An Examination of the Effects of Environmental Regulations on Retail Gasoline Price Seasonality

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PRELIMINARY VERSION: PLEASE DO NOT CITE

Over the last decade there has been much discussion of the rise in gasoline prices. Prices rose sharply in the middle of ‘00s. Also there has been a dramatic rise in the seasonal variation of prices since 2000. Figure 1 shows the difference between the national average June and January gasoline prices. From 1983 to 1999 there was variation from year to year, but the difference only hovered around 10 cents. Between 2000 and 2006, there was a sharp increase in the difference.

We examine one specific suspect for the cause of this increase, the Reformulated Gasoline Program (RFG). In 2000 Phase II of the RFG program went into effect. This regulation placed more stringent environmental requirements on gasoline during the summer than the winter.

Studies looking at gasoline price seasonality prior to 2000 find little evidence in support of seasonality. Davis and Hamilton (2004) find no evidence in support of seasonality, and Chouinard and Perloff (2007) find statistically significant but small evidence of seasonality. Davis (2009) examines seasonal adjustment of monthly average retail prices and finds that there is substantially more variation in prices since 2000 than before. Because of the lack of data available, since the post 2000 sample only included up to 2004, he does not find that the monthly dummy variables are significantly different from zero.

In addition to Davis’s (2009) examination of the seasonal components associated with the RFG program, other studies have found price effects of the RFG program. Bulow et al. (2003) show that the initiation of the RFG program was partially responsible for the price spikes that happened in the Midwest in 2000. Muehlegger (2006) find that it caused larger price spikes in Wisconsin, Illinois and California. Chakravorty, Nauges and Thomas (2008) find that wholesale prices increased in response to the RFG program. Walls and Rusco (2007) find that areas with the most unique requirements typically have the highest prices.

The finding of increased seasonality is important for researchers. In previous work the presence of seasonality was found not to exist or to be negligible, so researchers could ignore its implications. But in data from recent years, the seasonal variation is large enough that ignoring it when examining gasoline prices will likely cause error in their work.

Seasonality is also important for public policy decisions. Policy changes based on high gasoline prices should not be made because of short term fluctuations in June which will be corrected in October. Policy makers need to be aware of the seasonal pattern so that they do no make misguided short term corrections with long term impacts.

RFG PROGRAM

The 1990 Clean Air Act includes provisions for emission standards for motor gasoline. One of these programs is the Reformulated Motor Gasoline (RFG) program. The RFG program is designed to reduce smog as well as toxic chemicals from gasoline emissions. Phase I of the program went into effect in December, 1994. The EPA estimates that Phase I has reduced emissions of the chemicals leading to smog by 17% and toxic pollutants by 22% (Environmental Protection Agency, 1999a). Phase II of the RFG program went into place in January 2000 and placed even more stringent standards to reduce both smog and toxic emissions further.

Phase II of the RFG program increased the emissions standards with regard to three pollutants: Toxic Air Pollutants, Volatile Organic Compounds and Nitrogen Oxides. Of these, only the requirements for Toxic Air Pollutants became more stringent year round. For the other two pollutants, the requirements placed much more stringent requirements during the summer, so we expect an increase in seasonality in gasoline prices. For more information on the environmental impact of the RFG program see the United States Environmental Protection Agency (1999a, 1999b) and Linderdale and Bohn (1999).

Linderdale and Bohn estimate that Phase II of the RFG program would add 2.5 cents per gallon in RFG areas in the winter, 4 cents in the RFG Northern areas in the summer and 3.5 cents in RFG Southern states in the summer. These estimates suggest an increase in seasonality of 1 to 1.5 cents per gallon for areas under the RFG program and no suggestion of increased prices in non-RFG areas. So while these effects are predictable, the increase in seasonality is much greater than the a priori estimates.

There are a few reasons why we might see higher seasonality in fuel prices since the imposition of stricter standards. First, the gasoline under the stricter standard would be more expensive to produce. Some of that increase in costs would naturally be passed on to the consumer in the form of higher prices. A second scenario is that the different standards could lead to greater market power for the gasoline producers (Chakravorty, Nauges and Thomas, 2008; Walls and Rusco, 2008). The different types of gasoline required for different areas could cause the individual markets for each gasoline type to be small. This problem is exacerbated by the extensive and differing state and local regulations. There are extensive economies of scale in gasoline production, making it very difficult to produce a small amount of gasoline of a particular type. Taken together these two issues suggest that when the regulations are in place there should be an increase in price.

There could also be switchover costs associated with producing gasoline. We might see jumps in the price in March/April and August/September as firms switch from winter gasoline to summer gasoline and back again. During these months, many firms run down inventories to make way for the other type of gasoline (Bulow et al., 2003).

The RFG fuel seems to get lower gas mileage (Linderdale and Bohn, 1999). The lower gas mileage would increase demand, at least partially, leading to higher prices. It is not clear however that this effect has a seasonal component, as it might just be result of the RFG gasoline and not specifically the RFG summer or winter gasoline.

Most of the above reasons specifically relate to price changes at the refined or wholesale (or rack) level. Since we are examining retail data, we should expect most of the price effect to be passed through from the wholesale price to the consumers. However, an additional effect at the retail level could be that firms are less likely to change their prices. In particular, they may start to exhibit a more pronounced asymmetric pattern to their prices.

There are a number of reasons we might see an increased asymmetry in gasoline prices from the RFG program. Borenstein, Cameron and Gilbert (1997) suggest that an increase in asymmetry may be caused by inventory constraints. When faced with a downward shock, the firms simply keep prices the same and sell less, but when faced with an upward shock they must react immediately and possibly run out of gasoline. The requirements on selling particular fuels at certain times of year may lead firms to optimally keep lower inventories, exacerbating the inventory constraint. If the higher input prices drive retailers out of the market, market power could increase, which could lead to greater asymmetry (see Borenstein, Cameron and Gilbert, 1997; Brown and Yucel, 2000). Douglas and Herrera (2009) discuss the possibility of Reis's (2006) rational inattention on the parts of consumers leading to an increase in asymmetry for gasoline prices. When firms make more small upward changes in their price, consumers do not bother to check if it is still the lowest price. In this case, the increased wholesale prices are exacerbated because a slightly larger change in price is now a smaller percentage change in price from the point of view of the consumers.

METHODOLOGY

For this study we employ three methodologies.

OLS

For both the monthly national data and the daily individual stations we test to see if there is any change in seasonality by regressing the price on monthly dummy variables, using the following regression:

$$P_t^G = \alpha + \gamma' X_t + \varepsilon_t \qquad (1)$$

where P_t^G is the price of gasoline and X_t is a vector of seasonal dummies.

For the individual stations we also examine the pattern of seasonality in the markup of retail prices over wholesale prices. For the national data series we examine the pattern of seasonality of the oil prices to see whether the seasonal pattern is also exhibited upstream.

