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Estimating the supply and demand of gasoline using tax data

David Coyle [a], Jason DeBacker [b,*,1], Richard Prisinzano [b,1]

[a] University of Minnesota, United States
[b] United States Department of the Treasury, 1500 Pennsylvania Ave, NW, Washington, D.C. 20220, United States

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ABSTRACT

We estimate supply and demand functions for the U.S. gasoline market using information from excise tax returns provided by the IRS for the period 1990–2009. We find price and income elasticities of demand similar to those found using EIA data. We find a price elasticity of supply of 0.29, which differs from the common assumption of a perfectly inelastic short-run supply curve. By using a novel data source, the analysis provides a robustness check of aggregate studies of gasoline demand and a consistent, econometric estimate of the price elasticity of gasoline supply. The results are useful in guiding tax and regulatory policies regarding gasoline consumption.

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1. Introduction

Facing large and growing deficits for both the Highway Trust Fund and the overall federal budget, as well as increasing concern over curbing carbon emissions, there is a renewed interest in the taxation of gasoline and other fossil fuels. Indeed, taxes on fossil fuels have not kept pace with either government expenditures on transportation infrastructure or inflation. Table 1 shows federal taxes on gasoline and diesel have been stagnant (in nominal terms) since 1993. Since receipts from the excise tax on gasoline are the largest source of overall excise tax revenues, these taxes represent an important funding source for federal spending on transportation infrastructure.

To understand how tax policies affect the behavior of consumers and producers, and impact government tax receipts, one must have estimates of the price elasticity of demand and supply for fuel. These elasticities are also necessary to uncover the incidence of such taxes. Yet, while there has been extensive study of the price elasticity of demand for gasoline (see Goodwin et al., (2004) for a recent survey), much less has been written about the price elasticity of supply. This study fills the gap by providing estimates of the price elasticities of both supply and demand for gasoline. Our analysis is novel in two ways. First, we use data from excise tax returns to provide quarterly observations on U.S. fuel consumption. Second, we are the first to estimate both supply and demand elasticities using the same data source and consistent models.

We use data on fuel consumption from 1990 to 2009 to estimate the short-run price elasticities of supply and demand for gasoline. Simultaneous equations models, which correct for the endogeneity of prices and quantities in the market equilibrium, suggest the price elasticity of demand for gasoline to be −0.07 and the price elasticity of supply for gasoline to be 0.29. These models yield an income elasticity of demand for gasoline of 0.41. The estimates of the price and income elasticities ofdemand fall within the range of estimates found in the vast literature on gasoline demand.[2] While we are unable to find model based estimates regarding gasoline supply, an EIA report, cited by CBO, (2003), suggests a long-run price elasticity of supply of 2. We find a short-run elasticity significantly lower than 2. Thus our estimates support the view that the supply is more inelastic in the short-run and provide a precise estimate of this elasticity. A more inelastic short-run supply curve implies that policies such as a gasoline tax holiday would have less of an impact on consumption and that relatively more of the resulting surplus would go to producers.

Much has been written on the price elasticity of demand for gasoline. Goodwin et al., (2004) provide a review of 69 published studies since

* Corresponding author. Tel.: +1 202 622 9858.
E-mail addresses: dcoylemn@gmail.com (D. Coyle), jason.debacker@treasury.gov (J. DeBacker), richard.prisinzano@treasury.gov (R. Prisinzano).
[1] The views expressed are solely those of the authors and do not represent the views of the Office of Tax Analysis or the Department of the Treasury.

[2] See Espey, (1996), Goodwin et al., (2004) for surveys of the empirical literature on gasoline demand.

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Table 1
Federal excise tax rates on gasoline and diesel.

Gasoline	Diesel	Time Period
4	4	1959Q4–1983Q1
9	9	1983Q2–1984Q3
9	15	1984Q3–1986Q4
9.1	15.1	1987Q1–1990Q4
14.1	20.1	1990Q4–1993Q3
18.4	24.4	1993Q4–1995Q3
18.4	24.4	1995Q4
18.3	24.3	1996Q1–1997Q3
18.4	24.4	1997Q4–present

*All rates are nominal cents per gallon.

