Redistributive Effects of Gasoline Prices*

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Abstract

Consumers face significantly different gasoline prices across gas stations. Using gasoline price data obtained from 98,753 gas stations within the U.S., it is shown that such differences can be explained by a model utilizing the gasoline demand of consumers depending on their income and commuting distance/time, where the pricing strategies of both gas stations and refiners are taken into account. The corresponding welfare analysis shows that there are significant redistributive effects of gasoline price changes among consumers, where the welfare costs of an increase in gasoline prices are found to be higher for lower income consumers.

JEL Classification: L11, L81, Q41

Key Words: Gasoline Prices; Gas-Station Level Analysis; United States

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1. Introduction

Gasoline prices have significant effects on an economy, because higher energy prices can slow economic growth and affect individual welfare in many ways.[1] As one example, gasoline prices have increased before any historical economic downturn in the U.S. (see Edelstein and Kilian, 2009). As another example, consider the survey reported by Bankrate.com in May 2012, which depicts that, from the end of December 2011 through mid-April 2012, the price of regular gas rose from a national average of \$3.30 per gallon to \$3.94 (an increase about 19%), and, as a result, 59% of consumers cut back on nonessential spending on things such as vacations and dining out, only because of gasoline price changes.[2] These macroeconomic examples provide an average picture of the gasoline price effects, but is the magnitude of these effects the same across consumers? The answer to this question is essential to understand the redistributive effects of gasoline prices, especially when gasoline prices differ across consumers.

To better understand the magnitude of gasoline price differences across consumers, consider a typical day (of September 14th, 2014) when the retail-level gasoline price difference between any two gas stations within the U.S. was as high as \$2.28 per gallon of regular gas.[3] If you think that this price dispersion was due to differences in state-taxes per gallon, which ranged between 42.75 cents (for New York) and 8 cents (for Georgia) in 2014, you are only partially right, because, for a typical day (of September 14th, 2014), the price difference between any two gas stations within any given state of the U.S. was as high as \$1.68 (for the state of Massachusetts) followed by \$0.99 (for the state of New York). Therefore, a detailed analysis is required to understand gasoline price dispersion at the gas-station level, which is the key to the investigation of the redistributive effects

[1] See Foote and Little (2011) for a survey of recent studies.

[2] Similarly, Ma et al. (2011) have shown that doubling gasoline prices results in 20% decrease in monthly shopping trips, 14% decrease in monthly purchase volume, or 6% decrease in monthly expenditure.

[3] The highest gasoline price of \$4.86 was observed at Mobil Gas Station located at 10 Airport Rd, Nantucket, MA 02554 while the lowest price of \$2.58 was observed at Sinclair Gas Station located at 16854 E Highway 20, Claremore, OK 74019. The source and other details of these data are provided in the data section of this paper.

of gasoline price changes.

We achieve such an investigation by modeling the gasoline consumption of individuals and the pricing strategy of gas stations and refiners. The optimization in the model results in the gasoline demand of consumers depending on their income and commuting requirements as well as the price of gasoline. Gas stations take this demand into consideration while maximizing their profits, which results in a linear gasoline price expression due to having Leontief production functions. Refiners take into account the demand coming from gas stations to maximize their own profits. When the behavior of all agents in the model are combined, a final expression for gasoline prices is obtained at the gas station level, which depends on the income and commuting behavior of consumers as well as refiner-related costs.[4]

Using data on gas-station level gasoline prices, zip-code level income and zip-code level commuting within the U.S., the implications of the model are estimated. The results show that most of the variation of gasoline prices (across gas stations) is explained by the proposed model. As a supplementary result, the average (across gas stations) markup per gallon is estimated about 16 cents, which is consistent with the surveys achieved by independent organizations.

After showing that the implications of the proposed model are consistent with gasoline price data, together with other supplementary data, we move to the welfare analysis to investigate the redistributive effects of gasoline price changes across consumers within the U.S.. The implications of the model combined with the results coming from the empirical investigation suggest that 1 percent of an increase in gasoline prices can lead to a reduction in consumer utility ranging between 0.08 percent and 2.76 percent (with an average of 0.82 percent) within the U.S.. Therefore, there are in fact significant redistributive effects of gasoline price changes. When the sources of

[4]See Yilmazkuday and Yilmazkuday (2016) for an alternative (spatial) investigation of gasoline price dispersion based on an unbalanced panel data obtained from gas stations within the U.S. They emphasize the importance of having a gas-station level analysis by showing that about half of the price dispersion in the panel data is due to time effects, while the other half is due to spatial factors. However, their analysis lacks any information on the welfare effects of gasoline price dispersion.

these redistributive effects are further investigated, it is shown that consumer income is the main determinant; i.e., welfare costs related to a gasoline price increase are higher for lower-income consumers. It is implied that, in order to minimize the redistributive welfare effects of gasoline price changes, special policies should be conducted for lower-income consumers, especially when gasoline prices increase significantly.

