ECO2450 Research Project

The Effect of a Carbon Tax on Gasoline Abatement for U.S. Consumers

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Abstract

This paper investigates consumer behaviour in response to a carbon tax system imposed in the United States. This paper focuses on the elasticity of substitution between gasoline and ethanol as one channel through which consumers can respond to the tax. These results indicate that while in the short run consumers are inelastic to a carbon pricing system, in the long run they are more likely to adapt their behaviour in the face of increased costs. These results can hold important policy implications in terms of incentivizing consumers to adapt their behaviour in the face of higher prices.

1 Introduction

The growing need to address the climate crisis has resulted in many countries pushing for carbon reduction policy. While carbon emissions play a significant role in the climate crisis, policy aimed at reducing carbon emissions has remained divisive. Despite many economists promoting a carbon pricing scheme such as a carbon tax, as a means of controlling pollution (Zhu et al., 2018), implementing such a policy has received much controversy. For example, in response to political push back, the Canadian government rolled back its recently implemented carbon pricing scheme (Khan, 2025). One critique against a carbon pricing scheme is that since our current economy is heavily reliant on gasoline, consumers would not respond to an increase in gasoline prices by reducing gasoline consumption. On the contrary, a tax on emissions would not lead to any abatement, only a higher financial burden on consumers.

This research paper seeks to determine if a carbon tax would in fact lead consumers to reduce their consumption of gasoline and abate their emissions. I will focus on one channel of gasoline abatement, which is consumer substitution from gasoline to ethanol. Ethanol production increased in the United States as a means of achieving energy security. It has since received further support by the United States government as a green energy source due to its lower green house gas emissions relative to gasoline (Congressional Budget Office, 2010). While measures of ethanol emissions vary, current estimates hold that ethanol's life cycle greenhouse gas emissions are approximately 46% less than gasoline's, with the ethanol industry aiming to improve this to a 70% reduction by 2030 (Xu et al., 2022). The result of U.S. policy has resulted in a significant increase in the availability of ethanol fuel, both in terms of E85 (85% ethanol, 15%) fueling stations and flex fuel vehicles that use them.

The availability of ethanol fuel in the United States provides one channel through which American consumers can substitute away from gasoline. By estimating the elasticity of substitution between gasoline and ethanol, I am able to see if an increase in gasoline prices as a result of a carbon tax will result in reduced gasoline consumption. By focusing on this channel, I am able to provide an informative illustration of consumer behaviour and their ability to abate gasoline consumption in the presence of carbon pricing.

Due to endogeneity in the relationship between prices and quantities, I rely on an instrumental variable approach for estimating the elasticity of substitution. Because the production of the key ingredient in ethanol, corn, is vulnerable to changing weather conditions, variation in extreme drought would serve as a supply shock. I can then use these supply shocks to estimate the demand-side elasticity of substitution. This ultimately allows me to estimate the demand-side elasticity of substitution. For robustness, I also use average monthly U.S. temperature for similar reasons.

My estimation relies on monthly U.S. level data from 1982 to present. I find that while in the short-run consumers are inelastic in substituting away from gasoline towards ethanol, in the long run, consumers are significantly more elastic. These results reflect the fact that a short run increase in prices

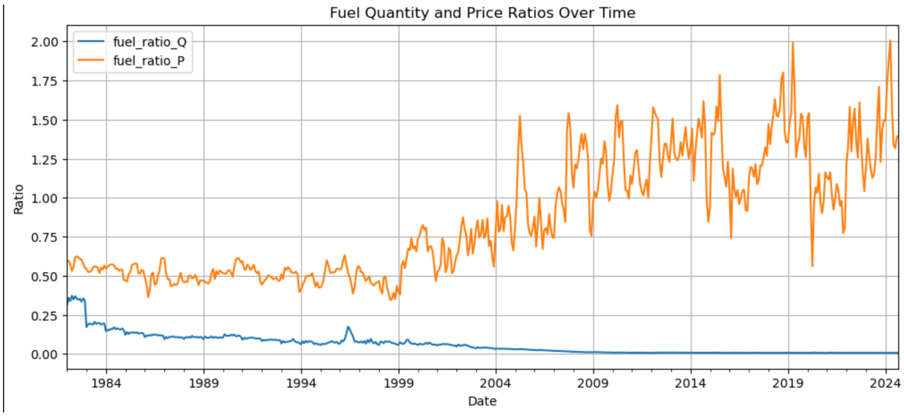

Figure 1: Trend in Ratios

does not lead to any significant changes in consumer behaviour, likely due to the high upfront costs in switching vehicles to adapt to these price increases. However, over the long run, consumers are more flexible, reflecting a greater ability to switch away from gasoline consumption. Based on these long run results, I construct a hypothetical U.S. carbon price regime based on the Canadian governments most recent carbon pricing. I find that this carbon pricing scheme would not have an impact on consumer behaviour in the short run. However, in the long run, the effect of such a policy would result in a drop in the demand for gasoline relative to ethanol by 0.13%. Furthermore, a carbon tax reflective of future ethanol emissions would lead to a 0.36% increase in the consumption of gasoline relative to ethanol.

