly minor, although they might be substantial at some terminals.

(d) An additional consequence of a RIN-long obligated party selling higher blends at its rack is that doing so could result in competition at the rack and reduce its ability to retain part of the RIN value, thus eroding its profits. The evidence in Pouliot, Smith, and Stock shows that there is more RIN pass-through at racks with multiple sellers of higher blends, than at racks with no or few sellers of higher blends. Pouliot, Smith, and Stock do not demonstrate that this correlation is causal; still, it is plausible that increasing competition for higher blends at the rack would increase pass-through.

(e) The logic in (2)(a) does not depend on there being collusion among terminal owners or RIN-long parties, nor does it appeal to long-term gaming among parties. It hinges on

  (i) A particular terminal ownership structure (owned or controlled by RIN-long parties),

(ii) Market power at the terminal. This market power can arise because of local history of terminals being open or closed, the very high fixed cost of opening a third-party terminal, and local features of the service area of terminals.

(iii) A very steep relationship between the D6 RIN price and the volume of the RIN obligation in excess of the RIN capacity of E10. The history of RIN prices indicates that relationship is in fact very steep, resulting in RIN prices of $0.50 to $1.00 for conventional RVOs that entail ethanol consumption on the order of hundreds of millions of gallons above the RIN capacity of E10. In effect, this very steep relationship provides every entity generating D6 RINs through the sale of higher blends into entities with market power in the RIN market, that is, the power to change the D6 RIN price.

(3) The foregoing argument about RIN-long parties having an incentive not to sell higher blends at their terminals rests on those parties being RIN long. Changing the POO would make those parties RIN short. Thus the key channel of this argument, which is retaining the economic profits from RIN sales (the retained RIN value), would no longer be present. Thus all parties, including currently RIN-long parties, would shift from having a disincentive to offer higher blends at the rack under the current Point of Obligation, to having an incentive to offer higher blends or E100, because all sellers of petroleum fuel would be RIN short if the conventional fuel obligation exceeds the ethanol capacity of E10.

(4) This said, there are several reasons why changing the Point of Obligation might not substantially increase the efficiency of the RFS, or substantially increase the amount of higher blends available at retail.

(a) Terminals that currently have local market power would continue to do so. While the formerly RIN-long owners of those terminals would, after the change, have an incentive to offer higher blends at the rack, because of their market power I would expect that there would continue to be incomplete pass-through of RIN prices to rack prices of E10 and higher blends. That is, while there might be more availability of higher blends, there would not necessarily be more pass-through, as long as the terminal remained closed.

(b) As shown by Lade and Bushnell (2016) and Li and Stock (2017), the ability of RIN prices to pass through to retail depends on how competitive is the local retail market for E85. Outside of some urban areas in the ethanol belt, the evidence is that this market is not competitive because E85 retailers are thinly spread out. Thus, even in the most optimistic interpretation of changing the Point of Obligation, I would expect modest effects on the availability of competitively priced higher blends at retail.

(c) An integrated RIN-long obligated party, which owns or has under contract retail outlets, currently has a disincentive to provide higher blends at that station, for the reasons outlined in (2)(a) (it is not in their short-run best interest to do so). This argument is strengthened because of the substantial investment costs of installing blender pumps, especially if it entails adding a tank at the retail outlet (logic of (2)(b)). This incentive would shift were the point of obligation to be moved to the owner of the fuel above the rack, because these integrated obligated parties would now be RIN short. This said, it would continue to be in the interests of the obligated parties to install blender pumps in a way that maximizes profits, which plausibly would mean upgrading stations spatially so as not to enhance local E85 retail competition. This way, more of the RIN value could be harvested at retail.

(d) The investment costs for E85 at retail are large, especially if they entail breaking concrete. As a result, I would expect that direct interventions at retail, such as the USDA BIP program, would be a more direct way to stimulate sales of higher blends than changing the Point of Obligation, especially if the associated subsidies for infrastructure upgrades were targeted to achieve station density in specific regions, rather than spread across the country and creating more retail outlets with local market power.

(e) Terminals are either open or closed. An open terminal allows access to its tanks and has multiple racks offering a menu of fuels. I would not expect the decision to change the point of obligation to result in closed terminals becoming open. Terminal openness provides for arbitrage opportunities for rack sellers and for retailers demanding fuel. At a closed terminal, fuel buyers cannot lease tank space and must purchase the blended fuels offered by sellers at the terminal. Potential rack sellers may be unable to perform an arbitrage if they cannot get tank space. A terminal, which has the opportunity to exert market power by limiting sales, can do so only by being closed to limit competition from within its own terminal. Opening its facility would mean eroding its market power, regardless of the location of Point of Obligation. Because changing the Point of Obligation from refiners to rack sellers in closed terminals would not impact a terminal's local market power, doing so would not create a new incentive for the terminal to open itself up.

(5) A remaining puzzle in this story is that some rack sellers that are RIN short do not offer higher blends at the rack, even though they have an incentive to do so: detaching a RIN from selling higher blends has the twin advantage of avoiding purchasing a RIN to meet its obligation, and driving down the RIN price because of the steep RIN price curve. But in Table 1 above, only 6 of the 35 terminals owned by RIN-short parties offer higher blends. One explanation is that the RIN-short party might not have long-term contractual relations with local retailers that would provide a retailer with the certainty needed to justify installing a blender pump; however, a RIN-short entity should be able to develop such a relationship, for example with a retail chain that wanted to establish an E85 presence. Another explanation for this puzzle is that there is insufficient demand at retail in the service area of these terminals. But if that is the reason for the fuels not being offered at these racks, it simply reinforces the comment above that policies targeted at increasing the number and density of retail E85 outlets would be more effective at increasing pass-through and stimulating sales of higher blends than changing the Point of Obligation.

(6) There is a risk that moving the POO could have some unintended consequences.

(a) Moving the Point of Obligation could reduce competition at the rack by removing some entities that currently buy fuel above the rack. Specifically, at an open rack, currently a non-obligated party can buy BOB and E100 above the rack, lease storage space, pay the terminal operator a fee for blending, and retain and sell the RIN. This provides a channel for arbitrage of rack prices, which serves to increase competition at the rack. We do not have data on the prevalence of this strategy, but it is our understanding that this is used, at least occasionally, by some retail chains to reduce rack markups and to harvest the RIN value generated at blending E100. Such entities would become obligated parties were the Point of Obligation to be changed to the owner of the fuel just above the rack. Becoming an obligated party would impose additional administrative compliance costs and legal risks, which could result in such entities ceasing to purchase above the rack and thus reducing competition at the rack. This said, one can also imagine third-party entities emerging to handle the additional compliance burden for such entities, which would mitigate this effect. I do not have data to quantify this risk that moving the Point of Obligation would actually decrease competition, and thus decrease pass-through, at the rack.

(b) Finally, I understand that moving the Point of Obligation would entail a substantial administrative burden on the EPA. That burden would likely crowd out other important work on the RFS. In particular, I expect it will shortly be necessary to reset the EISA statutory table. In my view, the reset provides substantial possibilities for improving the functioning of the RFS and providing certainty to industry participants. In my view, it would be undesirable for the substantial effort associated with moving the Point of Obligation to crowd out thoughtful and important work on other RFS priorities such as the reset and pathway approvals.

Sincerely,

James H. Stock

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The Pass-Through of RIN Prices to Wholesale and Retail Fuels under the Renewable Fuel Standard

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Extended Abstract

The U.S. Renewable Fuel Standard (RFS) requires blending increasing quantities of biofuels into the U.S. surface vehicle fuel supply. In 2013, the fraction of ethanol in the gasoline pool effectively reached 10%, the ethanol capacity of the dominant U.S. gasoline blend (the "E10 blend wall"). During 2013-2015, the price of RINs—tradeable electronic certificates for complying with the RFS—fluctuated through a wide range, largely because of changes in actual and expected policy combined with learning about the implications of the E10 blend wall. RINs are sold by biofuels producers and purchased by obligated parties (refiners and importers), who must retire RINs in proportion to the petroleum they sell for surface transportation. As a result, RINs in effect serve as a charge on obligated fuels and a corrective subsidy for lower-carbon renewable fuels, and are neutral for fuels outside the RFS. In theory, RIN prices provide incentives to consumers to use fuels with a high renewable content and to biofuels producers to produce those fuels, and as such are a key mechanism of the RFS.

This paper examines the extent to which RIN prices are passed through to the price of obligated fuels, and provides econometric results that complement the graphical analysis in Burkholder (2015). We analyze daily data on RINs and fuel prices from January 1, 2013 through March 10, 2015. When we examine wholesale prices on comparable obligated and non-obligated fuels, for example the spread between diesel and jet fuel in the U.S. Gulf, we find that that roughly one-half to three-fourths of a change in RIN prices is passed through to obligated fuels in the same day as the RIN price movement, and this fraction rises over the subsequent few business days. Using six different wholesale spreads between obligated and non-obligated fuels, we estimate a pooled long-run pass-through coefficient of 1.01 with a standard error of 0.12.

We also examine the transmission of RIN prices to retail fuel prices. The net RIN obligation on E10 is essentially zero over this period, and indeed we find no statistical evidence linking changes in RIN prices to changes in E10 prices. We also examine the price of E85 which, with an estimated average of 74% ethanol, generates more RINs than it obligates and thus in principle receives a large RIN subsidy. In contrast to the foregoing results, which are consistent with theory, the pass-through of RIN prices to the E85-E10 spread is precisely estimated to be zero if one adjusts for seasonality (as we argue should be done), or if not, is at most 30%. Over this period, on average high RIN prices did not translate into discounted prices for E85.

JEL codes: Q42, C32

Key words: fuels markets, energy prices, E85, RBOB, wholesale fuel spreads, retail fuel spreads

1. Introduction

The U.S. Renewable Fuel Standard (RFS) requires the blending of increasing quantities of biofuels into the U.S. surface vehicle transportation fuel supply. Developed initially in 2005 and expanded in the Energy Independence and Security Act (EISA) of 2007, the goals of the RFS program are to reduce both greenhouse gas emissions and US dependence on oil imports. The RFS requirements are met through a system of tradable compliance permits called RINs ("Renewable Identification Numbers").

RINs are generated when a renewable fuel is produced or imported and are detached when the renewable fuel is blended with petroleum fuel for retail sale, at which point RINs can be traded. Refiners and refined-petroleum product importers ("obligated parties") must hand in ("retire") RINs annually to the U.S. Environmental Protection Agency (EPA) in proportion to the number of gallons of non-renewable fuels they sell into the surface transportation fuel pool. The sale of a RIN by a biofuel producer to an obligated party serves as a tax on petroleum fuels and a corrective subsidy to renewable fuels, and is revenue-neutral across the fuel market as a whole.

This paper examines the extent to which RIN prices are passed through to wholesale and retail fuel prices. This question is of interest for several reasons. First, if RIN prices are less than fully passed through to wholesale fuel prices, then an obligated party with a net RIN obligation is left with net RIN price exposure, so that an increase in RIN prices creates a financial burden on the obligated party that is not recouped by higher refined product prices. Second, the goal of the RFS is to increase the consumption of renewable fuels, and in theory the market mechanism whereby that happens is by RIN prices passing through to reduced pump prices for fuels with high renewable content and to increased pump prices for fuels with low renewable content. Thus a central question for the RFS is whether this pass-through of RIN prices occurs at the retail level. Third, a more general question on which there is a large literature concerns the pass-through of costs to wholesale and retail fuel prices. The costs studied here, RIN prices, fluctuate substantially on a daily basis, providing an opportunity to estimate dynamic pass-through relations at the daily level.

Through 2012, RIN prices were low, and the RIN market received little public attention. Starting in the winter of 2013, however, RIN prices rose sharply in response to an enhanced understanding that the RFS volumetric standards were approaching the capacity of the fuel supply to absorb additional ethanol through the predominant blend, E10, which is up to 10% ethanol, referred to in the industry as the "E10 blend wall." Throughout 2013-2015, RIN prices fluctuated through a wide range. These fluctuations have been widely and convincingly attributed by market observers and academics as stemming from the E10 blend wall combined with policy developments concerning the direction of the RFS (Irwin (2013a,b, 2014), Lade, Lin, and Smith (2014)). As a result, these RIN price fluctuations serve as an exogenous source of variation that allows us to identify RIN price pass-through.

The question of RIN price pass-through to retail fuels has been addressed recently by the EPA in the context of its proposed rule for the 2014, 2015, and 2016 standards under the RFS (Burkholder (2015)). That work examines the link between RIN prices and refined fuels by examining the relationship between price spreads on physically comparable fuels with different RIN obligations to the value of the net RIN obligation of that spread. For example, diesel fuel and jet fuel have similar chemical compositions, but diesel fuel is obligated under the RFS whereas jet fuel is not. Thus the spread between the spot prices of diesel and jet fuel, both in the U.S. Gulf, provides a comparison that in theory should reflect the price of the RIN obligation of diesel fuel under the RFS while controlling for factors that affect the overall price of oil, local supply disruptions, and evolving features of the petroleum market that might affect the diesel-gasoline spread or the crack spread. In the retail market, Burkholder (2015) also examines the spread between E85, a fuel with between 51% and 83% ethanol, and E10, the dominant fuel during this period, which contains up to 10% ethanol. As is explained in the next section, during this period the net RIN obligation from blending E10 is essentially zero, so Burkholder (2015) also examines the effect of daily RIN price fluctuations on E10 prices.

This paper complements the analysis in Burkholder (2105). Burkholder's (2015) analysis is based on inspection of time series plots. The main contribution of this paper is to use econometric methods to estimate the extent of pass-through, to estimate pass-through dynamics, and to quantify the sampling uncertainty of these estimates. Like Burkholder (2015), we examine the link between fuel price spreads and the value of net RIN obligation of those fuels. We also use a longer data set and examine some wholesale spreads between obligated and non-obligated fuels not examined in Burkholder (2015).[1]

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[1] For diesel, these spreads are the spread between U.S. diesel and jet fuel (both in the Gulf; diesel is obligated but jet fuel is not) and U.S. diesel and diesel sold into the European market (and thus not subject to the RFS), specifically

The empirical analysis in this paper examines both the long-run pass-through coefficient and the short-run pass-through dynamics. We examine the long-run pass-through using levels regressions. Because many of these prices fluctuate seasonally, our base specifications control for seasonality. Even in thick wholesale markets, this pass-through might not be immediate for various reasons including information lags. We therefore examine the dynamic pass-through of RIN prices using both structural vector autoregressions and distributed lag regressions.

This paper also relates to the substantial literature estimating the pass-through of changes in crude oil prices to retail prices, as well as whether this pass-through depends on the direction of the change in crude prices; see, for example, Borenstein et al. (1997), Bachmeier and Griffin (2003), and Lewis (2011). Relative to this literature, the contribution of this paper is to examine pass-through for this specific cost which is central to the design and operation of the RFS, and to provide additional evidence on price pass-through dynamics at the daily level.

Section 2 provides additional background on RINs, the RFS program, and RIN obligations. Section 3 describes the data. The regression methods and results are presented in Section 4, and Section 5 concludes.

2. RINs and the RFS Program

The RFS program divides renewable fuels into four nested categories: total renewable, advanced, biomass-based diesel (BBD), and cellulosic. Under the EISA, each of these four categories has its own volumetric requirements, which the EPA translates into four corresponding fractional requirements through annual rulemakings. As is shown in Figure 1, these categories are defined by the reduction in life-cycle emissions of greenhouse gasses (GHGs), relative to petroleum, by feedstock, and by fuel characteristics.

Production of renewable fuels generates RINs, and there are four types of RINs corresponding to the different categories of fuel under the RFS: cellulosic fuels generate D3 RINs, BBD generates D4 RINs, advanced non-cellulosic non-BBD fuels generate D5 RINs, and conventional fuels (renewable fuels that meet the 80% lifecycle GHG emissions reduction

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the New York Harbor diesel – Rotterdam diesel spread and the U.S. Gulf diesel – Rotterdam diesel spread. For gasoline, these spreads are the New York Harbor RBOB (reformulated blendstock for oxygenate blending) – Euro-BOB spread (RBOB is obligated, Euro-BOB is not), and the spread between New York Harbor RBOB – Brent oil and Los Angeles RBOB – Brent oil.

requirement, but do not qualify as advanced biofuels) generate D6 RINs. During the period of the data, most of the renewable fuels produced were conventional (primarily corn ethanol), followed by biomass-based diesel and advanced biofuels. As a fraction of the overall market, a negligible amount of cellulosic biofuels were produced during this period so D3 RINs are ignored for the empirical analysis here.

The annual RFS regulations specify that for each gallon of petroleum fuel (diesel or gasoline) blended into the fuel supply, a minimum fraction of a gallon of each category of renewable fuels must also be blended. Compliance with this mandate is demonstrated by turning in RINs with the EPA. The compliance system is nested, so a D4 RIN can be used to demonstrate compliance with the BBD mandate, the Total Advanced mandate, or the Total Renewable mandate. Similarly, a D5 RIN can be used to demonstrate compliance with the Total Advanced or Total Renewable mandate. A D6 RIN can only be used to demonstrate compliance with the Total Renewable mandate. During 2013, there were 13,351 million D6 RINs generated, almost entirely from corn ethanol, there were 558 million D5 RINs generated, slightly over 80% of which were produced by advanced non-cellulosic ethanol (mainly Brazilian cane ethanol), there were 2,739 million D4 RINs, corresponding to 1,765 million wet gallons of biomass-based diesel, and there were 0.4 million D3 RINs generated.

Figure 2 shows RIN prices for the period of our data, January 1, 2013 – March 10, 2015. For the purpose of the empirical research in this paper, this was a period of high RIN price volatility, primarily in 2013 but also, to a lesser extent, in 2014-15. In the winter of 2013, D6 RIN prices rose from under $0.10 to much higher prices, hitting at $1.40 in the summer of 2013 before falling back to under $0.30 in the late fall of 2013. Prices were more stable during 2014, although they rose in the winter of 2014-15. As discussed in Burkholder (2015), the initial rise in RIN prices in the winter of 2013 stemmed from increasing market awareness that the RFS standards were approaching or exceeding the so-called E10 blend wall, the amount of ethanol that can be blended into E10, the dominant blend of gasoline which is up to 10% ethanol. As is suggested by the event markers in Figure 2 and as is discussed in detail by Irwin (2013a,b, 2014) and Lade, Lin, and Smith (2014), the subsequent variations in RIN prices arose in large part because of changing expectations about future RFS policy, including a leaked proposal for 2014 volumes, a 2014 proposal which was never finalized, and EPA public statements indicating evolving policy, and repeated delays of proposed standards for 2015. More generally, the movements in RIN prices over this period were not linked to economic growth, shifts in diesel vs. gasoline demand, or other features that might affect price spreads between obligated and non-obligated fuels other than through RIN prices themselves.

Two additional features of the RIN prices in Figure 2 bear comment. First, because of the nested structure, the RIN prices satisfy the inequalities, $P_{D4} \geq P_{D5} \geq P_{D6}$. Second, during most of this period, the three RIN prices tracked each other closely. The reason for this is that during most of this period, biodiesel was being produced in excess of its volumetric requirement and D4 RINs were being used to satisfy the total advanced and total renewable requirements.

Fractional RIN obligation. During the time period of our data, the only fractional standards that were subject to a final rulemaking were the 2013 standards. For each gallon of petroleum gasoline or diesel sold into the surface fuels market, the 2013 standards required retiring with EPA 0.0113 D4 RINs to meet the BBD standard, 0.0162 D4 or D5 RINs to meet the Total Advanced standard, and 0.0974 D4, D5, or D6 RINs to meet the Total Renewable standard; because of the RFS nesting structure, a D4 RIN retired to meet the BBD standard also counts towards the Total Advanced and Total Renewable standard. Assuming the Total Advanced residual requirement is met by turning in 0.0049 (= 0.0162 - 0.0113) D5 RINs and the Total Renewable residual (i.e. conventional) requirement is met by turning in 0.0812 (= 0.0974 - 0.0162) RINs, the value of the 2013 RIN obligation to an obligated party, per gallon of petroleum fuel sold into the transportation market, is:

$$P_{RIN\ bundle} = .0113P_{D4} + .0049P_{D5} + .0812P_{D6}, \tag{1}$$

where P_{D4}, P_{D5}, and P_{D6} are the price of a D4, D5, and D6 RIN, respectively.[2] Because each of the wholesale spreads is the price difference between an obligated fuel and an exempt fuel, the value of the per-gallon RIN obligation in (1) is the predicted per-gallon RIN price effect on each of the wholesale spreads.

The predicted RIN price obligation on retail fuels depends on the fractions of gallons of petroleum and renewable fuel blended into a gallon of retail fuel. Specifically, we also examine

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[2] Because of the nested structure, the Total Advanced residual (Total Advanced minus BBD standards) can be met with either a D5 RIN or a D4 RIN generated by BBD production in excess of the BBD standard. Because of market arbitrage, however, even if the Total Advanced residual is met by an excess D4 RIN, then the D4 and D5 RIN prices will be the same, so (1) still provides the value of the RIN bundle.

the pass-through of RIN prices to retail (pump) prices of E10 and E85 (which can be between 51% and 83% ethanol). Blending one gallon of E10 generates 0.1 D6 RINs, but obligates 0.9 gallons of RIN obligations. The Energy Information Administration has estimated that, on average, E85 is 74% ethanol, so blending 1 gallon of E85 generates 0.74 D6 RINs and entails 0.26 gallons of RIN obligations. Thus, for these two retail fuels, the value of the net RIN obligations are:[3]

$$\textit{Net E10 RIN obligation price} = -0.1P_{D6} + 0.9\times P_{RIN\,bundle} \tag{2}$$

$$\textit{Net E85 RIN obligation price} = -0.74P_{D6} + 0.26\times P_{RIN\,bundle} \tag{3}$$

For example, if the prices of D4, D5, and D6 RINs are all one dollar, then the price of the RIN bundle is 0.097, the net E10 RIN obligation is -0.012, and the net E85 RIN obligation is -0.715. For RIN prices observed since 2013, the basic pattern is that the net E10 RIN obligation is near zero and negative, while the net E85 RIN obligation is large and negative. Diesel, which is not considered in this study, has a small positive net RIN obligation over this period.

The price of the net RIN obligation for the E85-E10 spread is the difference in the net RIN obligation prices of the respective fuels:

$$P^{net}_{RIN,E85-E10,t} = \textit{Net E85 RIN obligation price} - \textit{Net E10 RIN obligation price}. \tag{4}$$

3. The Data and Descriptive Statistics

The data consist of daily fuel and D4, D5, and D6 RIN prices from January 1, 2013 to March 10, 2015. Prices on D4, D5, and D6 RINs are from Progressive Fuels Limited (PFL).[4]

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[3] Equations (2) and (3) make two approximations: (a) all the ethanol blended into E10 and E85 is conventional (corn) ethanol, however in reality some of this ethanol is cane ethanol that generates a D5 RIN; (b) all biodiesel generates D4 RINs, however in reality some biodiesel generates D5, D6, and D7 RINs. However the omitted volumes are small so these approximations have negligible effect on the predicted net RIN obligation prices.

[4] RIN price data from PFL are proprietary. PFL can be reached online at www.progressivefuelslimited.com and by phone at 239-390-2885. Our PFL data end November 30, 2014, and were filled in using OPIS data. The OPIS data has some missing values (most notably D5 prices for January 2015), which were filled in using Bloomberg. Some missing values remained, all for D5 RINs in January 2015, and those missing values were filled in using data from the most recent nonmissing trading day. These RIN prices are traded prices and do not necessarily reflect prices embedded long-term contracts for RINs.

Domestic wholesale prices were obtained from the Energy Information Administration:[5] NYMEX prompt-month futures prices for reformulated blendstock for oxygenated blending (RBOB)-New York Harbor, and spot prices for Brent oil, RBOB-Los Angeles, Ultra-low sulfur No. 2 diesel-New York Harbor and U.S. Gulf Coast, and Kerosene-type jet fuel-U.S. Gulf Coast. Two wholesale European prices, reported by Argus, were used: the Rotterdam barge German diesel (10ppm sulfur) price, and the price of European blendstock for oxygenated blending (EBOB), FOB Rotterdam (both quoted in dollars per tonne, converted to dollars per gallon). Retail fuels prices for diesel, E10, and E85 are national average pump prices produced by the American Automobile Association and reported by (and downloaded from) Bloomberg.[6]

Weekends and U.S. holidays were dropped, so the resulting data are for U.S. business days. In some cases we aggregate the data to weekly, by which we mean five consecutive business days.

From these data, we constructed six wholesale spreads and one retail spread (E85-E10) which, along with changes in E10 prices, are the focus of the analysis. Recall that obligated fuels are those sold for use in the surface transportation sector in the United States; non-obligated fuels are fuels used in Europe and fuels used domestically for purposes other than surface transportation, such as jet fuel. The wholesale prices are the price differences, in dollars per gallon, between a fuel that is obligated under the RFS and a similar fuel that is not obligated:

Diesel spreads

Gulf diesel-jet fuel spread = Ultra-low sulfur No. 2 diesel spot, U.S. Gulf – Jet fuel, U.S. Gulf

NY-Rotterdam diesel spread = Ultra-low sulfur No. 2 diesel spot, New York Harbor – Barge diesel, Rotterdam

Gulf-Rotterdam diesel spread = Ultra-low sulfur No. 2 diesel spot, U.S. Gulf – Barge diesel, Rotterdam

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[5] Spot prices were downloaded from http://www.eia.gov/dnav/pet/pet_pri_spt_s1_d.htm, and futures prices were downloaded from http://www.eia.gov/dnav/pet/pet_pri_fut_s1_d.htm.

[6] The only adjustment for outliers was for the E85 price, which has five episodes of large measured price changes that are reversed within one to four days and appear to be measurement errors; these observations were omitted from the regressions.