In the related literature, studies such as by Kayser (2000; using city-level retail gasoline prices covering the U.S.) and by Spiller and Stephens (2012; using state-level retail gasoline prices covering the U.S.) have shown that consumers living in rural areas suffer more (due to higher gasoline prices or taxes) than consumers in urban areas. Using longitudinal individual survey data for gasoline prices in South Carolina, Pitts et al. (1981) have shown that welfare costs (of higher gasoline prices) are higher for consumers that are financially constrained. However, none of the mentioned studies have used gas-station level data on gasoline prices, combined with data on zip-code level income and commuting, which are important to measure the micro details of consumer behavior and pricing strategy of gasoline retail chains.[5] More importantly, none of these studies have shown/decomposed the reasons behind possible redistributive effects, either, due to not considering any micro-founded economic model to explain consumer/producer behavior in the gasoline market. This paper bridges these gaps by using such highly disaggregated data and having a full/generalized picture of the redistributive effects of gasoline prices within the U.S., where the main determinant is shown to be the consumer income through a decomposition analysis.

The remainder of this paper is organized as follows. Based on a model introduced in the Appendix, the next section provides the details of the estimation methodology and data. Section 3 reveals the empirical results. Section 4 achieves the welfare analysis that is the key in understanding the redistributive effects of gasoline prices. Section 5 concludes by providing policy suggestions.

[5] An exception is a pure empirical study by Hosken et al. (2008) who focus on the time dimension of gasoline price differences across 272 stations in Northern Virginia; however, they do not have any welfare analysis on consumers as in this paper.

2. Estimation Methodology and Data

A simple model is introduced for motivating the empirical investigation, where a typical consumer purchases gasoline from the closest gas station to her residence for commuting purposes, and a typical gas station purchases gasoline from the closest refiner.[6] Consumers, who are modeled at the zip-code level, are imposed a linear gasoline demand function through optimization. Gas stations, which have Leontief production functions, take into account the demand coming from consumers around it to maximize profits; the optimization results in a linear pricing strategy. Each refiner maximizes profits based on the demand coming from gas stations around it; accordingly, the optimization of refiners is reflected in the final expression for gasoline prices. In order to close the model, consumers also consume local goods (other than gasoline) that are produced by their labor supplied. Both gas stations and refiners are assumed to make zero profits due to positive profits being used to cover fixed costs of production. The complete details of the model are given in the Appendix.

The model implies that gas-station level gasoline prices depend on the commuting time/distance of individuals together with their wages obtained due to supplying labor. Since refiners supply gasoline to the gas stations, refiner-specific costs are also reflected in gasoline prices. Accordingly, the following expression that is implied by the model is estimated by using data on gas-station level gasoline prices p_z^g, zip-code level commuting distance/time d_z, zip-code level wages w_z, and refiner fixed effects:

$$\underbrace{p_z^g}_{\text{Data on Gas Prices}} = \varphi \times \underbrace{\frac{3d_z w_z}{2}}_{\text{Data on Commuting and Wages}} + \underbrace{RFE_r}_{\text{Refiner Fixed Effects}} + \underbrace{\gamma_z^g}_{\text{Residuals}} \tag{2.1}$$

where $\varphi > 0$ represents a utility parameter that can be estimated as the coefficient in front of $d_z w_z$.[7]

[6] This is consistent with studies such as by Jiménez and Perdiguero (2011) who show that no rational consumer should travel further than the nearest petrol station in search of lower prices.

[7] Also see studies such as by De Palma and Lindsey (2004), Fujii and Kitamura (2004), Sabir et al. (2011), Xiao et al. (2011), where commuting behaviour of individuals are investigated in more details.

While the commuting time/distance captures the gasoline demand due to commuting purposes, wages represent the purchasing power of individuals within each zip code.

By using the implications of the model, the fitted refiner fixed effects RFE_r are further connected to the capacity of refiners according to the following secondary regression:

$$\log \underbrace{\left(\widehat{RFE_r}\right)}_{\text{Fitted Refiner Fixed Effects}} = \left(\frac{1}{\alpha} - 1\right) \times \underbrace{\log\left(r_r\right)}_{\text{Data on Refiner Capacity}} + \underbrace{\log p_r^o - \log 4\alpha}_{\text{Constant and Residuals}} \tag{2.2}$$

where r_r represents the capacity of refiner r, p_r^o represents the price/cost of oil that is faced by the refiner, and α represents the returns to scale that can be estimated using the coefficient in front of refiner capacity data. This second regression not only tests the concept of non-constant returns to scale (i.e., whether or not α is equal to 1), but also reveals how much of the variation across refiner fixed effects can be explained by refiner capacities. In order to control for the ownership of these refiners, fixed effects for the companies owning these refiners are also considered in this secondary regression. Since refiners that are located in different states may have different costs (e.g., due to the transportation costs that they face, or due to state-level taxes), state fixed effects are also considered.