2 Data

I will be focusing on monthly U.S. level data from 1982 to present. My unit of observation will be the month, as I focus on average monthly gas and ethanol prices and quantity. I will be relying on the US Bioenergy Statistics which publishes data on ethanol and gasoline fuel prices (dollars per gallon), ethanol production (1,000 gallons), and corn prices (dollars per bushel) (Economic Research Service, 2025).I rely on the U.S. Energy Information Administration for data on the supply of finished motor gasoline (U.S. Energy Information Administration, n.d.).Since I am interested in the elasticity of substitution between prices and quantities, I take the ratio between gasoline and ethanol, which I then log linearize. Since I am interested in the price ratio between the two fuels, I do not need adjust for nominal values. In order to adjust for nominal corn prices, I rely on the consumer price index for all urban consumers in the U.S. (CPIAUCNS) (U.S. Bureau of Labor Statistics, 1913). In Figure 1, we can see the log linearized trend in the price and quantity ratios over time. The initial decline in the quantity ratio (and increase in the price ratio) reflects the U.S.'s policy direction to ramp up ethanol production for energy independence. This is made evident by Figure 2. The presence of this trend motivated me to focus on short-run analysis using month-to-month difference in prices and quantities to understand consumer behaviour, as this partially addresses concerns with time trends.

For drought data I rely on the U.S.'s Standardized Precipitation Index (SPI), which measures the percentage of land affected by drought in the United States on a weekly basis, which I aggregated to monthly averages (NOAA, 2017). The data is constructed from the NOAA's National Centers for Environmental Information (NCEI). SPI has 4 intensity measures of drought, ranging from the least intense drought, D1, to the most intense level of drought, D4. SPI also has a precipitation index, which ranges from W1 to W4. I found that D4 drought had the most significant effect on corn prices and thus

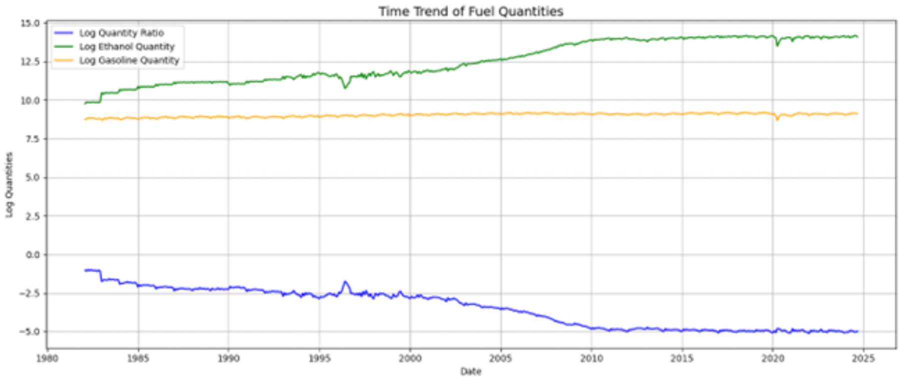

Figure 2: Log Quantities time trend

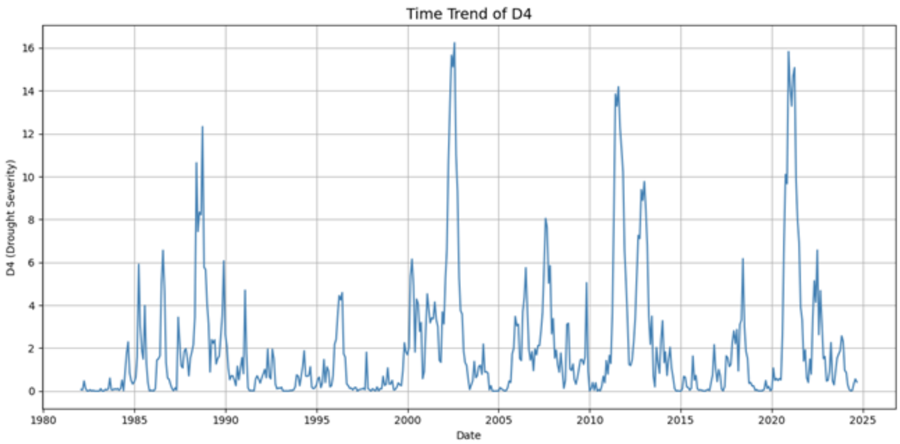

Figure 3: Percent area of U.S. land effected by instense drought (D4)

ethanol prices. Important to note is that D4 level drought does not appear to experience any time trend, as seen in Figure 3

For additional robustness, I also use temperature as an instrument. For this, I rely on Monthly U.S. Temperature and Precipitation data (in farenheit) from the NOAA's Climate Change Institute (Climate Change Institute, 2024). The data here relies on the annual average temperature anomaly from the 1901-2000 Climate Baseline.

