

Market Power and Second Degree Price Discrimination in Retail Gasoline Markets

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January 28, 2019

Abstract

Empirical evidence of ‘quality-based’ second degree price discrimination is scarce. The co-existence of regular-grade 10% ethanol-blended gasoline (E10) and regular-grade non-blended gasoline (E0) in a major metropolitan city allows for second degree price discrimination to be examined while eliminating the issue of endogenous product differentiation because the two blends of gasoline are near-perfect substitutes. Using a unique data set including daily price information for 402 retailers that sell only E0 gasoline, only ethanol-blended E10 gasoline, or both blends simultaneously, I find evidence that retailers use second degree price discrimination to segment the population between perceived lower and higher quality gasoline; despite the fact that both blends can safely be used in nearly all vehicles. Additionally, I uncover two elasticities of demand for gasoline and discuss the welfare effects of price changes and market segmentation.

JEL Codes: D22, L11, Q41

Keywords: Price Discrimination; Gasoline; Ethanol; Renewable Fuel Standard

*I acknowledge funding from the University of Central Oklahoma’s Student Transformative Learning Record (STLR), a Department of Education Title III grant program.

1 Introduction and Background

Second degree price discrimination or ‘quality-based’ price discrimination is a theoretical mainstay in the industrial organization field. However, empirical evidence of quality-based second degree price discrimination remains somewhat of an enigma due to precision issues, endogenous product differentiation, endogeneity of menu choices, and the sheer existence of product variants. For example, were power windows in cars introduced as an add-on feature due to latent consumer demand, or does consumer demand only exist because suppliers introduced power windows? What percentage of credit should be assigned to demanders or suppliers for the introduction of power windows? Further, are cars with power windows (or leather seats, or any other ‘upgrade’) too different from cars without power windows to truly discuss price discrimination? This type of quality-based price discrimination can be seen throughout the ‘damaged goods’ literature which was formalized by Mussa and Rosen (1978) and popularized with Deneckere and Preston McAfee (1996). Damaged goods are products that are deliberately ‘damaged’ to lower quality versions of themselves so that firms may offer a menu of product qualities and price choices. By offering targeted price-quality packages firms are able to raise profitability and extract consumer surplus without full information on the consumer (first degree price discrimination) nor an identifying characteristic to segment consumers into groups (third degree price discrimination). Deneckere and Preston McAfee (1996) mostly discuss differences in computer chip capacities, and their prices, to show how firms are able to segment their customer base and become more profitable. Historical railway regulation of third class passenger cars that were roofless while the other two classes of train cars were properly roofed shows just how far price discrimination and endogenous product differentiation can go.¹

Using the co-existence of 10% ethanol-blended regular-grade gasoline (commonly referred to as E10) and non-blended regular-grade gasoline (“E0”) in a major metropolitan area I am able to circumvent the issue of endogenous product differentiation and arbitrage because the two non-durable goods are near-perfect physical substitutes.² Both types of gasoline have the same octane rating, and both are marketed as ‘regular-grade’ gasoline (while midgrade and premium are also offered). Indeed, in nearly every other state in the United States you are not able to make a choice between E0 or E10 because only E10 is provided. According to the Energy Information Administration (EIA), E10 makes up more than 95% of the fuel consumed in vehicles with gasoline-run engines. Moreover, the market share of E0 among

¹See the Railway Regulation Act of 1844 in the United Kingdom.

²There is a small energy efficiency difference between E10 and E0 that I discuss and account for below.

all gasoline sales has been in decline from its already small market share. Despite the broad-acceptance, and in most cases full switch to E10, gas stations in Oklahoma City are nearly evenly split between E0 and E10 with an array of stations that sell either only E10, only E0, or both types simultaneously.

The dual existence of E0 and E10 persists despite the fact that the EPA has stated that E10 can safely be used in nearly all vehicles.³ Notwithstanding broad vehicle compatibility, there is a substantial population that believes E10 is a lower quality fuel than non-blended regular gasoline - especially in Oklahoma (Ulmer et al. (2004)). The impetus of this belief could be due to reports about vehicle damage or mislabeling⁴, the fact that E10 cannot be used safely in other gas-run motors (e.g. lawn equipment), or a sort of regional pride due to the heavy presence of the oil and gas industry. I remain agnostic to the origins of ethanol aversion and instead take as given that ethanol-blended fuels are viewed by some as a lower quality fuel. I am thus able to use the unique retail gasoline market in Oklahoma City as a way to investigate differences in market power and price discrimination between two goods that are homogeneous and only vary in perceived quality.

To preview results, I find that E0 is able to command a price-premium over E10 without cost-based justifications. The E0 price premium is approximately 13.4 cents per gallon, 8.3% higher. The price premium is 7.5 cents per gallon after accounting for energy content differences. I further find that retailers that offer both E10 and E0 at the same station charge a lower price on E0 than their E0-only competitors in order to persuade the marginal consumer to reveal their preferences and purchase E0. The results of such pricing behavior has implications for firm-level sales as well as aggregate fuel sales. I conservatively approximate station-level elasticities of demand and find that stations selling both fuels are able to increase sales of E0 by more than 5% due to price discrimination. Further, because E0 sells at a price premium I find that aggregate fuel sales are lower by more than 15 million gallons per year depending on the share of the population that consumes only E0 and the aggregate elasticity of demand.