2.1. Data on Gasoline Prices

Data on gas-station level *regular* gasoline prices p_z^g have been obtained from MapQuest between September 8th and September 14th, 2014.[8] The data include 416,808 observations coming from 98,753 gas stations around the U.S.. MapQuest receives gasoline prices from Oil Price Information Service (OPIS), a leading provider of petroleum data collecting gas price data based on fleet transaction data.[9] Accordingly, MapQuest gas prices are updated as qualifying transactions

[8] We downloaded the gasoline price data at midnight of each day from http://gasprices.mapquest.com/. For example, the gasoline price data for September 8th has been downloaded at 12am on September 9th.

[9] Focusing on other topics, earlier studies such as by Abrantes-Metz et al. (2006), Doyle and Samphantharak (2008), and Chandra and Tappata (2011) have also used this data set.

are processed by OPIS. The approximate time of the gasoline-price update is also provided by MapQuest. The information on the location of gas stations is at the address level.

In order to give the reader a better idea, a typical observation is the *regular* gasoline price of \$3.79 charged by BP gas station located at 980 E Grand Ave, Lake Villa, IL 60046 on September 8th, 2014 between 12am and 1am in the morning. During the sample period, the average gasoline price is about \$3.28 (with a standard deviation of 13 cents), while the minimum and maximum prices are \$2.58 and \$5.00, respectively. Regarding the gasoline price dispersion across the U.S., the gasoline prices are represented on the U.S. map in Figure 1, where the average of daily prices between September 8th and September 14th, 2014 are depicted for 98,753 gas stations. As is evident, while the gasoline prices are more expensive in the Northeast and the West (including Alaska and Hawaii), they are relatively cheaper in the Southeast.

The daily observations are pooled in the regressions. In order to control for differences across time (of observation/update), the corresponding time (both day and hour) fixed effects are also included in the estimation of Equation 2.1; since gasoline prices are also subject to state-level taxes (and other possible state-related costs), state fixed effects are also included to control for them. In order to control for differences across brands, brand fixed effects are included in the estimation of Equation 2.1 using the brand information obtained from MapQuest.

2.2. Data on Zip-Code Level Variables

The data on commuting distance/time (at the zip-code level) d_z have been obtained from the 2006-2011 U.S. Census American Community Survey as 5-year estimates. The data are represented in minutes of driving obtained from survey questions based on commuting; e.g., the average (across zip codes) daily commuting time in the U.S. is about 24 minutes (with a standard deviation of 6 minutes), while the minimum and maximum commuting times are 5 minutes (for the zip code of 84734 in Hanksville, UT) and 67 minutes (for the zip code of 70585 in Turkey Creek, LA 70585), respectively. Hence, commuting times differ across zip codes, which are important determinants of gasoline prices according to Equation 2.1.[10]

Data on per-capita wages (at the zip-code level) have been obtained from Internal Revenue Service (IRS) for the year of 2011.[11] The average (across zip codes) annual wage in the U.S. is about $55K (with a standard deviation of $29K), while the minimum and maximum annual wages are about $8K (for the zip code of 30303 in Atlanta, GA) and $1076K (for the zip code of 33109 in Miami Beach, FL), respectively.[12]

2.3. Data on Refiners

The list, exact locations, and the production capacity r_r of gasoline-producing refiners have been obtained from http://refineryreport.org/. We considered the possibility of gas stations purchasing gasoline from both U.S. and Canadian refiners due to the open nature of trade between the two countries, as stipulated by the North American Free Trade Agreement (NAFTA). There are 131 gasoline-producing refiners in this list, where 117 refiners are located in the U.S. and 14 refiners are located in Canada. Since gas stations are assumed to purchase gasoline from the closest refinery, by using the exact locations of refiners and gas stations, the closest refinery for each gas station has been found. Accordingly, dummies to capture refiner fixed effects have been created.

3. Estimation Results

The estimation results of Equation 2.1 are given in Table 1. As expected, φ is positive and significant in all regression cases considered; therefore, gas-station level gasoline prices increase in commuting distance/time and income of consumers, consistent with earlier studies such as by

[10] In order to be consistent with the frequency of the gasoline price data, we convert commuting time in minutes to days in the estimation (by dividing them by 60×24).

[11] The year of 2011 was the latest year for which such data were available at the time of this study.

[12] In order to be consistent with the frequency of the gasoline price data, the annual wage data have been converted to daily wages (by dividing the annual wages by 365).

Kayser (2000) focusing on city-level retail gasoline prices covering the U.S..[13] The explanatory power in all regression cases is also high, suggesting that the proposed model explains much of the price dispersion across gas stations within the U.S.. When the cases with and without refiner fixed effects are compared, it is evident that the fixed effects do not contribute much to the explanatory power, although they are significant according the F-test results (i.e., case #1 is selected econometrically). Hence, we consider/use the empirical results in case #1 for the rest of this paper.