BOB spreads (wholesale)

NY RBOB-EBOB spread = RBOB prompt-month futures, New York – EBOB, Rotterdam

NY RBOB-Brent spread = RBOB prompt-month futures, New York – Brent spot

LA RBOB-Brent spread = RBOB spot, Los Angeles – Brent spot

In addition, we consider the retail fuel E85-E10 spread (= E85 price – E10 price).[7]

Summary statistics. Table 1 provides the mean and standard deviation of the seven spreads, the E10 price, and the net RIN obligations. The standard deviations of the wholesale refined product spreads over this period are less than \$0.10. The RBOB-Brent spreads have a larger standard deviation, reflecting in part seasonal movements in RBOB. The value of the net RIN bundle for these wholesale fuels averaged \$0.056 over this period, with a standard deviation which is one-half to one-fourth that of the refined product spreads. The largest fluctuations are in the E10 price, which moved significantly over this period both for seasonal reasons and because of the sharp drop in oil prices starting in July 2014. The net RIN obligation on the E85-E10 spread is large and negative, averaging \$0.393/gallon over this period. Notably, the standard deviation of the E85-E10 net RIN obligation exceeds the standard deviation of the E85-E10 spread by one-fourth; this large variation in the E85-E10 net RIN obligation this sample provides an opportunity for precise estimation of RIN pass-through to E85. The fact that the standard deviation of the E85-E10 net RIN obligation exceeds that of the spread is suggestive of incomplete pass-through, however in principle this inequality also could arise with complete long-run pass-through where the retail spread smooths out high frequency fluctuations in the net RIN obligation, a possibility examined in the regression analysis in the next section.

Time series plots. Figures 3-5 plot, respectively, the time series data on the wholesale diesel spreads, the RBOB spreads, and the E85-E10 spread along with the value of the RIN obligation per gallon of petroleum, all in dollars per gallon. First consider the wholesale spreads. There are several common features of the data that are evident across the time series. First, many of the spreads show seasonal patterns. This is particularly the case for the BOB-Brent spreads:

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[7] Another spread of interest is the pump diesel-E10 spread. Pump diesel has a lower renewable content than E10 so entails a net RIN obligation, however this RIN obligation is small, with small variation over the sample compared to variation in the pump diesel-E10 spread, making econometric analysis of the pump diesel-E10 spread challenging. We therefore leave analysis of the pump diesel-E10 spread

from 2006-2015, seasonals explains half the variance in the daily NY RBOB-Brent spread and have a range of $0.30. There are also seasonal patterns in the diesel spreads, although they are smaller, for example the range of seasonal fluctuations in the Gulf diesel – Gulf jet fuel spread is approximately $0.05.[8] Second, several of the series have substantial high-frequency noise in the form of quickly reverting prices. This is particularly true for the NY-Rotterdam and Gulf-Rotterdam diesel spreads, but also for the NY RBOB – EBOB spread and the E85-E10 spread. Third, while the range of variation of the diesel spreads is roughly the same as the RIN price obligation, the BOB and retail spreads vary over much larger ranges than the RIN price obligation, consistent with the standard deviations in Table 1.

Consistent with the analysis in Burkholder (2015), the wholesale spreads in Figures 3 and 4 broadly move with the RIN obligation price; however, variation in the RIN obligation price is just one of many reasons for movements in these spreads. Some of these non-RIN movements are idiosyncratic to certain spreads, for example the spikes in the NY-Rotterdam diesel spread during the late winters of 2014 and 2015, indicating temporarily tight markets for diesel and heating oil in the Northeast U.S. Other non-RIN movements are more persistent, such as the decline in the NY RBOB-EBOB spread during the summer of 2014 at a time that the value of the RIN obligation was slowly increasing.

Figure 5 presents mixed evidence on the comovements of the E85-E10 spread and its net RIN obligation price. E85 prices fell, relative to E10, during the spring and summer of 2013 as RIN prices initially rose (and the net E85-E10 RIN obligation price fell, because E85 is a renewables-heavy fuel), however E85 prices rose only slightly as RIN prices fell in the fall of 2013, and through 2014 and 2015 fluctuations in the RIN obligation price appear less connected to the spread.

Scatterplots. The plots in Figures 3-5 show broad trends but do not illustrate the link between timing in changes in RIN prices and the fuel spread. Figures 6-8 therefore provide an initial look at the link between changes in the value of the RIN bundle and the change in the spread. For these scatterplots, the data are aggregated to weekly averages and the changes are weekly changes of weekly averages (the weeks are the five business days ending on Tuesday to minimize missing weeks due to holidays).

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[8] These seasonal statistics are computed by regressing the spread on the seasonal variables discussed in Section 4, using data from October 2005-March 2015 for the NY RBOB-Brent spread and from June 2006-March 2015 for the Gulf diesel-jet fuel spread, the full period for which EIA provides these data.

For the wholesale fuels (Figures 6 and 7), the scatterplots show the weekly change in the spread vs. the weekly change in the RIN price obligation in the same week. The scatterplots generally show a positive association between changes in RIN prices and changes in the wholesale spreads between obligated and non-obligated fuels. However, consistent with the spreads changing for many reasons other than RIN prices, the scatters are dispersed.

Because of delays in pricing in retail fuels markets, the scatterplots for the retail fuels in Figure 8 show the weekly change in the E85-E10 spread (upper) and the change in the E10 price (lower) against the prior-week change in the net RIN obligation price. In contrast to the wholesale fuel scatterplot, the E85-E10 scatterplot shows very little evidence of pass-through, at least at this relatively short time lag. Because E10 has a net RIN obligation of approximately zero under the 2013 RFS standards, theory suggests that there would be little relationship between changes in RIN prices and changes in E10 prices, and the E10 scatterplots in Figure 8 are consistent with this theoretical prediction of no relationship, whether the data are seasonally adjusted or not.[9] These scatterplots, however, are not able to capture fully the dynamics of the RIN price-spread relationship; doing so requires turning to time series regressions.

4. Time Series Analysis: Methods and Empirical Results

We now turn to time series regression analysis of the relation between changes in the spreads and changes in the price of the net RIN obligation. The first set of specifications estimate levels relations with no lags which, as is discussed further below, have the interpretation of estimating the long-run pass-through coefficient. The second set of specifications uses vector autoregressions to estimate pass-through dynamics. In the vector autoregressions, the dynamic effect of a RIN price shock is identified by assuming that the shock to the RIN bundle is exogenous at the daily level. Finally, as a specification check we present a third set of results in which the dynamic pass-through is estimated using distributed lag regressions. In all cases, we initially present results for each spread individually. Generally speaking, we find that the pass-through coefficients and their dynamics are similar across wholesale spreads, but are estimated imprecisely. Because the pass-through theory does not differentiate among wholesale spreads,

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[9] For the purpose of Figure 8, the seasonally adjusted E10 series was by regression-based seasonal adjustment as described in Section 4, with the seasonal coefficients estimated over the period October 2006 to January 2012.

and because the markets are connected and have overlapping participants, we therefore estimate pooled specifications for the wholesale spreads in which the pass-through coefficients are constrained to be the same across spreads.

Because of the seasonal movements in many of the prices, and because the 2013 RIN price increase in the spring and decline in the fall coincides with some seasonal fuel patterns, in all specifications the leading cases include seasonal adjustment. A typical method for seasonally adjusting monthly data is to include 11 monthly indicator variables, however with these daily data, monthly indicators would induce jumps between months. Instead, we use sines and cosines evaluated on calendar days at the first four seasonal harmonic frequencies.[10]

Levels specifications. We begin by investigating the long-run pass-through relation between the level of the net RIN obligation price and the spreads, which is the focus of the discussion in Burkholder (2015).

Visual inspection of Figures 2-5 indicates that, for the relatively short data span at hand, there are long swings (low-frequency movement, or persistence) in both the spreads and RIN prices. It is natural to expect the spreads to be revert to a mean value over a sufficiently long period, that is, for the spreads to be stationary. Over the short sample at hand, however, the assumption of stationarity might not be a good statistical description of these series. A large body of econometric methods and practice has developed around handling time series data with low-frequency movements. The benchmark approach is to ascertain whether the series at hand are integrated of order zero or one and, if they are integrated of order one, whether they are cointegrated, that is, have common long-term movements. If the series are stationary but have long-term comovements, as is evident in the time series plots, or if the series are cointegrated, then regressions of the level of the spread on the level of the net RIN obligation price produce estimates of the long-term coefficient linking the two series, which in this case is the long-term pass-through coefficient.

Table 2 summarizes the levels regression results for the individual series. First consider the unit root and cointegration tests reported in the lower panel of the table. The RIN prices

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[10] Including the first six seasonal harmonics would be equivalent, with monthly data, to including twelve monthly indicators. Preliminary investigation indicated that the full six harmonics were not necessary so for parsimony the first four harmonics were used, and the results are robust to this choice.

appear to be well-approximated as having a unit root over the full sample.[11] As can be seen in Table 2, there is more evidence against the unit root model for the spreads, with all but 3 of the 12 unit root tests for wholesale spreads rejecting the unit root null at the 10% level. The notion that the RIN obligation price and the spread have different orders of integration is internally inconsistent and makes these results difficult to interpret. This said, five of the six cointegration tests reject non-cointegration, which suggests that if the unit root model is adopted then the assumption of cointegration is appropriate. With the preponderance of tests rejecting the unit root model, we focus on levels regressions estimated by OLS. Under the assumption that RIN prices are exogenous, inference on the OLS estimator is valid even if the series are cointegrated, however in that case the OLS estimator will be an inefficient estimator of the long-run relation. As a check, we therefore also report levels regressions estimated using the dynamic OLS (DOLS) efficient cointegration estimator.

We now turn to the levels regression results for the six wholesale spreads. In all specifications, the units of the spread and the RIN price obligation align, so that a coefficient of 1 corresponds to perfect pass-through. Five features of the wholesale spread regression results in Table 2 are noteworthy.

First, for the base specification in row (1) (OLS in levels with the seasonal controls), the estimated coefficients range from 0.68 to 1.57. There is, however, a wide range of precision of the estimates, ranging from a tight standard error of 0.14 for the Gulf diesel-Rotterdam diesel spread to 0.70 for the L.A. RBOB-Brent spread. This precision is consistent with the large non-RIN variation in several of these series evident in Figures 3 and 4.

Second, there are only small differences between the DOLS and OLS estimators. This finding is consistent with the price of the RIN obligation being exogenous and indicates robustness of the long-run pass-through coefficient to whether the series are modeled as cointegrated.

Third, for most of the series the estimated pass-through coefficient is sensitive to whether seasonals are included (compare regressions (4) and (1)). Because the seasonal coefficients are strongly statistically significant for all the spreads and, as discussed above, ignoring seasonals

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[11] DF-GLS and augmented Dickey-Fuller unit root tests, applied to the D4, D5, and D6 RIN price series with a constant (no drift, AIC lag selection), fail to reject the null hypothesis of a unit root at the 10% level in 5 of the 6 cases, and in the 6th case rejects the unit root at the 10% but not 5% level.

has the potential for confounding movements in RIN prices with normal seasonal movements in the spreads, we will focus on the results that include the seasonal variables.

Fourth, the subsample estimates are far more precise for 2013 than for 2014-15, consistent with 2013 being the period with the greatest fluctuation in RIN prices. Because these regressions span only a year, or just over a year, they do not include seasonal variables so serve here to confirm that most of the variation in the data is arising from the first half of the sample.

Fifth, regression (3) augments the base set of seasonals (the first four harmonics) with two additional harmonics, so that they would be equivalent to monthly indicators in monthy data. Although using the base set of seasonal variables matters substantially for the results, the differences between using the base set and the augmented set of seasonal variables are negligible.

A straightforward interpretation of the theory of pass-through provides no reason to think that the RIN pass-through should differ across the wholesale spreads, each of which compare an obligated fuel to a non-obligated counterpart. Table 3 therefore presents pooled levels regression in which the pass-through coefficient is constrained to be the same across series (all other coefficients, including seasonals, are unconstrained).

The pooled levels regression results in Table 3 present strong evidence in favor of a precisely estimated unit pass-through coefficient. The regressions in Table 3 are for the three specifications in Table 2 that include seasonals. As expected, pooling improves the precision of the estimators, especially for the RBOB spreads. For diesel, the estimated pass-through coefficient is slightly greater than one, while for gasoline it is less than one, but in all cases it is within one standard deviation of one. When the six wholesale spreads are pooled, the long-run pass-through coefficient is estimated to be 1.01 using OLS or DOLS with the base set of seasonal variables, with a standard error of 0.12.

The results for the E85-E10 retail spread, given in the final two columns of Table 2, are quite different than for the wholesale spreads. Three features of the E85-E10 results are noteworthy. First, regardless of the specification, the pass-through coefficient is in all cases small (the negative coefficients for 2014-15 are relatively imprecisely estimated and do not include seasonals so we put little weight on these estimates). Second, because of the large variation in the E85-E10 net RIN obligation price, the pass-through coefficients estimated using the full sample, and using the 2013 subsample, are all precisely estimated. Third, the results are sensitive to whether seasonals are included. Unfortunately, unlike the wholesale spreads historical data on E85 prices are spotty and we are unable to examine historical seasonal fluctuations in the E85-E10 spread. Because the average ethanol content of E85 varies seasonally, and because ethanol is less expensive than petroleum gasoline on a volumetric basis for most of this sample period, one would expect seasonal fluctuations in the E85-E10 spread and indeed the seasonal coefficients in the E85-E10 regressions are strongly statistically significant. These considerations lead us to put greater weight on the regressions including seasonals. Fourth, consistent with the gasoline pass-through literature, one would expect a delay between changes in the net RIN obligation price and when it shows up in retail prices, even with perfect long-run pass-through. The final column in Table 2 therefore presents regressions in which the net RIN obligation price is replaced by its value 20 business days (approximately one month) prior. With this modification, the negative coefficients in specifications (1) and (2) become approximately zero, and the OLS estimate without seasonals becomes 0.26. In short, ignoring seasonals yields a precisely estimated long-run pass-through coefficient of roughly one-fourth; including seasonals, this coefficient is precisely estimated to be zero.

Structural vector autoregressions by fuel spread. We now turn to an examination of the short-run pass-through dynamics between the net RIN obligation price and the spreads. We initially estimate the pass-through dynamics using bivariate structural vector autoregressions (SVARs), then in the next section compare the SVAR results to ones obtained from distributed lag models.

The SVARs estimate the dynamic response of the two included variables, the net RIN obligation price and the spread, to a structural shock to the net RIN obligation price. Motivated by the discussion in Section 2, we identify the net RIN structural shock by assuming that it is uncorrelated at the daily level with any of the other news determining daily innovations in the spread; this corresponds to ordering the net RIN obligation price first in a Cholesky factorization. All SVARs include the base set seasonal variables. The SVARs are specified in differences, for two reasons. First, the bulk of the statistics in Table 2 on unit roots suggests that the variables are most plausibly treated as stationary. Second, this evidence is not clear-cut, and the estimates obtained from a levels specification will be consistent under unit roots with or without cointegration, although in the latter cases the levels VAR estimates will be inefficient.

Table 4 presents the SVAR estimates of the dynamic pass-through effect, specifically, the structural impulse response of the (level of the) spread to a shock to the net RIN obligation price, for the first 15 business days. As in the levels regression, there is considerable variation in precision across the VARs and, not surprisingly, the estimates of the dynamics are less precise than the estimates of the long-run relations. Still, several interesting patterns emerge. All the SVARs indicate that roughly half to two-thirds of the RIN price is passed through to the wholesale spread in the first day, and by the end of the business week the estimated pass-through is approximately 1, albeit quite imprecisely estimated for some of the series. As in the levels regressions, the most precise estimates are for the Gulf diesel-Gulf jet fuel spread and the Gulf diesel-Rotterdam diesel spread.

Because the wholesale fuels markets are deep and many of the participants are the same, and because the theoretical effect of the RIN obligation price is the same for each of the spreads, we also estimated SVARs pooled across the wholesale spreads, in which the SVAR coefficients on the spread and the net RIN obligation price were constrained to be the same for each spread (seasonals were allowed to differ across spreads).[12]

The pooled SVAR results are given in Table 5. The structural impulse response functions for diesel and for gasoline both show a large, but incomplete, impact effect, with a pass-through that rises over time, and the two sets of 3-fuel impulse response functions are within a standard error of each other. The 6-spread pooled results estimate a pass-through of 0.71 in the first day, rising to 0.90 after five business days. Even with pooling, the dynamic effects remain less precisely estimated than the levels long-run estimate, however there is substantial evidence consistent with large, but initially incomplete pass-through, that becomes complete pass-through after roughly one week.

SVAR results for retail fuels are given in Table 6. The first three columns present different SVARs using daily data; the fourth column estimates a SVAR using weekly data (weeks ending in Tuesday, specified in first differences as an additional specification check). As is the case in the levels regressions, the SVAR results for E85-E10 are quite different than for the

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[12] Specifically, this was implemented by estimating a VAR with n spreads and the RIN price obligation, for n+1 variables. The constrained n+1 variable SVAR imposed no feedback across spreads, coefficients at a given lag being equal across spreads, and the same structural impact coefficient, where the RIN price obligation ordered first in a Cholesky factorization. This is equivalent to estimating n bivariate SVARs constrained to have the same coefficients on the spread and the RIN obligation across each SVAR, but allowing different seasonals and intercepts for each spread. In the case n=1 this specializes to the bivariate SVARs in Table 4.

wholesale spreads. With or without seasonals, there is little evidence of pass-through within a week, although without seasonals there is evidence of perhaps 20% pass-through after three weeks in both the daily and weekly regressions. In the weekly regression, even after 8 weeks the pass-through is only 0.29, consistent with the more precise estimates of long-run pass-through obtained from the levels regressions in Table 2 without seasonals. If seasonals are included, then the dynamic pass-through of RIN prices to E85 is essentially zero.

Finally, theory predicts that E10 prices should not be affected by RIN prices, and that is what is found in the SVAR in the final column of Table 6.

Distributed lag regressions by fuel spread. An alternative approach to estimating the dynamic effect of a change in the net RIN obligation price is to use distributed lag regressions. As an additional check, these regressions are specified in first differences. The distributed lag regressions are of the form:

$$\Delta Spread_{i,t} = \mu_i + \beta_i(\mathrm{L})\,\Delta P^{net}_{RIN,i,t} + \gamma_i' W_t + u_{it}, \tag{5}$$

where i varies across the spreads, $\beta_i(\mathrm{L})$ is a lag polynomial, W_t are additional control variables in some of the specifications, and $P^{net}_{RIN,i,t}$ is the price of the net RIN obligation bundle for that spread. The cumulative effect on the spread of a change in the net RIN obligation price after k days is the sum of the first k coefficients in the distributed lag polynomial $\beta_i(\mathrm{L})$.

The results for the individual spreads are summarized in Table 7. For comparability to the VAR results, the specifications include seasonal controls and are estimated over the full sample, and include the current value and fifteen lags of the net RIN obligation price so as to estimate the first fifteen cumulative dynamic multipliers. In general, the results for the individual spreads are consistent with those for the counterpart SVAR impulse response functions, although the estimates from the distributed lag regressions, which have more coefficients than the SVARs, have larger standard errors and are less smooth. For the wholesale fuels, the results are consistent with complete pass-through, although the estimates are imprecise. For the E85-E10 spread, the dynamic pass-through over these first three business weeks is precisely estimated to be small, and is statistically indistinguishable from zero. Also consistent with the previous results, there is also no evidence of pass-through from RIN prices to E10 prices.

Results for pooled distributed lag regressions are given in Table 8. The estimates are comparable to those from the SVARs, although (like the individual distributed lag estimates) have larger standard errors and are less smooth.

Appendix Tables A1 and A2 present additional distributed lag specifications, including specifications in weekly differences to reduce the number of parameters and specifications that include changes in Brent prices (current and lagged) as additional control variables. These results are also consistent with the SVAR and daily distributed lag regressions presented in the text and show (a) general evidence of pass-through for the wholesale fuels, (b) that the 2013 data are more informative than the 2014-2015 data, (c) that some of the results, particularly for the gasoline spreads, are sensitive to controlling for seasonality, and in those cases the seasonal coefficients are typically statistically significant (so the seasonal specifications should be used), (d) there is little evidence that E10 prices move with RIN prices, and (e) the pass-through of RIN prices to E85 is small, and once seasonals are accounted for, is roughly zero.

5. Discussion and Conclusions

Taken together, these results support the view that RIN prices are passed through quickly, but not immediately, into the wholesale prices of obligated fuels. Based on the pooled, six-fuel SVAR, 57% of a shock to the price of the RIN obligation is passed through in the same day, rising to 97% after six business days (standard error of 31 percentage points). The pooled long-run pass-through estimate is 1.01 with a standard error of 0.12. This rapid and complete pass-through is consistent with economic theory and with efficiently operating wholesale fuels markets.

The results for E10 are also consistent with economic theory: the net RIN obligation of E10 is negligible, and there is no statistically discernable movement of E10 prices with RIN prices.

In contrast to these results, there appears to be little or no pass-through of RIN prices to E85 retail prices. Because the variation in the E85-E10 net RIN obligation price is very large during this sample, this absence of pass-through is precisely estimated, however whether the estimate is zero or roughly 30% depends on whether the results adjust seasonal fluctuations or not, respectively. The presence of seasonals in E10 prices and in the other fuels, and in the physical composition of E85, suggests that seasonals should be included in the specifications, which leads to a precise estimate of no pass-through.

This analysis is subject to several caveats. Throughout, identification of the pass-through coefficients is predicated on some aspect of exogeneity of RIN price movements, for example the SVAR analysis identifies unexpected changes in RIN prices as arising from features related to the RFS or biofuels markets. We argued that this is plausible given unique features of the biofuels market and the RFS during this data span, in which RIN prices fluctuated due to policy developments, fundamentally, changing perceptions of how the blend wall would be handled within the RFS program. To the extent that RIN prices moved because of broader economic or petroleum market developments that would directly affect the spreads, this identifying assumption would be brought into question.

One implication of these results, discussed in detail in Burkholder (2015), is that an obligated party with a net RIN obligation, such as a merchant refiner, is able to recoup their RIN costs on average through the prices they receive in the wholesale market, although this mechanism would not be apparent on the balance sheet of the obligated party because there is no explicit revenue line item offsetting the explicit cost of purchasing RINs. Even with full pass-through, however, an obligated party could face RIN price risk because of timing differences between when the RIN obligation is incurred and when RINs are acquired.

To us, the most intriguing and challenging finding here is the near absence of pass-through of RIN prices to retail E85 prices. While RIN prices might be passed through at some retail outlets at some times, this is not the case on average using national prices. The goal of the RFS program is to expand the use of low-carbon domestic biofuels, and the key economic mechanism to induce consumers to purchase high-renewables blends is the incentives provided by RIN prices. If the RIN price savings inherent in blends with high biofuels content are not passed on to the consumer, then this key mechanism of the RFS is not functioning properly. Obtaining a better understanding of the disconnect between fluctuations in RIN prices and pump E85 pricing is an important question for understanding how to achieve efficiently the goals of the RFS.

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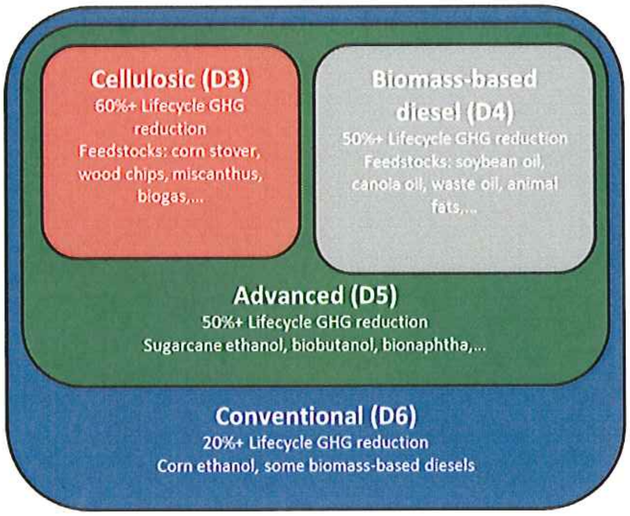
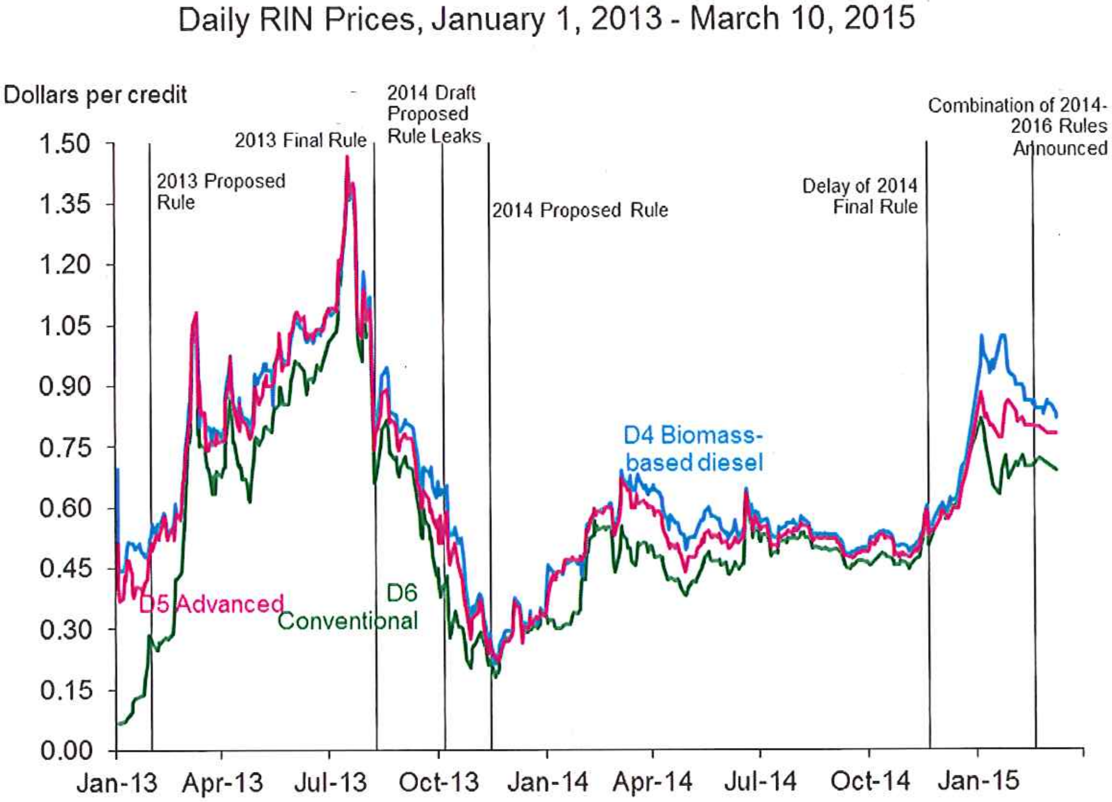


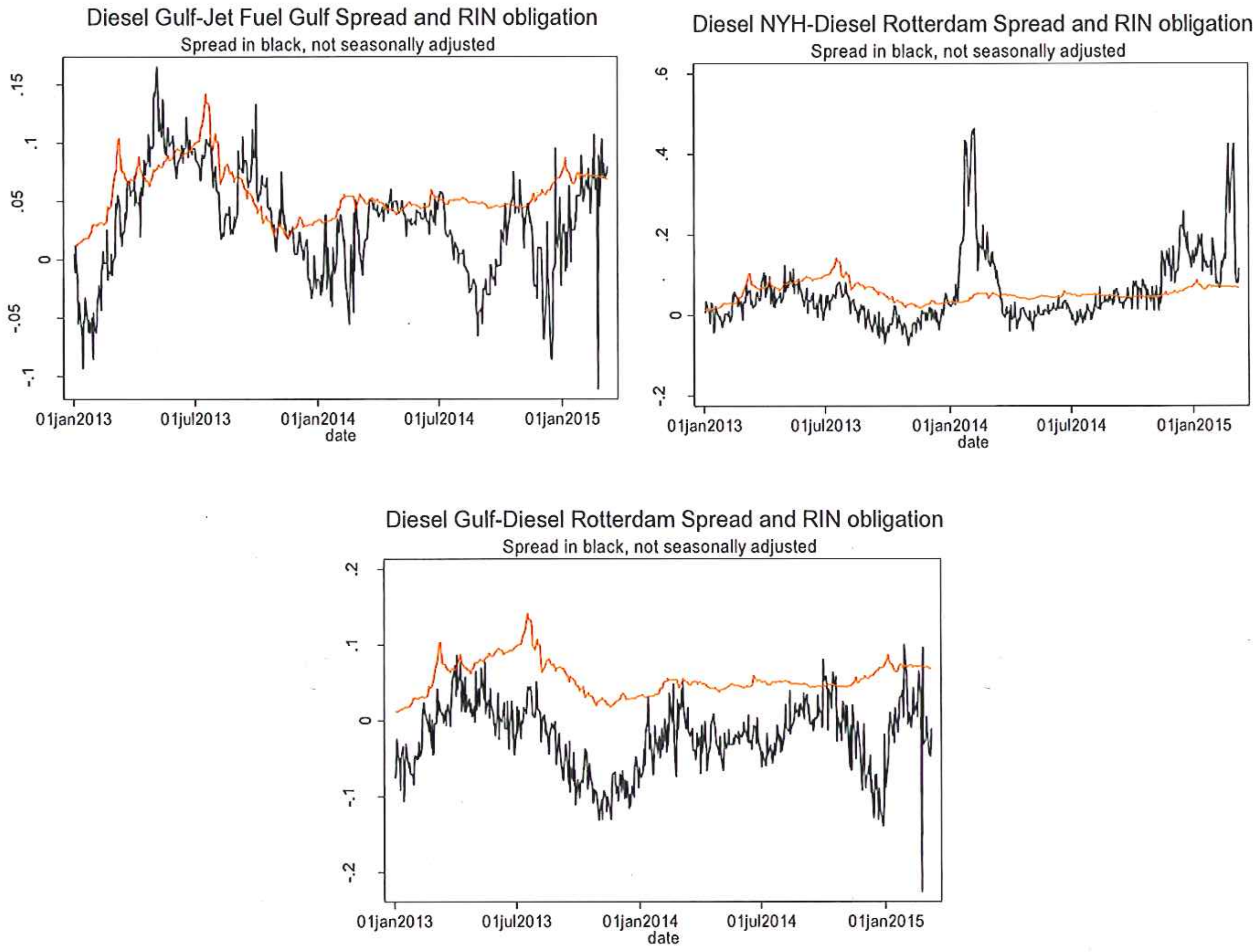
Source: EPA

Figure 1. The RFS Nested Fuel Structure



Source: Progressive Fuels Limited (through November 2014) www.progressivefuelslimited.com, OPIS, Bloomberg.