Beyond providing a new empirical example of a theoretical mainstay, the present paper offers an example of potential future market responses outside of Oklahoma due to changing Renewable Fuel Standard (RFS) ethanol requirements and the ‘blend-wall’. In order to achieve increasing ethanol volume requirements set out by the RFS, the EPA has approved the sale of E15, a 15% ethanol blend, for some vehicles. Warranty and vehicle damage con-

³‘Classic cars’ or those produced prior to the 1970’s are not able to use E10.

⁴See Chandler (n.d.) and *Equipment error leads to excess ethanol in local gasoline* | *News OK* (n.d.) for just two examples of ethanol reporting in the region.

cerns abound with this fuel, and public information regarding higher blends of ethanol fuel are wanting if the history of confusion and E85 sales may serve as an indicator (Liao et al. (2016)). Too, Qiu et al. (2014) shows that an unintended consequence of relaxing the blend-wall and moving to E15 may actually lead to more petroleum-based gasoline consumption. As E15 becomes more prevalent, and if E10 continues to exist in these same markets as a near perfect substitute, then the results of this paper indicate that firms will be able to charge higher premiums on lower ethanol blends, and that firms that offer both fuel-types simultaneously may price discriminate between the two blends.

1.1 Prior Literature

Despite a robust literature discussing market power and the ability to extract consumer surplus and raise profit margins by using quality-based price discrimination, econometric evidence of such pricing is scant. The reasoning behind this is that identification among differentiated products is difficult. Or as Clerides (2004) notes, “[i]t is important to keep in mind that the identification of price discrimination becomes increasingly tenuous the further one moves away from a world of homogeneous products and equal costs” (Clerides (2004)).

Verboven (2002) comments on the dearth of empirical evidence of quality-based price discrimination when discussing tax incidence and sales of gasoline and diesel cars in Europe. This author finds that diesel vehicles sell at a premium consistent with price discrimination. Busse and Rysman (2005) discuss the non-linearity in prices for space in yellow page advertising. They find that as the amount of competitors increase (other directory services), the price for large ads decreases relative to smaller ads. The prior finding is indicative of quantity-based discrimination which closely resembles quality-based discrimination. Clerides (2002) discusses quality-based price discrimination between hard and soft cover books. He finds that margins are a stronger indicators of price discrimination. Leslie (2004) uses differences in Broadway theater ticket pricing and runs simulated experiments to compare the welfare effects of second and third degree price discrimination. The most closely related study to the present paper is Shepard (1991) in which pricing discrimination between self-service and full-service gas stations is investigated. Shepard (1991) finds that stations that offer both types of service at one location use non-linear price schedules to segment their customer population and drive high-end consumers to their full-service product.

The majority of the retail gasoline literature is focused on regular grade gasoline as regular typically accounts for 70-90% of gasoline sales at the station-level (Noel (2016)),

and currently 87% of all fuel sales in the United States.⁵ There are a few exceptions to this literature, however, that are pertinent to the present research because they look into non-linear pricing differences between fuel grades. Borenstein (1991) shows that there were higher margins on unleaded versus leaded gasoline during the transition away from leaded gasoline, and that this may have resulted from price discrimination. Borenstein notes that the impetus behind this likely occurred because firms knew that vehicles that used unleaded were newer, and hence may have been owned by wealthier individuals. Leach et al. (2008) show that midgrade and premium prices are generally set as fixed price-differentials over regular, but note that grade pricing is non-linear in octane-rating. Although midgrade gasoline is simply a 50-50 blend of regular and premium grades, midgrade generally sells for more than the average of its two constituent prices. Setiawan and Sperling (1993) discuss purchasing decisions between different fuel grades. Interestingly, premium grade gasoline is considered by consumers to be a higher quality fuel, even though there is no engineering evidence to support it. The defining difference between grades is the octane rating, and vehicles that do not require a higher octane fuel to avoid engine knock do not require, nor benefit, from choosing premium fuel over of regular (or midgrade). The authors find that consumers are over-purchasing both midgrade and premium fuel. Barron et al. (2004) later add that the premium to regular price differential increases in areas with higher incomes, decreases as the distance between competitors grows, and is larger when midgrade is also offered.

The balance of this paper continues as follows: Section 2 describes the unique station-level data set; Section 3 shows the theory behind second degree price discrimination and develops the econometric specification used to estimate price differences. Too, robustness exercises are carried out to confirm that price differences are in fact due to price discrimination and not some unobserved factor; Section 4 discusses the implications of price discrimination and market power using an approximation of station-level elasticities; Section 5 concludes.

2 Data Description

The data on retail and wholesale (rack) prices for gasoline, ethanol, and diesel fuel primarily come from Oil Price Information Service (OPIS). I use daily price information for stations across the Oklahoma City metropolitan area for the five month period from January to May 2016. This sample includes more than 48,500 observations. The OPIS data is incomplete,

⁵In March 2017 the market shares for premium, midgrade, and regular were 11.27%, 1.81% and 86.91%, respectively. The 10-year average for regular grade is 86.72%.