The estimation results of Equation 2.2 are given in Table 2. As is evident, we cannot reject the null hypothesis of constant returns to scale in the production of refiners in case #1, where all necessary fixed effects are included. The F-test results also suggest that case #1 is selected econometrically; therefore, we conclude that there are constant returns to scale in the production of refiners. It is implied that refiner characteristics such as their ownership or location contribute more to the refiner fixed effects, while the role of refiner production/capacity measures are relatively minor (if any).

Although both regressions suggest that the proposed model explains much of the gasoline price dispersion, we are interested more in the implications of these results. Accordingly, we first consider the implications for estimated markups calculated according to implications of the model given in the Appendix, where the estimate of φ is used. The results suggest that the average markup (across gas stations) is about 15.87 cents per gallon. This result, which has completely been obtained from the estimation of the proposed model, is consistent with the average markup that is discussed in the media or by organizations making research/surveys on gas stations; e.g., according to The Wall Street Journal, "The station owners, in turn, set their gas prices for consumers so that

[13] Nevertheless, this result is opposed to some other studies such as by Myers et al. (2011) who show that retail gasoline prices are higher in poor neighborhoods; one reason for this deviation may be the spatial coverage of gasoline prices which consists of only three cities within the U.S. in Myers et al. (2011), while this paper covers almost all cities within the U.S..

the average markup, or gross margin, on gas is typically around 15 cents or 16 cents a gallon.[14]" Similarly, according to The National Association of Convenience Stores, "Over the past five years, the retail mark-up (the difference between retail price and wholesale cost) has averaged 17.1 cents per gallon.[15]" Nevertheless, different gas stations have different markups as the corresponding distribution (across stations) shows in Figure 2, where markups are as high as 44 cents per gallon.

Showing that the proposed model explains much of the price dispersion across gas stations within the U.S. and that further implications are consistent with supplementary data, we now move to the welfare analysis.

4. Welfare Analysis

We are interested in the redistributive welfare effects of a gasoline price change across consumers. Accordingly, welfare costs defined as the (absolute value of) elasticity of utility with respect to gasoline prices is calculated as follows:

$$\begin{aligned} \varepsilon_z^g &= -\frac{\partial u_z}{\partial p_z^g}\frac{p_z^g}{u_z} = \left(\frac{p_z^g}{2w_z}\right)^2 u_z \\ &= \left(\frac{p_z^g}{2w_z}\right)^2 \left(\varphi d_z g_z + c_z - \left(c_z^2 + g_z^2 + n_z\right)/2\right) \end{aligned} \tag{4.1}$$

where we have data for p_z^g, w_z, and d_z that can also be used to obtain values for the gasoline demand g_z, the consumption of the goods other than gasoline c_z, and the labor supplied n_z.[16] Finally, the estimate of φ is borrowed from Table 1.

The results of the welfare analysis are given in Figure 3. As is evident, 1 percent of an increase in gasoline prices can lead up to 2.76 percent of a reduction in utility, where the average reduction

[14] http://www.wsj.com/articles/SB10001424052702303299604577323661725847318

[15] http://www.nacsonline.com/YourBusiness/FuelsReports/GasPrices_2014/Documents/2014NACSFuelsReport_full.pdf.

[16] In particular, the demand for gasoline is calculated according to $g_z = \varphi d_z - \frac{p_z^g}{2w_z}$; and $c_z = n_z = y_z$, where $y_z = \frac{1}{4} + \sqrt{\frac{1}{16} + \frac{p_z^g g_z}{2w_z}}$.

is about 0.82 percent, and the minimum reduction is about 0.08 percent. Therefore, there are significant redistributive effects of gasoline price changes across consumers within the U.S..

According to Equation 4.1, it is evident that welfare costs are higher for lower-income consumers that face higher gasoline prices. When we investigate the highest welfare cost of 2.76 percent of a reduction in utility, we find that this cost belongs to the consumers of Hess Gas Station located at 2655 S Kirkman Rd, Orlando, FL 32811, where consumers have an average annual income of about \$24K (which is less than half of the national average), the gasoline price (per gallon) is \$3.26 (that is about the national average in our sample), and the commuting time is about 27 minutes (that is slightly above the national average in our sample). When we investigate the lowest welfare cost of 0.08 percent of a reduction in utility, we find that this cost belongs to the consumers of Valero Gas Station located at 14360 Memorial Dr, Houston, TX 77079, where consumers have an average annual income of about \$145K (which is more than double the national average), the gasoline price (per gallon) is \$3.22 (that is about the national average in our sample), and the commuting time is about 23 minutes (that is slightly below the national average in our sample). Therefore, at least for these two extreme examples, consumer income seems to be the main determinant of the redistributive welfare effects due to gasoline price changes.