Figure 2.


Diesel Gulf-Jet Fuel Gulf Spread and RIN obligation

Spread in black, not seasonally adjusted

Diesel NYH-Diesel Rotterdam Spread and RIN obligation

Spread in black, not seasonally adjusted

Diesel Gulf-Diesel Rotterdam Spread and RIN obligation

Spread in black, not seasonally adjusted

Figure 3. Wholesale diesel fuel spreads and net RIN obligation.

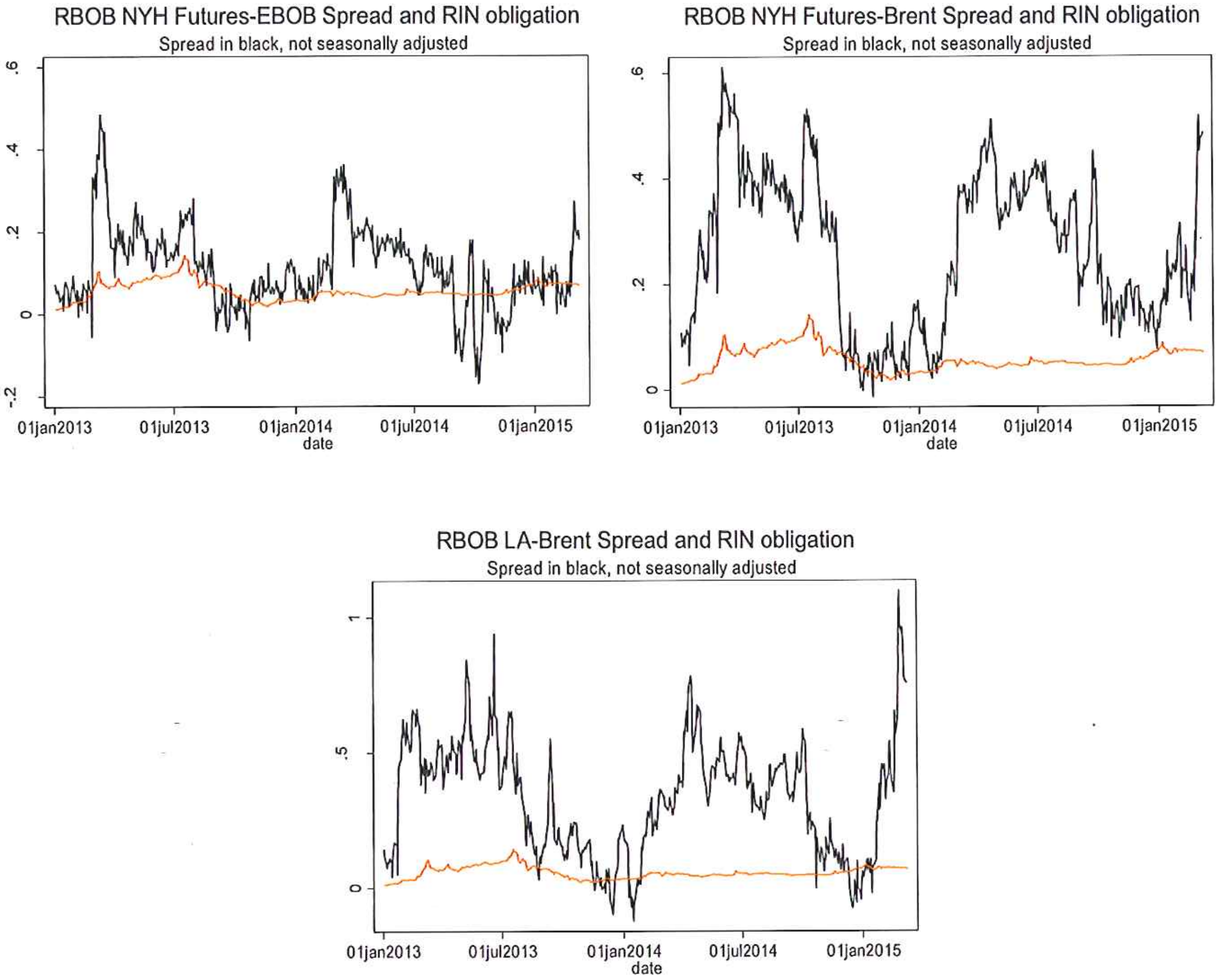


Figure 4. Wholesale gasoline fuel spreads and net RIN obligation.

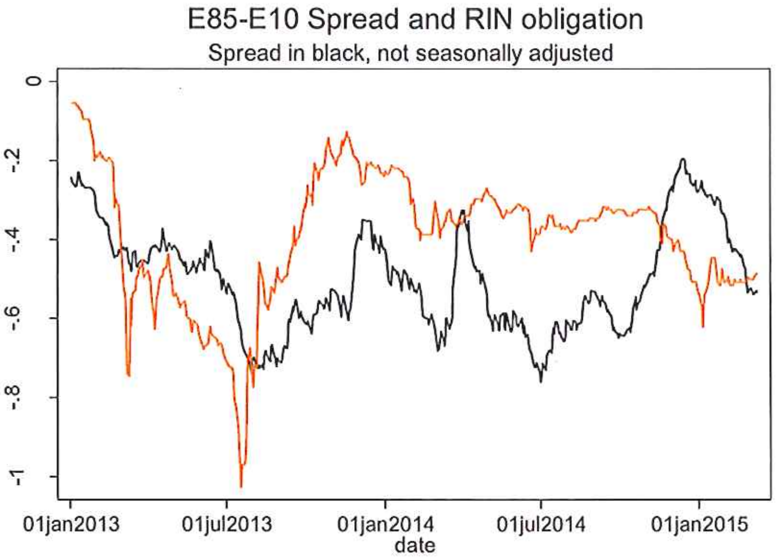


Figure 5. Retail E85-E10 spread and net RIN obligation.

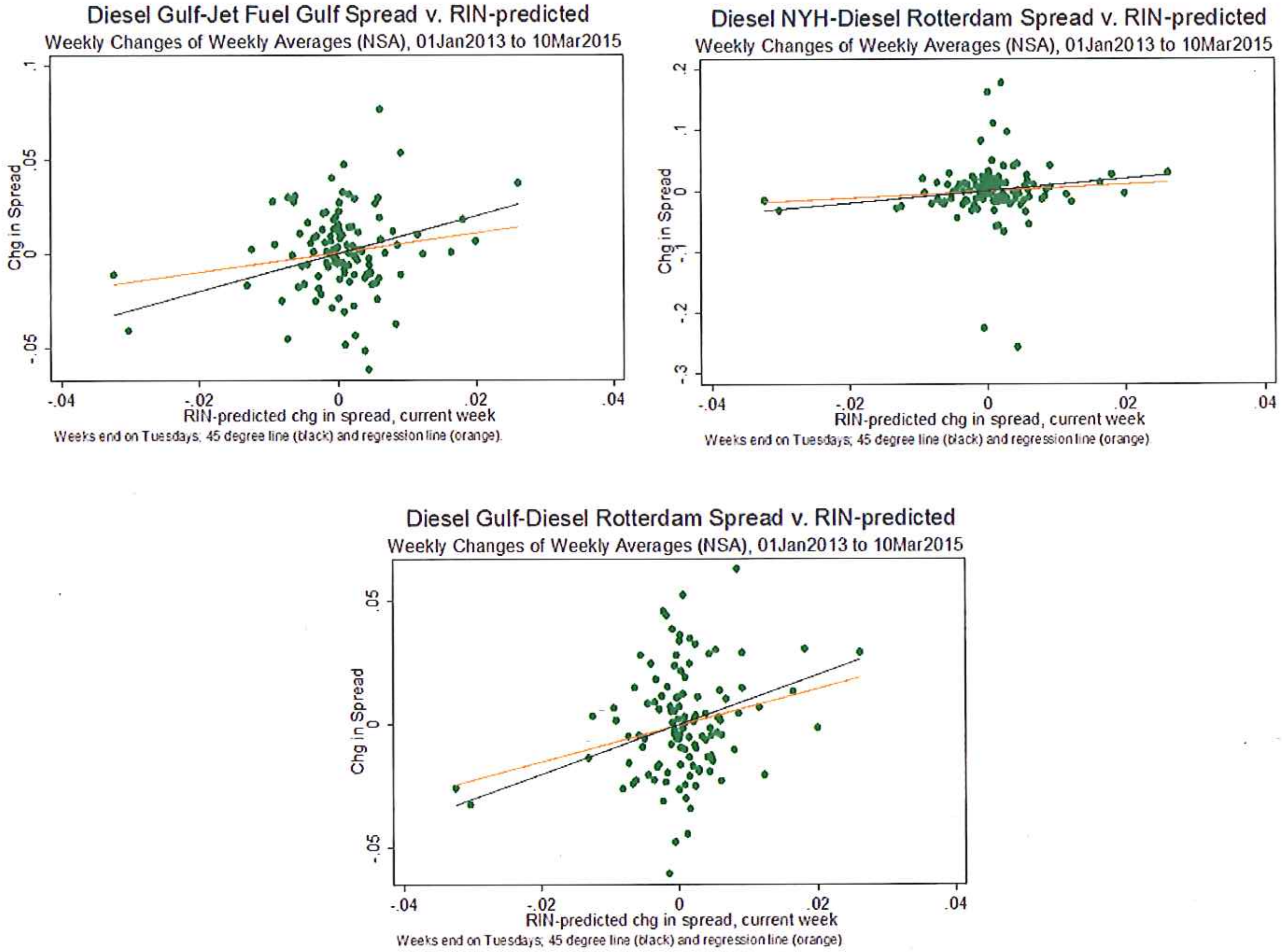
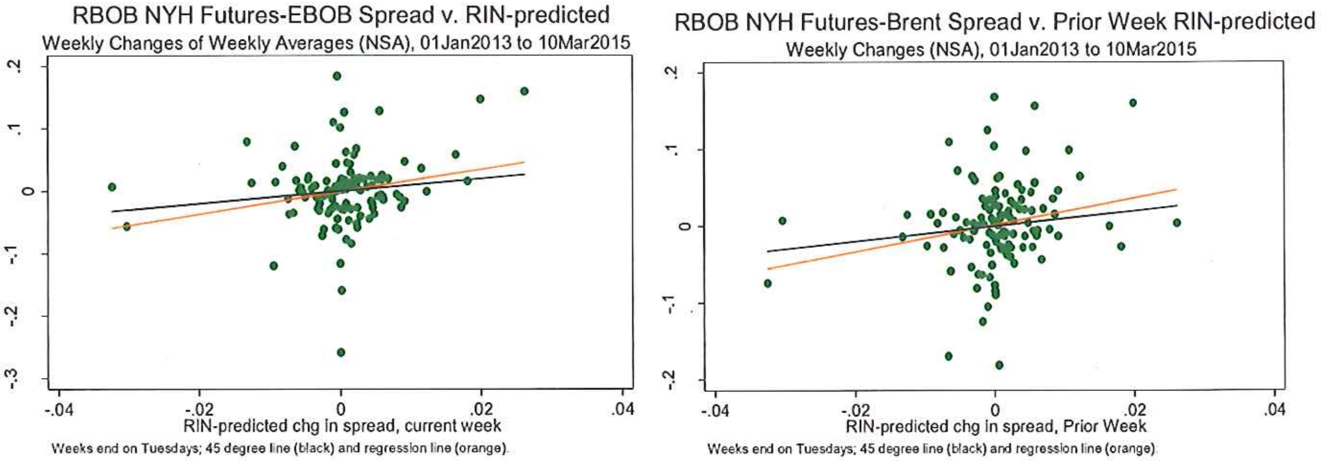


Figure 6. Scatterplots: Wholesale diesel spreads vs. RIN obligation, weekly changes.



RBOB NYH Futures-EBOB Spread v. RIN-predicted

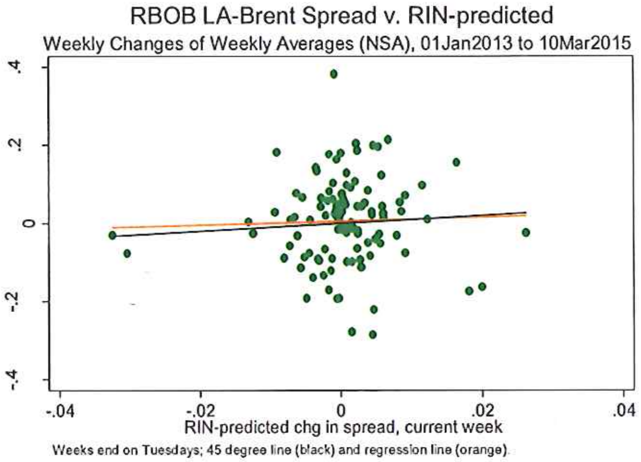
Weekly Changes of Weekly Averages (NSA), 01Jan2013 to 10Mar2015

Weeks end on Tuesdays; 45 degree line (black) and regression line (orange).

RBOB NYH Futures-Brent Spread v. Prior Week RIN-predicted

Weekly Changes (NSA), 01Jan2013 to 10Mar2015

Weeks end on Tuesdays; 45 degree line (black) and regression line (orange).



RBOB LA-Brent Spread v. RIN-predicted

Weekly Changes of Weekly Averages (NSA), 01Jan2013 to 10Mar2015

Weeks end on Tuesdays; 45 degree line (black) and regression line (orange).

Figure 7. Scatterplots: Wholesale gasoline spreads vs. RIN obligation, weekly changes.

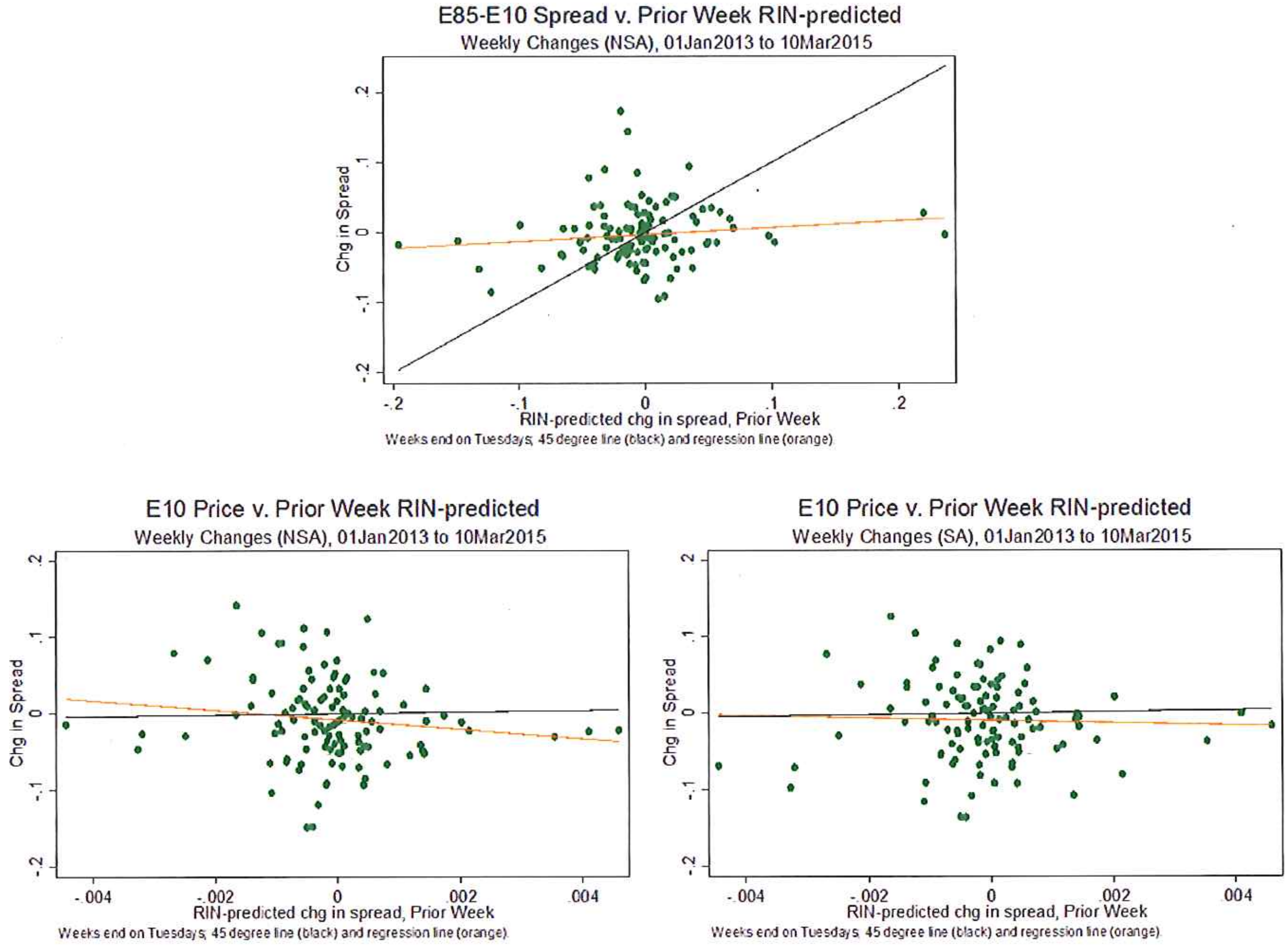


Figure 8. Scatterplots, retail fuels: E85-E10 vs. prior-week RIN obligation (top) and E10 price vs. prior-week net RIN obligation (bottom, NSA and SA), weekly changes.

Table 1. Spreads and prices: summary statistics

	mean	std. dev.	min	max
Fuels and fuel spreads				
Gulf diesel – gulf jet	0.032	0.045	-0.111	0.165
NY diesel – Rotterdam diesel	0.056	0.086	-0.074	0.464
U.S. Gulf diesel – Rotterdam diesel	-0.022	0.046	-0.225	0.100
NY RBOB – Euro BOB	0.109	0.099	-0.171	0.484
NY RBOB - Brent	0.264	0.147	-0.013	0.611
Los Angeles RBOB – Brent	0.331	0.213	-0.123	1.095
E85 – E10	-0.503	0.131	-0.759	-0.195
E10	3.316	0.429	2.037	3.786
Net RIN obligations				
RIN bundle (obligation on wholesale fuels)	0.056	0.023	0.013	0.142
E85-E10 net RIN obligation	-0.393	0.165	-1.026	-0.053

Notes: Units are dollars. Statistics are evaluated over the full sample, Jan. 1, 2013 – March 10, 2015.

Table 2. Fuel spreads levels regressions and unit root/cointegration statistics

	Gulf diesel – Gulf jet	NY diesel – Rott'm diesel	U.S. Gulf diesel – Rott'm diesel	NY RBOB – Euro BOB	NY RBOB - Brent	Los Angeles RBOB - Brent	E85 – E10	E85 – E10 (one-month lag)
Regression coefficients (SEs):								
(1) OLS, full sample, seasonals	1.161***	1.567***	0.818***	0.684**	1.089***	0.720	-0.176*	-0.058
	(0.154)	(0.424)	(0.142)	(0.332)	(0.310)	(0.704)	(0.090)	(0.099)
(2) DOLS, full sample, seasonals	1.214***	1.656***	0.834***	0.573*	1.025***	0.735	-0.196**	-0.066
	(0.155)	(0.459)	(0.159)	(0.307)	(0.327)	(0.730)	(0.091)	(0.107)
(3) OLS, full sample, augmented seasonals	1.152***	1.545***	0.844***	0.620**	1.068***	0.676	-0.194**	-0.050
	(0.152)	(0.411)	(0.135)	(0.266)	(0.304)	(0.613)	(0.089)	(0.097)
(4) OLS, full sample, no seasonals	1.160***	0.771	0.985***	1.812***	3.530***	3.550***	0.095	0.260**
	(0.225)	(0.521)	(0.247)	(0.416)	(0.714)	(1.268)	(0.140)	(0.107)
(5) OLS, 2013, no seasonals	1.153***	0.754***	1.229***	2.045***	4.299***	3.999***	0.243*	0.376***
	(0.271)	(0.153)	(0.248)	(0.377)	(0.647)	(1.238)	(0.127)	(0.078)
(6) OLS, 2014-15, no seasonals	0.723	3.193*	-0.021	0.073	-0.368	1.415	-0.839**	-0.546**
	(0.567)	(1.634)	(0.687)	(1.122)	(2.684)	(5.881)	(0.344)	(0.254)
Test statistics (no seasonals)								
F on seasonals (*p*-value)	11.38	3.27	6.45	28.35	42.69	29.48	14.40	8.56
	(0.000)	(0.001)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
DF-GLS, dependent variable	-1.996**	-2.916***	-1.744*	-3.712***	-1.469	-2.060**	-1.130	-1.130
ADF, dependent variable	-2.441	-3.410**	-2.884**	-4.002***	-2.481	-2.984**	-3.021**	-3.021**
Engle-Granger cointegration	-3.260*	-3.435**	-3.250*	-4.359***	-2.605	-3.349**	-3.162*	-3.140*

Notes: The data are daily and the full sample is Jan. 1, 2013 – March 10, 2015. In the OLS regressions, the dependent variable is the spread and the regressor is its net RIN obligation. The coefficient and standard error are on the level of the RIN-predicted spread. DOLS regressions additionally include five leads and five lags of the first difference of the RIN-predicted spread (coefficients not shown). The seasonal controls are sins and cosines evaluated at the first four seasonal frequencies, the augmented seasonals add the fifth and six seasonal frequencies. DOLS and OLS standard errors are Newey-West with 30 lags. The DF-GLS and ADF statistics test the null hypothesis that the dependent variable (the spread) has a unit root, against the alternative that it is stationary (intercept, no time trend, maximum of 6 lags, lagged determined by AIC); DF-GLS uses asymptotic critical values, ADF uses MacKinnon critical values. The Engle-Granger statistic is (the Engle-Granger augmented ADF) tests the null of no cointegration against the alternative of cointegration, using asymptotic critical values. Tests/coefficients are significant at the *10% **5% ***10% significance level.

Table 3. Pooled levels regressions for wholesale spreads

	Diesel	**Gasoline**	**Diesel and Gasoline**
No. of spreads:	3	3	6
Regression coefficients (SEs):			
(1) OLS, full sample, seasonals	1.182***	0.831***	1.006***
	(0.154)	(0.269)	(0.115)
(2) DOLS, full sample, seasonals	1.235***	0.777***	1.006***
	(0.164)	(0.283)	(0.121)
(3) OLS, full sample, augmented seasonals	1.180***	0.788***	0.984***
	(0.147)	(0.260)	(0.109)

Notes: All regressions are of the form of the spread in levels against its RIN obligation in levels, with additional regressors. The coefficient on the levels is constrained to be the same for the spreads in the column pooled regression but the other coefficients are allowed to differ across spreads. Standard errors are Newey-West with 30 lags and allow both for own- and cross-serial correlation in the errors. Coefficients are significant at the *10% **5% ***10% significance level. See the notes to Table 1.