Table 1. Summary Statistics

| | Avg | Std Dev | Min | Max |
|-------------------|-------|---------|-------|-------|
| Non-blended Price | 182.0 | 22.1 | 108.9 | 264.9 |
| Non-blended Rack | 127.6 | 25.2 | 67.9 | 162.7 |
| E10 Price | 156.3 | 17.7 | 93.9 | 219.9 |
| E10 Rack | 113.0 | 19.3 | 67.9 | 142.6 |
| Diesel Price | 179.5 | 16.4 | 119.9 | 249.9 |
| Diesel Rack | 114.0 | 12.5 | 89.1 | 142.6 |

Notes: All prices shown in cents per gallon

however, in that stations that offer both types of fuel simultaneously are not fully reported because only one price per day is recorded for each station. I supplement the OPIS data with ‘hand-collected’ daily observations from stations across the city that sell both types of gasoline simultaneously.⁶ All prices were collected at the same time of day, each day.⁷ All firms that were operating at the beginning of the sample were still in operation at the end of the sample. There were two firms that entered the market at the end of the sample that I remove from the data to remove bias, and because there is only five days of pricing information available. I discuss these firms briefly in the conclusion. Summary statistics are shown in table 1.

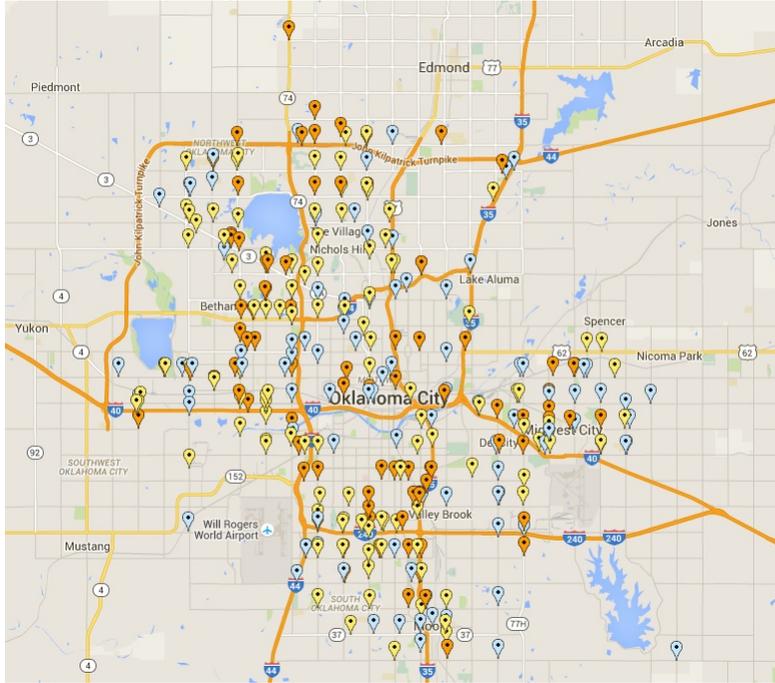
Interestingly, the market is segmented in such a way that the stations are nearly evenly split between those that sell E10 only (34.91%), E0 only (34.91%), or both simultaneously (30.19%). In addition to E10 and E0 price information I use diesel retail and wholesale prices from OPIS to run a robustness exercise. For stations that sell both diesel and gasoline there is still a near-even split among gasoline-types offered - 34.46%, 30.05%, 35.48% for E10 only, E0 only, and both, respectively.

A potential concern lies in the fact that station types could be distributed across the city in such a way that spatial differentiation is the driving factor behind price differences, not price discrimination between fuel types. Figure 1 shows the distribution of station types across the Oklahoma City metropolitan area. In this figure orange markers indicate stations that sell E0 only, yellow markers indicate stations that sell E10 only, and blue markers indicate stations that sell both types. While figure 1 provides anecdotal evidence that the station-type is not spatially correlated, I later control for fixed effects based on location and cluster standard errors to guarantee that spatial variation does not drive price discrimination.

⁶I am thankful to STLR for funding to support two truly stellar undergraduate research assistants.

⁷Unlike some other retail gasoline markets, prices are very ‘sticky’ in the OKC metro area, so multiple within day price changes are extremely unlikely. Noel (2007) discusses the three main variants of retail gasoline markets.

Figure 1: Station Distribution



3 Empirical Strategy

Ethanol-blended and non-blended gasoline are, for all intents and purposes, perfect physical substitutes. Vehicles manufactured since the 1970's have been approved by the EPA to safely consume E10. However, a non-trivial population in Oklahoma will only purchase E0, and the reasoning behind the decision making is somewhat vague as Ulmer et al. (2004) show. These authors find that 21.8% of survey respondents believe engine performance will fall with E10 use, and 33.3% believe E10 is harmful to an engine. Even though the impetus of ethanol aversion is unclear, I take as given that ethanol-blended fuels are viewed by some as a lower quality fuel.

Due to the simultaneous existence of these products I am able to measure how perceived product differentiation effects prices. Across all station-types if regular grade gasoline sells at a premium to E10, without cost-based justification, then it must be the case that these firms have some degree of market power (e.g. price \neq marginal cost). While accounting for differences in market power I am able to also determine if stations that offer both blends simultaneously adjust their prices in a way consistent with the theory of second degree price discrimination.

3.1 Theory

I follow the standard model of second degree price discrimination that has been rigorously developed since Mussa and Rosen (1978) and Deneckere and Preston McAfee (1996) which is documented in great detail in Stole (2007).