In order to have a more systematic approach to explain the empirical sources of redistributive welfare effects, we also consider the following variance decomposition analysis for the elasticity of utility with respect to gasoline prices that has been obtained by taking the covariance of both sides of the log version of Equation 4.1 with respect to $\log \varepsilon_z^g$:

$$1 = \underbrace{\frac{2cov\left(\log p_z^g, \log \varepsilon_z^g\right)}{var\left(\log \varepsilon_z^g\right)}}_{\substack{\text{Variation due to Gasoline Prices} \\ -0.28\%}} - \underbrace{\frac{2cov\left(\log w_z, \log \varepsilon_z^g\right)}{var\left(\log \varepsilon_z^g\right)}}_{\substack{\text{Variation due to Wages} \\ 100.52\%}} + \underbrace{\frac{cov\left(\log u_z, \log \varepsilon_z^g\right)}{var\left(\log \varepsilon_z^g\right)}}_{\substack{\text{Variation due to Initial Utilities} \\ -0.24\%}} -$$

where $cov\left(\cdot\right)$ represents covariance and $var\left(\cdot\right)$ represents variance. The results show that virtually all (100.52%) redistributive welfare effects are due to income differences across consumers. Therefore, welfare costs of an increase in gasoline prices are higher for some consumers just because they have lower levels of income. This result is consistent with earlier studies such as by Pitts et al.

(1981) who show that welfare costs (of higher gasoline prices) are higher for financially-constrained consumers. Similarly, since poverty rates are highest in remote rural areas (e.g., see Weber and Jensen, 2004), we also have consistency with studies such as by Kayser (2000) or Spiller and Stephens (2012) who show that consumers living in rural areas suffer more (due to higher gasoline prices or taxes) than consumers in urban areas. Because these mentioned studies either use city- or state-level gasoline price data or data coming from surveys, the results in this paper can be seen as the generalization of the results in these papers, providing a much better insight regarding the full picture and measurement of the redistributive effects of gasoline prices within the U.S. at the gas-station level.

5. Concluding Remarks and Policy Suggestions

Using data obtained from gas stations within the U.S., this study has shown that gasoline prices differ significantly across consumers due to their income, commuting distance/time, and location affected by the retail chain of gasoline. Such differences are reflected as welfare costs in case of an increase in gasoline prices. In particular, 1 percent of an increase in gasoline prices corresponds to the reduction of consumer utility ranging between 0.08 percent and 2.76 percent among consumers. When the sources of this variation across welfare costs faced by different consumers are further investigated, it is found that income is the main determinant; in particular, welfare costs are higher for lower income consumers.

Although gasoline prices can be affected by income, commuting distance/time, oil prices, and refiner costs according to the proposed model, they can also be affected by local or national taxes that have not been modeled here (nevertheless, they have been controlled for in the empirical investigation). Therefore, a change in any of these variables would change gasoline prices, and, thus, any policy conducted on such variables would result in redistributive welfare effects among consumers according to the analysis, above. Accordingly, one policy suggestion would be to provide gasoline tax cuts for neighborhoods with lower-income consumers, consistent with studies such as by Spiller and Stephens (2012). Providing tax reimbursements for lower-income consumers depending on their gasoline consumption and/or the gasoline (or oil) price changes over the preceding year can also be considered. Another one would be to promote/subsidize fuel-efficient cars for lower-income consumers that would effectively reduce the share of gasoline in their expenditure.[17] Even though the formal investigation of such suggestions is out of the scope of this paper, future research can focus on the public policy implications of a more local analysis based on the insights of this study.

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6. Appendix: The Model

6.1. Consumers

A typical consumer residing in zip code z gets utility from consuming gasoline combined with commuting and other goods, while she gets disutility from supplying labor. In formal terms, she has the following quadratic utility function:

$$u_z = \varphi d_z g_z + c_z - \left(g_z^2 + c_z^2 + n_z \right)/2 \tag{6.1}$$

where $\varphi > 0$ is a utility parameter, d_z is the commuting distance/time, g_z represents the gallons of gasoline purchased from the closest gas station to the consumer residence, c_z is the consumption of the goods other than gasoline, and n_z is the labor supplied. Such a utility function is imposed to have a linear function representing the demand for gasoline, which is useful to have a clear empirical investigation, below. The budget constraint is given by:

$$p_z^g g_z + p_z c_z = w_z n_z \tag{6.2}$$

where p_z^g is the price of gasoline, p_z is the price of c_z, and w_z represents wages.