Table 4. Bivariate VARs for wholesale spreads: cumulative structural IRFs, with RIN obligation ordered first

	Gulf diesel – gulf jet		**NY diesel – Rott'm diesel**		**Gulf diesel – Rott'm diesel**		**NY RBOB - EBOB**		**NY RBOB - Brent**		**L.A. RBOB - Brent**	
Lag												
0	0.450	(0.285)	0.637	(0.476)	0.619	(0.385)	0.484	(0.591)	1.272**	(0.540)	0.585	(0.885)
1	0.554*	(0.313)	1.128*	(0.605)	0.808**	(0.403)	0.223	(0.697)	1.588**	(0.681)	0.448	(1.178)
2	0.892***	(0.340)	0.855	(0.697)	0.519	(0.411)	0.554	(0.785)	1.603**	(0.783)	0.901	(1.385)
3	0.611*	(0.357)	1.279*	(0.746)	1.102***	(0.423)	0.855	(0.823)	1.497*	(0.841)	0.740	(1.516)
4	0.825***	(0.284)	1.255*	(0.707)	0.937***	(0.296)	0.939	(0.711)	1.406*	(0.791)	0.744	(1.480)
5	0.903***	(0.261)	1.340**	(0.658)	0.846***	(0.261)	0.974	(0.631)	1.344*	(0.728)	0.680	(1.382)
6	1.004***	(0.232)	1.292**	(0.596)	0.824***	(0.261)	0.953*	(0.521)	1.298**	(0.650)	0.668	(1.244)
7	1.085***	(0.220)	1.304**	(0.575)	0.869***	(0.260)	0.940**	(0.469)	1.259**	(0.612)	0.652	(1.158)
8	1.143***	(0.215)	1.296**	(0.565)	0.832***	(0.249)	0.925**	(0.439)	1.221**	(0.589)	0.641	(1.109)
9	1.186***	(0.215)	1.303**	(0.563)	0.813***	(0.249)	0.913**	(0.427)	1.185**	(0.579)	0.629	(1.084)
10	1.218***	(0.216)	1.301**	(0.564)	0.806***	(0.251)	0.900**	(0.422)	1.150**	(0.576)	0.617	(1.074)
11	1.240***	(0.219)	1.299**	(0.568)	0.798***	(0.253)	0.885**	(0.421)	1.117*	(0.576)	0.604	(1.073)
12	1.254***	(0.221)	1.293**	(0.574)	0.780***	(0.255)	0.869**	(0.421)	1.085*	(0.579)	0.592	(1.076)
13	1.262***	(0.224)	1.286**	(0.580)	0.767***	(0.259)	0.853**	(0.422)	1.055*	(0.583)	0.579	(1.083)
14	1.264***	(0.227)	1.277**	(0.587)	0.755***	(0.262)	0.836**	(0.421)	1.027*	(0.588)	0.567	(1.091)
15	1.262***	(0.229)	1.266**	(0.594)	0.742***	(0.265)	0.819*	(0.419)	1.000*	(0.593)	0.556	(1.098)
Seasonals?	Y		Y		Y		Y		Y		Y	
Sample	Full		Full		Full		Full		Full		Full	

Notes: Entries are cumulative structural impulse responses, with asymptotic standard errors in parentheses. Spreads and RIN obligations are specified in levels. The RIN price shock is identified by assuming it equals the RIN obligation price innovation (i.e. the RIN obligation ordered first in Cholesky factorization). Coefficients are significant at the *10% **5% ***1% level.

Table 5. Pooled VARs: Cumulative structural impulse response functions, wholesale spreads

	Diesel		Gasoline		Diesel and Gasoline	
# spreads	3		3		6	
Lag						
0	0.570**	(0.265)	0.884*	(0.519)	0.711***	(0.259)
1	0.695**	(0.319)	0.887	(0.670)	0.815**	(0.326)
2	0.893**	(0.350)	0.999	(0.783)	1.044***	(0.368)
3	0.885**	(0.377)	0.994	(0.858)	0.948**	(0.400)
4	0.759*	(0.393)	0.786	(0.904)	0.826**	(0.418)
5	0.866**	(0.349)	0.763	(0.850)	0.896**	(0.385)
6	0.968***	(0.314)	0.759	(0.776)	0.992***	(0.351)
7	1.052***	(0.286)	0.791	(0.678)	1.078***	(0.317)
8	1.109***	(0.272)	0.800	(0.617)	1.141***	(0.300)
9	1.163***	(0.264)	0.822	(0.568)	1.193***	(0.292)
10	1.202***	(0.262)	0.833	(0.548)	1.231***	(0.290)
11	1.233***	(0.264)	0.844	(0.542)	1.260***	(0.291)
12	1.254***	(0.267)	0.848	(0.546)	1.279***	(0.293)
13	1.267***	(0.271)	0.848	(0.551)	1.289***	(0.295)
14	1.274***	(0.274)	0.844	(0.554)	1.293***	(0.297)
15	1.277***	(0.277)	0.836	(0.553)	1.291***	(0.299)
Seasonals?	Y		Y		Y	
Sample	Full		Full		Full	

Notes: Entries are cumulative structural impulse responses, with parametric bootstrap standard errors in parentheses. VARs for all indicated spreads are constrained to have the same coefficients, including the same impact coefficient. All VARs have 4 lags, exogenous seasonal controls, and are estimated in levels. The RIN price shock is identified by assuming it equals the RIN obligation price innovation (RIN obligation ordered first in Cholesky factorization). Coefficients are significant at the *10% **5% ***1% level.

Table 6. Bivariate VARs for retail prices: cumulative structural IRFs, with RIN obligation ordered first

Lag	E85-E10		E85-E10		E85-E10		Weekly E85-E10		E10	
0	-0.013	(0.036)	-0.002	(0.036)	-0.001	(0.039)	-0.050	(0.070)	0.004	(0.012)
1	-0.043	(0.053)	-0.020	(0.054)	-0.017	(0.056)	0.068	(0.117)	0.011	(0.023)
2	-0.063	(0.064)	-0.029	(0.067)	-0.009	(0.066)	0.170	(0.159)	0.029	(0.033)
3	-0.039	(0.073)	0.004	(0.078)	0.025	(0.073)	0.203	(0.188)	0.027	(0.043)
4	-0.027	(0.076)	0.025	(0.084)	0.052	(0.075)	0.288	(0.212)	0.021	(0.052)
5	-0.019	(0.075)	0.040	(0.086)	0.071	(0.072)	0.308	(0.222)	0.011	(0.060)
6	-0.015	(0.074)	0.052	(0.086)	0.087	(0.069)	0.312	(0.222)	0.000	(0.066)
7	-0.011	(0.073)	0.064	(0.086)	0.102	(0.068)	0.297	(0.216)	-0.012	(0.071)
8	-0.008	(0.073)	0.074	(0.086)	0.117*	(0.069)	0.289	(0.214)	-0.024	(0.075)
9	-0.005	(0.074)	0.085	(0.087)	0.132*	(0.070)			-0.037	(0.080)
10	-0.001	(0.076)	0.094	(0.088)	0.147**	(0.071)			-0.050	(0.084)
11	0.002	(0.077)	0.104	(0.090)	0.160**	(0.072)			-0.063	(0.088)
12	0.005	(0.079)	0.113	(0.092)	0.173**	(0.074)			-0.076	(0.093)
13	0.007	(0.081)	0.122	(0.094)	0.186**	(0.076)			-0.089	(0.098)
14	0.010	(0.082)	0.130	(0.096)	0.198**	(0.077)			-0.102	(0.102)
15	0.012	(0.084)	0.138	(0.098)	0.209***	(0.079)			-0.115	(0.107)
Seasonals?	Y		N		N		N		Y	
Sample	Full		Full		2013		Full		Full	

Notes: Entries are cumulative structural impulse responses, with asymptotic standard errors in parentheses. For the E85-E10 spread, the variables are the spread and its net RIN obligation. For the E10 VAR, the variables are the E10 price and the D6 RIN price. All VARs with daily data are estimated in levels. The weekly VAR is estimated using end-of-week data, for weeks ending on Tuesdays, and is specified in first differences. The RIN price shock is identified by assuming it equals the RIN obligation price innovation (i.e. the RIN obligation ordered first in Cholesky factorization). Coefficients are significant at the *10% **5% ***1% level.

Table 7. Cumulative dynamic multipliers from distributed lag regressions of changes in spreads on changes in net RIN obligation

Lag	Gulf diesel – Gulf jet	NY diesel – Rott'm diesel	U.S. Gulf diesel – Rott'm diesel	NY RBOB – Euro BOB	NY RBOB - Brent	Los Angeles RBOB - Brent	E85 – E10	E10
0	0.674**	0.639**	0.493	0.645	1.216**	0.646	-0.012	0.007
	(0.287)	(0.265)	(0.330)	(0.503)	(0.511)	(0.713)	(0.025)	(0.029)
1	0.576**	0.960***	0.737*	0.553	1.431**	0.380	-0.025	0.019
	(0.242)	(0.355)	(0.378)	(0.636)	(0.648)	(0.754)	(0.040)	(0.047)
2	0.856***	0.673*	0.437	1.145	1.263*	0.563	-0.033	0.039
	(0.273)	(0.395)	(0.299)	(0.767)	(0.724)	(0.815)	(0.052)	(0.062)
3	0.609*	1.219***	1.006***	1.410	1.279*	-0.145	0.003	0.042
	(0.363)	(0.388)	(0.292)	(0.927)	(0.736)	(1.291)	(0.067)	(0.076)
4	0.724**	0.666	0.685**	1.042	0.757	0.427	0.052	0.037
	(0.293)	(0.482)	(0.348)	(0.908)	(0.740)	(1.258)	(0.071)	(0.087)
5	0.706**	0.719	0.565	1.924	0.847	0.472	0.031	0.017
	(0.327)	(0.463)	(0.366)	(1.263)	(0.854)	(1.350)	(0.069)	(0.098)
6	0.691*	0.429	0.520	2.401**	2.209**	0.466	0.044	0.007
	(0.396)	(0.662)	(0.368)	(1.120)	(0.930)	(1.579)	(0.071)	(0.106)
7	0.985***	0.708	1.098**	3.408**	2.385**	0.680	0.043	0.013
	(0.349)	(0.744)	(0.430)	(1.557)	(0.953)	(1.634)	(0.078)	(0.115)
8	0.954*	0.817	1.020**	3.245**	2.527**	1.106	0.049	0.003
	(0.536)	(0.725)	(0.488)	(1.437)	(1.001)	(1.777)	(0.096)	(0.123)
9	0.445	0.989	1.180***	3.708**	3.213***	0.109	0.091	0.015
	(0.479)	(0.794)	(0.425)	(1.565)	(1.054)	(1.966)	(0.093)	(0.130)
10	0.896**	0.621	0.836*	3.224**	1.841*	-1.076	0.132	0.011
	(0.438)	(0.752)	(0.475)	(1.596)	(1.012)	(2.037)	(0.091)	(0.134)
11	0.779*	0.478	0.379	2.263	1.620	-1.464	0.142	0.008
	(0.448)	(0.820)	(0.506)	(1.382)	(1.010)	(1.913)	(0.104)	(0.139)
12	1.132***	0.639	0.938	2.599*	2.443**	0.025	0.120	0.008
	(0.431)	(0.917)	(0.578)	(1.564)	(1.237)	(2.226)	(0.102)	(0.144)
13	1.221**	0.289	0.783	2.493*	2.498*	0.761	0.098	0.005
	(0.520)	(0.946)	(0.667)	(1.480)	(1.285)	(1.986)	(0.106)	(0.146)
14	0.845*	0.574	0.856	1.392	2.154	-0.754	0.147	-0.006
	(0.491)	(0.977)	(0.692)	(1.628)	(1.541)	(2.179)	(0.106)	(0.148)
15	1.363**	1.416	1.453**	2.164	2.552	-0.138	0.186*	-0.019
	(0.620)	(0.987)	(0.624)	(1.656)	(1.855)	(2.482)	(0.112)	(0.152)
Seasonals?	Y	Y	Y	Y	Y	Y	Y	Y
Sample	Full	Full	Full	Full	Full	Full	Full	Full

Notes: Entries are cumulative dynamic multipliers and standard errors from distributed lag regressions of the change in the spread on the change in the net RIN obligation (contemporaneous value and 15 daily lags), including seasonal controls. The data are daily and the full sample is Jan. 1, 2013 – March 10, 2015. Standard errors are Newey-West with 15 lags. Significant at the *10% **5% ***1% level.

Table 8. Cumulative dynamic multipliers from constrained distributed lag regressions: Wholesale spreads

	Diesel		**Gasoline**		**Diesel and Gasoline**	
# spreads	3		3		6	
Lag						
0	0.597***	(0.219)	0.826**	(0.380)	0.712***	(0.266)
1	0.749***	(0.240)	0.766*	(0.448)	0.758***	(0.290)
2	0.630***	(0.211)	0.959**	(0.488)	0.794***	(0.300)
3	0.920***	(0.226)	0.838	(0.654)	0.879**	(0.349)
4	0.672***	(0.255)	0.731	(0.616)	0.702**	(0.355)
5	0.658**	(0.260)	1.030	(0.779)	0.844**	(0.411)
6	0.563*	(0.321)	1.667**	(0.756)	1.115***	(0.425)
7	0.918**	(0.358)	2.085***	(0.782)	1.501***	(0.434)
8	0.898**	(0.386)	2.217***	(0.810)	1.557***	(0.453)
9	0.876**	(0.410)	2.303**	(0.945)	1.590***	(0.549)
10	0.774*	(0.403)	1.291	(0.950)	1.033*	(0.565)
11	0.513	(0.401)	0.764	(0.936)	0.639	(0.544)
12	0.925**	(0.447)	1.714	(1.114)	1.319**	(0.632)
13	0.744	(0.478)	1.942*	(1.009)	1.343**	(0.597)
14	0.801*	(0.452)	1.035	(1.183)	0.918	(0.664)
15	1.380**	(0.574)	1.520	(1.460)	1.450	(0.888)
Seasonals?	Y		Y		Y	
Sample	Full		Full		Full	

Notes: Spread regressions in a given column are constrained to have the same distributed lags across spreads; seasonal coefficients are not constrained to be the same across spreads. Estimation is by constrained OLS. Standard errors are Newey-West (15 lags). Coefficients are significant at the *10% **5% ***1% level.

Appendix Tables

Table A-1a. Distributed lag regressions: Wholesale Gulf Diesel– Gulf Jet Fuel spread

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Change (days):	5-day	5-day	5-day	5-day	1-day	1-day	1-day	5-day	1-day	5-day	1-day
Cumulative Impulse Response (SE) after lags:											
0					0.674**	0.672**	0.652**		0.642**		0.555
					(0.287)	(0.287)	(0.273)		(0.251)		(1.045)
1					0.576**	0.586**	0.537**		0.456*		0.616
					(0.242)	(0.258)	(0.238)		(0.236)		(0.923)
2					0.856***	0.850***	0.804***		0.915***		-0.127
					(0.273)	(0.272)	(0.266)		(0.204)		(0.972)
3					0.609*	0.549	0.544		0.881***		-1.423
					(0.363)	(0.358)	(0.353)		(0.275)		(1.343)
4					0.724**	0.736**	0.647**		0.750***		-0.064
					(0.293)	(0.302)	(0.306)		(0.270)		(1.370)
5					0.706**	0.680**	0.616*		0.783***		-0.474
					(0.327)	(0.326)	(0.316)		(0.264)		(1.331)
6					0.691*	0.588	0.586		0.847**		-1.083
					(0.396)	(0.428)	(0.374)		(0.344)		(1.323)
7					0.985***	0.929**	0.866***		0.922***		0.132
					(0.349)	(0.379)	(0.328)		(0.280)		(1.438)
8					0.954*	0.879	0.818*		0.871**		0.071
					(0.536)	(0.563)	(0.470)		(0.423)		(1.718)
9					0.445	0.351	0.294		0.299		-0.226
					(0.479)	(0.535)	(0.455)		(0.419)		(1.805)
10					0.896**	0.868*	0.736*		0.914***		-0.335
					(0.438)	(0.482)	(0.397)		(0.345)		(1.543)
RIN obligation$_t$	0.555***	0.558***	0.559***	0.535**				0.633***		-0.101	
	(0.212)	(0.209)	(0.204)	(0.223)				(0.211)		(0.684)	
RIN obligation$_{t-5}$		0.034	0.019								
		(0.242)	(0.254)								
Observations	551	551	551	551	549	549	549	253	251	298	298
Sample	Full	Full	Full	Full	Full	Full	Full	2013	2013	2014-15	2014-15
Sum of coeffs (se)	0.555	0.592	0.578	0.535	1.363	1.212	1.144	0.633	1.296	-0.101	-0.179
	0.212	0.306	0.320	0.223	0.620	0.698	0.463	0.211	0.416	0.684	1.989
F (seasonals)	4.726	4.620	4.169		2.871	1.988					
p-val (seas)	1.28e-05	1.80e-05	7.46e-05		0.00391	0.0460					
F (lags)		0.0194	0.00580		1.249	1.158	1.290		1.290		1.290
p-val (lags)		0.889	0.939		0.230	0.302	0.203		0.203		0.203
F (Brent)			0.169			1.159					
p-val (Brent)			0.845			0.327					

Notes: The data are daily and the full sample is Jan. 1, 2013 – March 10, 2015. All regressions are of the form of a transformed spread (five-day or one-day differences) on the value of the RIN obligation for that spread (five-day or one-day differences), either contemporaneous or contemporaneous and lags. The first differences distributed lag specifications have 15 lags, the first ten cumulative dynamic multipliers are reported, and the 15-day cumulative multiplier is reported as "Sum of coeffs"; in regression (6), the current through fifth lag of the change in Brent prices are also included. Standard errors are Newey-West with 15 lags. Significant at the *10% **5% ***1% level.

Table A-1b. Distributed lag regressions: Wholesale New York Diesel – Rotterdam Diesel Spread

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Change (days):	5-day	5-day	5-day	5-day	1-day	1-day	1-day	5-day	1-day	5-day	1-day
Cumulative Impulse Response (SE) after lags:											
0					0.639**	0.554**	0.608**		0.385		1.088
					(0.265)	(0.270)	(0.265)		(0.280)		(0.804)
1					0.960***	0.853**	0.911***		0.665*		1.653
					(0.355)	(0.399)	(0.337)		(0.380)		(1.110)
2					0.673*	0.578	0.601		0.579*		0.360
					(0.395)	(0.445)	(0.370)		(0.320)		(1.502)
3					1.219***	0.875**	1.122***		1.013***		1.301
					(0.388)	(0.438)	(0.326)		(0.246)		(1.455)
4					0.666	0.281	0.545		0.735***		-1.043
					(0.482)	(0.570)	(0.463)		(0.279)		(2.934)
5					0.719	0.392	0.566		0.394		0.993
					(0.463)	(0.530)	(0.398)		(0.259)		(2.610)
6					0.429	-0.211	0.238		0.181		-0.600
					(0.662)	(0.733)	(0.590)		(0.348)		(3.790)
7					0.708	-0.065	0.476		0.556		-1.157
					(0.744)	(0.864)	(0.694)		(0.468)		(4.115)
8					0.817	0.182	0.546		0.601		-1.165
					(0.725)	(0.912)	(0.627)		(0.418)		(4.263)
9					0.989	0.343	0.678		1.057**		-2.497
					(0.794)	(1.025)	(0.714)		(0.453)		(4.305)
10					0.621	0.100	0.280		0.399		-1.681
					(0.752)	(0.993)	(0.656)		(0.472)		(4.334)
RIN obligation$_t$	0.714***	0.703***	0.672**	0.669***				0.579***		1.229	
	(0.234)	(0.254)	(0.279)	(0.185)				(0.146)		(1.078)	
RIN obligation$_{t-5}$		-0.119	-0.131								
		(0.516)	(0.525)								
Observations	551	551	551	551	532	532	532	253	242	298	290
Sample	Full	Full	Full	Full	Full	Full	Full	2013	2013	2014-15	2014-15
Sum of coeffs (SE)	0.714	0.583	0.541	0.669	1.416	0.630	0.827	0.579	0.969	1.229	-1.813
	0.234	0.665	0.701	0.185	0.987	1.315	0.759	0.146	0.506	1.078	4.836
F (seasonals)	0.886	0.854	0.865		0.593	0.604					
p-val (seas)	0.528	0.556	0.546		0.784	0.775					
F (lags)		0.0536	0.0623		1.276	1.212	1.263		1.263		1.263
p-val (lags)		0.817	0.803		0.213	0.258	0.221		0.221		0.221
F (Brent)			0.852			8.846					
p-val (Brent)			0.427			3.48e-09					

Notes: See the notes to Table A-1a.

Table A-1c. Distributed lag regressions: Wholesale Gulf Diesel – Rotterdam Diesel Spread

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Change (days):	5-day	5-day	5-day	5-day	1-day	1-day	1-day	5-day	1-day	5-day	1-day
Cumulative Impulse Response (SE) after lags:											
0					0.493	0.437	0.475		0.283		0.841
					(0.330)	(0.354)	(0.325)		(0.338)		(0.943)
1					0.737*	0.657	0.706*		0.457		1.463
					(0.378)	(0.449)	(0.371)		(0.419)		(0.971)
2					0.437	0.348	0.393		0.399		0.290
					(0.299)	(0.388)	(0.283)		(0.281)		(0.933)
3					1.006***	0.702*	0.952***		1.018***		0.572
					(0.292)	(0.365)	(0.283)		(0.281)		(1.236)
4					0.685**	0.353	0.621*		0.506*		1.345
					(0.348)	(0.412)	(0.329)		(0.273)		(1.475)
5					0.565	0.230	0.492		0.261		1.712
					(0.366)	(0.357)	(0.350)		(0.282)		(1.638)
6					0.520	-0.085	0.435		0.216		1.169
					(0.368)	(0.417)	(0.349)		(0.345)		(1.264)
7					1.098**	0.368	1.001**		0.699		2.047
					(0.430)	(0.451)	(0.414)		(0.431)		(1.359)
8					1.020**	0.340	0.912**		0.494		2.687
					(0.488)	(0.503)	(0.437)		(0.387)		(1.701)
9					1.180***	0.515	1.061***		1.034***		1.056
					(0.425)	(0.532)	(0.384)		(0.396)		(1.561)
10					0.836*	0.307	0.709		0.555		1.810
					(0.475)	(0.580)	(0.431)		(0.429)		(1.821)
RIN obligation$_t$	0.689***	0.713***	0.689***	0.675***				0.659***		0.767	
	(0.159)	(0.158)	(0.166)	(0.127)				(0.126)		(0.507)	
RIN obligation$_{t-5}$		0.263	0.220								
		(0.194)	(0.175)								
Observations	551	551	551	551	532	532	532	253	242	298	290
Sample	Full	Full	Full	Full	Full	Full	Full	2013	2013	2014-15	2014-15
Sum of coeffs (SE)	0.689	0.976	0.909	0.675	1.453	0.608	1.294	0.659	0.996	0.767	2.520
	0.159	0.258	0.240	0.127	0.624	0.734	0.530	0.126	0.460	0.507	2.499
F (seasonals)	0.983	1.079	0.987		0.644	1.023					
p-val (seas)	0.448	0.376	0.445		0.740	0.417					
F (lags)		1.832	1.585		2.472	1.431	2.419		2.419		2.419
p-val (lags)		0.176	0.209		0.00163	0.128	0.00209		0.00209		0.00209
F (Brent)			1.065			10.67					
p-val (Brent)			0.345			0					

Notes: See the notes to Table A-1a.

Table A-1d. Distributed lag regressions: New York RBOB – Euro-BOB

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Change (days):	5-day	5-day	5-day	5-day	1-day	1-day	1-day	5-day	1-day	5-day	1-day
Cumulative Impulse Response (SE) after lags:											
0					0.645	0.695	0.709		0.675		1.190
					(0.503)	(0.498)	(0.512)		(0.515)		(1.471)
1					0.553	0.519	0.660		0.563		0.290
					(0.636)	(0.582)	(0.657)		(0.779)		(1.122)
2					1.145	1.068	1.296*		1.486*		0.354
					(0.767)	(0.692)	(0.755)		(0.821)		(1.438)
3					1.410	1.466*	1.602*		1.868*		-0.173
					(0.927)	(0.840)	(0.929)		(1.049)		(1.914)
4					1.042	0.785	1.272		1.630*		-1.106
					(0.908)	(0.874)	(0.886)		(0.960)		(1.849)
5					1.924	1.611	2.198*		2.753**		-1.360
					(1.263)	(1.106)	(1.199)		(1.201)		(2.147)
6					2.401**	2.249**	2.721**		2.757**		1.673
					(1.120)	(0.997)	(1.150)		(1.265)		(2.151)
7					3.408**	2.920*	3.778**		4.632***		-2.218
					(1.557)	(1.504)	(1.511)		(1.568)		(2.116)
8					3.245**	2.548*	3.657**		4.136**		-0.077
					(1.437)	(1.337)	(1.443)		(1.631)		(2.325)
9					3.708**	3.210**	4.160***		4.794***		-0.715
					(1.565)	(1.453)	(1.509)		(1.607)		(2.414)
10					3.224**	2.650*	3.711**		4.485***		-1.384
					(1.596)	(1.575)	(1.492)		(1.533)		(2.552)
RIN obligation$_t$	1.449**	1.646***	1.720***	1.716**				1.743**		1.528*	
	(0.672)	(0.596)	(0.544)	(0.756)				(0.876)		(0.855)	
RIN obligation$_{t-5}$		2.099***	2.124***								
		(0.725)	(0.639)								
Observations	551	551	551	551	532	532	532	253	242	298	290
Sample	Full	Full	Full	Full	Full	Full	Full	2013	2013	2014-15	2014-15
Sum of coeffs (SE)	1.449	3.745	3.844	1.716	2.164	1.327	2.802	1.743	2.766	1.528	1.350
	0.672	1.200	1.049	0.756	1.656	1.598	1.464	0.876	1.529	0.855	2.945
F (seasonals)	1.223	1.033	1.172		0.690	0.915					
p-val (seas)	0.283	0.410	0.314		0.701	0.503					
F (lags)		8.378	11.06		1.608	2.310	1.648		1.648		1.648
p-val (lags)		0.00395	0.000941		0.0674	0.00348	0.0579		0.0579		0.0579
F (Brent)			4.798			4.332					
p-val (Brent)			0.00860			0.000283					

Notes: See the notes to Table A-1a.