Error Correction Model

In trying to examine how much of the pattern is due to changes in the pattern in oil prices, we control for oil prices by using an error-correction model originally developed by Engle and Granger (1987). This approach used by Bachmeier and Griffin

(2004) to examine the responses of gasoline prices (P_t^G) to oil prices (P_t^O) uses the following system of equations:

$$P_t^G = \alpha + \beta P_t^O + z_t \tag{2}$$

$$\Delta P_t^G = \alpha + \beta_1 \Delta P_{t-1}^O + \beta_2 \Delta P_{t-2}^O + \beta_3 \Delta P_{t-1}^G + \beta_4 \Delta P_{t-2}^G + \theta z_{t-1} + \gamma' X_t + \varepsilon_t \tag{3}$$

where the residual of the first equation (z_t) is used as an explanatory variable in the second equation.

The inclusion of monthly dummies (X_t) into the second equation was added by Davis (2009). We will use Davis's model but with a slightly different time span to see if the results still exist with the extended data set.

Logit

With monthly average data, the price is changing every day. With daily retail prices, there are many days on which the firms do not change prices. For these data, an error-correction model which assumes a constantly changing price would be inappropriate. For data of this type Davis and Hamilton (2004) and Davis (2007) find that a logit model fits the data well. The logit is as follows:

$$\Pr(y_i = 1 \mid z_i, \beta) = \frac{e^{z_i' \beta}}{\left(1 + e^{z_i' \beta}\right)} \tag{4}$$

Specifically we will test whether there is a change in behavior in the way that firms change their prices not under the RFG summer program and under the RFG summer program. We look at the response of the data to the gap between the actual gasoline price and the frictionless gasoline price, using the asymmetric approach of Davis and Hamilton (2004),

$$\begin{aligned} \mathbf{z}_{it} &= [\theta_{it}, \theta_{it}(P_{i,t} - P^*_{i,t-m}), (1-\theta_{it}), -(1-\theta_{it})(P_{i,t} - P^*_{i,t-m}), \\ &\theta_{it} * RFGsummer, (1-\theta_{it}) * RFGsummer]' \end{aligned} \tag{5}$$

where θ_{it} is a variable that is 1 if the gap between the price and the frictionless price is positive and 0 otherwise. A new inclusion in this model is the allowance for a difference in reaction to the RFG summer period, the months in 2000 and 2001 in which the RFG program is in force. m represents the number of days since the last observation. If the number of days since the last observation exceeds three, then it is not used in the analysis. The most likely days to be missed from the data collection are Saturdays and Sundays which are also probably the days least likely to see a price change. A three-day gap seems a reasonable compromise to keep the Monday data in the data set.

The frictionless price is derived using the predicted values from the following regression:

$$P_t^G = \alpha + \beta_1 P_1^W + \gamma' X_t + \delta * RFG + \lambda' X_t * RFG + \varepsilon_t \quad (6)$$

where (P_t^G) is the station's price of gasoline (P_t^O) is the crude oil price, X_t is a vector of dummy variables representing the months and *RFG* is a dummy variable that is 1 in the years that the RFG is in effect (2000 and 2001). This equation varies from that of Davis (2007) in that it includes seasonal effect in calculating the frictionless price. The change is necessitated by the findings of Davis (2009) and in the work here. One series of variables that might make sense to include in the price, the days of the week, has been shown not to be significant in the price of gasoline (Hall, Lawson and Raymer, 2007). Davis (2010) did show that these variables can significantly affect the probability of a price change, but we excluded the variables to keep the model as simple as possible.

DATA

The gasoline prices for the entire United States are monthly average gasoline prices collected by the Energy Information Agency. The sample runs from 1976-2008, which is the time period currently available from the EIA. The oil prices are first purchase prices of crude oil, a monthly series provided by the EIA.

The individual station gasoline prices were obtained from Oil Price Information Services (OPIS). The data contain individual stations' daily prices, including the wholesale price, the retail price and the margin.

We are analyzing stations from six zip codes. The zip codes represent sections of six cities: Charleston, SC, Lansdale, PA, Scranton, PA, Norfolk, VA, Rolla, MO and St. Louis, MO. Three of the areas would be subject to the requirements of the RFG program. Norfolk, VA and St. Louis, MO are subject to the standards of the RFG South program.

Lansdale, PA, which is a suburb in the Philadelphia metropolitan area, is subject to the RFG North program. The other three cities are not subject to the RFG.

The six cities are not chosen at random, but selected for particular reasons. First, states with local regulations or the OXY program are excluded to keep the effects specific to the RFG program. Cities west of the Rocky Mountains are excluded as well because they tend to follow a different pattern of pricing relative to gas stations east of the Rockies. Charleston is selected because it represents one of the larger cities not affected by the RFG program. Norfolk is selected because it makes a nice parallel with Charleston but is subject to the RFG program. The Norfolk metropolitan area is larger than Charleston, but like Charleston it is a Southern port city. Another pair of cities is selected from Pennsylvania. Lansdale gives us a suburban city that is subject to the RFG regulation, while Scranton is a small city not subject to regulations. The last pair comes from Missouri, where we have the small rural city of Rolla, not subject to RFG regulations, combined with St. Louis which is subject to the regulations. Both cities (and specifically the part of the city in St. Louis which is selected) are located along the same Intestate, I-44. Since the data is supplied by zip code, we choose zip codes in which we expect many gasoline stations in them.

The quality of the data is quite uneven. Many of the individual stations do not have a large number of observations. We restrict the sample to only those stations which have at least 694 observations, representing at least two thirds of the weekdays during the four-year period. Table 1 provides summary statistics for the retail prices from the ten gasoline stations that are analyzed. Table 2 presents the same data for the rack prices that those stations pay for their gasoline. There is no apparent pattern relating the RFG program to the average price, which is to be expected. State and local factors, in particular taxes, will outweigh the importance of the RFG program when analyzing means. However, when comparing the prices during the RFG program months (the 2000 and 2001 summers) to the prices not during those periods, there does seem to be a difference in the change in prices. The non-RFG stations in Charleston and Scranton experience a smaller jump in both rack and retail prices than the RFG stations in Lansdale, Norfolk and St. Louis.

Interestingly, the Rolla stations exhibit a pattern similar to the RFG stations. One possibility is that Rolla is using the RFG gasoline obtained from wholesalers in St. Louis. We examine the correlation coefficient between the Phillips 66-branded Rolla 1 station and two other Phillips 66-branded stations in St. Louis. The two St. Louis stations' rack prices are perfectly correlated. Rolla 1's rack prices have correlation coefficients of .982 and .994 with the two stations. The lack of perfect correlation leaves open whether the Rolla station is getting its wholesale gasoline from St. Louis.