1990 that estimate price elasticities of demand for different countries, and present price elasticities ranging from 0.00 to −1.81 depending upon the estimation technique and data used. More recently, Hughes et al., (2008), Wadud et al., (2010) estimate demand elasticities with more current gasoline consumption data and innovative techniques. Hughes et al., (2008) control for macroeconomic factors such as inflation, and use supply disruptions in an instrumental variables model to control for the endogeneity of prices and quantities. The paper finds short-run price elasticities ranging from −0.03 to −0.34 depending upon the model, estimation technique, and time period. Wadud et al., (2010) control for household characteristics such as urban/rural residence and find a median price elasticity of −0.47.

Less is written on supply elasticities. Austin and Dinan, (2005) and a Congressional Budget Office study CBO, (2003) of fuel taxes and fuel economy standards assume a price elasticity of supply of 2.0. However, this value is from an U.S. Energy Information Administration (EIA) report and not based on any econometric analysis of fuel supply. Often, such as in Davis and Kilian, (2010), it is assumed that supply is perfectly elastic (i.e. the marginal cost of refining fuels is independent of the quantity supplied) in the long-run and perfectly inelastic in the short-run. Others, such as Hsing, (1994) attempt to make inferences about the effects of tax policy on gasoline consumption without specifying a supply function. Providing a precise estimate of the elasticity of supply is an important contribution of the paper.

The remainder of this paper is organized as follows. Section 2 describes the data. Section 3 outlines the econometric model and presents the main results. Section 4 discusses the results and the important strengths and limitations of the study. Section 5 concludes.

2. Data description

We approximate fuel consumption with gallons of fuel sold, as reported on excise tax Form 720. This form is required to be filed quarterly by any individual or business that is liable for, or responsible for collecting, the tax associated with gasoline or diesel fuel, as well as other goods and services that face a federal excise tax. Form 720 contains gallon sold and taxes owed by type of fuel. The Internal Revenue Service (IRS) processes the filing and tabulates the total tax revenue by fuel type and by tax liability and processing quarter. The liability quarter corresponds to the quarter in which the fuel was sold (and the tax liability created). The processing quarter is the quarter the IRS receives and tabulates the payment. Late payments and corrections to past returns may be processed later, but the tax liability is attributed to the quarter in which the fuel was sold. Because we are interested in fuel consumption, we use the IRS tabulations for the liability quarter. These data correspond to the time of sale and track consumption better than does the processing quarter data.

Excise taxes are generally remitted by producers. In the case of gasoline and diesel, this is generally the refinery from which the fuel was first sold. We therefore cannot identify consumption by geographic area. Our analysis is thus restricted to the national level and is comparable to that done using the aggregate series on fuel supply provided by EIA. The EIA series is the source of fuel consumption data for almost all aggregate studies of the price elasticity of demand for U.S. consumers.[3] Fig. 1 shows gasoline consumption as measured by the IRS and EIA data.[4] These two data sources find very similar quantities of gasoline sold in each quarter from 1990 to 2009.

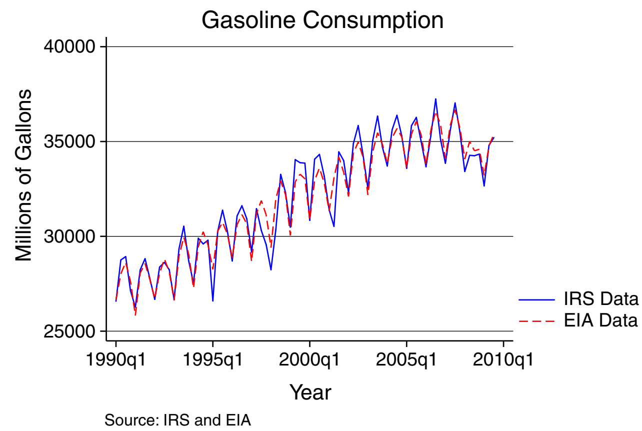

Fig. 1. Gasoline consumption, 1990–2009.