Table A-1e. Distributed lag regressions: New York RBOB – Brent

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Change (days):	5-day	5-day	5-day	5-day	1-day	1-day	1-day	5-day	1-day	5-day	1-day
Cumulative Impulse Response (SE) after lags:											
0					1.216**	1.154**	1.338***		1.263**		1.406
					(0.511)	(0.499)	(0.497)		(0.539)		(1.139)
1					1.431**	1.381**	1.638**		1.482*		2.015*
					(0.648)	(0.609)	(0.645)		(0.777)		(1.089)
2					1.263*	1.169	1.556**		1.707**		0.699
					(0.724)	(0.710)	(0.702)		(0.830)		(1.063)
3					1.279*	0.936	1.655**		1.829**		0.847
					(0.736)	(0.678)	(0.741)		(0.882)		(1.337)
4					0.757	0.449	1.218*		1.598**		-0.780
					(0.740)	(0.716)	(0.719)		(0.755)		(1.757)
5					0.847	0.526	1.392*		1.544*		0.498
					(0.854)	(0.867)	(0.783)		(0.827)		(1.805)
6					2.209**	1.568*	2.846***		2.597**		3.482**
					(0.930)	(0.890)	(0.912)		(1.040)		(1.764)
7					2.385**	1.686*	3.129***		3.352***		1.421
					(0.953)	(1.010)	(0.927)		(1.082)		(2.044)
8					2.527**	1.842*	3.374***		3.680***		1.186
					(1.001)	(1.020)	(0.982)		(1.165)		(2.348)
9					3.213***	2.473**	4.155***		4.508***		2.109
					(1.054)	(1.078)	(1.023)		(1.160)		(2.483)
10					1.841*	1.311	2.867***		3.298***		0.304
					(1.012)	(1.107)	(0.912)		(0.970)		(2.650)
RIN obligation$_t$	1.649***	1.753***	1.744***	2.171***				2.324***		1.162	
	(0.615)	(0.566)	(0.558)	(0.605)				(0.691)		(0.979)	
RIN obligation$_{t-5}$		1.111***	1.022***								
		(0.316)	(0.306)								
Observations	551	551	551	551	549	549	549	253	251	298	298
Sample	Full	Full	Full	Full	Full	Full	Full	2013	2013	2014-15	2014-15
Sum of coeffs (SE)	1.649	2.864	2.767	2.171	2.552	1.498	4.040	2.324	3.906	1.162	4.920
	0.615	0.677	0.693	0.605	1.855	2.013	1.391	0.691	1.564	0.979	3.121
F (seasonals)	2.128	1.635	1.661		1.103	1.294					
p-val (seas)	0.0317	0.112	0.105		0.360	0.244					
F (lags)		12.39	11.18		2.196	2.342	2.436		2.436		2.436
p-val (lags)		0.000467	0.000883		0.00580	0.00298	0.00191		0.00191		0.00191
F (Brent)			0.393			3.385					
p-val (Brent)			0.675			0.00277					

Notes: See the notes to Table A-1a.

Table A-1f. Distributed lag regressions: Los Angeles RBOB – Brent

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Change (days):	5-day	5-day	5-day	5-day	1-day	1-day	1-day	5-day	1-day	5-day	1-day
Cumulative Impulse Response (SE) after lags:											
0					0.646	0.507	0.813		0.749		0.425
					(0.713)	(0.711)	(0.691)		(0.746)		(1.808)
1					0.380	0.293	0.662		0.515		1.419
					(0.754)	(0.776)	(0.744)		(0.873)		(1.867)
2					0.563	0.434	0.952		0.595		3.545**
					(0.815)	(0.768)	(0.780)		(0.873)		(1.726)
3					-0.145	-0.535	0.359		-0.246		3.746*
					(1.291)	(1.262)	(1.222)		(1.206)		(2.115)
4					0.427	0.201	1.042		0.514		4.569
					(1.258)	(1.276)	(1.194)		(1.229)		(2.845)
5					0.472	0.432	1.191		0.390		6.129**
					(1.350)	(1.333)	(1.278)		(1.296)		(3.107)
6					0.466	0.142	1.294		0.253		6.500**
					(1.579)	(1.633)	(1.501)		(1.525)		(2.981)
7					0.680	0.595	1.637		1.145		4.474
					(1.634)	(1.656)	(1.568)		(1.673)		(4.457)
8					1.106	1.342	2.188		2.020		3.219
					(1.777)	(1.806)	(1.715)		(1.881)		(3.483)
9					0.109	0.376	1.293		1.364		1.226
					(1.966)	(2.085)	(1.857)		(1.931)		(4.517)
10					-1.076	-0.374	0.205		-0.039		1.603
					(2.037)	(2.102)	(1.910)		(1.918)		(5.611)
RIN obligation$_t$	0.443	0.463	0.344	1.013				0.764		2.530	
	(1.038)	(1.091)	(0.839)	(0.975)				(1.017)		(2.225)	
RIN obligation$_{t-5}$		0.209	0.497								
		(0.997)	(0.966)								
Observations	551	551	551	551	549	549	549	253	251	298	298
Sample	Full	Full	Full	Full	Full	Full	Full	2013	2013	2014-15	2014-15
Sum of coeffs (SE)	0.443	0.671	0.841	1.013	-0.138	0.631	1.660	0.764	1.374	2.530	3.752
	1.038	1.815	1.498	0.975	2.482	2.784	2.010	1.017	2.066	2.225	5.631
F (seasonals)	1.865	1.826	1.431		1.285	1.041					
p-val (seas)	0.0632	0.0697	0.180		0.249	0.404					
F (lags)		0.0438	0.265		2.267	2.316	2.656		2.656		2.656
p-val (lags)		0.834	0.607		0.00420	0.00335	0.000666		0.000666		0.000666
F (Brent)			5.814			5.030					
p-val (Brent)			0.00318			5.00e-05					

Notes: See the notes to Table A-1a.

Table A-2a. Distributed lag regressions: E85 – E10 spread

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Change (days):	5-day	5-day	5-day	5-day	1-day	1-day	1-day	5-day	1-day	5-day	1-day
Cumulative Impulse Response (SE) after lags:											
0					-0.012	-0.014	-0.007		-0.008		-0.041
					(0.025)	(0.025)	(0.024)		(0.025)		(0.075)
1					-0.025	-0.027	-0.016		-0.009		-0.054
					(0.040)	(0.042)	(0.039)		(0.044)		(0.093)
2					-0.033	-0.032	-0.021		0.007		-0.180
					(0.052)	(0.054)	(0.052)		(0.051)		(0.158)
3					0.003	0.003	0.018		0.037		-0.108
					(0.067)	(0.068)	(0.067)		(0.077)		(0.176)
4					0.052	0.057	0.069		0.111		-0.191
					(0.071)	(0.069)	(0.068)		(0.073)		(0.201)
5					0.031	0.041	0.051		0.083		-0.165
					(0.069)	(0.066)	(0.064)		(0.067)		(0.227)
6					0.044	0.056	0.066		0.083		-0.097
					(0.071)	(0.068)	(0.065)		(0.066)		(0.246)
7					0.043	0.063	0.070		0.081		-0.019
					(0.078)	(0.075)	(0.071)		(0.073)		(0.261)
8					0.049	0.080	0.079		0.104		-0.095
					(0.096)	(0.092)	(0.085)		(0.086)		(0.312)
9					0.091	0.122	0.123		0.146*		-0.010
					(0.093)	(0.089)	(0.083)		(0.084)		(0.312)
10					0.132	0.160*	0.166**		0.171**		0.084
					(0.091)	(0.086)	(0.081)		(0.079)		(0.337)
RIN obligation$_t$	-0.035	-0.032	-0.033	0.004				0.019		-0.086	
	(0.047)	(0.047)	(0.043)	(0.049)				(0.053)		(0.144)	
RIN obligation$_{t-5}$		0.048	0.066								
		(0.047)	(0.043)								
Observations	551	551	551	551	535	535	535	253	244	298	291
Sample	Full	Full	Full	Full	Full	Full	Full	2013	2013	2014-15	2014-15
Sum of coeffs (SE)	-0.0352	0.0162	0.0326	0.00434	0.186	0.238	0.233	0.0190	0.293	-0.0864	-0.162
	0.0468	0.0825	0.0735	0.0491	0.112	0.108	0.0938	0.0528	0.0980	0.144	0.392
F (seasonals)	4.516	3.937	2.792		2.974	2.258					
p-val (seas)	2.49e-05	0.000153	0.00490		0.00290	0.0224					
F (lags)		1.055	2.381		1.455	1.582	1.876		1.876		1.876
p-val (lags)		0.305	0.123		0.117	0.0743	0.0233		0.0233		0.0233
F (Brent)			3.093			1.746					
p-val (Brent)			0.0462			0.108					

Notes: See the notes to Table A-1a.

Table A-2b. Distributed lag regressions: E10 (dependent variable is change in D6 RIN price)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Change (days):	5-day	5-day	5-day	5-day	1-day	1-day	1-day	5-day	1-day	5-day	1-day
Cumulative Impulse Response (SE) after lags:											
0					0.007	0.004	0.023		0.034		-0.047
					(0.029)	(0.023)	(0.024)		(0.028)		(0.045)
1					0.019	0.016	0.047		0.070		-0.081
					(0.047)	(0.035)	(0.036)		(0.044)		(0.070)
2					0.039	0.038	0.078*		0.102*		-0.070
					(0.062)	(0.045)	(0.046)		(0.055)		(0.103)
3					0.042	0.042	0.091		0.119*		-0.094
					(0.076)	(0.056)	(0.056)		(0.064)		(0.147)
4					0.037	0.047	0.097		0.124*		-0.096
					(0.087)	(0.063)	(0.064)		(0.074)		(0.186)
5					0.017	0.037	0.088		0.120		-0.130
					(0.098)	(0.070)	(0.072)		(0.085)		(0.200)
6					0.007	0.035	0.089		0.129		-0.181
					(0.106)	(0.077)	(0.077)		(0.091)		(0.235)
7					0.013	0.061	0.107		0.145		-0.140
					(0.115)	(0.086)	(0.084)		(0.101)		(0.267)
8					0.003	0.072	0.110		0.146		-0.137
					(0.123)	(0.092)	(0.091)		(0.109)		(0.301)
9					0.015	0.090	0.134		0.174		-0.151
					(0.130)	(0.098)	(0.098)		(0.113)		(0.350)
10					0.011	0.093	0.140		0.184		-0.177
					(0.134)	(0.103)	(0.099)		(0.117)		(0.356)
RIN obligation$_t$	0.042	0.041	0.030	0.099				0.144**		-0.184	
	(0.081)	(0.085)	(0.053)	(0.061)				(0.068)		(0.183)	
RIN obligation$_{t-5}$		-0.018	0.021								
		(0.058)	(0.036)								
Observations	551	551	551	551	551	551	551	253	253	298	298
Sample	Full	Full	Full	Full	Full	Full	Full	2013	2013	2014-15	2014-15
Sum of coeffs (SE)	0.0420	0.0231	0.0509	0.0986	-0.0187	0.111	0.165	0.144	0.241	-0.184	-0.351
	0.0812	0.139	0.0848	0.0606	0.152	0.121	0.123	0.0679	0.141	0.183	0.504
F (seasonals)	5.721	5.502	4.446		5.348	3.581					
p-val (seas)	5.27e-07	1.07e-06	3.12e-05		1.78e-06	0.000466					
F (lags)		0.0919	0.330		1.575	1.354	1.376		1.376		1.376
p-val (lags)		0.762	0.566		0.0760	0.165	0.154		0.154		0.154
F (Brent)			48.12			21.21					
p-val (Brent)			0			0					

Notes: See the notes to Table A-1a.

The Pass-Through of RIN Prices to Wholesale and Retail Fuels under the Renewable Fuel Standard: Analysis of Post-March 2015 Data

November 23, 2016

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Ben S. Meiselman, University of Michigan
James H. Stock, Harvard University

Summary

Knittel, Meiselman, and Stock (2015) (KMS)[1] examine the pass-through of RIN prices under the RFS to three categories of fuels: bulk wholesale petroleum fuels, bulk wholesale biofuels, and retail gasoline blends. The KMS period of analysis is January 1, 2013 – March 9, 2015. This note extends the analysis of bulk wholesale petroleum fuel prices in KMS to data through Nov. 14, 2016.

KMS compare wholesale prices of two similar fuels, one of which is regulated under the RFS and one of which is not. The regulated fuel must retire a bundle of RINs when it is sold into the fuel supply. Because the two fuels have different RIN obligations, the difference (spread) between their prices should respond to a change in RIN prices. Using daily prices of fuels and RINs, KMS regress the obligated/non-obligated fuel price spread on the price of the RIN obligation to estimate the fraction of the RIN price that is passed through to the price of the obligated fuel (the "pass-through coefficient"). They also estimate a dynamic system involving the spread and the RIN prices (a vector autoregression) to estimate the dynamic response of fuel prices to a change in the RIN price. The reason for using the spread between two chemically and/or geographically similar fuels, rather than just the price of the obligated fuel, is to control

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[1] Knittel, C., B. Meiselman, and J.H. Stock, "The Pass-Through of RIN Prices to Wholesale and Retail Fuels under the Renewable Fuel Standard," NBER Working Paper 21343, July 2015. That paper was revised in July 2016 and again in November 2016, both times in response to comments by referees and editors. The references to KMS in this note all refer to the November 2016 revision. The July 2016 revision substantially shortened the July 2015 version including dropping and renumbering tables and figures; there was no change in the data and no change in conclusions, however there was one methodological change. In all versions, the base specifications include eight seasonal variables (sines and cosines at first four harmonics). In the July 2015 version, KMS reported sensitivity results in which the regressions were estimated dropping the seasonal variables. In the July 2016 version, KMS instead reported sensitivity results using seasonally adjusted data, where the seasonals were estimated using pre-2013 data. The November 2016 version updates the data used in the previous versions to the data set used here, but still restricted to the same sample as the original paper (Jan. 1, 2013 – March 9, 2016). This update filled in a few missing observations on RIN prices, and extended backwards the pre-2013 Rotterdam diesel and BOB series for use in estimating the seasonals for constructing seasonally adjusted spreads; this data update resulted in some second- and third-decimal changes in the results but no change in conclusions.

for non-RFS factors that affect the price of the obligated fuel, thereby reducing the risk of omitted variable bias and increasing precision.

Their main finding for bulk petroleum fuels is that RIN prices were passed through one-for-one in the prices of bulk petroleum fuels, specifically, they estimate a pooled levels pass-through coefficient of 1.00 (SE = 0.11).

This note uses the six spreads in KMS, extended using the same data sources. Three of these are diesel spreads: Gulf diesel – Gulf jet fuel, New York Harbor diesel – Rotterdam diesel, and Gulf diesel – Rotterdam diesel. Three are gasoline spreads: New York Harbor RBOB (prompt month future) – Rotterdam EBOB, New York Harbor RBOB (prompt month future) – Brent (spot), and Los Angeles RBOB (spot) – Brent (spot). In addition, in this note we augment the gasoline spreads by New York Harbor CBOB (spot) – Rotterdam EBOB. This provides a spot-spot comparison of NYH CBOB to EBOB, which complements the NYH RBOB future – EBOB comparison.

Our main findings are:

1. For the four spreads between refined products in KMS – that is, all the spreads in KMS except NYH RBOB-Brent and LA RBOB-Brent – and also for the additional refined product spread NYH CBOB-EBOB newly analyzed here, the findings of KMS hold in the extended sample. These findings are illustrated in the following figures, which show the refined product spread (in green); the predicted value of the spread (orange) from the benchmark estimated levels model from KMS (Table 2, regression 1); and the predicted value of the spread that modifies the orange line to impose a unit pass-through coefficient (blue). The benchmark KMS levels model (orange) regresses the spread against the RIN price over the KMS sample period. Results are shown for the Gulf diesel-Gulf jet spread and the NYH RBOB-EBOB spread. The red line denotes the end of the KMS sample, and subsequent dates denote the out-of-sample period. For the RBOB-EBOB spread, the fit is visually as good out of sample as in-sample, an observation supported by statistical tests. For the Gulf diesel-Gulf jet spread, there is a period during the summer of 2015 in which a gap of approximately $0.05 opens up for several months during the diesel glut of the summer of 2015, an unusual period in which wholesale diesel prices fell substantially below wholesale gasoline prices.[2] After those summer months in 2015 the spread returns to its predicted value.[3]

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[2] Contemporaneous sources attributed the low diesel prices to excess supply of middle distillates as refineries increased production to meet strong gasoline demand, to gasoline supply pressures because of refinery outages earlier in 2015, and to recent expansion of middle distillate refining capacity (Wall Street Journal, July 22, 2015; EIA August 2015 STEO, July 22, 2015 EIA *This Week in Petroleum*).

[3] The gap in the summer of 2015 also appears if the model is estimated using seasonally adjusted data as discussed below. In contrast, the gap in September-November 2016 evident in the left panel of Figure A is not present using seasonally adjusted data, which suggests that this later gap is associated with the seasonal adjustment method in the benchmark model.

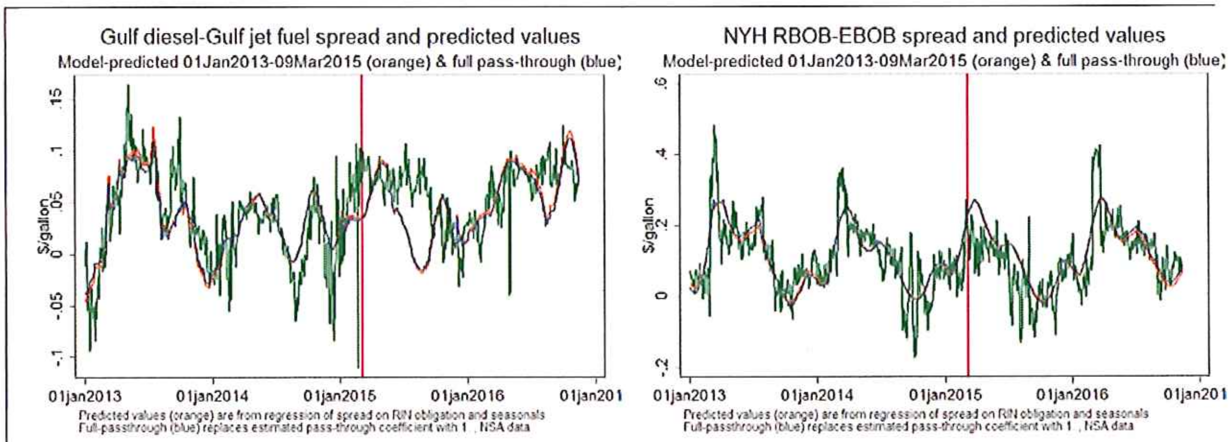


Figure A. Spread between obligated and nonobligated fuels: actual values (green), predicted values based on the KMS benchmark levels model estimated on the KMS sample (orange), and predicted values based on complete pass-through (blue). The vertical line separates the KMS sample and the out-of-sample period.

When these five refined product spreads are pooled together (using the pooling method in KMS), imposing the restriction that the pass-through coefficient is the same and using the benchmark levels regression from KMS (KMS, Table 3, regression 1), the pass-through coefficient is estimated to be 1.03 (SE=0.11) in the KMS sample. When this pooled regression is re-estimated using the full sample, the estimate is 1.12 (SE = 0.09).

2. For the five refined product spreads, the estimated RIN pass-through dynamics of KMS also hold up in the full sample and point to complete pass-through. The following chart presents the dynamic effect of a change in the RIN obligation on the spread, estimated in a pooled VAR using all five refined product spreads using the method of KMS Table 4. The left panel is estimated on the KMS sample, and the right panel is estimated on the full data set. In both the KMS sample and the full sample, approximately half the RIN price is passed through on the same day. Using the KMS sample and seasonally adjusted data, the pass-through coefficient after 10 days is .99 (SE = .28), and after 15 days is 1.01 (SE = .30). The dynamics estimated using the full sample are slightly slower, but not statistically different than, the KMS sample estimates: in the full sample, the 10-day pass-through coefficient is .91 (SE = .21) and the 15-day pass-through is .97 (SE = .22). The full-sample estimates are more precise than the KMS sample estimates.

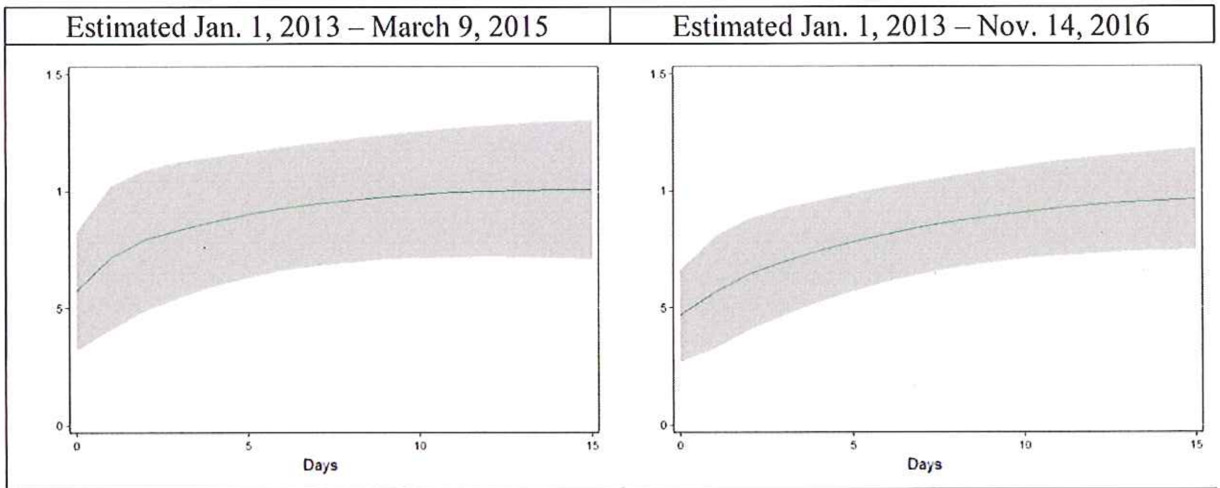


Figure B. Dynamic response of price spread between obligated and nonobligated fuels to a change in the price of the RIN obligation: pooled VAR for the five refined product spreads). Estimated using seasonally adjusted data.

3. Results from estimating pass-through using only the out-of-sample data are sensitive to how seasonals are handled. Because the spreads have seasonal swings, and because RIN price movements are mainly at the monthly or lower frequencies, it is important to control for normal seasonal variation in the spreads to reduce the risk of omitted variable bias. KMS do so in two ways: including seasonal variables (sines and cosines) in the regression, and using seasonally adjusted data, where the spread seasonal adjustment is done using data before the RFS had a material influence on spreads (pre-2013). The main results in KMS were robust to using either method, but for the shorter out-of-sample period here, the two different approaches give different results.

   The figure below shows the pass-through dynamics estimated using the pooled VAR for the five refined product spreads. The left panel includes seasonals in the VAR (the method of Figure B), the right panel uses seasonally adjusted data (the alternative method used in KMS). The upper panel shows results for the March 10, 2015 – Nov. 14, 2016 out-of-sample period. Although the two methods give very similar results in the KMS and full extended samples, the results differ when applied to just the out-of-sample period. The results when seasonally adjusted data are used are similar to those in the KMS and full sample with 15-day pass-through being within a standard error of 1, although with large standard errors because of the short out-of-sample period. The results when seasonals are included are quite different, and the differences are even more pronounced when the sample is shortened to end in May 31, 2016 (lower panel). The reason the results differ is that, when seasonals are included, the seasonals are being estimated with just over one year of data. Because RIN prices mainly move at relatively low frequencies – monthly swings, with typically small daily changes – including seasonals in the regression with just over one year of data confounds seasonal movements with RIN price movements when using only 19 months of data. Using seasonally adjusted data avoids this problem by estimating the spread seasonals on pre-sample data. Thus, for estimates based on the out-of-sample period only, the preferred specification is to include seasonals (although this distinction does not matter for the longer KMS and full extended samples, where both methods give the similar results).