There are obviously a number of missing days in each series. To determine whether a change in price took place, we examine the price relative to the price from the preceding observation. This process is different from the assumptions made by Davis (2007) when working with OPIS data.

RESULTS

National Gasoline Results

We re-estimate the models from Davis (2009) to examine whether adding four more years of data changes the results with regard to the increase in seasonality. Table 3 presents the results of the regression equation using equation (1) explained above. The three gasoline columns are broken into separate time periods: 1976-2006, 1976-1999 and 2000-2008. These time periods vary from Davis's trio of 1974-2004, 1974-1999 and 2000-2004.[1] The results show the same pattern with regard to increasing seasonality. The same regression is performed on oil prices. The results for those regressions can be found in Columns (4)-(6). Again the results confirm Davis's earlier finding of greater seasonality in oil prices since 2006. Table 4 uses the error-correction framework shown in equations (2) and (3). These results show that there is an increase in gasoline-price seasonality beyond what can be attributed to oil prices.

Individual Gasoline Station Results

For the individual stations we regress the retail price and the margin on monthly dummies and a constant to see if there is a seasonal pattern. We break up the sample into

[1] The difference in time periods relates to slight differences in the data available at the time from the Energy Information Agency.

two time periods, before and after the RFG program is in place. First we examine the behavior of the prices (Tables 5-7). All of the stations show an increase in seasonality. The results do vary somewhat with regard to when the seasonality begins but in general all show prices peaking in the summer months.

The results for the margins are presented in Tables 8-10. Only three of the stations show an increase in the seasonality of gasoline price margins. Two of them are in areas in which the RFG program is in place. The station in Lansdale and the station in Norfolk show a significant pattern of seasonality in the price margin in the later sample. Among the non-RFG affected areas, only Rolla 2 shows an increase in seasonality in the margin and it is not as dramatic as for the two RFG affected areas. The rest of the stations in Charleston, Rolla and Scranton do not show much of a change in seasonality in the margins. The St. Louis station, unlike the other RFG-affected stations does not show an increase in seasonality.

After estimating the logit model of equations (4-6), the probability of a change is calculated for price differences between -20 and +20 cents. Since the price differences represent the actual minus the expected, a negative value implies a likely price increase, while a positive value implies a price decrease. In Figure 2, we present the findings for the non-RFG periods. The results show a pretty mixed picture with some firms exhibiting the standard asymmetry of raising their prices faster than they lower them. Some stations exhibit a reverse asymmetry, being more likely to make small upward changes and large downward changes. This result is usually explained by assuming that firms are worried about upsetting their customers (see Davis and Hamilton, 2004; Douglas and Herrera, 2009; Davis, 2007). In Figure 3, the periods when the RFG is in place are presented and the results are similar to Figure 2. A few firms exhibit a more pronounced asymmetry, such as Charleston 1. Figure 4 presents the difference in probabilities from Figures 3 and 2. From this figure we can see that the non-RFG stations increase their likelihood of raising prices much more than the RFG stations. Only the two Charleston stations exhibit a dramatic increase in their asymmetric response. In contrast, both the Norfolk and Lansdale stations increase their likelihood of making downward changes relative to upward changes.

DISCUSSION

We support previous findings that there has been an increase in seasonality in gasoline prices. The results from the individual gasoline stations also suggest that the seasonality is much more prevalent in 2000 and 2001 than in 1998 and 1999, supporting the contention that Phase II of the RFG program increased the seasonal variation in gasoline prices.

Wholesale price increases seem to be the primary cause fort the retail price increases, as many of the firms are not able to increase their margins during the summer. There is both evidence in support of the cost increase story at the wholesale level as the RFG firms experience the greatest increase in their wholesale price, and the market power story as all of the firms see some increase in their wholesale prices.

There are some interesting results at the retail level as well. Two firms increased their margins, but at the same time increased their probability of making downward changes relative to upward ones. Since these two stations are RFG stations, the inventory story is unlikely to be correct. The RFG stations would be the ones most likely to have to switch over from one gasoline to another and should therefore show the most marked upward asymmetry. The two Charleston stations seem to have increased their probability of making upward changes relative to downward changes. Since these two stations are non-RFG stations, this result is difficult to interpret.

CONCLUSION

We find support for increasing seasonality of gasoline prices following the imposition of the RFG Phase II program. We find some evidence supporting both the increasing costs of producing such gasoline and increasing market power of retailers through increases in wholesale gasoline prices. There also seems to be a substantial change in price dynamics at the retail level, but not one with a notable pattern across stations.

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Table 1: Description of Individual Stations' Retail Prices

Label	City	Brand	RFG	# of Obs	Mean	Station Name	Mean not RFG	Mean RFG
Charleston 1	Charleston	BP	None	859	122.26	Pantry	113.20	140.51
Charleston 2	Charleston	Hess	None	798	118.26	Ashley River	110.88	138.13
Rolla 1	Rolla	Phillips 66	None	743	115.08	MPC50	105.82	140.20
Rolla 2	Rolla	Unbranded	None	794	119.98	Delano	108.20	141.36
Scranton 1	Scranton	BP	None	880	129.64	Unimarts	121.45	151.75
Scranton 2	Scranton	Sunoco	None	838	132.41	S7th	124.69	150.35
Scranton 3	Scranton	Sunoco	None	1007	131.61	Stafford	123.37	152.10
Lansdale 1	Lansdale	Gulf	RFG North	833	127.88	North Penn	117.42	151.19
Norfolk 1	Norfolk	Texaco	RFG South	948	125.01	Suffolk	116.04	150.54
St. Louis 1	St. Louis	Shell	RFG South	726	126.32	Spirit	114.98	149.14

Table 2: Description of Individual Stations' Rack Prices

Label	City	Brand	RFG	# of Obs	Mean	Station Name	Mean not RFG	Mean RFG
Charleston 1	Charleston	BP	None	859	73.38	Pantry	65.68	88.88
Charleston 2	Charleston	Hess	None	798	73.04	Ashley River	65.61	88.32
Rolla 1	Rolla	Phillips 66	None	743	73.38	MPC50	64.28	98.04
Rolla 2	Rolla	Unbranded	None	794	75.83	Delano	65.94	98.53
Scranton 1	Scranton	BP	None	880	70.17	Unimarts	62.86	89.91
Scranton 2	Scranton	Sunoco	None	838	73.53	S7th	66.76	89.27
Scranton 3	Scranton	Sunoco	None	1007	71.39	Stafford	64.16	89.36
Lansdale 1	Lansdale	Gulf	RFG North	833	75.13	North Penn	64.98	95.86
Norfolk 1	Norfolk	Texaco	RFG South	948	72.48	Suffolk	63.61	97.61
St. Louis 1	St. Louis	Shell	RFG South	726	82.04	Spirit	70.10	106.07