3 Model

My model estimates the price elasticity of demand between gasoline and ethanol fuel. My model assumes constant elasticity of substitution. While this may be a strong assumption, it allows for ease in analysis as it allows me to estimate how much gasoline consumption is abated in response to a carbon tax.

Elasticity of Substitution:

$$\text{EOS}_{12} = -\frac{d\log\left(\frac{q_g}{q_e}\right)}{d\log\left(\frac{p_g}{p_e}\right)}$$

If we assume constant elasticity of substitution, then we can define sigma as:

$$\sigma = -\frac{d\log\left(\frac{q_g}{q_e}\right)}{d\log\left(\frac{p_g}{q_e}\right)}$$

With this definition of sigma, I construct my structural equation:

$$\log\left(\frac{q_g}{q_e}\right) = \alpha_{ge}^S + \sigma^S \log\left(\frac{p_g}{p_e}\right) + \gamma^S z_{ge} + \eta_{ge}^S$$

$$\log\left(\frac{q_g}{q_e}\right) = \alpha_{ge}^D + \sigma^D \log\left(\frac{p_g}{p_e}\right) + \gamma^D z_{ge} + \eta_{ge}^D$$

From this, we can write the reduced form as:

$$log(\frac{p_g}{p_e}) = \frac{\alpha_{ge}^D - \alpha_{ge}^S}{\sigma^S - \sigma^D} + \frac{\gamma^D - \gamma^S}{\sigma^S - \sigma^D} z_{ge} + \frac{\eta_{ge}^D - \eta_{ge}^S}{\sigma^S - \sigma^D}$$

$$\log\left(\frac{q_g}{q_e}\right) = \frac{\alpha_{ge}^D \sigma^S - \alpha_{ge}^S \sigma^D}{\sigma^S - \sigma^D} + \frac{\gamma^D \sigma^S - \gamma^S \sigma^D}{\sigma^S - \sigma^D} z_{ge} + \frac{\eta_{ge}^D \sigma^S - \eta_{ge}^S \sigma^D}{\sigma^S - \sigma^D}$$

where $\log\left(\frac{q_g}{q_e}\right)$ is the relative log quantity of gasoline to ethanol, and $\log\left(\frac{p_g}{p_e}\right)$ is the relative log price of gasoline to ethanol. α_{ge} represents the constant on the supply and demand side. z_i represents the instrument, either variation in drought intensity (or in the alternative model, temperature level). σ represents the percent change in relative quantity as a result of a percent change in relative price. η_{ge}^D represents the unobserved demand heterogeneity , and η_{ge}^S represents the unobserved supply heterogeneity. γ represents a percent change in relative quantity as a result of a unit change in my instrument. I assume that both drought intensity and temperature will not effect the relative quantity demanded, and thus γ^D would equal 0. Assuming that an increase in droughts and temperature effects relative quantity supplied by reducing the production of corn and thus ethanol, γ^S would be some negative number as an increase in my instrument would decrease q_e, increasing p_e and thus decreasing $\log\left(\frac{p_g}{p_e}\right)$. In addition, I assume that γ^S is uncorrelated with the error term η^D. Intuitively, this means that the only channel through which drought and temperature effect the ratio of quantity demanded is through its effect on the price ratio. I believe this is a more reasonable assumption for droughts, as the the slow acting nature of droughts makes it unlikely for consumers to radically change their behaviour.Based on these assumptions, z_{ge} will serve as an ideal instrument for estimating prices.

Because I am also interested in short run responses, I construct my short run model as:

$$\Delta\log\left(\frac{q_g}{q_e}\right) = \alpha_{ge}^S + \sigma^S \Delta\log\left(\frac{p_g}{p_e}\right) + \gamma^S z_{ge} + \eta_{ge}^S$$

$$\Delta\log\left(\frac{q_g}{q_e}\right) = \alpha_{ge}^D + \sigma^D \Delta\log\left(\frac{p_g}{p_e}\right) + \gamma^D z_{ge} + \eta_{ge}^D$$

Where $\Delta\log\left(\frac{q_g}{q_e}\right)$ and $\Delta\log\left(\frac{q_g}{q_e}\right)$ reflects the short term, month to month variation in log quantities and price ratios.

4 Model Estimation

4.1 Short Run Responses

As mentioned in Section 2, one major source of concern is that the presence of time trends will lead to endogeneity issues, as what may be attributed to the effect of prices is in fact the result of year-over-year improvements in ethanol production. To address this issue, I will look at the monthly variation in prices and their effect on production. As a result, I difference prices, quantities, drought, and temperature at the monthly level, which allows me to capture consumer's short-run responses. Sigma in Table 1 represents my key elasticity, which captures the elasticity of substitution from gasoline to ethanol as a result of a price increase in gasoline relative to ethanol. Looking at Figure 4 and column 1 of Table 1, we can see that in the short run, consumers face inelastic substitution between ethanol and gasoline.