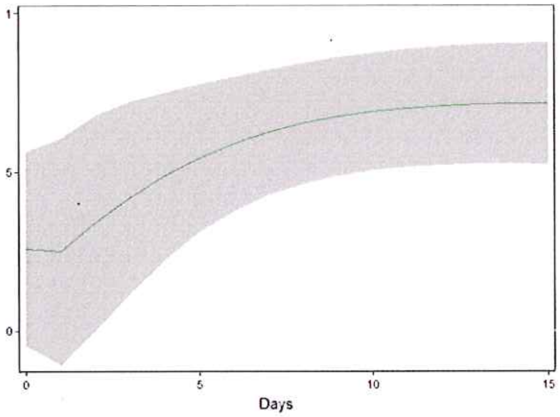
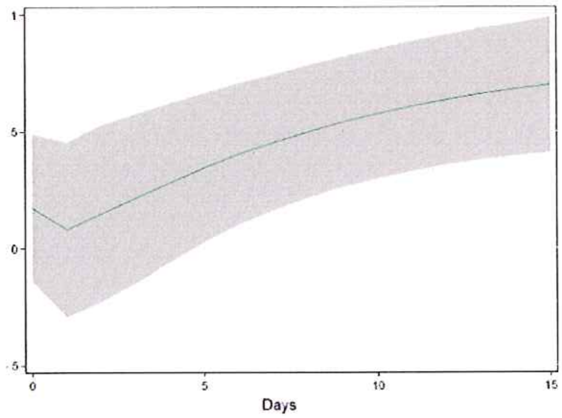
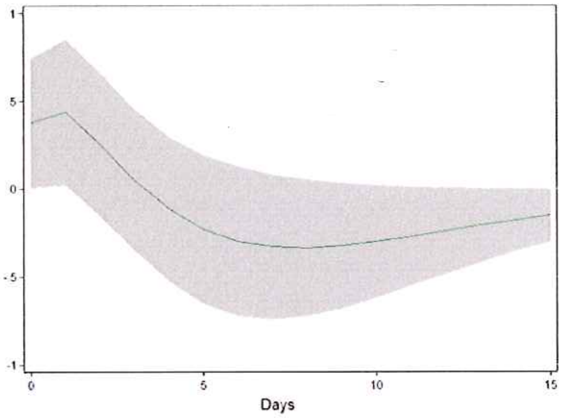
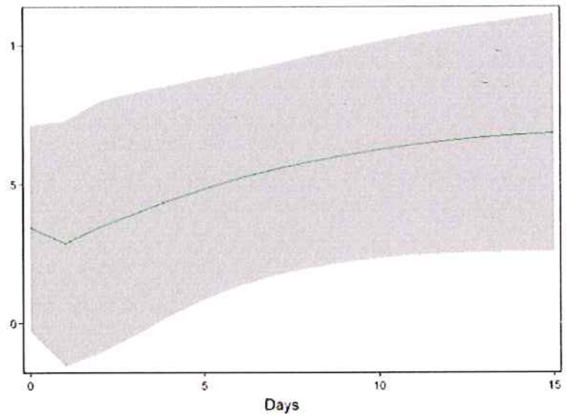
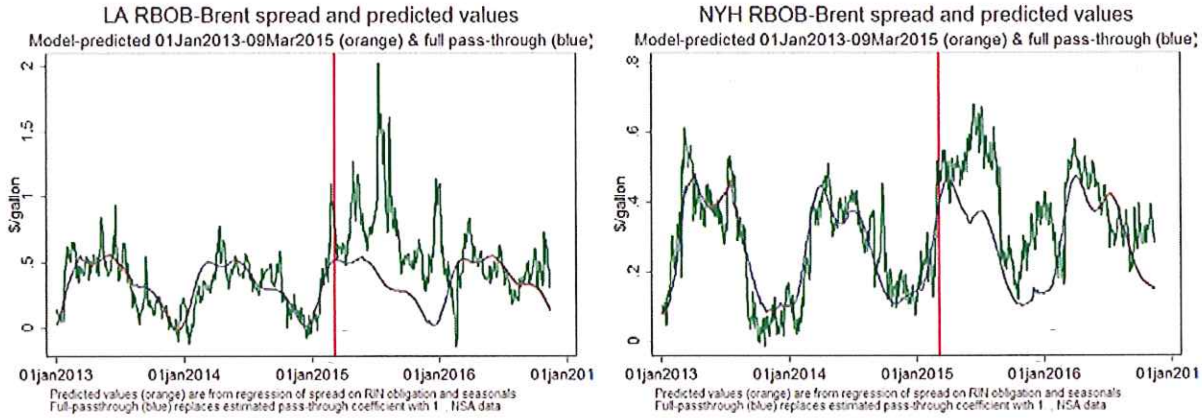
<table>
<tr><th></th><th>With seasonals in regression</th><th>Seasonally adjusted data</th></tr>
<tr><td>Estimated
3/10/15-
11/14/16</td><td>
</td><td>
</td></tr>
<tr><td>Estimated
3/10/15-
5/31/16</td><td>
</td><td>
</td></tr>
</table>

Figure C. Effect of seasonal adjustment method and sample length on estimation of the dynamic response of spreads to RIN prices for the five refined product spreads in the out-of-sample period.

4. There were large and persistent departures of spreads involving Brent from normal seasonal patterns during 2015. Those large departures were related to supply disruptions and expanding gasoline demand because of low prices, not the RFS. The high crack spreads occurred when RIN prices were low; by the time they returned to normal, RIN prices had risen (see Figures D and E). Although the crack spreads returned to the model predicted values, the crack spread widened again towards the end of the sample. Because of these large swings in the crack spread due to non-RFS features of the oil and refined product markets, during the out-of-sample period Brent ceased to be a useful control fuel and instead introduced additional confounding factors.

It is important to keep in mind that the goal of this regression analysis is not to describe all the movements in the spreads, rather, it is to estimate the effect of a change in RIN prices on the price of an obligated fuel. The other non-RIN factors that move the spreads comprise the regression error term. In the out-of-sample period for the Brent spreads, those other factors (e.g, supply disruptions) were negatively correlated with RIN prices. Because those other factors are omitted from the regression but are correlated with RIN prices, the pass-through coefficient estimated during the out-of-sample period is subject to omitted variable bias and in fact estimates a nonsensical pass-through that is large and negative. This omitted variable bias undercuts the usefulness of Brent as a control fuel for estimating the pass-through coefficient in the out-of-sample period.


LA RBOB-Brent spread and predicted values
Model-predicted 01Jan2013-09Mar2015 (orange) & full pass-through (blue)

NYH RBOB-Brent spread and predicted values
Model-predicted 01Jan2013-09Mar2015 (orange) & full pass-through (blue)

Predicted values (orange) are from regression of spread on RIN obligation and seasonals
Full-passthrough (blue) replaces estimated pass-through coefficient with 1 , NSA data

Predicted values (orange) are from regression of spread on RIN obligation and seasonals
Full-passthrough (blue) replaces estimated pass-through coefficient with 1 , NSA data

Figure D. Spread between obligated and nonobligated fuels: actual values (green), predicted values based on the KMS benchmark levels model estimated over the KMS sample (orange), and predicted values based on complete pass-through (blue). The vertical line separates the KMS sample and the out-of-sample period.


Price of RIN obligation, 01Jan2013-14Nov2016

Figure E. Price of RIN obligation, Jan. 1, 2013 – Nov. 14, 2016

Data and methods

Data. The data were updated from the same source as in KMS; see the Data Appendix to this note. A seventh spread, newly added in this analysis, is the NYH CBOB spot – Rotterdam EBOB spread. Because the NYH RBOB is a prompt-month futures price while the Rotterdam EBOB is a spot price, adding this seventh spread creates a spot-spot comparison.

Each of the spreads is the price difference (in dollars per gallon) of an obligated petroleum fuel and a non-obligated fuel. Thus each spread has the same RIN obligation per gallon of fuel. The RIN obligation is the value, based on that day's RIN prices, of the bundle of RINs that an obligated party must retire with EPA per gallon of obligated fuel. The price of this RIN depends on the fractional RIN requirement for that year under the RFS.[4] The original KMS RIN price data set had some missing RIN observations, for which RIN prices were imputed using prior day data. For this analysis and for the concurrently updated KMS paper (see footnote 1), the missing values in the KMS data set have been filled in using OPIS data.

For convenience, henceforth we refer to the original KMS sample period of Jan. 1, 2013 – March 9, 2015 as the KMS sample, and the period March 10, 2015 – Nov. 14, 2016 as the out of sample (OOS) period. The full sample is the combined KMS and OOS periods, Jan. 1, 2013 – Nov. 14, 2016. The pre-sample period is the later of Jan. 1, 2005 or the first date at which a given series is available, through Dec. 31, 2012

Methods. We briefly summarize the two methods of KMS, highlighting two issues that are important for this extension, cointegration and the use of seasonals.

Let $S_t^{ij} \equiv P_t^i - P_t^j$ denote the spread between the price of an obligated fuel i and a non-obligated fuel j, and let R_t^{ij} denote the net RIN obligation on the spread.

The first set of methods are levels regressions of the form,

$$S_t^{ij} = \alpha_{ij} + \theta_{ij} R_t^{ij} + [\gamma' Seaonals] + u_t^{ij}, \tag{1}$$

see KMS equation (1). The (levels) pass-through coefficient is θ_{ij}, and full pass-through corresponds to $\theta_{ij} = 1$. This coefficient represents a long-run effect of RIN prices on the spread and this method does not estimate the dynamics of RIN price adjustment.

The second method estimates the dynamics of RIN price adjustment using a vector autoregression (VAR). Let $Y_t = (R_t^{ij}, S_t^{ij})$. The VARs are specified in levels of Y_t and have the form:

---

[4] In 2016, for each gallon of petroleum fuel imported or refined and sold into the domestic surface transportation market, the importer or refiner (obligated party) must turn in a total of 0.101 RINs, of which 0.0159 must be D4 (biomass-based diesel) and 0.0201 must be D4 or D5 (advanced), so up to 0.0809 can be D6 (conventional). Because the EPA delayed issuing the 2014 and 2015 rules, from Jan. 1, 2014 through the EPA proposed rule issued May 29, 2015, we use the 2013 fractional obligations. For May 29, 2015 – Dec. 31, 2015, we use the 2015 proposed fractional obligations. For 2016, we use the 2016 fractional obligations, which were finalized in November 2015.

$$Y_t = \Psi_0 + \sum_{k=1}^{p} \Psi_k Y_{t-k} + [\Gamma Seasonals_t] + \eta_t \ , \qquad (2)$$

where the coefficient matrix Ψ_k is a matrix of autoregressive coefficients on the k^{th} lag of Y. The coefficients in the matrices $\{\Psi_k\}$ and Γ are unrestricted.

Two methodological points, noted in KMS, turn out to be relevant in analyzing the extended data set.

First, the levels regression in equation (1) is valid either if the spread and the RIN obligation are jointly stationary (no unit root), or if they both have a unit root and are cointegrated. If, however, both the spread and RIN obligation have a unit root but they are not cointegrated, then the error term in equation (1) has a unit root and the levels regression is invalid in the sense of giving neither a consistent estimator of θ_{ij} nor a valid standard error. In contrast, the VAR in equation (2) is valid in all three cases (both stationary, both unit roots and cointegrated, both unit roots but not cointegrated) because it includes lags.

Second, many of the spreads have strong seasonal patterns, so it is important to handle that seasonality to avoid potential omitted variable bias. KMS provide two methods. The first is to include seasonal variables in the regression, specifically sines and cosines at the first 4 harmonic frequencies (a total of 8 seasonal variables). The second is to seasonally adjust the spreads, but not the RIN prices, using pre-sample data (pre-2013); see KMS equation (5) and the surrounding discussion. The logic of this second procedure is the standard logic of seasonal adjustment: the spreads typically have seasonal patterns, but because those seasonal patterns are driven by seasonal shifts in fuel demand they should not change substantially from one year to the next. Estimating the seasonals on pre-2013 data avoids confusing seasonals and RIN-driven movements. There is no reason that RIN prices should have seasonals[5] so in this second procedure, RIN prices are not seasonally adjusted.

Empirical results

We first explain the figures and tables of results before turning to a substantive discussion.

Figures 1-7 present charts for each of the 7 spreads. We explain figure 1 in detail for the Gulf diesel-Gulf jet fuel spread; figures 2-6 have the same format for the other six spreads. The upper left panel presents the time series plot of the spread (green) over the full sample, with the vertical line denoting the boundary between the KMS sample and the OOS sample. The orange line is the predicted value from regression (1), estimated over the KMS sample, using seasonally unadjusted data and including seasonals in the regression (this is model 1 in Table 2 of KMS). Values of the orange line in the OOS period are the out-of-sample predicted values of the spread,

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[5] RINs are electronic and bankable and can be retired with the EPA at any point through the true-up period, typically February following the obligation year. As a result, they are not subject to storage costs or any of the demand, supply, and physical factors that drive seasonal fuel price fluctuations.

given RIN prices, computed using the coefficients estimated using the KMS sample. The blue line is the predicted value with full pass-through (the estimated pass-through coefficient in the orange line is set to 1).

The upper right panel presents the same set of results, except that the spreads are seasonally adjusted so the levels regression omits the seasonal variables (this is model 4 in Table 2 of KMS). The orange line is the predicted value estimated using the KMS sample and the blue line is full pass-through.

The middle left panel is a scatterplot of the change in the spread versus the change in the price of the RIN obligation, both expressed as changes in the weekly average. The green dots are from the KMS sample, the blue triangles are from the OOS sample, and the green and blue lines are the regression lines for the KMS and OOS samples respectively. The black line is the 45° line that represents complete pass-through. This scatterplot updates KMS Figure 6 (working paper version).

The final three panels are impulse response functions from the VAR in equation (2), estimated using the seasonally adjusted data. The middle-right panel is for the KMS sample, the bottom-left panel is for the OOS sample, and the bottom-right panel is for the full sample. The grey areas denote ± one standard error bands.

Figures 8-10 present impulse response functions for pooled VARs, in which the same dynamics are imposed for multiple spreads (see KMS for the details). Figure 8 presents results for VARs that pool the three diesel spreads. Figure 9 presents results for VARs that pool the same six wholesale spreads analyzed by KMS. Figure 10 presents results for VARs that pool five refined product spreads (the four refined product spreads analyzed by KMS and also the NYH CBOB spot-EBOB spread). The two Brent spreads that were analyzed by KMS are not included in the pooled VARs in Figure 10. In figures 8-10, impulse response functions in the left column are for VARs that include seasonal variables, and impulse response functions in the right column are for VARs estimated on seasonally adjusted spreads. The top row is for the KMS sample, the middle row is for the OOS sample, and the bottom row is for the full sample.

Table 1 presents the levels regressions results. The first panel presents results for the KMS sample and corresponds to Table 2 in KMS (regressions 1, 2, and 4). The second panel presents results for the OOS sample, and the third panel presents results for the full sample. For the full sample, Table 1 also reports results of the *t*-test for a break in the coefficients between the two samples.

Table 2 presents pooled levels regression results for various combinations of spreads: diesel, the original KMS gasoline spreads, the original KMS pooled diesel and gasoline spreads, and in the final column, the five refined product spreads (original KMS four and also CBOB-EBOB). Regressions 1, 2, and 4 in Table 2 extends the same regressions in KMS Table 3 to the new estimation samples.

Table 3 presents the impulse response functions from the pooled VARs for the diesel spreads and the five refined product spreads, for the two methods of handling seasonals and for the KMS and full sample. The first two columns of the first panel are the first two columns of KMS, Table 4.

Discussion

Broadly speaking, the results for the five spreads between refined product prices are similar to each other, the results for the two RBOB-Brent spreads are similar to each other, and the results for these two groups differ. We begin by discussing the five refined product spreads.

1. For the five refined product spreads, the pooled models estimated on the KMS sample are stable out of sample, both in the levels specifications and in the dynamics estimated by the VARs. Dynamic pass-through estimates from the pooled VARs estimated using seasonally adjusted data are quantitatively and qualitatively similar in the KMS sample, the OOS sample, and in the full sample. Using the KMS sample and seasonally adjusted data, the pass-through coefficient after 10 days is .99 (SE = .28), and after 15 days is 1.01 (SE = .30). The dynamics estimated using the full sample are slightly slower, but not statistically different than, the KMS sample estimates: in the full sample, the 10-day pass-through coefficient is .91 (SE = .21) and the 15-day pass-through is .97 (SE = .22). Using the seasonal adjustment method in KMS (that is, including seasonals in the VAR), the 10-day pass-through coefficients for the five pooled refined product spreads are 1.25 (SE = .26) for the KMS sample and .96 (SE = .18) for the full sample. Static and dynamic pass-through estimates for individual spreads differ between the KMS sample and the OOS sample but with no particular pattern across the five refined product spreads, with estimates for some spreads indicating greater pass-through and for others indicating less, frequently with large standard errors in the OOS period. Overall, the results for these five refined product spreads are consistent with complete pass-through.

    a. The amount of information in the OOS period is more limited than in the KMS period, both because the number of observations is fewer and because the variation in RIN prices is less during the OOS period than during the KMS period. This is most readily seen by inspecting the scatterplots in Figures 1-7, in which the spread of green dots is substantially larger than the spread of the blue triangles. In the scatterplots, the correlations in the OOS period seem to be driven by a few large outliers, which suggests caution interpreting results for the OOS period.

    b. The fact that the OOS period is only 19 months creates a challenge for handling seasonal variation using only the OOS sample. Regressions that include seasonals in the model estimated on the OOS sample are effectively estimating seasonal patterns based just over a single observation (~1½ years). Consequently, including seasonal terms in the regression absorb fluctuations at the monthly level, whether or not those actually are seasonals. A preferable approach to handling seasonals in such a short sample is to use prior data to estimate the seasonals, then estimate regressions using the seasonally adjusted data. Comparing results across the two approaches – including seasonals in the model, or using seasonally adjusted data – shows that they yield similar results in the longer KMS sample and in the full sample, but can yield sharply different results in the short OOS sample. Because the method of using seasonally adjusted data is better suited for the OOS sample, we focus here on results using seasonally adjusted data.

c. The upper panel of Figures 1-4 and 7 indicates generally stable performance of the in-sample fit during the OOS period. Qualitatively, the RIN-predicted value (KMS sample estimated and full pass-through) tracks a smooth mean of these noisy spreads, both in the model with seasonals and using seasonally adjusted data. However, tests for a break in the pass-through coefficient are mixed, with two rejecting stability at the 5% level, one at the 10% level, and two not rejecting. We discuss two of these spreads that reject, the Gulf diesel-Gulf jet spread and the NYH CBOB-EBOB spread, below.

d. The results of the levels regressions for the five refined product spreads are consistent with complete pass-through. Of the 15 pass-through coefficients (five refined product spreads estimated over the KMS, OOS, and full sample) estimated using seasonally adjusted data, only three reject complete pass-through at the 10% significance level (Gulf diesel-Rotterdam diesel in the KMS sample, and Gulf diesel-Gulf jet and NYH CBOB-EBOB in the OOS sample). Two of these rejections are in the direction of less-than complete pass-through, while one is in the direction of more-than-complete pass-through. This said, the standard errors in the OOS sample are quite large for some of the spreads, consistent with point 1a about there being limited information in the OOS period.

e. Two of the refined product spreads exhibit large but transitory departures from their RIN-predicted value during the OOS period. The Gulf diesel-Gulf jet spread remained high during the summer of 2015, in contrast to its estimated seasonal pattern As a result, the estimated pass-through coefficient for this spread is attenuated in the OOS period (high spread but low RIN obligation for the first part of the OOS period). This period coincides with the "diesel glut" of the summer of 2016, in which there was a relative oversupply of diesel and undersupply of gasoline (see footnote 2). Re-estimating the pass-through coefficient for the Gulf diesel-Gulf jet spread from September 1, 2015 – Nov. 14, 2016, i.e. after the "diesel glut" subsided, results in a pass-through coefficient of .88 (SE = .20) using seasonally adjusted data, compared to .49 in the OOS sample. For the CBOB-EBOB spread, the aberrant period is in the spring of 2016, where the RIN price is high but the spread is even higher, even after seasonal adjustment. Mechanically, this results in a large pass-through coefficient for the CBOB-EBOB spread (high RIN prices, even higher spread) during the OOS period. These periods of departure account for the rejection for these two series of the test for coefficient stability. From a theoretical perspective, price spreads are determined by multiple factors including inventory developments, supply chain disruptions, and refinery decisions, and RIN prices are only one of these multiple factors. In these regressions, those factors are relegated to the error term, and because they are persistent (lasting several months, a substantial fraction of the OOS sample) they can pose problems for the levels regressions with RIN prices in the short sample. In the longer samples (KMS and full), these departures are a smaller fraction of the sample so they pose less of a risk of omitted variable bias.

f. The pooled levels regressions (Table 2, final column) for the diesel spreads, and for the five refined product spreads, are consistent with the findings for the individual spreads levels regressions. Of the pooled estimates using all five spreads, among the 9 estimates, the only ones that reject at the 5% level are those in which seasonals are included in the model and the regression is estimated in the subsample. As discussed before this is an inappropriate method for handling seasonals in a short sample. When seasonally adjusted data are used in the KMS sample for the five refined product spreads, the pass-through coefficient is 0.81 (SE = 0.15). In the full sample, all estimates are within a standard deviation of one, regardless of the seasonal adjustment method. The KMS abstract refers to a pooled pass-through coefficient of 1.00 (SE = 0.11). Using the full sample and the same method, for the five refined product spreads, the estimate is 1.12 (SE = 0.09). Using seasonally adjusted data, it is 1.00 (SE = 0.14).

g. The IRFs for the VAR estimated using the pooled diesel spreads, estimated on seasonally adjusted data, are similar (within one standard error) in the KMS sample and in the OOS period (Figure 8, right column). For the five pooled refined product spreads, the IRFs are again similar in the KMS and OOS periods using seasonally adjusted data (Figure 10, right column). For the pooled three diesel spreads and the pooled five refined product spreads, the IRFs using seasonally adjusted data and the IRFs using seasonals in the VAR are similar in both the KMS and OOS samples. For the pooled diesel spreads and the pooled refined product spreads, the dynamic estimates using the full sample point to complete pass-through. Using the full sample improves the precision of the estimates relative to using just the KMS sample.

2. In contrast to the five refined fuel spreads, the two BOB-Brent spreads exhibit large and persistent departures from the RIN-predicted value. In brief, supply developments unrelated to the RFS, such as the Exxon-Torrance refinery fire, produced high crack spreads in the spring through fall of 2015, when RIN prices were relatively low, and the spreads returned to normal later in the sample, when RIN prices were relatively high. As a result, in the out-of-sample period, the levels regressions spuriously estimate negative pass-through coefficients.

    a. The central idea of using spreads between obligated and non-obligated fuels is that the non-obligated fuel serves as a "control" for common factors that influence the price of the two fuels. The closer the two fuels are chemically and geographically, the better the control. On *a-priori* grounds, the most compelling comparisons are Gulf diesel to Gulf jet, and NYH RBOB (or CBOB) to Rotterdam EBOB. In contrast, comparing refined product prices to Brent introduces the additional determinants of the crack spread including crude and refined inventories and changes in refiner operations. As noted in KMS, the crack spreads are much noisier than the refined product spreads, making the econometric exercise of finding the RIN price signal more difficult. Thus, on *a-priori* grounds, Brent is a less reliable control fuel than a comparable refined product.

    b. It further appears that developments in the crude and refined product market in 2015 undercut the statistical utility of Brent as a control fuel. The LA RBOB – Brent spread fluctuated in the range of zero to fifty cents during the KMS period but rose to around one dollar during the spring through fall of 2015. This persistently high price of LA RBOB, relative to crude, was associated with particularly high gasoline prices in California, relative to the rest of the country, and these high prices attracted a great deal of public attention. These high prices have been variously attributed to the February 18, 2015, fire at Exxon's Torrance refinery, to the expansion of California's cap and trade program to gasoline on January 1, 2015, to supply restrictions stemming from the limited number of refineries that produce CARBOB, and to other factors.[6] High LA RBOB prices during the spring-fall of 2015 in the presence of low RIN prices, followed by normal LA RBOB prices by the end of the sample when RIN prices had risen, produce a negative correlation that results in a large negative estimated pass-

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[6] See Borenstein (2015) at https://energyathaas.wordpress.com/2015/09/28/why-are-californias-gasoline-prices-so-high/.

through coefficient. This large negative pass-through coefficient can be attributed to omitted variable bias, where the omitted variables are the supply-side disturbances that widened the California BOB-Brent spread. The persistent, supply-side factors that affected California gasoline markets confound the relationship between spreads and RIN prices, rendering unreliable the econometric analysis of the LA RBOB-Brent spread. In principle, this omitted variable bias could be addressed by including additional regressors that control for the supply disruptions and other factors leading to the high crack spread. However, needing to look for such factors underscores that Brent is not a useful control fuel during the out-of-sample period.

c. The NYH RBOB-Brent spread also exhibits persistent departures from the RIN-predicted value during this period. EIA attributed the historically high crack spreads in the spring of 2015 to expanding demand in the face of low oil prices, among other factors.[7]

d. The dynamic pass-through estimates using the six pooled spreads in KMS are statistically close to each other in both the KMS sample and the full sample (Figure 9) using both seasonal adjustment methods, and these four estimates are consistent with complete pass-through after ten days (0.89, SE = 0.25 with seasonals in the regression, 0.87, SE = 0.26 for seasonally adjusted data, both for the full sample). That said, the foregoing discussion of the persistent departures of the crack spreads in 2015 lead us to prefer the pooled estimates in Figure 10 based on the five refined product spreads, omitting the two crack spreads because of the supply-side omitted variables discussed above.

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[7] See http://www.eia.gov/forecasts/steo/uncertainty/pdf/may15_uncertainty.pdf and https://www.eia.gov/forecasts/steo/archives/feb16.pdf.

Data Appendix

Prices of D4, D5, and D6 RINs are from the following hierarchy: Progressive Fuels Limited[8] when available (through 30Nov2014); if missing, then from OPIS (through 14Nov2016). The July 2015 version of KMS had some missing RIN prices during the KMS period, here and in the contemporaneous revision of KMS we have used OPIS data to fill in those missing RIN prices.

Domestic wholesale prices were obtained from the Energy Information Administration:[9] New York Mercantile Exchange prompt-month futures prices for reformulated blendstock for oxygenated blending (RBOB) New York Harbor, and spot prices for Brent oil, RBOB Los Angeles, CBOB New York Harbor, Ultra-low sulfur No. 2 diesel New York Harbor and U.S. Gulf Coast, and Kerosene-type jet fuel U.S. Gulf Coast.

Two wholesale European prices are used: the price of Rotterdam barge German diesel (10ppm sulfur), and the price of European blendstock for oxygenated blending (EBOB) free on board Rotterdam (both quoted in dollars per ton, converted to dollars per gallon). We use Argus data 03Jan2012-10Mar2015, before and after that Rotterdam diesel and Rotterdam EBOB prices are from Bloomberg. During the period that the Argus data are available, the standard deviations of the difference between the Bloomberg and Argus series are very small: \$.0056 for Euro diesel and \$.0067 for EBOB.

The data are for U.S. business days, typically close of business local time. For this analysis and in KMS, business days are defined to be days for which the NYMEX prices from EIA are non-missing.