Table 3: Ordinary Least Squares Regressions for National Gasoline Average

	Δ Gas 1976-2008	Δ Gas 1976-1999	Δ Gas 2000-2008	Δ Oil 1976-2008	Δ Oil 1976-1999	Δ Oil 2000-2008
Constant	-3.670 (1.717)	-0.896 (0.655)	-11.067 (5.716)	-0.952 (0.515)	-0.295 (0.261)	-2.701 (1.728)
January	3.704 (2.447)	0.039 (0.936)	13.378 (8.084)	1.215 (0.734)	0.266 (0.373)	3.712 (2.444)
February	4.382 (2.428)	0.183 (0.926)	15.578 (8.084)	1.185 (0.728)	0.044 (0.369)	4.227 (2.444)
March	6.882 (2.428)	0.242 (0.926)	24.589 (8.084)	1.336 (0.728)	0.073 (0.369)	4.704 (2.444)
April	9.318 (2.428)	3.450 (0.926)	24.967 (8.084)	1.564 (0.728)	0.580 (0.369)	4.188 (2.444)
May	8.333 (2.428)	3.367 (0.926)	21.578 (8.084)	1.562 (0.728)	0.413 (0.369)	4.627 (2.444)
June	5.082 (2.428)	2.129 (0.926)	12.956 (8.084)	1.441 (0.728)	0.665 (0.369)	4.879 (2.444)
July	3.118 (2.428)	0.596 (0.926)	9.844 (8.084)	1.529 (0.728)	0.828 (0.369)	4.508 (2.444)
August	2.921 (2.428)	1.413 (0.926)	6.944 (8.084)	1.067 (0.728)	0.665 (0.369)	2.138 (2.444)
September	4.509 (2.428)	1.167 (0.926)	13.422 (8.084)	0.862 (0.728)	0.828 (0.369)	0.950 (2.444)
October	-0.024 (2.428)	0.533 (0.926)	-1.511 (8.084)	0.456 (0.728)	0.681 (0.369)	-0.144 (2.444)
November	-0.903 (2.428)	0.483 (0.926)	-4.600 (8.084)	0.062 (0.728)	0.009 (0.369)	0.203 (2.444)

Standard errors in parentheses.
The gasoline data are measured in cents per gallon and the oil data are in cents per barrel.

Table 4: Error Correction Model for National Gasoline Average

	Δ Gas 1976-2008	Δ Gas 1976-1999	Δ Gas 2000-2008
Constant	-1.043 (1.015)	-0.381 (0.431)	-4.006 (3.425)
ΔOil	1.809 (0.134)	1.021 (0.124)	1.924 (0.265)
ΔOil(-1)	0.567 (0.179)	0.641 (0.166)	0.407 (0.401)
ΔOil(-2)	0.001 (0.197)	0.075 (0.162)	-0.497 (0.427)
ΔGas(-1)	0.294 (0.051)	0.320 (0.059)	0.334 (0.109)
ΔGas (-2)	-0.216 (0.053)	-0.192 (0.053)	-0.105 (0.112)
Z(-1)	-0.074 (0.019)	-0.020 (0.011)	-0.249 (0.071)
January	1.015 (1.427)	0.070 (0.611)	4.130 (4.760)
February	0.393 (1.434)	-0.023 (0.613)	0.749 (4.761)
March	3.022 (1.434)	0.140 (0.603)	9.662 (4.843)
April	4.415 (1.443)	2.825 (0.604)	10.331 (4.999)
May	3.407 (1.473)	1.609 (0.633)	9.823 (5.232)
June	1.399 (1.478)	1.394 (0.630)	2.774 (5.208)
July	0.082 (1.454)	0.186 (0.625)	2.028 (4.929)
August	0.375 (1.425)	0.837 (0.620)	2.585 (4.709)
September	2.148 (1.412)	-0.321 (0.606)	12.125 (4.629)
October	-1.962 (1.417)	-0.715 (0.606)	-2.105 (4.723)
November	-0.381 (1.219)	0.132 (0.604)	-1.553 (4.667)

Standard errors in parentheses.
The gasoline data are measured in cents per gallon

Table 5: OLS Regressions for Individual Stations' Prices (RFG Stations)

	Lansdale 1 (98 & 99)	Norfolk 1 (98 & 99)	St. Louis 1 (98 & 99)	Lansdale 1 (00 & 01)	Norfolk 1 (00 & 01)	St. Louis 1 (00 & 01)
Constant	113.11	112.80 (1.509)	102.6 (3.804)	117.71	119.64 (1.893)	116.57 (1.978)
January	-12.582 (2.536)	-11.125 (2.207)	-17.367 (3.804)	20.631 (2.654)	16.388 (2.643)	18.507 (3.002)
February	-17.034 (2.414)	-17.539 (2.259)	-17.008 (4.011)	18.983 (2.619)	18.335 (2.612)	20.650 (2.909)
March	-20.243 (2.435)	-16.780 (2.134)	-13.700 (3.637)	22.169 (2.619)	26.346 (2.533)	25.141 (2.888)
April	-13.064 (2.435)	-10.543 (2.161)	3.800 (3.716)	27.679 (2.692)	34.426 (2.598)	36.799 (2.888)
May	-8.624 (2.536)	-7.632 (2.191)	1.967 (7.521)	40.926 (2.587)	38.354 (2.584)	44.069 (2.869)
June	-6.957 (2.435)	-6.952 (2.147)	5.217 (4.135)	45.256 (2.558)	38.001 (2.612)	37.416 (2.782)
July	-7.207 (2.599)	-5.246 (2.279)	4.100 (3.034)	39.166 (2.712)	27.982 (2.799)	19.538 (3.002)
August	-1.249 (2.536)	-2.073 (2.134)	1.019 (2.980)	25.745 (2.558)	22.831 (2.584)	23.602 (2.738)
September	0.085 (2.536)	-4.327 (2.260)	4.670 (3.129)	21.264 (2.636)	23.073 (2.612)	33.276 (2.850)
October	0.524 (2.482)	-2.508 (2.176)	0.559 (3.129)	14.575 (2.558)	15.133 (2.557)	12.516 (2.814)
November	-4.278 (2.991)	-4.109 (2.344)	-4.644 (3.566)	5.703 (2.530)	7.589 (2.557)	5.659 (2.814)

Standard errors in parentheses.