Let consumer fuel preferences be represented by combinations of price and quality, θ , with consumer quality preference distributed on the interval $\Theta = [\theta_l, \theta_h]$ according to the density and distribution functions, $f(\theta)$ and $F(\theta)$, respectively. Consumer surplus for a purchase of type θ gasoline is represented by:

$$u_\theta(q, \theta) - P(q_\theta) \tag{1}$$

Further, assume that $u_\theta(q, \theta) > 0$ and that consumers have a greater willingness to pay for increasing product quality. This ensures that consumer preferences exhibit the standard single-crossing property.

Firms do not have exact knowledge of consumer preferences, but seek to set price schedules in such a way that consumers reveal their preferences via their product choice. In essence, firms seek to satisfy the following participation constraints for both ‘high-quality’ and ‘low-quality’ preference types

$$u_l(q_{\theta_l}) - P(q_{\theta_l}) > 0 \tag{2}$$

$$u_h(q_{\theta_h}) - P(q_{\theta_h}) > 0 \tag{3}$$

while at the same time setting prices such that they are incentive compatible so that consumers purchase ‘their’ package

$$u_h(q_{\theta_h}) - P(q_{\theta_h}) > u_h(q_{\theta_l}) - P(q_{\theta_l}) \tag{4}$$

$$u_l(q_{\theta_l}) - P(q_{\theta_l}) > u_l(q_{\theta_h}) - P(q_{\theta_h}) \tag{5}$$

In words, the utility a high- θ type consumer receives (u_h) from consuming the high- θ product and paying the higher price is greater than the utility received from consuming the low- θ type product and paying the low- θ price (and vice versa for low- θ type consumers). For example, firms set prices such that a high- θ type air-traveler will choose to fly first class and pay the first class price instead of putting up with less comfortable seating in order to pay a lower price.

For all $q > 0$ it can be shown that since $u_h(q) > u_l(q)$, condition (2) implies that $u_h(q_{\theta_l}) - P(q_{\theta_l}) > 0$ which by condition (5) implies that $u_h(q_{\theta_h}) - P(q_{\theta_h}) > 0$. Thus, from

the incentive compatibility constraint we find that high- θ type consumers must be receiving a *positive surplus*.

$$u_h(q_{\theta_h}) > P(q_{\theta_h}) \tag{6}$$

Additionally, it is straightforward to show that low- θ type consumers will receive no additional surplus and will be charged their valuation of the product.

It is important to note that the positive surplus that high- θ consumers receive is expressed here in utility terms and not necessarily a price discount. Shepard (1991) shows that the price difference for the higher-quality good between multi-product firms and single product firms should be positive. The intuition behind this is that the inframarginal effect of raising prices at a multi-product station is simply customers switching to the lower-quality product. However, I later show that the opposite occurs in this fuel market.⁸ That is to say, the ‘high- θ ’ good, E0, sells at a discount at multi-product stations compared to their single product counterparts.

The surprising result that multi-product stations sell their high quality good at a lower price may be due to the nature of retail gasoline markets which exhibit stiff horizontal competition. Armstrong and Vickers (2001) and Rochet and Stole (2002) offer a theoretical construct that more closely matches the nature of the market in study. In their work duopolists earn profits based their locational advantage, but because they have no competitive advantage in supplying quality they do not gain by distorting quality. These authors find that equilibrium prices take the form of cost-plus-fixed-fee pricing.⁹ This equilibrium pricing strategy depends critically upon firm symmetry in providing utility and upon market coverage, though. Given the homogeneous nature of retail gasoline both of these conditions are most likely fulfilled. Taken together with the result that high- θ consumers must receive some positive surplus, a slight discount on the cost plus fixed fee pricing strategy (compared to E0-only stations) may be the driving factor behind the price discrimination result found here.

Connecting to the market in study, there are three types of retail gasoline stations: those that sell E10 only, those that sell non-blended E0 only, and those that sell both fuel types simultaneously. If price discrimination is *not* present at the stations that sell both blends, then there should not be a significant difference between the price for the perceived higher quality good (E0) at stations that sell both fuel types and competing stations that

⁸In Shepard (1991) quality is ‘distorted’ more so than here because firms are offering two complete different service packages.

⁹An empirical example of this in gasoline markets is Leach et al. (2008) which shows that different grades are typically sold at fixed price intervals.

only sell the higher-quality good (E0). That is, regular E0 fuel sold at E0-only or ‘both’ stations will be priced equally to be competitive with one another. If price discrimination *is* present, however, then we expect the price at stations that sell both blends together to be different than the price at E0-only type stations in order to attract consumers at the margin to consume the ‘high- θ ’ good instead of the perceived lower quality good. Additionally, we would expect that E10 would be priced the same across E10-only stations and ‘both’ stations as it is not profit-maximizing to give ‘low- θ ’ consumers any surplus. I test these two assertions and find evidence of second degree price discrimination at stations that sell both goods simultaneously while controlling for differences in wholesale costs and other characteristics.

3.2 Econometric Specification

The defining feature of price-discrimination is that firms that sell both ‘high’ and ‘low’ quality goods offer differing prices to different consumer groups with no cost-based justification. That is to say, in the absence of price discrimination the price differential between blended and non-blended gasoline should be based solely on differences between the wholesale price of gasoline and ethanol. For example, consider an extreme case where the effective price of ethanol is zero. In this scenario, E0 gasoline would be sold at a 10% premium to ethanol-blended gasoline based solely on the difference in marginal costs to produce the two types of fuel.¹⁰ Thus, the hypothetical maximum price differential between the two types of fuel should be 10%.