IRS data has advantages over other available data. The data are available quarterly, providing relatively high frequency observations. Despite the incentive to misrepresent tax return information, the cost of an audit and subsequent penalties associated with non-compliance deter this behavior. Such incentives for compliance are not present in survey data. Furthermore, this paper aims to inform policy makers tasked with evaluating excise taxes associated with fuels. Using data on actual, taxable fuel sales provides the most appropriate basis and provides consistency in the discussion. It is these tax data that policy makers at Treasury, the Congressional Budget Office, and the Joint Committee on Taxation are likely to use when evaluating gasoline tax policy proposals.

EIA data suffer from two shortcomings that tax data do not. Neither of these are large errors, but they provide motivation for the use of an alternative data source, if only as a robustness check.[5] The goal of many studies, such as ours, is to measure U.S. demand for gasoline. Typically, gasoline supplied is used as a proxy for gasoline demand. One must be careful to add net imports to the production data, such as that measured by the EIA, in order to get the correct measure of domestic demand. While the EIA surveys refineries and gathers information on imports, it does not do the same for exports. In order to calculate U.S. supply, the EIA uses historical trends to impute exports in its weekly supply projections. The *Petroleum Supply Monthly* then uses aggregate export data from the U.S. Census to more accurately account for gasoline exports. This opens the door for potential errors when using EIA gasoline production data as a measure of domestic gasoline supply and demand. The potential errors have become more important, as gasoline exports have increased since 2008. The tax data correctly and consistently account for exports and imports because imports face a federal excise tax, but exports do not.

In addition, EIA data may suffer from non-trivial non-sampling error. The explanatory notes for the *Petroleum Supply Monthly* data suggest that as much as 2% of the sample is non-respondent. EIA sampling errors, particularly for calculations of inventory, have been noted to be problematic for oil industry analysts who use weekly

[3] The Consumer Expenditure Survey is the common source for studies of gasoline demand at the individual level.

[4] In making these series comparable, we add gallons of gasohol to gallons of gasoline in the IRS data. These two fuels are taxed at different rates and therefore separated on Form 720. However, the EIA reports the sum of the supply of the two fuels. The supply of gasohol is equivalent to about 5% of the supply of gasoline.

[5] In addition, recent budget cuts have threatened the EIA's ability to conduct its surveys. See, for example, Bird, (2011).

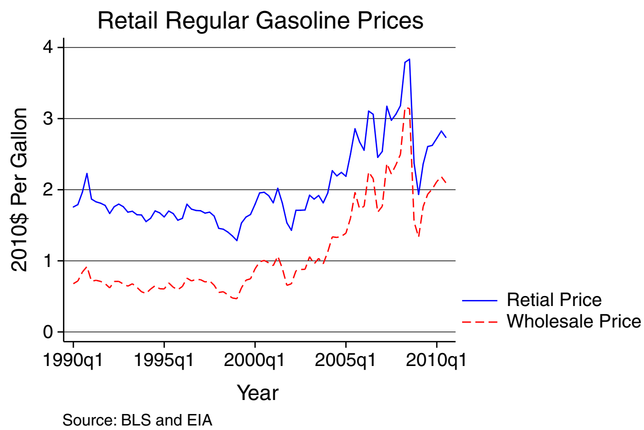

Fig. 2. Gasoline prices, 1990–2009.

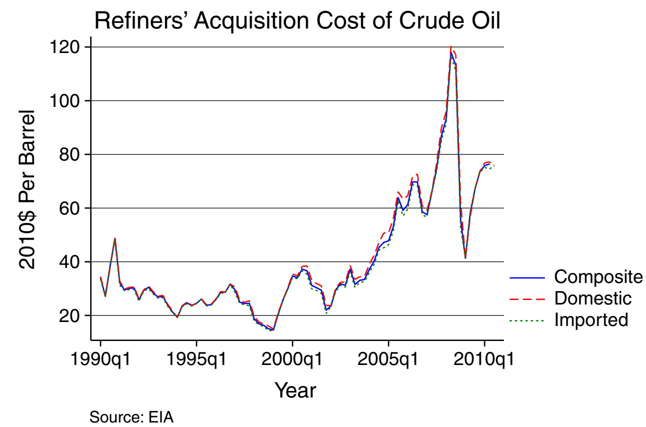

Fig. 3. Refiners' acquisition cost of crude oil, 1990–2009.

reports.[6] While monthly data are likely much more accurate than weekly data, it remains useful to compare EIA data to alternative sources. The tax data have a near zero non-sampling error, providing a valuable data source against which to check the EIA data.