Table 6: OLS Regressions for Individual Stations' Prices (Scranton Stations)

	Scranton 1 (98 & 99)	Scranton 2 (98 & 99)	Scranton 3 (98 & 99)	Scranton 1 (00 & 01)	Scranton 2 (00 & 01)	Scranton 3 (00 & 01)
Constant	115.11 (1.583)	117.93 (1.858)	120.36 (1..536)	134.85 (1.617)	132.36 (1.455)	135.57 (1.257)
January	-7.339 (2.312)	-21.780 (3.598)	-12.457 (2.241)	8.489 (2.272)	13.167 (2.145)	10.042 (1.884)
February	-13.839 (2.312)	-24.197 (3.127)	-19.582 (2.222)	12.140 (2.244)	12.048 (2.158)	8.009 (1.906)
March	-14.634 (2.222)	-23.830 (3.024)	-20.241 (2.142)	12.140 (2.185)	15.047 (2.087)	12.975 (1.863)
April	-9.261 (2.207)	-10.266 (3.186)	-14.931 (2.128)	15.101 (2.244)	17.229 (2.247)	13.995 (1.895)
May	-5.794 (2.239)	-7.173 (2.979)	-10.743 (2.172)	19.077 (2.244)	23.466 (2.199)	21.578 (1.895)
June	-5.692 (2.193)	-7.767 (3.074)	-10.432 (2.103)	21.842 (2.287)	23.204 (2.199)	20.284 (1.895)
July	-5.496 (2.292)	-11.471 (2.608)	-9.686 (2.172)	17.295 (2.372)	17.142 (2.185)	20.284 (1.918)
August	-2.331 (2.153)	-6.413 (2.608)	-8.222 (2.187)	12.119 (2.196)	11.495 (2.121)	11.196 (1.844)
September	-2.206 (2.292)	-6.063 (2.669)	-8.393 (2.241)	16.903 (2.258)	16.090 (2.2640	14.176 (1.918)
October	-2.071 (2.193)	-5.447 (2.572)	-7.720 (2.128)	8.153 (2.258)	11.211 (2.185)	7.668 (1.873)
November	-5.380 (2.492)	-7.430 (2.830)	-9.057 (2.379)	3.053 (2.258)	5.580 (2.133)	1.981 (1.884)

Standard errors in parentheses.

Table 7: OLS Regressions for Individual Stations' Prices (Charleston & Rolla Stations)

	Rolla 1 (98 & 99)	Rolla 2 (98 & 99)	Char. 1 (98 & 99)	Char. 2 (98 & 99)	Rolla 1 (00 & 01)	Rolla 2 (00 & 01)	Char. 1 (00 & 01)	Char. 2 (00 & 01)
Con	93.275 (1.709)	95.32 (1.707)	102.53 (1.560)	100.01 (1.843)	112.72 (2.407)	109.39 (2.133)	119.99 (1.546)	117.02 (1.603)
Jan	-4.513 (2.636)	-17.554 (3.209)	-19.063 (3.092)	-18.907 (3.121)	11.554 (3.138)	16.179 (2.914)	10.168 (2.279)	10.189 (2.317)
Feb	-7.981 (2.542)	-18.737 (2.957)	-20.190 (2.824)	-20.261 (3.274)	15.989 (3.190)	20.466 (2.945)	13.125 (2.279)	15.403 (2.391)
Mar	-7.875 (2.522)	-14.725 (2.780)	-15.907 (2.640)	-16.238 (2.745)	20.129 (3.138)	22.769 (2.945)	18.199 (2.253)	18.686 (2.291)
Apr	0.730 (3.012)	5.329 (2.907)	-1.884 (2.724)	-4.869 (2.816)	19.275 (3.321)	26.684 (2.979)	26.081 (2.279)	26.044 (2.463)
May	7.125 (3.558)	5.722 (2.861)	-2.034 (2.824)	-3.274 (3.366)	35.149 (3.250)	41.436 (3.016)	29.186 (2.321)	31.103 (2.391)
Jun	3.773 (2.692)	5.779 (3.740)	-2.034 (2.724)	-6.107 (2.999)	41.921 (3.321)	44.036 (2.962)	25.663 (2.293)	25.982 (2.278)
Jul	5.219 (2.564)	2.095 (2.547)	-2.664 (2.336)	-6.403 (2.631)	16.558 (3.374)	20.243 (3.057)	14.741 (2.253)	14.530 (2.303)
Aug	2.883 (2.586)	2.023 (2.448)	-3.180 (2.336)	-3.569 (2.657)	18.538 (3.155)	23.308 (2.929)	12.352 (2.186)	13.082 (2.330)
Sep	6.589 (2.663)	7.579 (2.621)	-4.051 (2.567)	-5.107 (2.563)	33.317 (3.209)	36.092 (3.036)	17.622 (2.241)	17.814 (2.291)
Oct	2.366 (2.692)	5.758 (2.399)	0.580 (2.449)	-1.137 (2.489)	17.694 (3.272)	22.297 (3.057)	16.232 (2.424)	10.112 (2.291)
Nov	-3.232 (2.913)	2.544 (2.595)	-3.253 (2.680)	-2.695 (2.999)	10.211 (3.321)	8.243 (3.057)	0.613 (2.218)	3.334 (1.603)

Standard errors in parentheses.

Table 8: OLS Regressions for Individual Stations' Margins (RFG Stations)

	Lansdale 1 (98 & 99)	Norfolk 1 (98 & 99)	St. Louis 1 (98 & 99)	Lansdale 1 (00 & 01)	Norfolk 1 (00 & 01)	St. Louis 1 (00 & 01)
Constant	8.229 (0.690)	20.189 (0.635)	10.699 (0.707)	3.215 (0.930)	11.880 (0.951)	11.467 (0.986)
January	-2.027 (1.026)	-3.471 (0.929)	-0.654 (1.354)	3.626 (1.401)	0.851 (1.328)	-3.776 (1.496)
February	-1.380 (0.976)	-6.039 (0.951)	2.004 (1.427)	-0.352 (1.383)	-2.147 (1.313)	-4.361 (1.449)
March	-7.064 (0.985)	-9.378 (0.898)	-4.754 (1.294)	1.482 (1.383)	2.244 (1.273)	-1.759 (1.439)
April	-6.698 (0.985)	-9.823 (0.910)	2.083 (1.322)	-0.904 (1.421)	3.446 (1.306)	2.829 (1.439)
May	-3.574 (1.026)	-7.605 (0.922)	-2.747 (2.676)	0.515 (1.366)	1.547 (1.299)	-5.975 (1.429)
June	-0.546 (0.985)	-5.248 (0.904)	-0.738 (1.471)	10.994 (1.350)	6.703 (1.313)	-1.257 (1.386)
July	-2.900 (1.051)	-5.126 (0.959)	-0.892 (1.080)	20.929 (1.432)	7.148 (1.407)	5.155 (1.496)
August	-1.725 (1.026)	-3.594 (0.898)	-2.332 (1.060)	4.683 (1.350)	0.010 (1.299)	-1.914 (1.364)
September	-2.891 (1.026)	-4.896 (0.951)	-0.475 (1.114)	-0.738 (1.392)	0.627 (1.313)	0.349 (1.420)
October	-0.371 (1.004)	-4.229 (0.916)	-0.373 (1.114)	4.783 (1.350)	5.376 (1.285)	-1.379 (1.402)
November	1.165 (1.026)	-0.666 (0.987)	3.026 (1.269)	-0.218 (1.336)	1.310 (1.285)	-3.490 (1.402)

Standard errors in parentheses.