Table 1: OLS Estimates with Differenced Prices and Quantities

	Dependent variable: Quantity ratio (log)	
	OLS	OLS (Month FE)
α	-0.007*	-0.096***
	(0.004)	(0.011)
σ	-0.013	-0.003
	(0.034)	(0.026)
Observations	512	512
R^2	0.000	0.462
Adjusted R^2	-0.002	0.449
Residual Std. Error	0.093 (df=510)	0.069 (df=499)
F Statistic	0.148 (df=1; 510)	35.748*** (df=12; 499)
Note:		*p<0.1; **p<0.05; ***p<0.01

Table 2: IV Regressions for Differenced Log Quantity Ratio

	IV1	IV2	IV1 FE	IV2 FE
α_{ge}	−0.0062	−0.0006	−0.0963***	−0.0963***
	(0.0057)	(0.0302)	(0.0255)	(0.0255)
σ	−0.7303	−4.0758	0.0056	0.0056
	(0.6013)	(10.767)	(0.2835)	(0.2835)
R^2	-0.8847	-28.392	0.4621	0.4621
Adj. R^2	-0.8884	-28.450	0.4492	0.4492
Observations	512	512	512	512
F-statistic	1.4752	0.1433	522.50	522.50
Instruments	d_D4	d_avg_temp	d_D4	d_avg_temp
Month FE	No	No	Yes	Yes
Note:				*p<0.1; **p<0.05; ***p<0.01

I then add month fixed effects as a control to account for natural variation in the quantity supplied or demanded during different months of the year. This addresses concerns regarding the seasonal availability of ethanol production inputs and concerns of fuel preference varying between cold months and warm months. The lack of additional controls can be attributed to the fact that I am looking at quantity and price ratios between the two fuels. This limits any unobservable bias to those that would differentially affect consumer demand for ethanol over fuel.

Both columns 1 and 2 in Table 1 indicate that consumers are unlikely to substitute away from their chosen fuel in the face of a change in the price ratio. Under a simple OLS, I find that a 1 percent

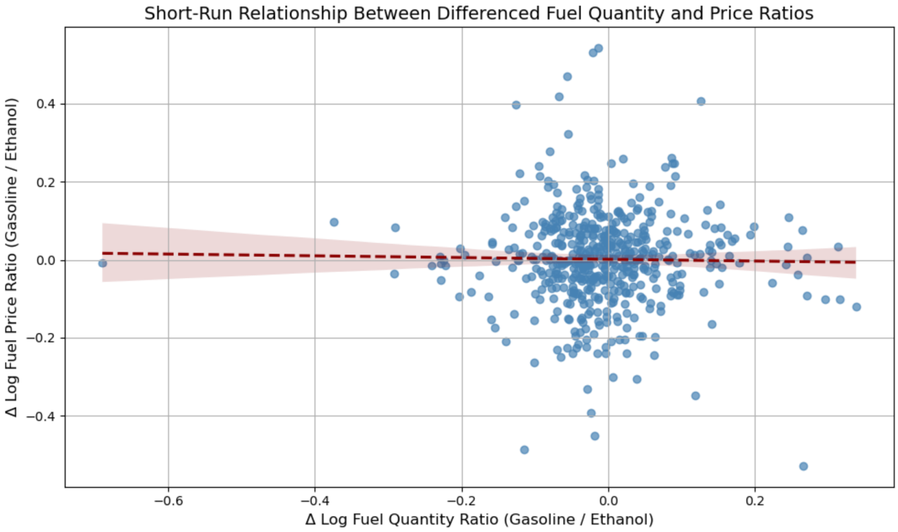

Figure 4: Inelastic Demand in the Short Run

increase in the price of gasoline relative to ethanol is associated with a 0.013% decrease in the relative consumption of gasoline to ethanol. This inelasticity is more pronounced with monthly fixed effects, which shows a a 0.003% decrease in relative consumption as a result of a 1% increase in the price ratio. The smaller standard error and higher R squared demonstrate that the fixed effects approach is a more precise zero effect.

4.1.1 Instrumental Variable Approach

Even with these controls, there is still inherent endogeneity between price and quantities. An increase in fuel price will increase both quantity supplied and decrease quantity demanded, both effects in turn having their own impact on prices. Furthermore, an increase in gasoline prices will also have an effect on crop production, which will in turn affect the prices of ethanol. To isolate the effect of a change in the price ratio on quantity demanded, I construct an instrument that serves as an exogenous supply shock. This instrument would need to only affect the quantity demanded through its effect on prices. For my instrumental variable approach, I use average temperature deviation and the percentage area of land affected by severe drought.