There is one other price differential to account for that is due to differences in fuel efficiency. The energy content in ethanol is approximately 33.3% less than pure gasoline; by extension, then, E10 is 3.33% less efficient than E0 gasoline.¹¹ Thus, one would need to purchase 3.33% more E10 gasoline than if they had purchased E0 gasoline to travel the same distance. This means that part of the price differential between blended and non-blended gasoline is justified on energy content grounds alone. Returning to the extreme case in which the wholesale cost of ethanol is zero, after adjusting for differences in energy-efficiency the maximum hypothetical price differential between the two fuel-types is approximately 13.33%. The difference between the average E0 and E10 retail price is 25.6 cents. Using the midpoint method this is a 15.2% price difference between the two types of fuel. Thus, even before

¹⁰In the other extreme if ethanol is more expensive than gasoline, then ethanol-blended fuel will sell at a premium.

¹¹Ethanol-free gasoline contains approximately 114,000 BTUs (British Thermal Units) of energy per gallon, E10 contains 110,300 BTUs.

considering wholesale prices the price differential between the two types is greater than it ‘should’ be indicating that firms are able to set higher prices on E0.

To fully examine how firms are price discriminating across fuel-types I control for differences in the wholesale cost of each fuel-type. I construct the wholesale cost of E10 and non-blended gasoline using gasoline and ethanol rack prices for branded and unbranded stations using information from OPIS. Within the E10 wholesale price I also account for changes in Renewable Identification Number (RIN) prices which are an implicit subsidy for ethanol blending. RINs are openly traded and are used as an accounting method for firms to meet requirements under the Renewable Fuel Standard. The average RIN price during this time period was \$0.713.

In addition to the wholesale prices of gasoline and ethanol I include a number of fixed effects that may also drive a distortion between E0 pricing and E10 pricing. First, day of the week fixed effects are included to account for price variation on weekends or weekdays. I also include fixed effects based on the zipcode a gas station is located in. Oklahoma City is a large metropolitan area, 620 square miles in total, that comprises 41 different zip codes that vary greatly in demographic and real estate makeup (downtown, commercial, residential, etc.). Individual station fixed effects can not be included because the type(s) of gasoline sold at each station does not vary over the time period studied here. Instead, I include a dichotomous indicator variable to denote whether or not the station sells branded gasoline (e.g. Phillips 66). The price discrimination model is shown below in equation (7).

$$\begin{aligned}
 Price_{ift} = & \beta_0 + \beta_1 E0_f + \beta_2 Both_i + \beta_3 E0_f * Both_i \\
 & + \beta_4 Branded_i + \sum_{i=0}^n \pi_{0+i} Rack_{if,t-i} + \mu_i + \lambda_t + \varepsilon_{ift}
 \end{aligned} \tag{7}$$

Where $Price_{ift}$ is the price of fuel type f at station i on day t ; $E0_f$ is a dichotomous variable equal to one if the sales series is for non-blended gasoline (zero for E10 gasoline); $Both_i$ is a dichotomous variable equal to one if the station sells both blends simultaneously; The interaction of these two variables yields the estimate of price discrimination (β_3). $Rack_{ift}$ is the station-type and fuel-type specific wholesale price with n possible lags; μ_i represents zip code fixed effects and λ_t represents day of the week fixed effects. Standard errors are clustered by brand.¹²

The major coefficients of interest are β_1 and β_3 as they represent the exertion of market power and price discrimination, respectively. If β_1 is statistically different from zero, then

¹²All variables of interest remain statistically significant at the same levels when standard errors are clustered by individual store or by zip code.

Table 2. Price Discrimination Model

| | Dep Var: Price | | | | Dep Var: ln Price | | | |
|---------------------------|----------------|-----------|---------------|-----------|-------------------|----------|---------------|----------|
| | (1) | | (2) | | (3) | | (4) | |
| Regular | 13.383 | *** | 12.921 | *** | 0.083 | *** | 0.081 | *** |
| | (0.676) | | (0.685) | | (0.004) | | (0.004) | |
| Both | 0.881 | * | 0.900 | * | 0.005 | * | 0.005 | * |
| | (0.501) | | (0.511) | | (0.003) | | (0.003) | |
| Regular*Both | -1.789 | ** | -1.982 | ** | -0.010 | * | -0.011 | * |
| | (0.919) | | (0.918) | | (0.006) | | (0.005) | |
| Branded | 2.588 | *** | 2.601 | *** | 0.015 | *** | 0.015 | *** |
| | (0.869) | | (0.866) | | (0.005) | | (0.005) | |
| Rack | 0.788 | *** | 0.237 | ** | 0.551 | *** | 0.190 | ** |
| | (0.025) | | (0.110) | | (0.020) | | (0.074) | |
| Rack _{t-1} | - | | 0.130 | *** | - | | 0.090 | *** |
| | | | (0.025) | | | | (0.015) | |
| Rack _{t-2} | - | | 0.062 | ** | - | | 0.048 | ** |
| | | | (0.027) | | | | (0.018) | |
| Rack _{t-3} | | | 0.392 | *** | | | 0.245 | *** |
| | | | (0.092) | | | | (0.061) | |
| Day of Week Fixed Effects | Y | | Y | | Y | | Y | |
| Zipcode Fixed Effects | Y | | Y | | Y | | Y | |
| Observations | 40,181 | | 39,237 | | 40,181 | | 39,237 | |
| R-Squared | 0.853 | | 0.871 | | 0.853 | | 0.871 | |

Notes: Clustered robust standard errors shown. Asterisks denote statistical significance at the traditional levels.

non-blended E0 gasoline commands a premium compared to ethanol-blended gasoline and firms receive a higher mark-up on this type of fuel after controlling for differences in wholesale marginal costs. If β_3 is statistically different from zero, then firms that offer both types of fuel simultaneously use price schedules to segment the customer population. Estimates of equation (7) are shown below in table 2. Columns 1 and 2 use the price level as the dependent variable. Columns 3 and 4 are analogous to 1 and 2 except that the natural log of the price level and the natural log of the rack price is used.