Table 9: OLS Regressions for Individual Stations' Margins (Scranton Stations)

	Scranton 1 (98 & 99)	Scranton 2 (98 & 99)	Scranton 3 (98 & 99)	Scranton 1 (00 & 01)	Scranton 2 (00 & 01)	Scranton 3 (00 & 01)
Constant	15.714 (0.643)	11.974 (0.365)	15.786 (0.509)	18.283 (0.897)	16.301 (0.669)	19.468 (0.844)
January	0.212 (0.939)	0.352 (0.706)	-0.445 (0.742)	-3.647 (1.260)	-0.718 (0.986)	-3.975 (1.265)
February	-2.927 (0.939)	0.161 (0.614)	-2.310 (0.736)	-7.810 (1.245)	-4.861 (0.992)	-9.134 (1.280)
March	-6.225 (0.903)	-6.140 (0.594)	-6.329 (0.710)	-5.757 (1.212)	-3.734 (0.960)	-5.850 (1.251)
April	-7.469 (0.896)	-3.796 (0.625)	-8.002 (0.705)	-6.353 (1.245)	-3.812 (1.033)	-8.320 (1.273)
May	-5.761 (0.909)	-1.564 (0.585)	-5.341 (0.719)	-8.917 (1.245)	-5.316 (1.011)	-10.534 (1.273)
June	-4.006 (0.891)	-1.144 (0.603)	-3.228 (0.697)	-0.931 (1.268)	0.571 (1.011)	-0.556 (1.273)
July	-5.854 (0.931)	-5.773 (0.512)	-5.191 (0.719)	6.677 (1.315)	6.002 (1.005)	9.760 (1.288)
August	-5.875 (0.874)	-4.237 (0.512)	-7.432 (0.725)	-2.573 (1.218)	-3.077 (0.975)	-2.999 (1.238)
September	-7.131 (0.931)	-5.223 (0.524)	-8.938 (0.742)	-2.713 (1.252)	-4.222 (1.041)	-5.471 (1.288)
October	-7.429 (0.891)	-3.383 (0.505)	-7.618 (0.705)	-0.642 (1.252)	-0.247 (1.005)	-1.654 (1.258)
November	-4.358 (1.012)	-0.651 (0.555)	-3.662 (0.788)	-4.010 (1.252)	-2.686 (0.980)	-3.587 (1.265)

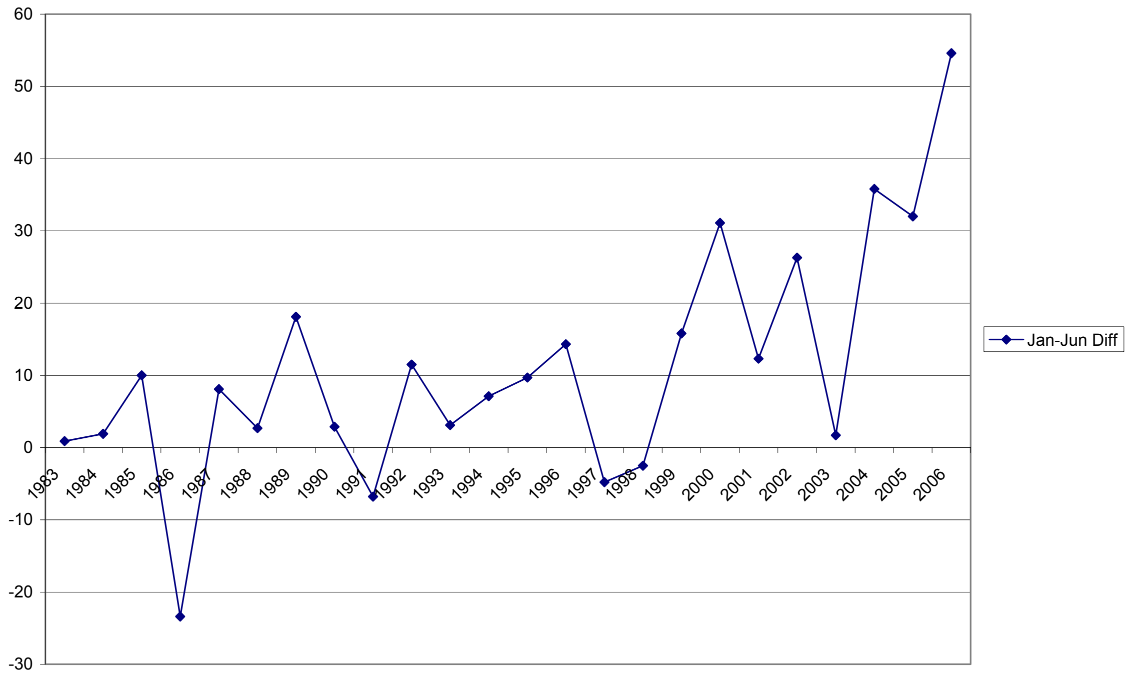
Standard errors in parentheses.

Table 10: OLS Regressions for Individual Stations' Margins (Charleston & Rolla Stations)

	Rolla 1 (98 & 99)	Rolla 2 (98 & 99)	Char. 1 (98 & 99)	Char. 2 (98 & 99)	Rolla 1 (00 & 01)	Rolla 2 (00 & 01)	Char. 1 (00 & 01)	Char. 2 (00 & 01)
Con	4.896 (0.767)	5.721 (0.617)	12.579 (0.405)	10.830 (0.466)	5.188 (1.086)	4.539	15.658 (0.848)	14.649 (0.933)
Jan	1.503 (1.183)	-3.343 (1.160)	-4.649 (0.802)	-3.976 (0.789)	-1.960 (1.416)	-0.990 (1.351)	-6.682 (1.250)	-10.056 (1.348)
Feb	-1.016 (1.141)	-3.943 (1.069)	-3.965 (0.733)	-4.708 (0.828)	-3.994 (1.439)	-2.329 (1.365)	-8.300 (1.250)	-7.091 (1.391)
Mar	-4.921 (1.131)	-10.853 (1.005)	-9.135 (0.685)	-9.179 (0.694)	-0.091 (1.416)	0.359 (1.365)	-1.880 (1.236)	-2.525 (1.333)
Apr	-1.055 (1.351)	1.305 (1.051)	-4.826 (0.707)	-6.671 (0.712)	-0.571 (1.498)	-0.621 (1.381)	1.610 (1.250)	-0.684 (1.433)
May	3.299 (1.597)	3.391 (1.034)	0.058 (0.733)	-5.704 (0.851)	-2.553 (1.466)	-0.629 (1.398)	-1.750 (1.273)	-2.718 (1.391)
Jun	1.857 (1.208)	4.004 (1.352)	-2.757 (0.707)	-6.335 (0.758)	5.018 (1.498)	7.928 (1.373)	2.274 (1.257)	1.925 (1.326)
Jul	-0.176 (1.150)	-2.159 (0.920)	-4.308 (0.606)	-6.464 (0.665)	2.588 (1.523)	3.916 (1.417)	2.379 (1.236)	1.620 (1.431)
Aug	-1.687 (1.161)	-2.236 (0.885)	-4.752 (0.606)	-5.614 (0.672)	-5.769 (1.423)	-5.915 (1.358)	-4.335 (1.199)	-4.965 (1.356)
Sep	0.095 (1.195)	-0.180 (0.947)	-6.643 (0.666)	-6.841 (0.629)	1.028 (1.448)	2.124 (1.408)	-3.578 (1.229)	-4.301 (1.333)
Oct	-0.205 (1.208)	3.603 (0.867)	-1.242 (0.636)	-2.411 (0.758)	-0.329 (1.476)	3.522 (1.417)	2.844 (1.330)	1.465 (1.333)
Nov	1.271 (1.307)	5.948 (0.938)	2.798 (0.696)	-0.166 (0.466)	-1.135 (1.498)	-0.985 (1.417)	-4.968 (1.216)	-4.120 (1.431)