Since ethanol relies on corn production, more intense temperatures will lead to crop failure, reducing the quantity of ethanol supplied, and therefore increasing the ratio of gasoline and ethanol. This may be a strong assumption as stronger temperatures may also affect consumer preferences for the use of different fuels, as ethanol and gasoline have different characteristics in the cold and hot weather. This means consumer preferences for the fuel may vary by season. To address this, my second 2SLS model will rely on month-fixed effects, which allow me to control for change in preference on a monthly basis. For additional robustness, I also use a second instrument, D4 level drought, which is the most intense form of drought. I specifically analyze how an increase in the percent area of land affected by D4 level drought affects the log quantity price ratio of the two goods. Since drought is a slow-moving natural phenomenon, I argue it is unlikely to serve as a demand shock that affects consumer preferences for the two fuels. I use these two instruments to predict the log price ratio. This predicted log price ratio is then used to estimate the log quantity ratio. Since monthly variation can affect preference for fuel and my climate instruments, I also include month-fixed effects, which allow me to control for monthly changes in preference. The monthly controls are additionally useful since this would control for expected changes in climate conditions due to seasonal change.

4.1.2 Results

Table 3 tests the relevancy condition of both temperature and drought on the fuel price ratio. Looking at columns 1 and 2 of Table 3, we can see a positive statistically significant relationship between drought and temperature on prices, which is consistent with the theoretical model. Columns 1 and 2 indicate that this effect weakens when looking at monthly variation in the short term, indicating a weaker short-run response from variation in climate conditions. This is made further evident in columns 1 and 2 of Table 4, with its very low F-statistic indicating instrument weakness. Fortunately, the much higher F-statistic in columns 3 and 4 within Table 4 demonstrates that monthly fixed effects can largely alleviate these concerns.

Table 3: First Stage Testing for Price Ratio (Levels and Differences)

	Dependent variable: Log Price Ratio			
	level		*differenced*	
	D4 (1)	Temperature (2)	D4 (3)	Temperature (4)
const	-0.282	-0.291	0.002	0.002
	(0.023)	(0.022)	(0.005)	(0.005)
Instrument	0.0188***	0.0415***	-0.006	0.001
	(0.006)	(0.009)	(0.004)	(0.002)
Observations	513	513	511	511
R^2	0.016	0.040	0.004	0.000
Adjusted R^2	0.014	0.038	0.002	-0.002
Residual Std. Error	0.120 (df=511)	0.118 (df=511)	0.122 (df=509)	0.122 (df=509)
F Statistic	8.433***	21.29***	2.009	0.159
Note:				*p<0.1; **p<0.05; ***p<0.01

The results in Table 4 are largely consistent with my OLS results, with none of my estimates being statistically significant. I find that drought serves as a more consistent instrument compared to average temperature, as made evident by the smaller standard errors, providing more precise estimations. At the same time, I find that including fixed effects appears to further shrink standard errors, improve the R-squared, and increase instrument relevancy with a higher F-statistic. These two factors lead to column 3 as the best estimate for σ. Here, I find that a 1% increase in the relative price of ethanol gasoline compared to gasoline leads to a %0.0056 increase in relative quantity demanded for the two fuels. The relatively small estimate, standard errors, high F-statistic, and high R-squared at 0.4621 (compared to the negative R-squared of the other estimates) indicate that consumers are simply inelastic in the face of price changes.

Fortunately, the 2SLS remains consistent, as seen in Table 6. Regardless of which instrument I use, and regardless of whether I control for seasonality, the elasticity of substitution is negative, with small standard errors leading to statistical significance at the 1% level. However, my R^2 is lower compared to my OLS results, and while I do maintain strong statistical significance, my standard errors are larger.

Table 4: IV Regressions for Differenced Log Quantity Ratio

	IV1	IV2	IV1 FE	IV2 FE
α_{ge}	-0.0062	-0.0006	-0.0963^{***}	-0.0557
	(0.0057)	(0.0302)	(0.0255)	(0.0908)
σ	-0.7303	-4.0758	0.0056	-0.7127
	(0.6013)	(10.767)	(0.2835)	(1.5024)
R^2	-0.8847	-28.392	0.4621	-0.3533
Adj. R^2	-0.8884	-28.450	0.4492	-0.3859
Observations	512	512	512	512
F-statistic	1.4752	0.1433	522.50	185.61
Instruments	d_D4	d_avg_temp	d_D4	d_avg_temp
Month FE	No	No	Yes	Yes