The optimization results in the following demand for gasoline:

$$g_z = \varphi d_z - \frac{p_z^g}{2w_z} \tag{6.3}$$

where the demand increases with the commuting distance/time d_z and wages w_z, while it decreases with the price of gasoline p_z^g.[18]

[18] The price elasticity of demand is implied as $-p_z^g / \left(2w_z g_z \right)$ which is consistent with studies such as by Liu (2014) who show that there is strong evidence of heterogeneous gasoline demand elasticities across states and over time. Also see Lin and Prince (2013) who show that gasoline price volatility also affects the elasticity of demand for gasoline. Havranek et al. (2012) achieve an excellent quantitative survey of the estimates of elasticity reported for various countries around the world.

6.2. Gas stations

Any gas station g in zip code z produces gasoline according to the following production function:

$$q_z^g = r_z^g$$

where r_z^g is the gasoline purchased from the closest refiner. Cost minimization results in the following marginal cost of production:

$$c_z^g = p_r^g \tag{6.4}$$

where p_r^g is the price of gasoline charged by the refiner. The profit maximization is given by:

$$\max \pi_z^g = q_z^g \left(p_z^g - c_z^g\right) - f_z^g$$

subject to the demand for gasoline coming from consumers for whom the gas station is the closest (i.e., Equation 6.3),where f_z^g represents fixed costs of the gas station.[19] The optimization results in:

$$p_z^g = \varphi d_z w_z + \frac{p_r^g}{2} \tag{6.5}$$

where we have also used Equation 6.4. Therefore, the price of gasoline increases with the commuting distance/time d_z, wages w_z, and costs charged by refiners p_r^g. The markups (per gallon) are implied as follows:

$$\begin{aligned} \mu_z^g &= p_z^g - c_z^g = \varphi d_z w_z - \frac{p_r^g}{2} \\ &= 2\varphi d_z w_z - p_z^g \end{aligned} \tag{6.6}$$

where the last equality of the first line has used Equation 6.4, and the second line, which will be used to obtain markup estimates after the empirical analysis, has been obtained by using Equation 6.5.

[19] Instead of the simple case of consumers purchasing gasoline from the closest gas station, in an alternative case, we could have a mass of consumers (say, h_z) and a mass of gas stations (say, m_z) in each zip code z. In such a case, assuming homogenous consumers/producers, in equilibrium, we would have the condition of $q_z^g = h_z g_z / m_z$, where the gasoline demand of each zip code (i.e., $h_z g_z$) is equally shared among the gas stations in that zip code. This case would result in the very same pricing strategy as in Equation 6.5.

6.3. Refiners

A typical refiner r has the following production of gasoline:

$$r_r = (o_r)^{\alpha}$$

where o_r represents oil input. Cost minimization results in the following marginal cost of production:

$$c_r = \frac{p_r^o (r_r)^{\frac{1}{\alpha}-1}}{\alpha}$$

where p_r^o represents the price/cost of oil that is faced by the refiner. Note that the marginal cost depends on the amount of gasoline produced r_r (as long as we have non-constant returns to scale through $\alpha \neq 1$; this will be tested empirically, below).

The refiner achieves profit maximization at the gas-station level:

$$\max \pi_r^g = r_r^g (p_r^g - c_r) - f_r^g$$

subject to the demand coming from the gas station g located in zip-code z:

$$r_r^g = q_z^g$$

where f_r^g represents fixed costs of the refiner. The optimization results in:

$$p_r^g = \varphi d_z w_z + \frac{p_r^o (r_r)^{\frac{1}{\alpha}-1}}{2\alpha} \tag{6.7}$$

As is evident, the gasoline price p_r^g charged by the refiner for a gas station located in zip code z positively depends on the commuting distance/time d_z and wages w_z (of consumers around the gas station), price of oil p_o, and the overall amount of gasoline produced by the refiner r_r.

6.4. Final Expression for Gas-Station Gasoline Prices

Substituting Equation 6.7 into Equation 6.5 implies the following expression for the gasoline price charged by the gas station g in zip-code z:

$$p_z^g = \frac{3\varphi d_z w_z}{2} + \frac{p_r^o (r_r)^{\frac{1}{\alpha}-1}}{4\alpha} \tag{6.8}$$

As is evident, gas-station gasoline prices are positively related to the commuting distance/time d_z and wages w_z in the same zip code, oil prices/costs p_r^o faced by the closest refiner, and gasoline production level of that refinery r_r.