Standard errors in parentheses.

Figure 1: Difference between June and Jan Retail Gasoline Prices (1983-2006)



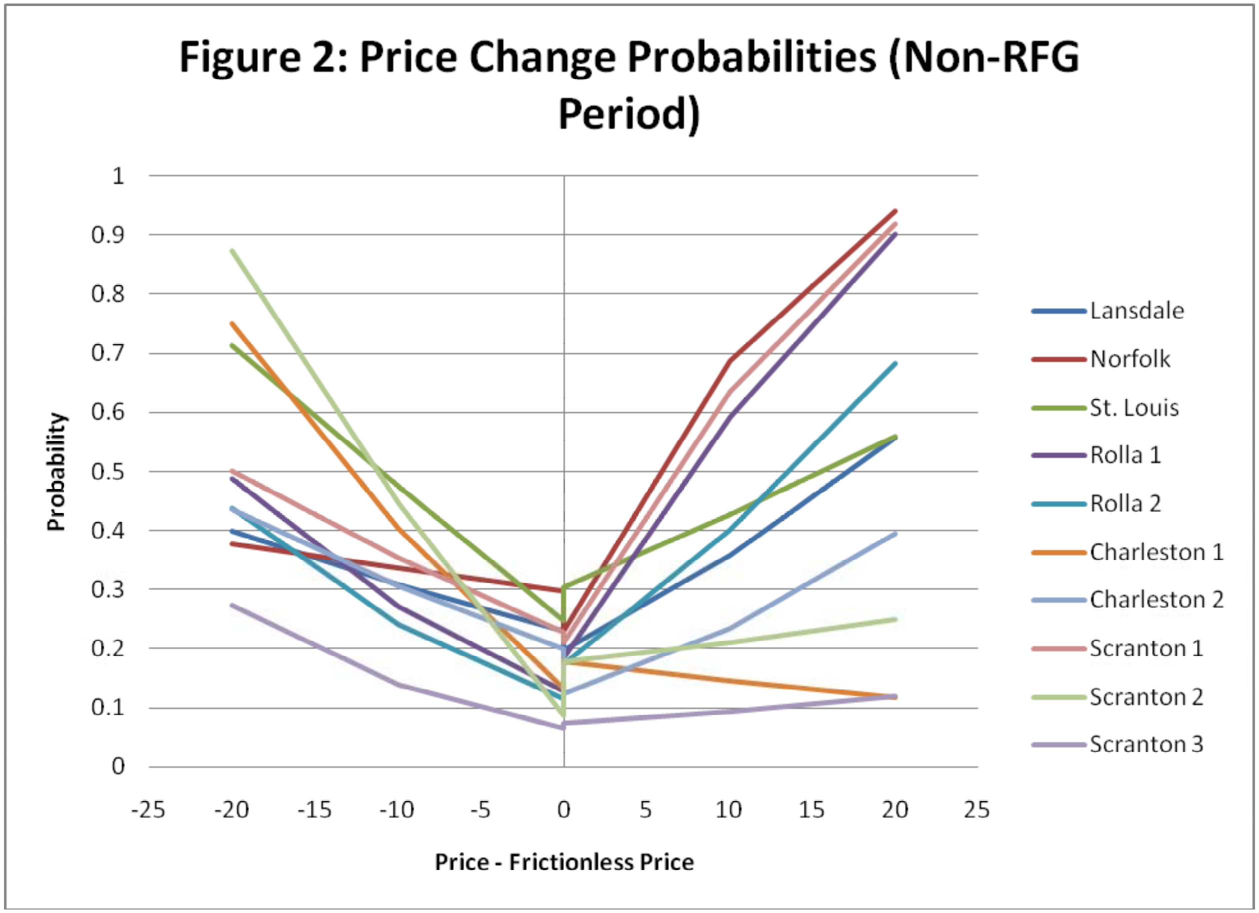


Figure 2: Price Change Probabilities (Non-RFG Period)
Probability
Price - Frictionless Price
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
-25
-20
-15
-10
-5
0
5
10
15
20
25
Lansdale
Norfolk
St. Louis
Rolla 1
Rolla 2
Charleston 1
Charleston 2
Scranton 1
Scranton 2
Scranton 3