Note: *p<0.1; **p<0.05; ***p<0.01

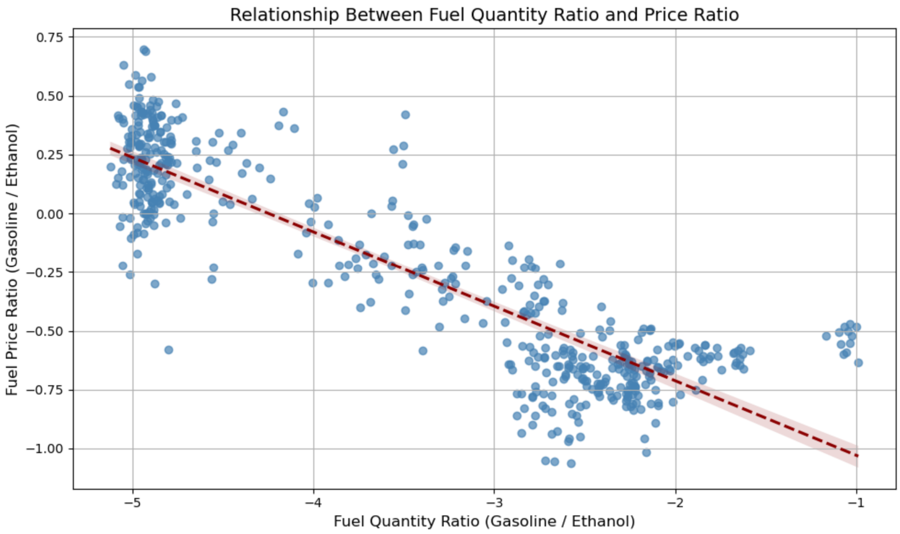

Figure 5: Log Price Ratio versus Log Quantity Ratio

4.2 Extension: Long Run Responses

While the endogeneity issues described in section 4.1 are present, investigating long run responses still provides important insight into fuel choice. Similar to section 4.1, my main regressor is the log price ratio between ethanol and gasoline, with the coefficient σ serving as my key elasticity. Running this simple regression, we can already see an inverse relationship between the log price ratio and the log quantity ratio, which is made evident by Figure 5.

Employing similar justifications as seen in the short-run estimations, I also add month fixed-effects as a control to account for natural variation in the quantity supplied or demanded during different months of the year. This makes sense as the inputs available for ethanol may fluctuate by the seasons, and fuel preference may vary between cold months and warm months. This again limits any unobservable bias to those that would differentially affect consumer demand for ethanol over fuel.

4.2.1 Results

To address the endogeneity issues present in OLS regressions, I employ the same two instruments: average temperature variation, and the percent area of land affected by extreme drought, which are used to predict log price ratio.

Table 5: OLS Regressions

	OLS	OLS w/ Month Fixed Effects
	(1)	(2)
σ	-2.478^{***}	-2.504^{***}
	(0.057)	(0.057)
α_{ge}	-4.083^{***}	-4.266^{***}
	(0.029)	(0.088)
Month Fixed Effects	No	Yes
Observations	513	513
R^2	0.785	0.796
Adjusted R^2	0.784	0.791
F Statistic	1864^{***}	162.5^{***}
Note:		*p<0.1; **p<0.05; ***p<0.01

Looking at Table 5 results, we can see that σ is statistically significant at the 0.01% level, and the substitution effect is indeed negative. These results hold even when controlling for monthly fixed effects. Both OLS regressions have a high R^2. Of course, these regression results face endogeneity issues due to the correlations involved in regressing prices on quantities.

Fortunately, the 2SLS remain consistent, as seen in Table 6. Regardless of which instrument I use, and regardless of whether I control for seasonality, the elasticity of substitution is negative, with small standard errors leading to statistical significance at the 1% level. However, my R^2 is lower compared to my OLS results, and while I do maintain strong statistical significance, my standard errors are larger.

Table 6: IV Regressions

	IV1	IV2	IV1 FE	IV2 FE
α_{ge}	-4.4175^{***}	-4.3339^{***}	-4.1771^{***}	-4.1569^{***}
	(0.1144)	(0.1117)	(0.1560)	(0.1510)
σ	-3.8525^{***}	-3.5087^{***}	-3.6751^{***}	-3.5729^{***}
	(0.4276)	(0.4788)	(0.3702)	(0.4798)
R^2	0.5433	0.6490	0.6221	0.6511
Adj. R^2	0.5424	0.6483	0.6130	0.6427
Observations	513	513	513	513
F-statistic	81.188	53.693	103.94	58.335
Instruments	D4	avg_temp	avg_temp	D4
Month FE	No	No	Yes	Yes
Note:			*p<0.1; **p<0.05; ***p<0.01	

Table 7: IV Regressions for Log Quantity Ratio (Long-Run with Fixed Effects)

	D4 FE	W4 FE	Temp FE
$\hat{\beta}$ (log_p_ratio)	0.5592	0.6603	-1.5604
	(0.6623)	(0.7438)	(4.2708)
R^2	0.9938	0.9925	0.9747
Adj. R^2	0.9930	0.9916	0.9717
F-statistic	1.76e+06	1.41e+06	3.01e+05
Observations	513	513	513
Instruments	D4	W4	avg_temp
Month-Year FE	Yes	Yes	Yes
Note:	Robust SEs in parentheses. $^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$		

One source of concern in my estimation can be seen in Table **??**. My first stage regressions are strong with high statistical significance, showing that both drought and average temperatures are relevant instruments in my estimation. As mentioned previously, γ^s is expected to be negative, since an increase in drought (or temperature) should lead to a decrease in corn yields and, in turn, ethanol production, which would increase the price of ethanol, all else constant. Therefore, an increase in ethanol price should decrease the price ratio (since ethanol price is the denominator) However, looking at Table 3, I found that γ^s actually increased the price ratio, as it effects both ethanol and gasoline production positively. These results challenge my previous assumption on my instrument, with these results indicating that my instrument may not be fully exogenous. As a result, I believe the short-run results to be more efficient estimates compared to the long run, as they are able to address this endogeneity concern.