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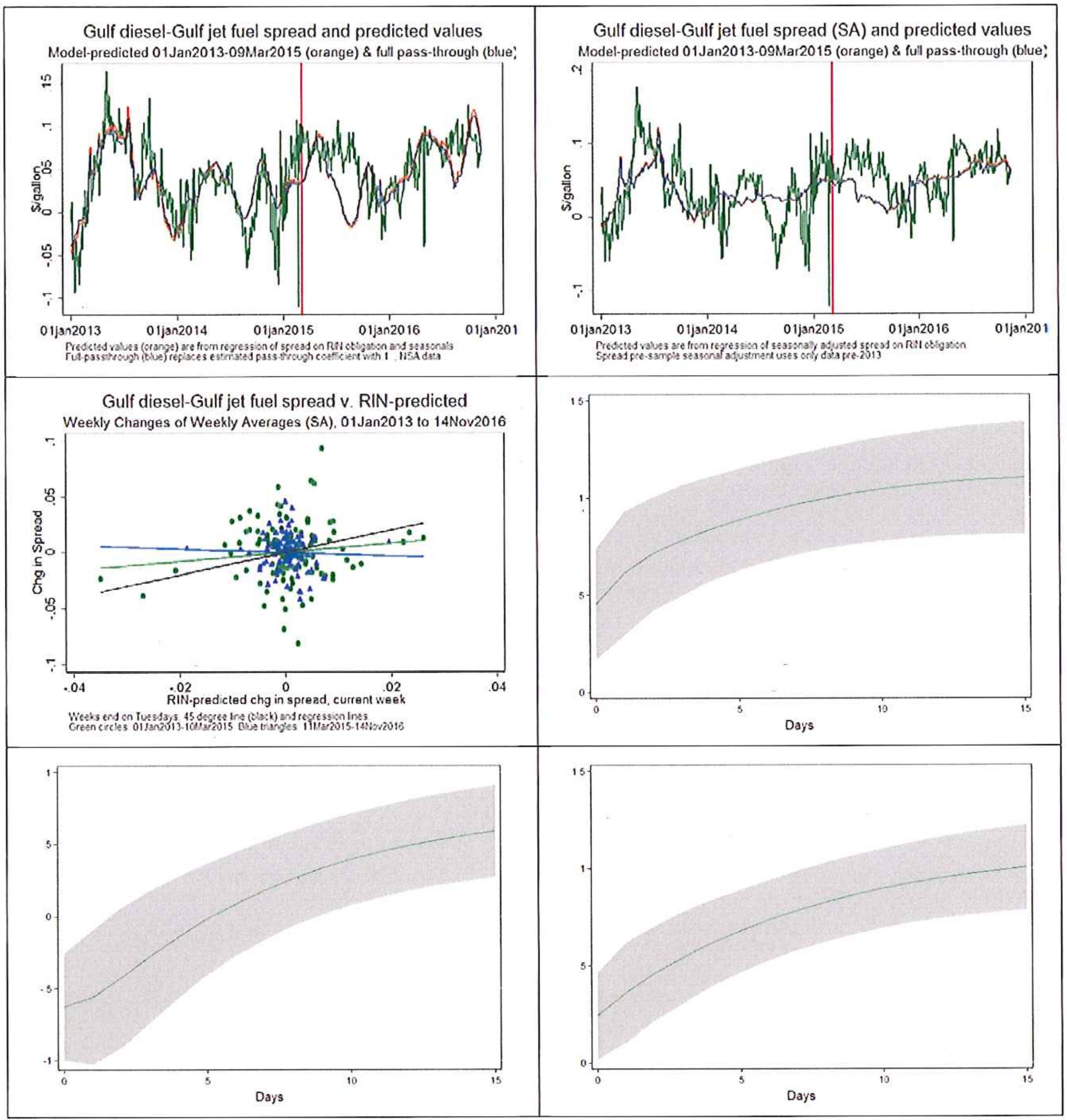
[8] RIN price data from Progressive Fuels Limited are proprietary. Progressive Fuels Limited can be reached online at www.progressivefuelslimited.com and by phone at 239-390-2885. These RIN prices are traded prices and do not necessarily reflect prices embedded long-term contracts for RINs.

[9] Spot prices were downloaded from http://www.eia.gov/dnav/pet/pet_pri_spt_s1_d.htm, and futures prices were downloaded from http://www.eia.gov/dnav/pet/pet_pri_fut_s1_d.htm.



Gulf diesel-Gulf jet fuel spread and predicted values

Model-predicted 01Jan2013-09Mar2015 (orange) & full pass-through (blue)

Predicted values (orange) are from regression of spread on RIN obligation and seasonals
Full-passthrough (blue) replaces estimated pass-through coefficient with 1 , NSA data

Gulf diesel-Gulf jet fuel spread (SA) and predicted values

Model-predicted 01Jan2013-09Mar2015 (orange) & full pass-through (blue)

Predicted values are from regression of seasonally adjusted spread on RIN obligation
Spread pre-sample seasonal adjustment uses only data pre-2013

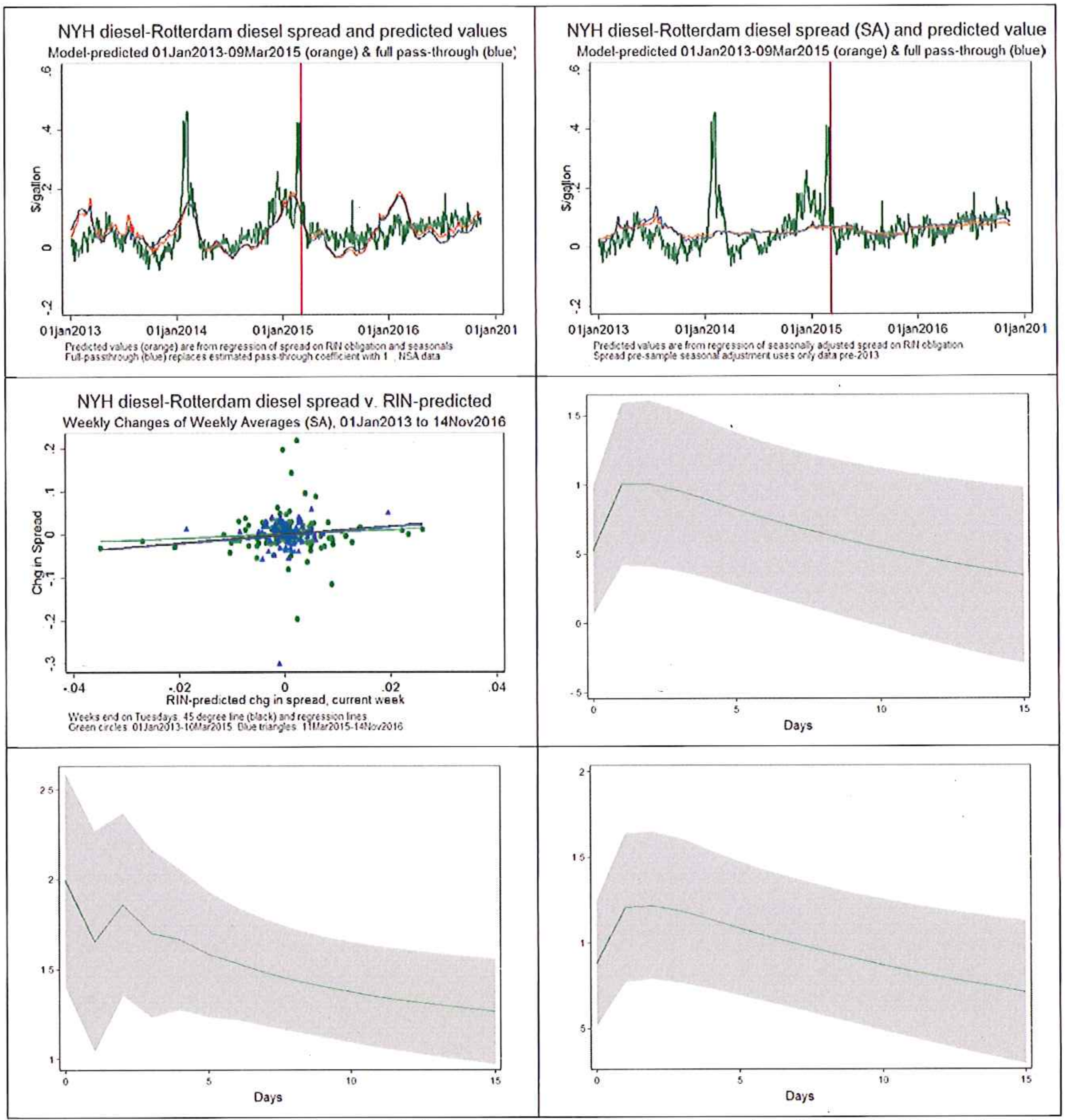
Gulf diesel-Gulf jet fuel spread v. RIN-predicted

Weekly Changes of Weekly Averages (SA), 01Jan2013 to 14Nov2016

Weeks end on Tuesdays, 45 degree line (black) and regression lines
Green circles 01Jan2013-10Mar2015 Blue triangles 11Mar2015-14Nov2016

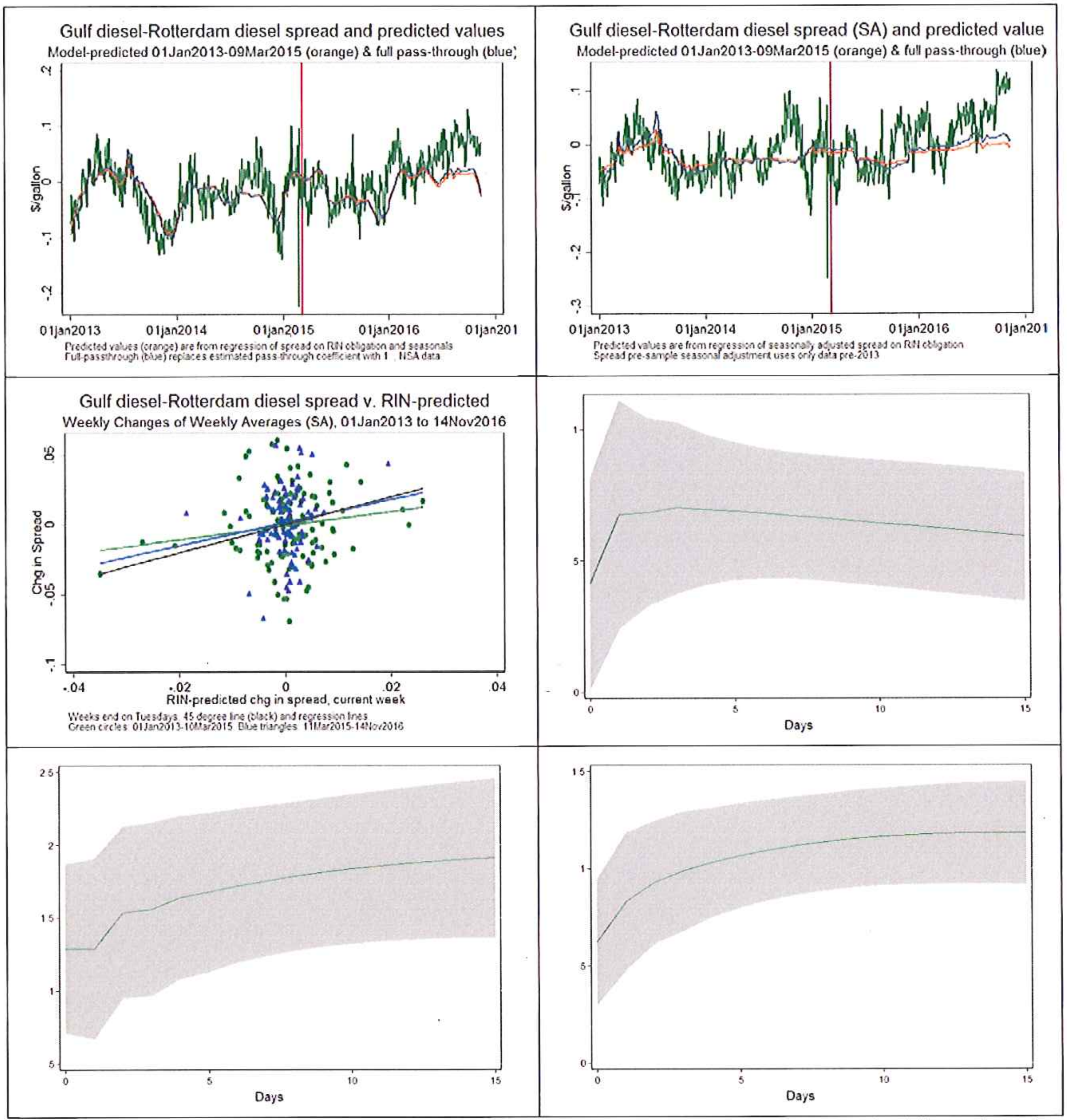
Notes: upper panels present spreads (green), KMS-sample predicted values (orange), and predicted under full pass through (blue), for seasonally unadjusted data/seasonals in model (left) and seasonally adjusted data (right). Middle left is scatterplot of weekly changes in spread on weekly changes in RIN obligation. Remaining panels are VAR impulse response presenting dynamic response of a change in the RIN obligation price on the spread, estimated using seasonally-adjusted data, in the KMS sample (middle-right), OOS (bottom-left), and full sample (bottom right).

Figure 1. Results for Gulf diesel – Gulf jet



Notes: upper panels present spreads (green), KMS-sample predicted values (orange), and predicted under full pass through (blue), for seasonally unadjusted data/seasonals in model (left) and seasonally adjusted data (right). Middle left is scatterplot of weekly changes in spread on weekly changes in RIN obligation. Remaining panels are VAR impulse response presenting dynamic response of a change in the RIN obligation price on the spread, estimated using seasonally-adjusted data, in the KMS sample (middle-right), OOS (bottom-left), and full sample (bottom right).

Figure 2. Results for NYH diesel – Rotterdam diesel



Gulf diesel-Rotterdam diesel spread and predicted values

Model-predicted 01Jan2013-09Mar2015 (orange) & full pass-through (blue)

Predicted values (orange) are from regression of spread on RIN obligation and seasonals
Full-passthrough (blue) replaces estimated pass-through coefficient with 1 . NSA data

Gulf diesel-Rotterdam diesel spread (SA) and predicted value

Model-predicted 01Jan2013-09Mar2015 (orange) & full pass-through (blue)

Predicted values are from regression of seasonally adjusted spread on RIN obligation
Spread pre-sample seasonal adjustment uses only data pre-2013

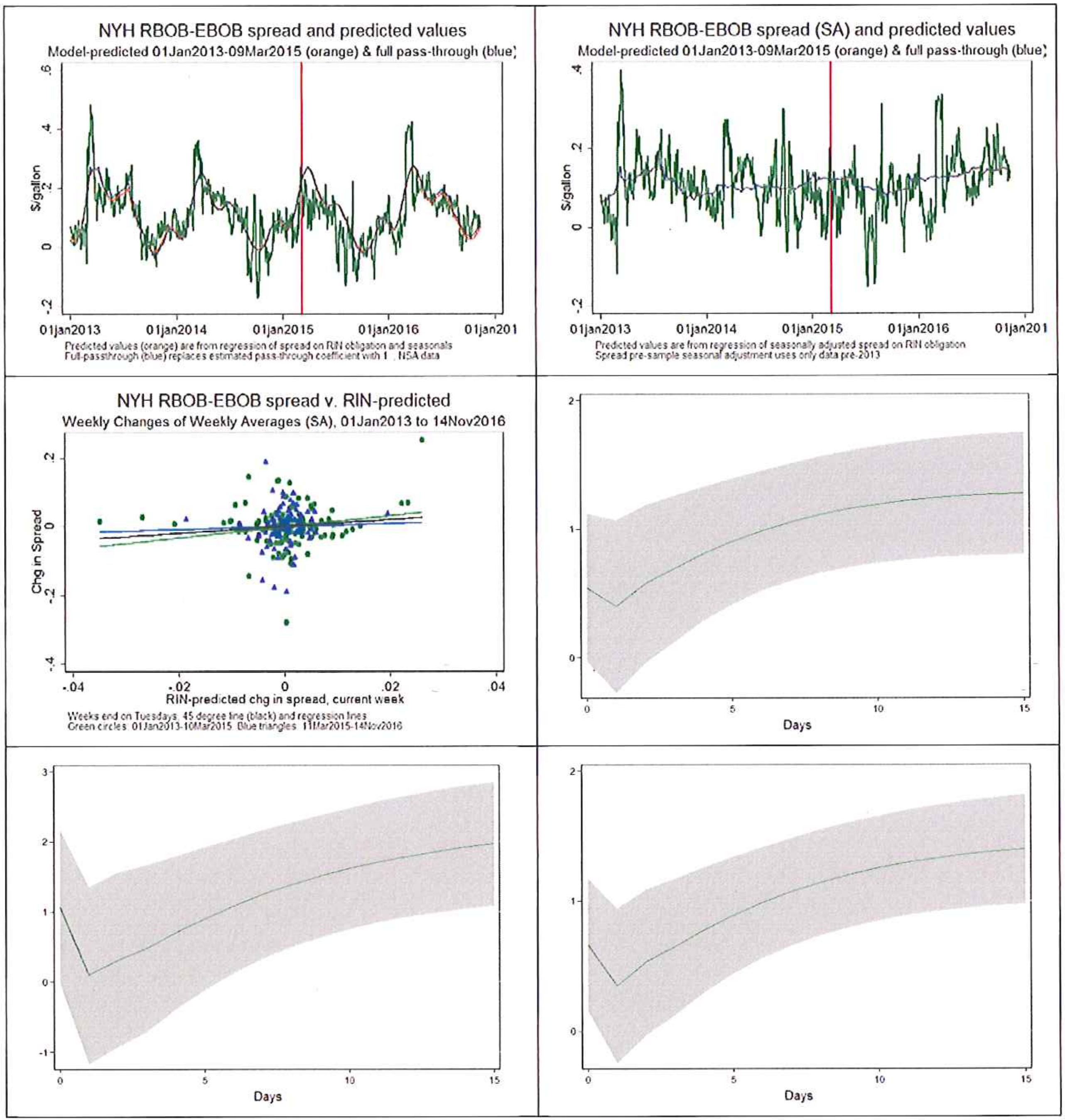
Gulf diesel-Rotterdam diesel spread v. RIN-predicted

Weekly Changes of Weekly Averages (SA), 01Jan2013 to 14Nov2016

Weeks end on Tuesdays. 45 degree line (black) and regression lines
Green circles: 01Jan2013-10Mar2015. Blue triangles: 11Mar2015-14Nov2016

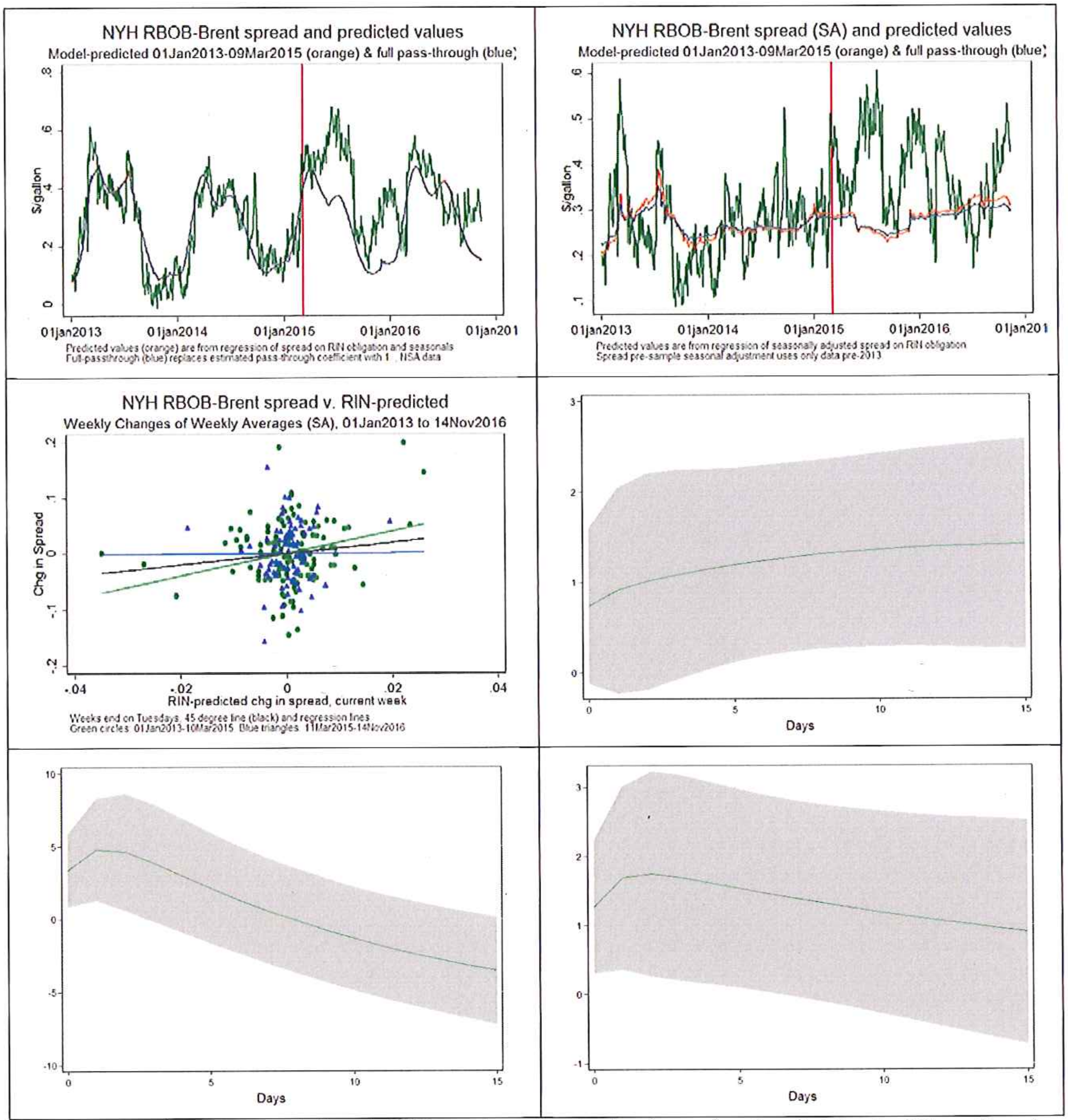
Notes: upper panels present spreads (green), KMS-sample predicted values (orange), and predicted under full pass through (blue), for seasonally unadjusted data/seasonals in model (left) and seasonally adjusted data (right). Middle left is scatterplot of weekly changes in spread on weekly changes in RIN obligation. Remaining panels are VAR impulse response presenting dynamic response of a change in the RIN obligation price on the spread, estimated using seasonally-adjusted data, in the KMS sample (middle-right), OOS (bottom-left), and full sample (bottom right).

Figure 3. Results for Gulf diesel – Rotterdam diesel



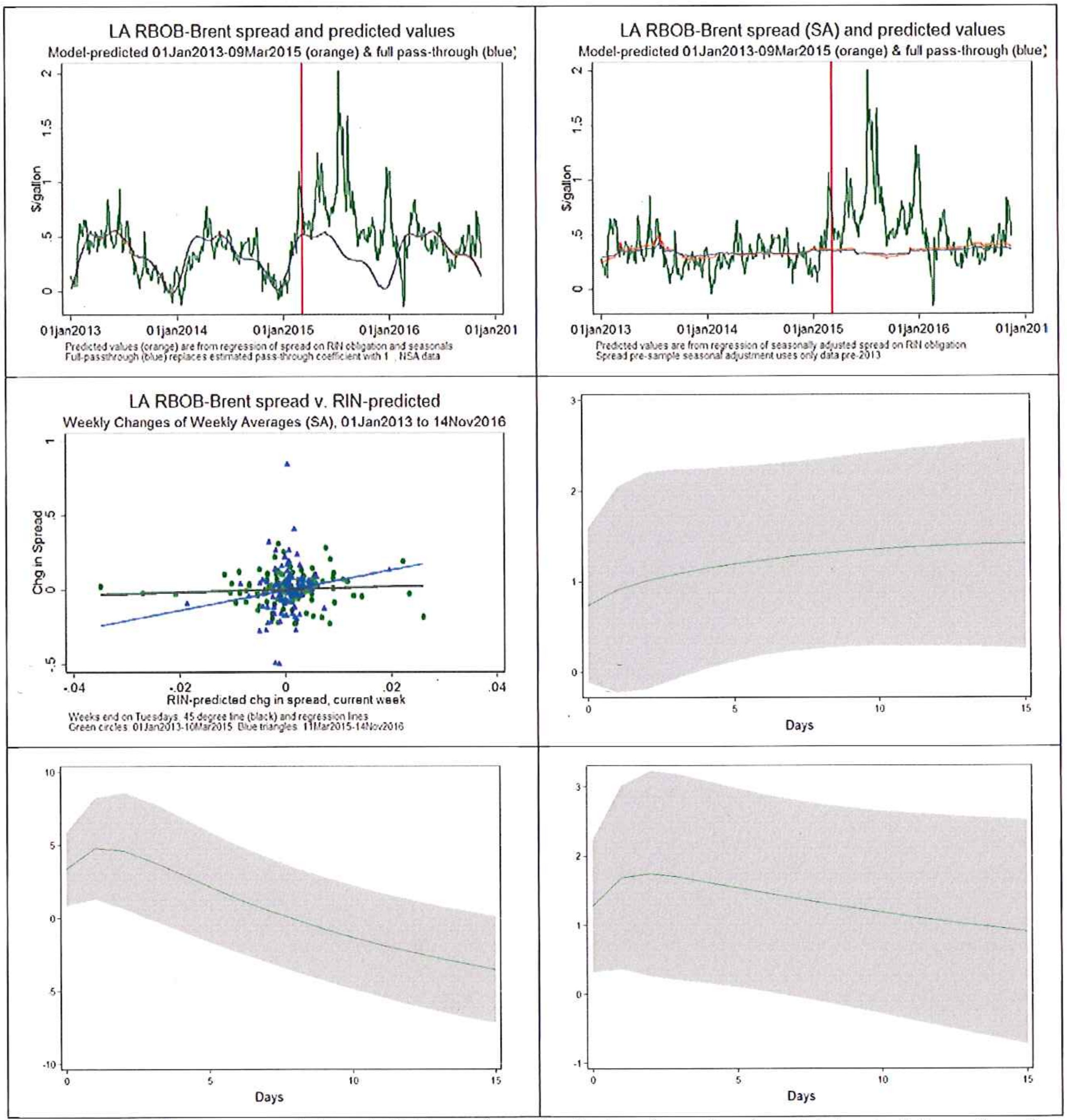
Notes: upper panels present spreads (green), KMS-sample predicted values (orange), and predicted under full pass through (blue), for seasonally unadjusted data/seasonals in model (left) and seasonally adjusted data (right). Middle left is scatterplot of weekly changes in spread on weekly changes in RIN obligation. Remaining panels are VAR impulse response presenting dynamic response of a change in the RIN obligation price on the spread, estimated using seasonally-adjusted data, in the KMS sample (middle-right), OOS (bottom-left), and full sample (bottom right).