3.3 Results

The dual existence of E10 and E0 leads to very interesting pricing phenomena. First, firms that sell E0 are able to exert some form of market power because sales of E0 are able to

command a price-premium to E10 while holding wholesale cost differences constant. I find that E0 fuel sells at approximately a 13.4 cent premium to E10 (a 12.9 cent premium when further lags in the rack price are used). Columns 3 and 4 show that this is tantamount to a 8.3% and 8.1% price premium, respectively. Some of this price premium is justified on energy-efficiency grounds because E0 is more efficient than E10 by 3.33%. However, it would only require 5.92 cents more on average. Thus, for every gallon of gasoline sold 7.5 cents are returned to the gas station without justification on energy-efficiency *or* wholesale cost grounds. According to the Department of Transportation, adults between the ages of 20 and 54 drive over 18,000 miles per year on average. For an average-sized tank of 15 gallons and for a car that travels 18,000 miles a year and gets 25 miles per gallon this translates into spending an additional \$54 per year.

Second, I find that firms that offer both E10 and E0 simultaneously alter their price schedules in a manner consistent with second degree price discrimination. Specifically, I find that stations that sell both fuel-types charge approximately 1.8 cents less for E0 than would be expected, 1% less on average. When further lags of the rack price are included in the model I find a price discrimination effect of nearly 2 cents or 1.1%. This is consistent with the result that these firms should offer some sort of consumer surplus to ‘high- θ ’ type consumers. Using the same hypothetical consumer as above, this results in paying \$13 less per year to consumer E0 from stations that sell both blends simultaneously. To the firm, however, this price difference drives more sales of E0 which has been shown to command a higher premium. This increase in sales, with respect to elasticities, is discussed in more detail in section 4.

3.4 Robustness

As a first measure of whether or not price differences at stations that sell both blends together can be attributed to price discrimination I look to see if there are statistically significant differences in the price of E10 sold at E10-only stations and ‘both’ stations. According to theory, the low- θ type customers will not receive any additional surplus and will be charged their valuation of the product. That is to say, there is no incentive for a firm to charge prices below the market price for E10. Using the baseline specification I re-estimate equation (7) using only E10 prices. In this model I find that the estimate for $Both_i$ cannot be differentiated from zero statistically. The point estimate is approximately one tenth of a cent per gallon.

The most telling measure of whether or not stations that sell both E0 and E10 price discriminate is to compare how these stations set their price for a completely separate type

Table 3. Price Discrimination Robustness

| Dep Var: Price | E10 | E10 | Diesel | Diesel |
|---------------------------|-------------------------|-------------------------|-------------------------|-------------------------|
| Regular | - | - | 6.792 *** (1.301) | 6.344 *** (1.470) |
| Both | 0.139 (0.777) | 0.152 (0.775) | 0.393 (1.077) | 0.706 (1.181) |
| Rack | 0.858 *** (0.014) | 0.463 *** (0.078) | -1.555 *** (0.100) | -0.517 *** (0.092) |
| Additional Lags of Rack | 0 | 3 | 0 | 3 |
| Day of Week Fixed Effects | Y | Y | Y | Y |
| Zipcode Fixed Effects | Y | Y | Y | Y |
| R-Squared | 0.882 | 0.897 | 0.428 | 0.528 |
| Number of Obs. | 21,411 | 20,976 | 16,061 | 6,841 |

Notes: Clustered robust standard errors shown. Asterisks denote statistical significance at the traditional levels.

of fuel with a distinct customer population. To test this I use information on diesel retail prices and diesel rack prices. There is no difference in the physical makeup of diesel fuel between stations types, and vehicles that purchase diesel are a distinct customer population that cannot use regular gasoline in their vehicles. If stations that offer both types of fuel have a statistically different diesel price than single-type stations, then there may be some other station characteristic that has not been accounted for that is actually driving the difference in prices (i.e. no price discrimination between goods). I again re-estimate equation (7) using only diesel prices and find that the estimate for $Both_i$ cannot be differentiated from zero. In fact, because prices are expressed in cents it is easy to tell just how near-zero this estimate is. The point estimate is only four tenths of a cent with a standard error of approximately one cent. Both robustness checks are shown in table 3.