Similarly, substituting Equation 6.7 into Equation 6.6 results in the following expression for markups:

$$\mu_z^g = \frac{\varphi d_z w_z}{2} - \frac{p_r^o \left(r_r\right)^{\frac{1}{\alpha}-1}}{4\alpha}$$

where they increase with commuting distance/time d_z and wages w_z but decrease with costs charged by refiners p_r^g.[20]

6.5. Closing the Model

In zip code z, optimization of any consumer (given by Equations 6.1 and 6.2) results in the following demand for the consumption of the goods other than gasoline:

$$c_z = 1 - \frac{p_z}{2w_z} \tag{6.9}$$

which are produced (using labor only) according to the following expression:

$$y_z = n_z \tag{6.10}$$

Hence, the market clearing condition for the goods other than gasoline is given as follows:

$$c_z = y_z \tag{6.11}$$

which implies through the quadratic equation solution of the combination of Equations 6.2 and 6.9 that:

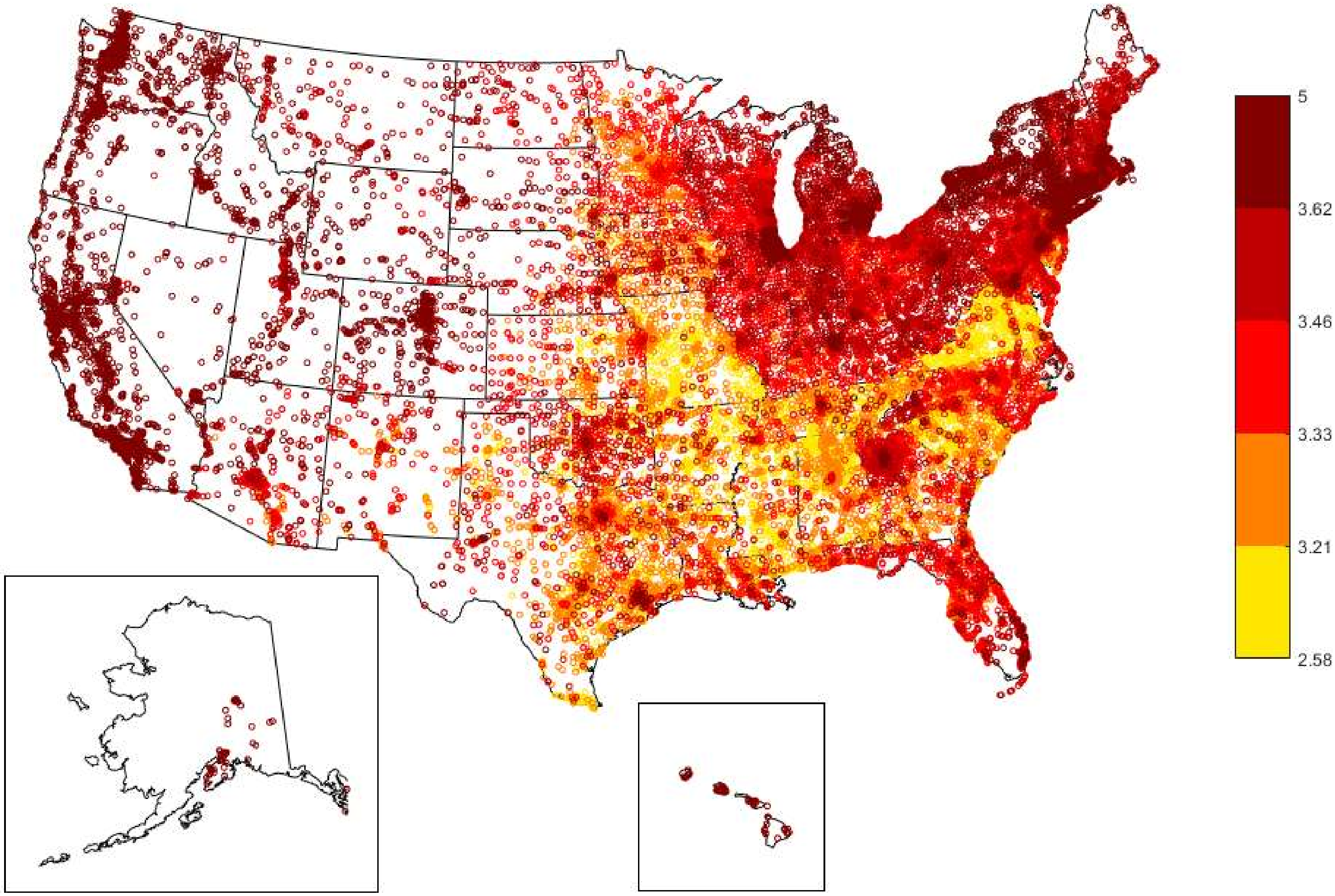
$$y_z = \frac{1}{4} + \sqrt{\frac{1}{16} + \frac{p_z^g g_z}{2w_z}} \tag{6.12}$$

where we have used $y_z > 0$.

Finally, zero-profit conditions for gas stations and refiners imply that their fixed costs are covered by their respective profits.