Figure 4. Results for NYH RBOB futures – Rotterdam EBOB



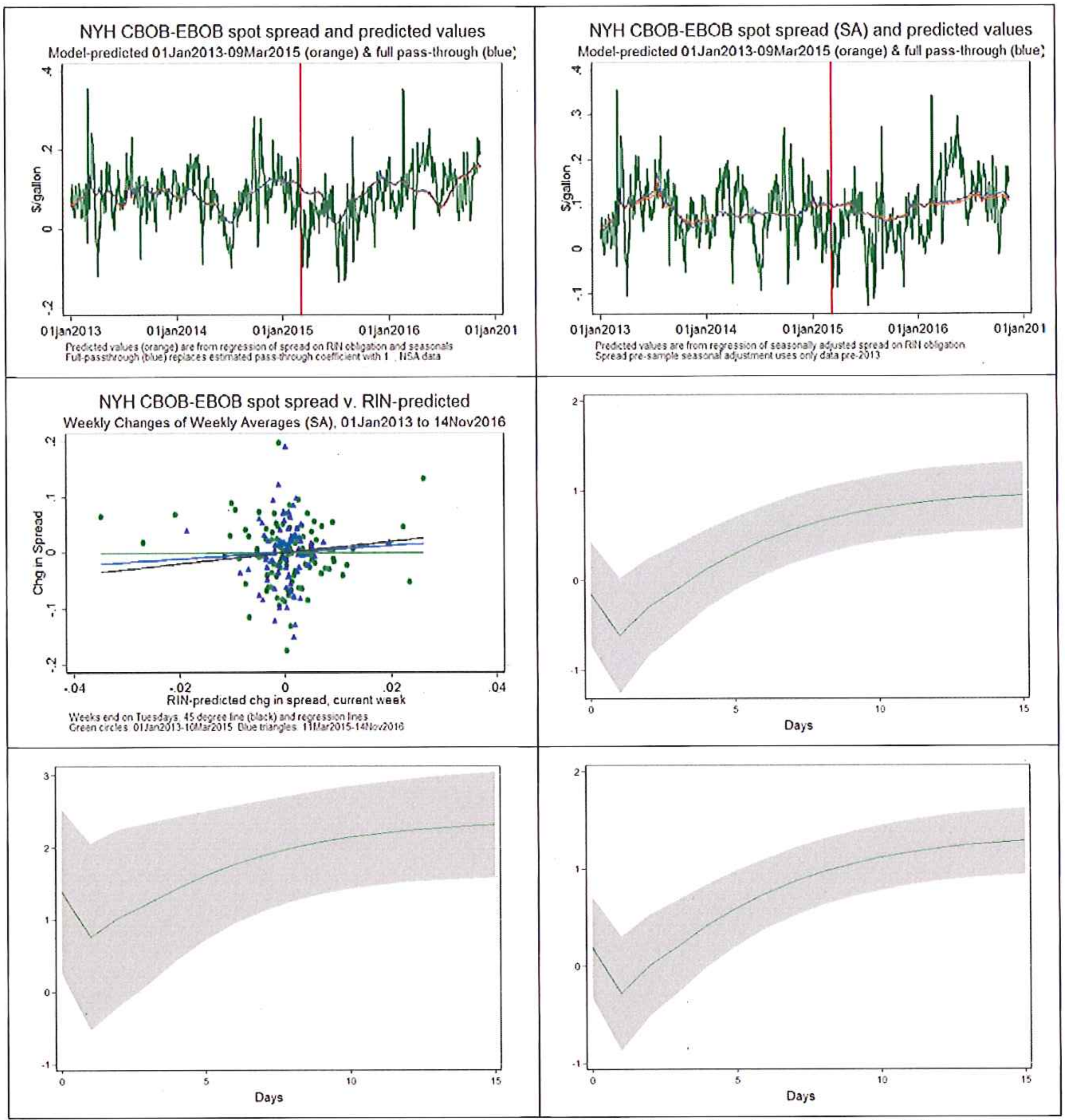
Notes: upper panels present spreads (green), KMS-sample predicted values (orange), and predicted under full pass through (blue), for seasonally unadjusted data/seasonals in model (left) and seasonally adjusted data (right). Middle left is scatterplot of weekly changes in spread on weekly changes in RIN obligation. Remaining panels are VAR impulse response presenting dynamic response of a change in the RIN obligation price on the spread, estimated using seasonally-adjusted data, in the KMS sample (middle-right), OOS (bottom-left), and full sample (bottom right).

Figure 5. Results for NYH RBOB futures – Brent



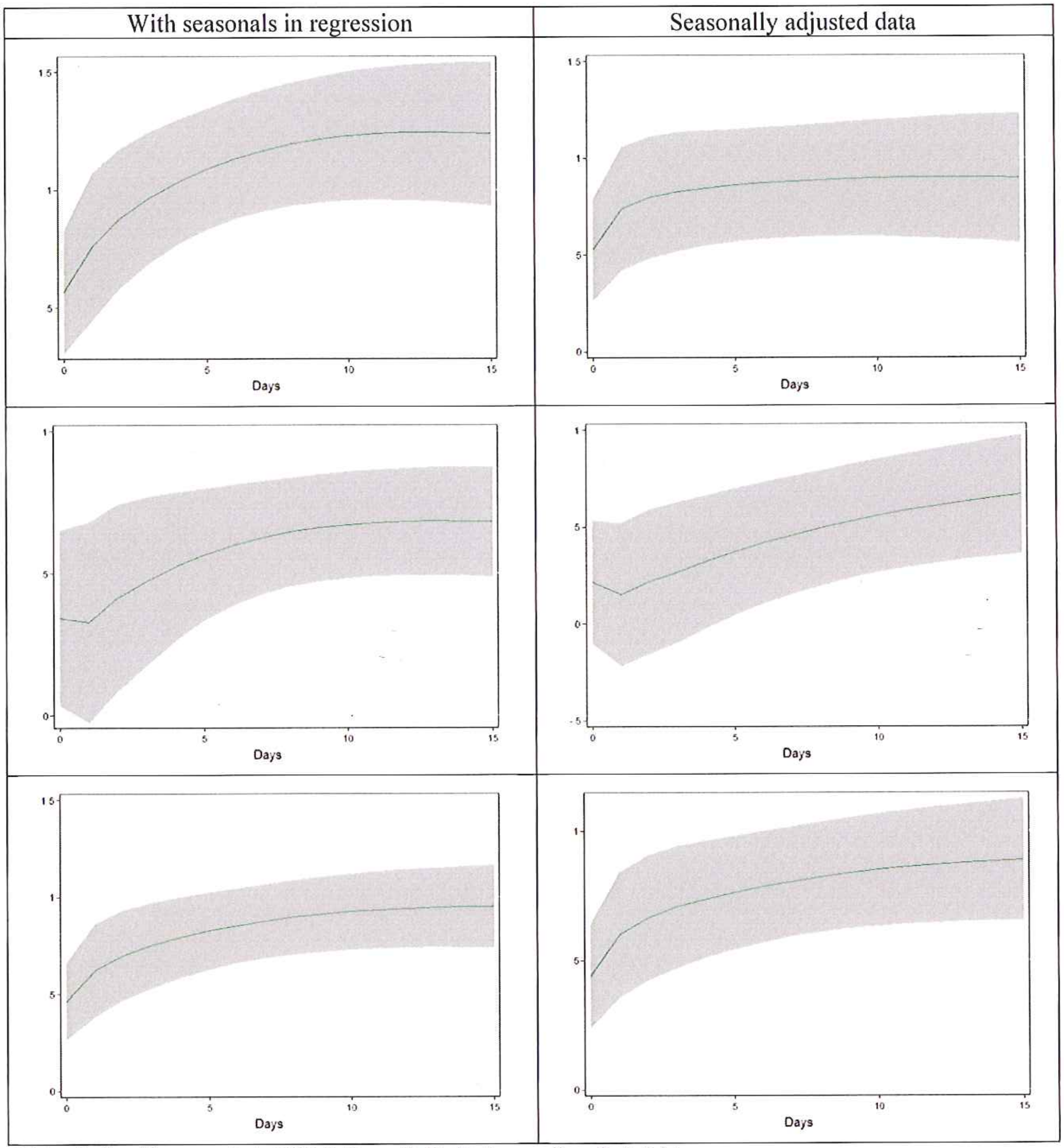
Notes: upper panels present spreads (green), KMS-sample predicted values (orange), and predicted under full pass through (blue), for seasonally unadjusted data/seasonals in model (left) and seasonally adjusted data (right). Middle left is scatterplot of weekly changes in spread on weekly changes in RIN obligation. Remaining panels are VAR impulse response presenting dynamic response of a change in the RIN obligation price on the spread, estimated using seasonally-adjusted data, in the KMS sample (middle-right), OOS (bottom-left), and full sample (bottom right).

Figure 6. Results for LA RBOB spot – Brent



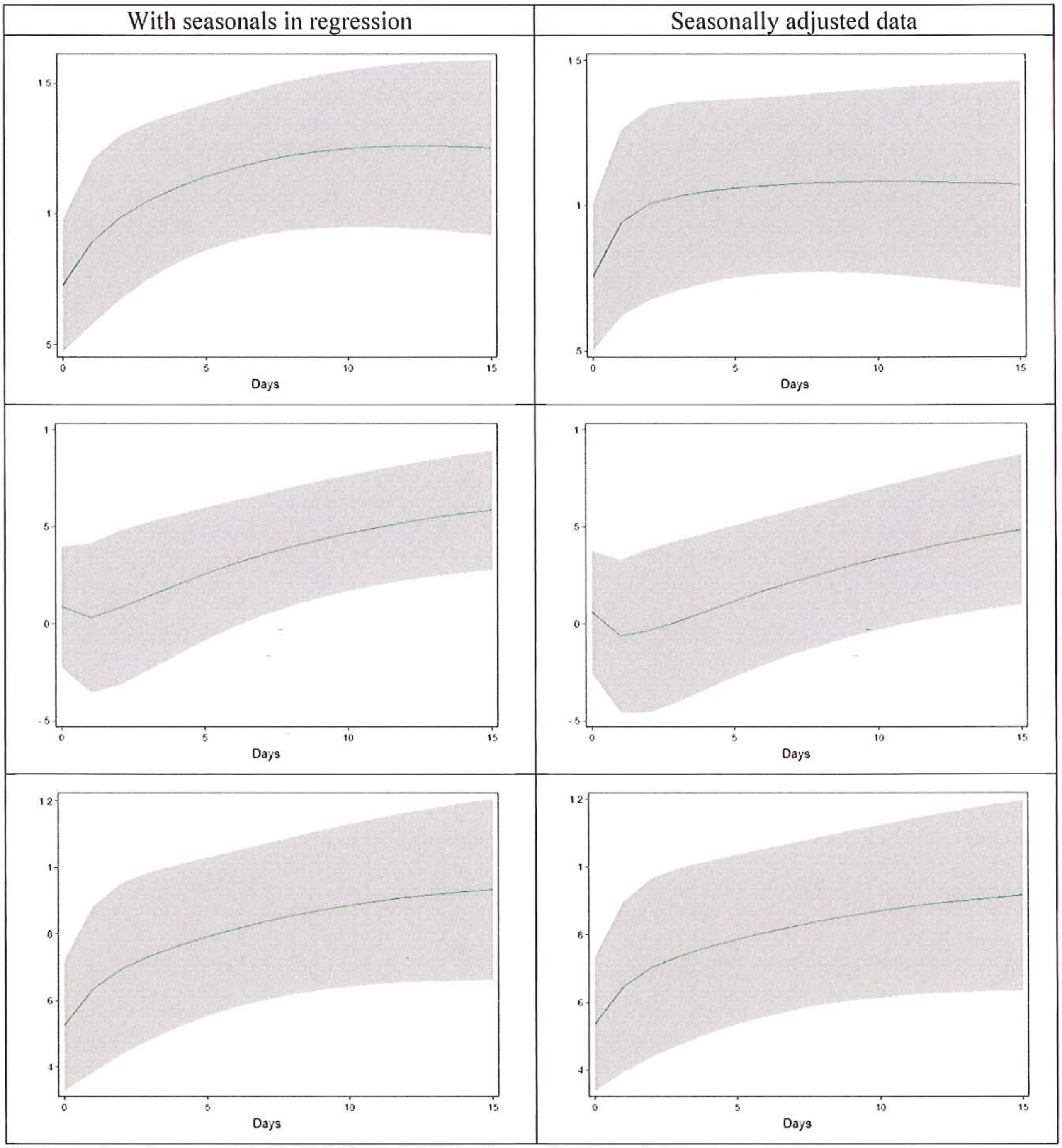
Notes: upper panels present spreads (green), KMS-sample predicted values (orange), and predicted under full pass through (blue), for seasonally unadjusted data/seasonals in model (left) and seasonally adjusted data (right). Middle left is scatterplot of weekly changes in spread on weekly changes in RIN obligation. Remaining panels are VAR impulse response presenting dynamic response of a change in the RIN obligation price on the spread, estimated using seasonally-adjusted data, in the KMS sample (middle-right), OOS (bottom-left), and full sample (bottom right).

Figure 7. Results for NYH CBOB spot – Rotterdam EBOB



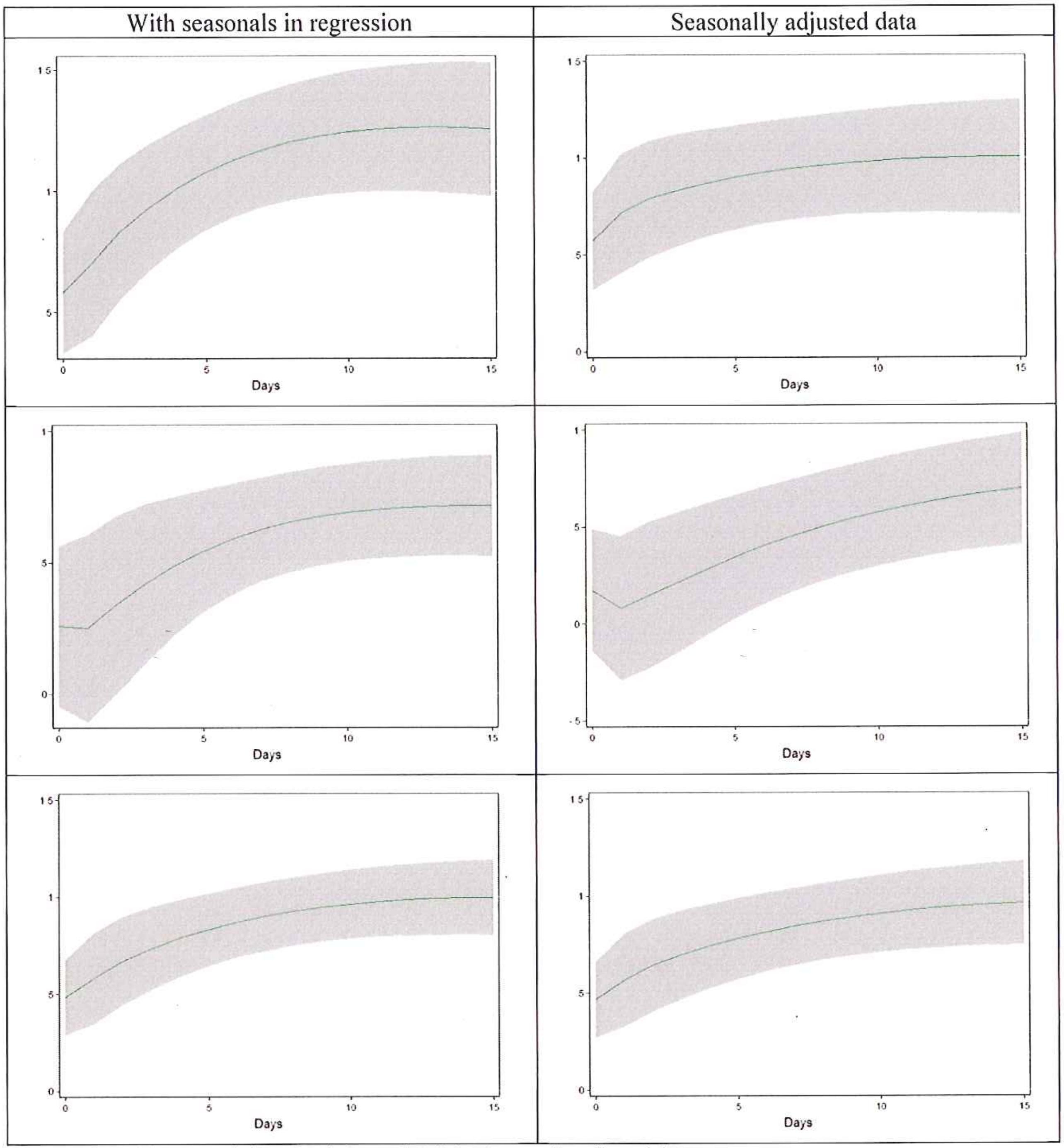
Notes: Left: with seasonals in VAR (left panel) Right: Seasonally-adjusted data
Top: KMS sample; Middle: post-09March2015. Bottom: full sample. *Note that the vertical scales vary across panels.*

Figure 8. Pooled impulse response functions: Diesel spreads



Notes: Left: with seasonals in VAR (left panel) Right: Seasonally-adjusted data
Top: KMS sample; Middle: post-09March2015. Bottom: full sample. *Note that the vertical scales vary across panels.*

Figure 9. Pooled impulse response functions: Diesel spreads + KMS original BOB spreads



Notes: Left: with seasonals in VAR (left panel) Right: Seasonally-adjusted data
Top: KMS sample; Middle: post-09March2015. Bottom: full sample. *Note that the vertical scales vary across panels.*

Figure 10. Pooled impulse response functions: Diesel spreads, NYH RBOB futures – EBOB, and NYH CBOB spot - EBOB

Table 1. Extended Sample: Estimated pass-through coefficients from levels fuel spread regressions (wholesale petroleum fuels only)

	Original KMS wholesale petroleum fuel spreads						**Additional**
Regression coefficients (standard errors):	**Gulf diesel– Gulf jet fuel**	**NYH diesel– Rott. diesel**	**Gulf diesel– Rott. diesel**	**NYH RBOB Fut –EBOB**	**NYH RBOB Fut –Brent**	**LA RBOB Spot –Brent**	**NYH CBOB Spot –EBOB**
01Jan2013-10Mar2015							
(1a) OLS, seasonals	1.159	1.565	0.818	0.682	1.086	0.711	0.903
	(0.154)	(0.424)	(0.142)	(0.332)	(0.310)	(0.701)	(0.278)
(2a) DOLS, seasonals	1.199	1.650	0.836	0.579	1.031	0.744	0.984
	(0.156)	(0.454)	(0.159)	(0.311)	(0.326)	(0.725)	(0.318)
(4a) OLS, SA data	1.059	0.628	0.603^^	0.952	1.436	1.906	0.799
	(0.225)	(0.469)	(0.185)	(0.353)	(0.477)	(0.749)	(0.181)
11Mar2015-14Nov2016							
(1b) OLS, seasonals	0.446^^^	1.045	1.834^^^	1.939^^^	-1.219^^	-7.007^^^	1.763^^
	(0.145)	(0.051)	(0.088)	(0.229)	(1.021)	(2.442)	(0.301)
(2b) DOLS, seasonals	0.466^^^	1.030	1.848^^^	2.018^^^	-1.225^^	-7.351^^^	1.748^^
	(0.149)	(0.052)	(0.093)	(0.253)	(1.030)	(2.460)	(0.312)
(4b) OLS, SA data	0.488^^	0.947	1.628	1.733	-1.282^^	-7.039^^^	1.750^
	(0.231)	(0.223)	(0.421)	(0.565)	(1.059)	(2.839)	(0.404)
01Jan2013-14Nov2016							
(1c) OLS, seasonals	0.800	1.158	1.408^^	1.152	0.951	-0.705	1.096
	(0.156)	(0.277)	(0.193)	(0.259)	(0.702)	(1.895)	(0.210)
(2c) DOLS, seasonals	0.828	1.179	1.428^^	1.145	0.887	-0.949	1.131
	(0.169)	(0.297)	(0.195)	(0.266)	(0.745)	(2.009)	(0.226)
(4c) OLS, SA data	0.943	0.731	1.117	1.129	1.102	0.305	1.075
	(0.152)	(0.310)	(0.268)	(0.280)	(0.574)	(1.322)	(0.203)
t-test for break (SA data)	-1.774*	0.610	2.238**	1.173	-2.347**	-3.054***	2.159**
Engle-Granger ADF test for cointegration	-4.232***	-4.526***	-4.592***	-5.646***	-3.054*	-3.983***	-7.019***

Notes: Regressions 1, 2, and 4 are regressions 1, 2, and 4 in KMS, Table 2. The *t*-tests in the final block test the hypothesis that the coefficients on the net RIN obligation are the same before and after 10Mar2015, maintaining constancy of the other coefficients in the regression. The final row reports the Engle-Granger Augmented Dickey-Fuller test for cointegration, computed over the full sample (rejection indicates cointegration). SA data are full-sample (through final series availability date) seasonally adjusted. Reported regression coefficients are significantly different from 1 at the ^10% ^^5% ^^^1% significance level. *t*-statistics reject the null at the ***1%, **5%, *10% significance level. See the notes to Table 2 of KMS.

Table 2. Pooled levels regressions for wholesale spreads

Regression coefficients (SEs):	**Diesel**	**Gasoline**	**Diesel and Gasoline**	**Five Refined Product Spread**
01Jan2013-09Mar2015				
(1) OLS, seasonals	1.181	0.826	1.003	1.026
	(0.154)	(0.268)	(0.114)	(0.109)
(2) DOLS, seasonals	1.228	0.785	1.007	1.049
	(0.164)	(0.283)	(0.121)	(0.113)
(4) OLS, seasonally adjusted data	0.764	1.431	1.098	0.808
	(0.211)	(0.305)	(0.158)	(0.149)
10Mar2015-14Nov2016				
(1) OLS, seasonals	1.108^^	-2.096^^	-0.494^^	1.406^^
	(0.055)	(1.074)	(0.554)	(0.088)
(2) DOLS, seasonals	1.115^	-2.186^^	-0.536^^	1.422^^
	(0.059)	(1.061)	(0.549)	(0.095)
(4) OLS, seasonally adjusted data	1.021	-2.196^^	-0.588^^	1.309
	(0.190)	(1.135)	(0.565)	(0.229)
01Jan2013-14Nov2016				
(1) OLS, seasonals	1.122	0.466	0.794	1.123
	(0.144)	(0.799)	(0.433)	(0.093)
(2) DOLS, seasonals	1.145	0.361	0.753	1.142
	(0.150)	(0.844)	(0.456)	(0.095)
(4) OLS, seasonally adjusted data	0.930	0.845	0.888	0.999
	(0.178)	(0.585)	(0.314)	(0.140)

Notes: This table extends regressions 1, 2, and 4 in KMS table 3 to the two new sample periods. All regressions are of the form of the spread in levels against its net RIN obligation in levels, with additional regressors. The diesel regressions pool three diesel spreads, the gasoline regressions pool three gasoline spreads, and the diesel and gasoline regressions pool all six spreads. The coefficient on the levels is constrained to be the same for the pooled spreads, but the other coefficients are allowed to differ across spreads. Standard errors are Newey-West with 30 lags and allow both for own- and cross-serial correlation in the errors. Reported regression coefficients are significantly different from 1 at the ^10%, ^^5%, and ^^^1% significance level. See the notes to Table 1.

Table 3. Pooled VARs: Cumulative structural impulse response functions, wholesale spreads

(a) Diesel spreads

	KMS data set (Jan. 1, 2013-March 9, 2015)				Full data set (Jan. 1, 2013-Nov. 14, 2016)			
	seasonals in VAR		seasonally adjusted data		seasonals in VAR		seasonally adjusted data	
Lag								
0	0.567	(0.266)	0.527^	(0.270)	0.464	(0.204)	0.441^^^	(0.206)
1	0.762	(0.319)	0.741	(0.328)	0.623	(0.244)	0.600	(0.248)
2	0.882	*(0.302)*	0.798	(0.324)	0.702	(0.236)	0.666	(0.247)
3	0.967	*(0.286)*	0.828	(0.316)	0.753	(0.225)	0.706	(0.241)
4	1.034	(0.271)	0.846	(0.305)	0.793	(0.212)	0.737	(0.232)
5	1.089	(0.263)	0.861	(0.298)	0.826	(0.203)	0.763	(0.225)
6	1.133	(0.261)	0.872	(0.295)	0.853	(0.198)	0.786	(0.220)
7	1.167	(0.264)	0.881	(0.295)	0.876	(0.195)	0.806	(0.218)
8	1.194	(0.268)	0.888	(0.298)	0.896	(0.195)	0.823	(0.218)
9	1.214	(0.274)	0.894	(0.303)	0.911	(0.197)	0.838	(0.219)
10	1.228	(0.280)	0.898	(0.309)	0.924	(0.199)	0.851	(0.222)

(a) Five refined product spreads

	KMS data set (Jan. 1, 2013-March 9, 2015)				Full data set (Jan. 1, 2013-Nov. 14, 2016)			
	seasonals in VAR		seasonally adjusted data		seasonals in VAR		seasonally adjusted data	
Lag								
0	0.583	(0.255)	0.574^	(0.259)	0.484	(0.198)	0.468^^^	(0.200)
1	0.702	(0.307)	0.717	(0.315)	0.581	(0.240)	0.566^	(0.244)
2	0.834	(0.288)	0.791	(0.309)	0.671	(0.232)	0.644	(0.243)
3	0.931	(0.269)	0.836	(0.298)	0.734	(0.217)	0.696	(0.234)
4	1.012	(0.253)	0.871	(0.284)	0.787	(0.202)	0.741	(0.222)
5	1.077	(0.244)	0.900	(0.275)	0.831	(0.191)	0.780	(0.213)
6	1.130	(0.241)	0.924	(0.270)	0.869	(0.184)	0.814	(0.207)
7	1.171	(0.243)	0.945	(0.269)	0.899	(0.181)	0.843	(0.204)
8	1.204	(0.246)	0.962	(0.270)	0.925	(0.180)	0.869	(0.203)
9	1.228	(0.251)	0.975	(0.273)	0.946	(0.181)	0.891	(0.203)
10	1.245	(0.257)	0.986	(0.277)	0.962	(0.183)	0.910	(0.205)

Notes: Entries are impulse responses, with standard errors in parentheses. VARs for all indicated spreads are constrained to have the same coefficients, including the same impact coefficient. All VARs have 2 daily lags and are estimated in levels. All spreads have the same net RIN obligation. The impulse response functions are identified by ordering the RIN obligation ordered first in a Cholesky factorization. Coefficients are statistically different from 1 at the ^10% ^^5% ^^^1% level.