3.4.1 Endogenous Comparative Advantage

The decision to offer both fuels, or only one, may be considered to be the result of two-stage decision making as in Champsaur and Rochet (1989) in which firms make capital decisions in the first stage of a two-stage game (choosing which fuel-type(s) to offer) and then compete in prices in the second stage game. The decision to offer both types of fuel, only E10, or only E0 is likely dependent on the corporate brand (or lack thereof) that the fuel is under. For example, due to the global nature of oil production, refinement, and disposition,

Table 4. Price Discrimination Robustness, Selection Model

| | "Both" Stations Only | | Single-type Stations Only | | All | |
|-----------------------------------|----------------------|-----|---------------------------|-----|-------------------|-----|
| Regular | 9.993 (0.661) | *** | 12.905 (0.736) | *** | 12.919 (0.689) | *** |
| Both | - | | - | | 1.196 (0.935) | |
| Regular*Both | - | | - | | -1.970 (0.894) | ** |
| Wald test of Independent Equation | 22.04 (0.000) | | 0.74 (0.390) | | 0.30 (0.586) | |

supply chains and upstream cost-efficiencies may dictate the fuel type offered by different brands at stations in Oklahoma City. Moreover, corporate governance differences may dictate the ability of firms to choose one station-type over another - e.g. retail stations that are independent operators that enter long-term agreements to sell one “brand” of gasoline, dealer-owned gas stations that market and sell their own gasoline brand, or a combination of the these retailing strategies. To account for this two-stage type of decision making I use a Heckman-style selection model in which the prices seen in the market are conditional on a prior-stage decision based on the parent brand and the choice to provide both fuel types at the same station. That is to say, the observed market price for E0 fuel at ‘both’ stations takes the same form as equation (7), but is only observed if

$$\gamma_0 + \sum_{i=1}^n \gamma_i \Gamma_i > 0 \quad (8)$$

where Γ_i represents brand fixed effects. Similarly, the regular price is observed at single-type stations if (8) is greater than zero.

The coefficients for the regular price premium are shown in table 4 along with the Chi-squared statistic and probability for the familiar Wald test of independent equations. A pooled model that includes all observations together is also presented with the dichotomous ‘both’ variable added as a selection equation variable. This final specification is shown in column 3. Standard errors are again clustered by brand for all specifications.

Even after accounting for potential selection and participation biases the nearly 2 cent discount for E0 at ‘both’ stations persists. The regular price premium at single-type stations is 12.9 cents whereas the regular price premium at ‘both’ stations is only 9.99 cents. Thus, after controlling for station-type selection firms offering both E0 and E10 continue to charge less than their single-type competitors for E0 fuel. In fact, the difference between these

two estimates indicates a larger discount than previous estimates at 2.9 cents. The Wald test of independent equations indicates that selection is not necessary for E0-only stations, but is statistically significant for selecting ‘both’ stations. Using all observations together, the price for E0 at both stations is estimated to be -1.97 cents. The Wald statistic in this specification, however, indicates that the selection equation is unnecessary.

4 Implications of Price Discrimination and Market Power

While aggregate demand elasticities have been estimated rather precisely with aggregate price and volume data, very few papers have used information at the retail station level to estimate firm-level price elasticities since high frequency volume data is difficult to obtain. To overcome this issue Barron et al. (2008) run a controlled experiment by randomly altering pricing decisions within a 2 cent window at a Southern California retail gasoline chain while observing prices at competing stations that are outside of the retail chain. These authors find station-level elasticities in the range of -3 to -6 in the short run, with higher elasticities in higher density areas.

While I do not have detailed volume data, or the ability to run a controlled pricing experiment, I am still able to approximate a station-level elasticity of demand using the traditional Lerner price index (inverse elasticity rule) with individual station price information and the wholesale (rack) price as a measure of marginal cost.

$$\frac{P_{ift} - MC_{ift}}{P_{ift}} = \frac{1}{|E_D|} \quad (9)$$

This elasticity measure, of course, requires a number of assumptions on the part of the researcher including that the firm is perfectly rational in determining fuel markups and that the rack price is the only relevant marginal cost. While refinements on the elasticity measure presented here are certainly possible, we may still use it to gauge how price discrimination effects fuel sales.

Using the Lerner index pricing rule I uncover an average station-level elasticity of demand of -2.811 for non-blended E0 fuel, and -2.767 for E10.¹³ While this estimate is less elastic than the findings of Barron et al. (2008), it is indicative of a rather competitive market which is expected at the retail level. Further, since there are more cost factors that should be included in the marginal cost of providing a gallon of gasoline than I am able to account for, this elasticity estimate underestimates the true station-level elasticity. Thus, it would be

¹³The standard error for each elasticity estimate is 0.054 and 0.016, respectively

reasonable to expect that the -2.811 and -2.767 elasticity estimates for E0 and E10 are the lower bounds for the true elasticities (in absolute value). Using these station-level elasticity estimates, I find that price-discriminating ‘both’ stations are able to increase regular non-blended sales by 3.1% as a result of charging less per gallon than their competitors (single-type regular stations). If these elasticity estimates are truly a lower-bound estimate, then we would expect that price discrimination actually leads to more than a 3.1% increase in sales. Given the finding that firms are able to charge a 13.4 cent premium on E0 gasoline, this 3.1% increase in sales occur for a product that yields higher margins to the firm - a non-trivial boost to profits in an otherwise competitive market. For example, if a station sells only 150,000 gallons of E0 gasoline in a month, then this would result in an additional \$17,385 for price-discriminating ‘both’ firms. It is clear why firms at stations selling both fuel types would seek to adjust their price schedules so that they incentivize customers to choose E0 fuel.