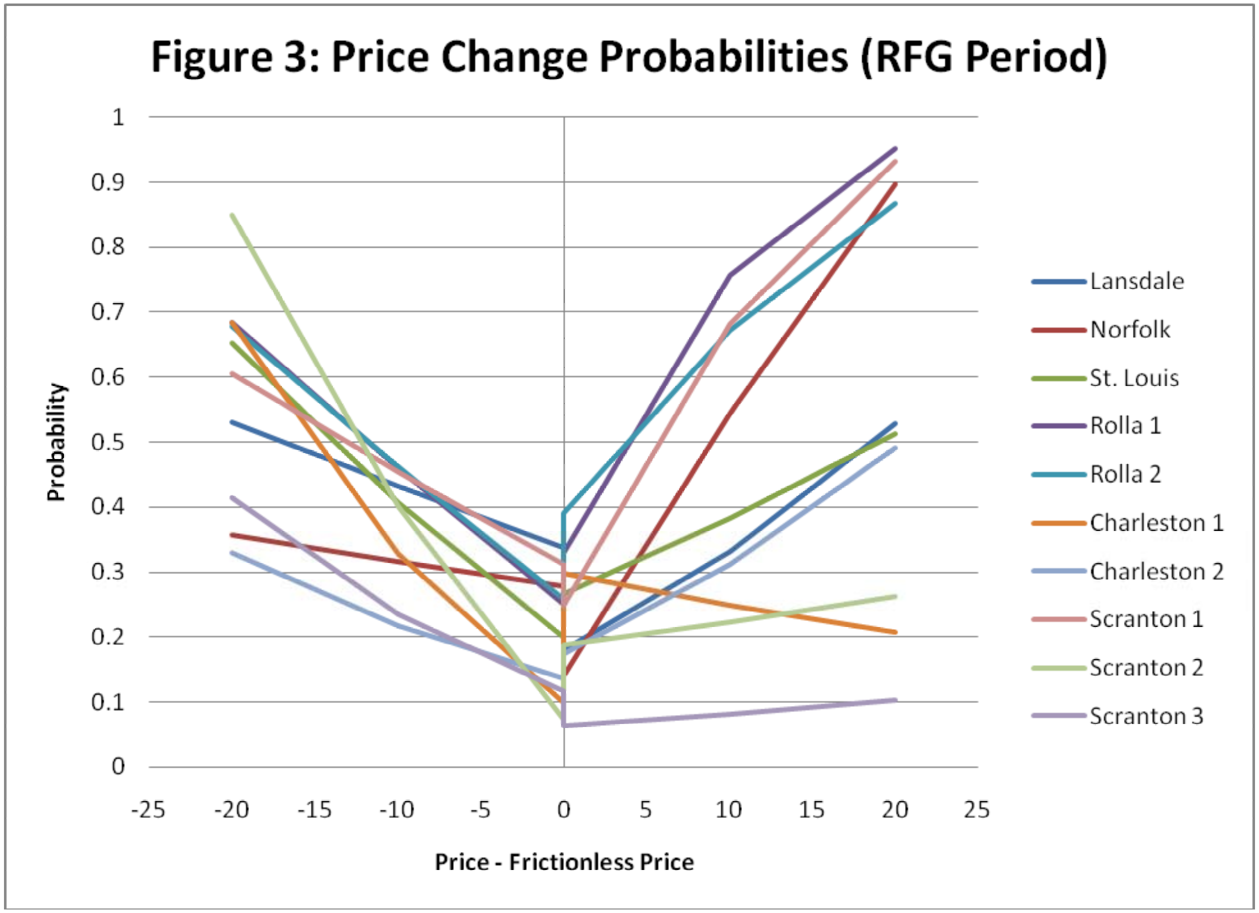


Figure 3: Price Change Probabilities (RFG Period)
Probability
Price - Frictionless Price
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
-25
-20
-15
-10
-5
0
5
10
15
20
25
Lansdale
Norfolk
St. Louis
Rolla 1
Rolla 2
Charleston 1
Charleston 2
Scranton 1
Scranton 2
Scranton 3

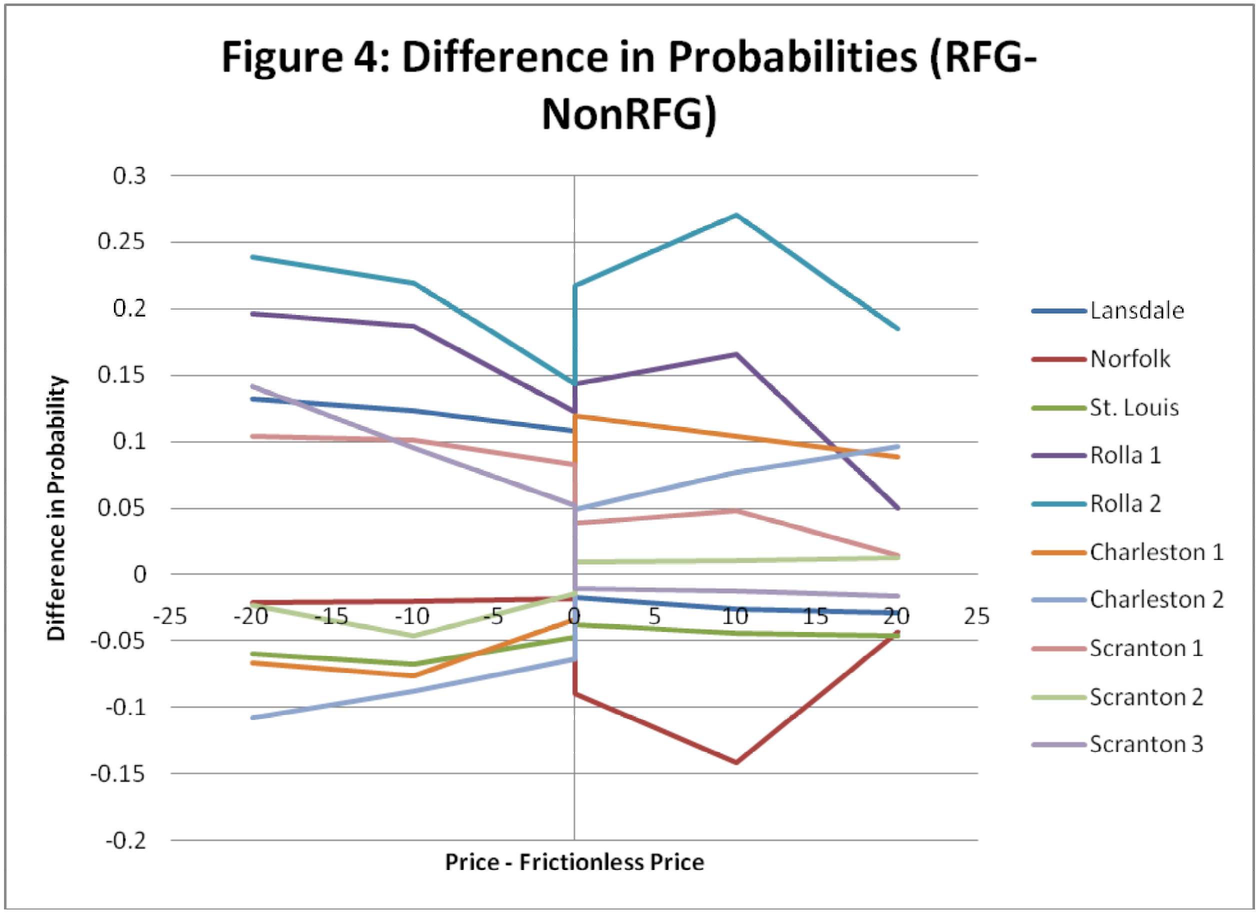


Figure 4: Difference in Probabilities (RFG-NonRFG)
0.3
0.25
0.2
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
-0.2
-25
-20
-15
-10
-5
0
5
10
15
20
25
Difference in Probability
Price - Frictionless Price
Lansdale
Norfolk
St. Louis
Rolla 1
Rolla 2
Charleston 1
Charleston 2
Scranton 1
Scranton 2
Scranton 3