5 Counterfactual Analysis

5.1 Short-Run Impact of a Carbon Tax

For reasons listed above, I rely on the elasticity of substitution, σ, and my intercept α estimated by my D4 instrumental variable approach with monthly fixed effects. My key outcome is relative ethanol consumption compared to gasoline. My key shock is thus a carbon tax imposed on consumers in the United States. According to the U.S. Department of Energy, ethanol fuel emits 44% less than gasoline fuel(Sarisky-Reed, 2022). Therefore, I aim to design a carbon tax regime that would properly price this difference in emission and allow consumers to adapt in the face of these new taxes.

Since the United States does not have a federal carbon pricing regime, I will rely on the Canadian carbon pricing scheme in building my key shock. For 2024, Canada priced carbon at \$50 CAD per tonne (Environment and Climate Change Canada, 2023). This results in a fuel charge of \$0.1761 CAD per litre (Canada Revenue Agency, 2023). Converting to gallons and then using the exchange rate of 1 CAD to 0.70 USD gives me \$0.47 USD per gallon. For the first counterfactual analysis, I reference the fact that ethanol emits 44% less than gasoline, this leads me to impose a carbon tax on ethanol at \$0.47 $\times 56\% =$ \$0.26per gallon.

For my second counterfactual analysis, I instead look at the scenario where ethanol will emit 70% less compared to gasoline, which is the emission rates currently targeted by the ethanol industry (Xu et al., 2022). I therefore construct a hypothetical carbon tax on ethanol that assumes the fuel to be cleaner than it currently is. This leads me to impose a carbon tax on ethanol at \$0.14 per gallon.

I use the most recent price given in my data as the basis of my analysis. I set $\eta = 0$ since unobserved heterogeneity has an expected value of 0, assuming that η^D is uncorrelated with z_{ge}. From this, I can compute the pre-tax and post-tax ratios, as well as estimate how the tax leads to a percent change in the quantity ratio demanded.

Table 8 shows a carbon tax that is equivalent to 0.47 per gallon on gasoline, and a \$0.28 per gallon on ethanol, will result in a 0.37% change increase in the price ratio, which in turn reduces the ratio of demand for gasoline versus demand for ethanol by 0.0002%. When we include projected carbon emissions for ethanol, these results change slightly. Now we find the key shock to be a 0.1% increase in the price ratio, which leads to a 0.0005% decrease in the consumption of gasoline relative to ethanol. These results illustrate that consumers do not adjust their consumption choices in the short run between the two fuels, and that a large carbon tax will not result in consumers abating their carbon emissions towards the greener fuel.

Table 8: Short-Run Effects of Ethanol Carbon Taxes

Variable	Large Ethanol Tax	Small Ethanol Tax
α	-0.096300	-0.096300
σ	0.005600	0.005600
Log price ratio	0.333933	0.333933
Gas price	2.360000	2.360000
Ethanol price	1.690000	1.690000
Log quantity ratio	-0.094430	-0.094430
Gasoline tax	0.470000	0.470000
Ethanol tax	0.263200	0.141000
Taxed gas price	2.830000	2.830000
Taxed ethanol price	1.953200	1.831000
Taxed log price ratio	0.370808	0.435414
Taxed log quantity ratio	-0.094223	-0.093862
Δ quantity ratio	0.000206	0.000568
Δ price ratio	0.036875	0.101481

5.2 Extension: Long-Run Impact of a Carbon Tax

The long-run counterfactual analysis will rely on the same counterfactual scenario as the short-run case. The only major difference is the change in α and σ, which instead rely on the values provided by D4 with fixed-effects in the long-run estimation model.

Table 9: Long-Run Effects of a Carbon Tax on relative consumption

Variable	Large Ethanol Tax	Small Ethanol Tax
α	-4.156933	-4.156933
σ	-3.572873	-3.572873
Log price ratio	0.333933	0.333933
Gas price	2.360000	2.360000
Ethanol price	1.690000	1.690000
Log quantity ratio	-5.350034	-5.350034
Gasoline tax	0.470000	0.470000
Ethanol tax	0.263200	0.141000
Taxed gas price	2.830000	2.830000
Taxed ethanol price	1.953200	1.831000
Taxed log price ratio	0.370808	0.435414
Taxed log quantity ratio	-5.481782	-5.712614
Δ quantity ratio	-0.131748	-0.362580
Δ price ratio	0.036875	0.101481

As we can see from Table 9, a carbon tax that is equivalent to 0.47 per gallon on gasoline, and a \$0.28 per gallon on ethanol, will result in a 0.37% change increase in the price ratio, which in turn reduces the ratio of demand for gasoline versus demand for ethanol by 0.13%. When we include projected carbon emissions for ethanol, these results change slightly. Now we find the key shock to be a 0.1% increase in the price ratio, which leads to 3.6% decrease in the consumption of gasoline relative to ethanol. This demonstrates that, in the long run, consumers do respond to higher prices, and that a carbon tax would in fact result in consumers abating their carbon emissions from gasoline.