Another avenue to explore is the effect of having two blends sold simultaneously on aggregate fuel sales. After all, non-blended regular E0 is able to command a 13.4 cent premium over E10 after controlling for wholesale costs. The price elasticity of demand for gasoline in the aggregate is generally very inelastic with estimates as low as -0.34 in the short run (Brons et al. (2008)). Long-run price elasticities are typically higher, yet still inelastic with many studies reporting elasticities between -0.8 and -0.9. Lin and Prince (2013) provide an improvement on this measurement and account for the degree of variance in prices. These authors find long-run elasticity estimates in the range of -0.244 and -0.293. Assuming an intermediate aggregate elasticity of demand from these studies of -0.25 I find that this price differential reduces fuel sales among E0 buyers by 3.35%. However, some customers will substitute to E10 when the price differential between the two grades is too drastic. Hence, the 3.35% reduction is an upper bound estimate of aggregate E0 fuel sales reductions among E0 buyers. The total reduction depends on the share of the population that will never purchase E10. It can be assumed that only a fraction of E0 consumers are truly ‘ethanol averse’ as in Noel and Roach (2016), so some consumers may choose to switch and purchase the lower priced E10 blend and some may never switch. In 2016 there were 5.13 million gallons of regular grade gasoline sold per day on average in Oklahoma - this amounts to 1.87 billion gallons over the year.¹⁴ Table 5 shows the reduction in aggregate sales due to the price-premium that retailers charge for non-ethanol fuel depending on the elasticity of demand for gasoline as well as the share of consumers that purchase E0 only.

If the elasticity of demand for gasoline is -0.25, then the 13.4 cent E0 price premium results

¹⁴EIA data.

Table 5: Gasoline Sales Effects

| Elasticity | E0 Consumer Population | Reduction in sales of E0 | Lost "pure gas" sales |
|------------|------------------------|--------------------------|-----------------------|
| -0.25 | 25% | -15.7 | -14.1 |
| | 50% | -31.4 | -28.2 |
| | 75% | -47.0 | -42.3 |
| -0.85 | 25% | -53.3 | -48.0 |
| | 50% | -106.6 | -95.9 |
| | 75% | -159.9 | -143.9 |

Notes: Yearly sales volume reductions in millions of gallons

in a decrease of 15.7 million gallons of gasoline sold per year if only 25% of the population consumes E0. If 50% of consumers will not purchase E10, then the implied reduction in sales due to the price premium increases to 31.4 million gallons per year. These figures increase substantially if the elasticity is -0.85 (which would be more indicative of a long-run elasticity). Given the heavy presence of oil and gas operations in the state of Oklahoma it is a quite ironic to find that the existence of E0 results in *less* gasoline being sold. Column 3 of table 5 shows the implied amount of extra gallons of ‘pure’ gasoline that would be sold if these E0 sales were replaced with E10. Afterall, E10 is comprised of 90% gasoline, so if each gallon of gasoline that wasn’t purchased due to the price premium were replaced with E10 this would result in a net increase of gasoline sales by 14.1 - 42.3 million gallons depending on the share of the population that purchases E0. If the aggregate elasticity is -0.85 the implied loss in sales is upwards of 48 million gallons. This finding is akin to that of Qiu et al. (2014) who finds that petroleum-based gasoline consumption increases following the relaxation of the 10% ‘blend wall’.

5 Discussion and Conclusion

This study has shown that interesting pricing dynamics exist when two goods are offered that only vary in perceived quality. Using the case of ethanol-blended (E10) and non-blended (E0) regular grade gasoline I find that firms use price schedules consistent with the theory of second degree price discrimination to sort customers between the two goods. This research improves upon prior research on second degree price discrimination because these two goods are near-perfect substitutes that only vary in perceived quality. After all, E10 is produced using 90% regular grade gasoline, both E0 and E10 have the same octane rating, both are marketed as regular-grade gasoline, and both can be used safely in nearly all vehicles. This

effectively eliminates the issue of endogenous product differentiation that may bias prior empirical work.

Beyond providing an empirical example of a classic theoretical problem, the findings of this research have implications for fuel markets outside of Oklahoma as the ethanol ‘blend-wall’ has been reached. The Renewable Fuel Standard calls for an increasing volume of ethanol to be blended into the fuel supply each year. This volumetric requirement does not account for reduced fuel demand due to vehicles that are more efficient and travel more miles per gallon, nor does it account for vehicle compatibility or manufacture warranties for blends higher than 10% ethanol. To confront the blend-wall and reach ethanol requirements set forth in the Renewable Fuel Standard, the EPA has recently approved E15 (a 15% ethanol blend) to be sold nation-wide and has released multiple statements on vehicle compatibility alleging that vehicles manufactured after 2001 can safely use the fuel. However, mis-fueling concerns abound as vehicle manufacturers state that using E15 will damage vehicle parts and will void any existing warranties. As E15 begins to become more prevalent throughout the country one can expect that ethanol-aversion (or at least, ethanol-confusion) may lead to the same type of pricing phenomena found here.

Lastly, while firm entry is outside of the purview of this study, a few interesting anecdotal points can be made. First, there were two stations that began operating during the time period studied here. Both of these observations were removed because only 5 days of pricing information was available. However, it is interesting to note that both of these entrants were ‘both’-type stations that sold E0 and E10. Further, since the data collection period ended at least four more stations that sell both blends have entered the market. Thus, it must be the case that in a relatively competitive market (with station-level elasticities that are conservatively estimated to be about -3) these firms find it profitable to enter and offer both types of fuel compared to the next-best alternative of offering only one type.

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