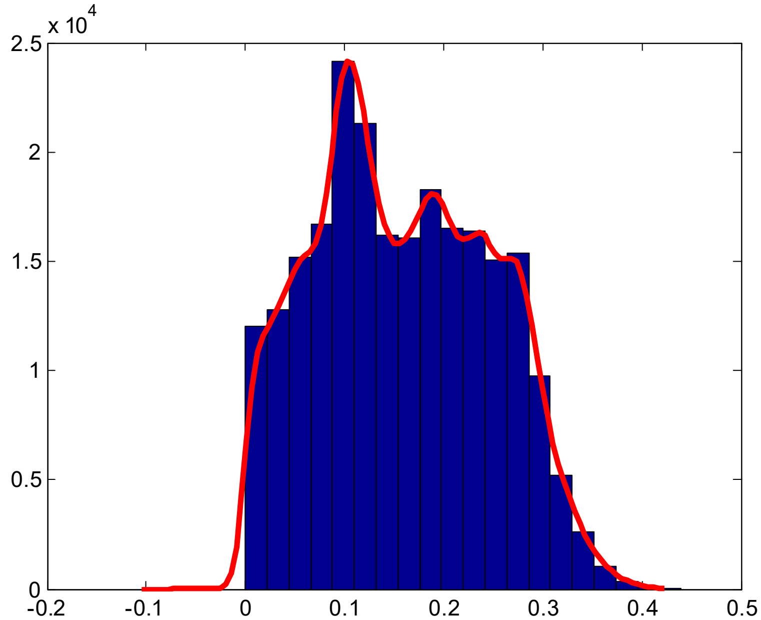
[20] This result also proposes a theoretical background to empirical studies of "kitchen sink" approach such as by Hosken et al. (2008).

Figure 1 – Gasoline Prices in the U.S.



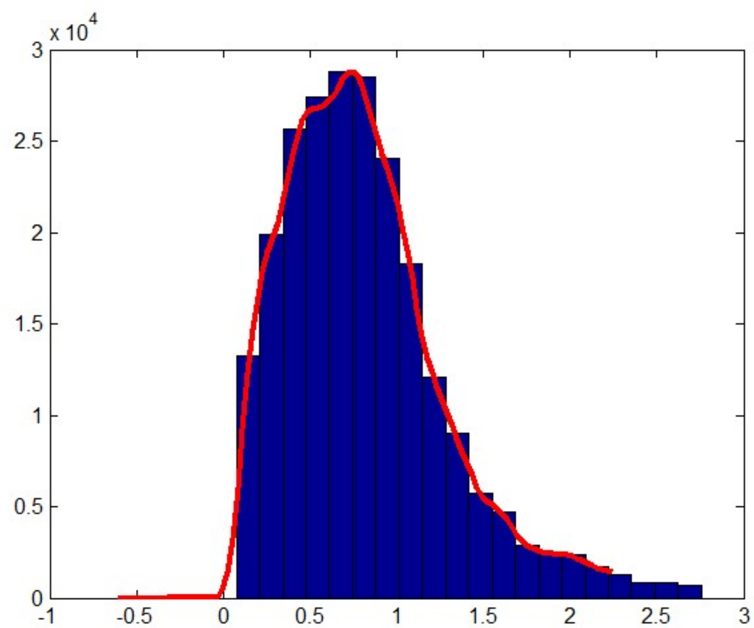
Notes: Each circle represents the location of a gas station. The prices are in U.S. dollars per gallon. Price intervals represent the intervals corresponding to the first, second, third, fourth and fifth 20 th percentile of average of daily gasoline prices obtained from 98,753 gas stations between September 8th and September 14th, 2014.

Figure 2 – Distribution of Markups (per gallon) across Gas Stations



Notes: The red line represents the estimated Kernel density. Markups are calculated by using the results given in Table 1.

Figure 3 – Elasticity of Utility with respect to Gasoline Prices across Consumers



Notes: The red line represents the estimated Kernel density. Elasticities are calculated by using the results given in Table 1.

Table 1 – Estimation Results

	(1)	(2)
φ	0.81 [0.79,0.82]	0.84 [0.83,0.85]
Refiner Fixed Effects	YES	NO
R-Squared	0.82	0.81

Notes: φ values, which represent the coefficient estimates in the regression of gasoline prices on the multiplication of commuting time and wages, have been multiplied by 100 for presentational purposes. 95% confidence intervals are given in brackets. All regressions include brand, state and time fixed effects. The sample size is 416,808, covering daily price data obtained from 98,753 gas stations between September 8th and September 14th, 2014.

Table 2 – Refiner Fixed Effects

	(1)	(2)	(3)	(4)
α	1.00 [0.97,1.03]	1.02 [1.02,1.02]	1.00 [1.00,1.00]	1.02 [1.00,1.04]
Owner Fixed Effects	YES	YES	NO	NO
State Fixed Effects	YES	NO	YES	NO
R-Squared	0.90	0.44	0.71	0.05

Notes: α values represent the coefficient estimates in the regression of log fitted refiner fixed effects (in Table 1) on refiner capacity. 95% confidence intervals that have been calculated using the Delta method are given in brackets. The sample size is 131, representing the number of refiners in the sample.