6 Conclusion

I investigate the effect of a carbon tax on U.S. consumers' willingness to substitute away from gasoline cars. I found that, in the short run, an increase in the price of gasoline relative to ethanol has no effect on consumer consumption, with a near-zero change in consumption. In the long run, a 1% increase in the price of gasoline relative to ethanol leads to a 3.68% decrease in the consumption of gasoline relative to ethanol, a result that is statistically significant at the 1% level. Next, I constructed a hypothetical carbon tax in the United States that would be equivalent to the Canadian carbon pricing scheme for gasoline. Since Canada does not have ethanol fuel stations prevalent at the level of the E85 fueling stations found in the United States, I constructed a hypothetical carbon tax for ethanol, which reflects the fact that ethanol emissions are 60% of gasoline emissions. This carbon tax scheme would lead to a hypothetical 0.37% increase in the price ratio. which, in the short run, would lead to a practically zero percent change in relative fuel consumption. However, in the long run, it reduces demand for gasoline relative to ethanol by 0.13%. This shows that while consumers are elastic in substituting to a cleaner fuel source like ethanol, a carbon pricing scheme that prices both ethanol and gasoline would only contribute a small amount to reducing emissions from gasoline cars. The impact may be even smaller, as E85 fuel is a fuel blend that contains *up to* 85%-15% ethanol to fuel ratio, and often contain even less. This could mean fuel charge for E85 fuel may be even closer to the fuel charge rates for gasoline. This would reduce the substitution effect even more.

The short run results are not very surprising. The high costs of switching vehicles to consume a different fuel type will mean that consumers are unlikely to immediately change vehicles in the face of fuel price increases. The long run results provide interesting insight into consumer behaviour. This model only captures one channel through which consumers may substitute away from gasoline. For example, the consumers may also be likely to switch to electric vehicles or hybrid electric vehicles, or rely on other forms of transportation more. Nonetheless, the results of my substitution model indicate that in the long run, consumers do respond to relative changes in gas prices. E85 fuel requires specific flex fuel vehicles in order to be purchased, which would require consumers to substitute vehicles as well. The presence of strong elasticity in substitution demonstrates that carbon pricing will result in consumers substituting to cleaner options in the long term.

Of course, long term analysis comes with its own risks. Of particular concern is that fuel production may be cumulative over time. This could arise as a result of fuel production and prices being largely determined by the previous time periods fuel production, which would lead to correlation in the error terms. It is possible that these cumulative effects and correlations across time may be driving my low standard errors and high statistical significance, especially for my first stage 2SLS regression. The presence of correlation may mean that my results are less significant than they actually appear to be. More research will need to be done to capture long-run consumer behaviour that properly captures this endogeneity.

Overall, my 2SLS estimates appear consistent with theory, as we see that an increase in the price ratio leads to a decrease in quantity demanded only in the long term, with no effect on consumer behaviour in the short term. I am quite confident in my short-run analysis, although more work could be done on exploring stronger instruments. For my long-run analysis, my very low standard errors and very high statistical significance admittedly make me less confident in my results, as these indicate autocorrelation may be present. Nonetheless, despite my uncertain magnitudes for the long-run, I do believe my approach in estimating the elasticity of substitutions provides valuable insight into consumer behaviour.

6.1 Policy Recommendation

These results carry important policy implications, as they show that consumer preferences for gasoline are elastic over the long term. This means that under a carbon pricing scheme that aims to abate carbon emissions, we would be likely to see consumers substitute to greener options. The low level of substitution, particularly using current ethanol emissions, can largely be attributed to the relatively small difference in carbon pricing between ethanol and gasoline. We may see a stronger substitution effect with even greener vehicle options, such as electric vehicles. Naturally, there may be other considerations that would need to be considered to make such comparisons, such as differences in price and consumer preference between flex fuel vehicles and other types of green vehicles. Nonetheless, the magnitude of these results is impressive when we consider that this estimation only captures one channel of substitution. At the same time, it is important that the carbon tax appears to be an ineffective policy at motivating consumers to change their consumption decisions in the short term. If policy-makers wish to see more immediate responses from consumers in abating their carbon emissions, they will also need to invest in additional polices instruments. For example, a policy that can address the high costs of switching vehicles may also be beneficial in promoting substitution away from gas-powered vehicles. In summary, while carbon pricing may be ineffective at changing fuel consumption in the short term, long-term consumer sensitivity to gasoline demonstrates that carbon pricing can play an effective role in abating carbon emissions amongst consumers.

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