Retail gasoline prices come from the Bureau of Labor Statistics (BLS) U.S. city average price series for regular gasoline. Wholesale prices come from the EIA's monthly series on wholesale gasoline prices. Quarterly prices are constructed by taking the mean price for the three months in the quarter. We deflate the prices using the BLS's CPI-U price index. Fig. 2 displays the time series for wholesale and retail gasoline prices in constant 2010 dollars. Real prices for gasoline are relatively flat from 1990 to 2004 when both prices experience a large run up preceding the 2007–2009 recession, followed by a sharp decline. Diesel prices come from the EIA's monthly series for wholesale diesel prices. To control for input prices to the refining process, we gather the refiner acquisition cost (RAC) of crude oil. The monthly price series is also available from the EIA. The real RAC price of crude (deflated using the CPI-U) is shown in Fig. 3, separately for the composite price and imported and domestically produced crude oil.

In addition to the prices and quantities of fuel, our econometric models also use data on disposable income and macroeconomic indicators. We obtain disposable income data from the U.S. Bureau of Economic Analysis (BEA) and deflate the series using the CPI-U. We use the interest rate on one-year Treasury bills collected from the Federal Reserve and inflation rates (calculated using the CPI-U) to control for macroeconomic fluctuations. Our sample period (1990 to 2009) encompasses three officially dated recessions.[7] Finally, to calculate disposable income and gasoline consumption in per capita terms, we use quarterly population estimates from the Census Bureau.

3. Model

3.1. System

The basic gasoline demand model we use reflects the approaches taken in previous studies (see, for example, Hughes et al., (2008)). We describe the relationship between log gasoline consumption (in gallons per capita) and log price as follows:

$$ln\left(G_{jt}^{D}\right) = \beta_1 ln\left(P_{jt}^{g}\right) + \beta_2 ln\left(Y_{jt}\right) + \beta_3 Infl_{jt} + \beta_4 ln\left(R_{jt}\right) + \epsilon_j + \epsilon_{jt}, \tag{1}$$

[6] See Baskin, (2010).

[7] The three National Bureau of Economic Research (NBER) dated recessions are July 1990 to March 1991, March 2001 to November 2001, and December 2007 to June 2009.

where $ln(G_{jt}^{D})$ is log gasoline demand in quarter j of year t, $ln(P_{jt}^{g})$ is the log of the per gallon retail price of regular gasoline in quarter j of year t, $ln(Y_{jt})$ is the log of per capita disposable income in quarter j of year t, $Infl_{jt}$ is the inflation ration in quarter j or year t, $ln(R_{jt})$ is the interest rate on 1-year Treasury Bills in quarter j of year t, ϵ_j are quarterly fixed effects to control for seasonality, and ϵ_{jt} is the error term.

We assume gasoline production is a function of the prices of refinery outputs (gasoline and diesel) and input prices (the cost of crude oil). Our model of gasoline supply can be written as:

$$ln\left(G_{jt}^{S}\right) = \alpha_1 ln\left(P_{jt}^{g}\right) + \alpha_2 ln\left(P_{jt}^{d}\right) + \alpha_3 ln\left(P_{jt}^{c}\right) + \alpha_{4-8} D_{jt} + u_j + u_{jt}, \tag{2}$$

where $ln(G_{jt}^{S})$ is log gasoline supply (in gallons per capita) in quarter j of year t, $ln(P_{jt}^{g})$ is the log of the wholesale price per gallon of regular gasoline in quarter j of year t, $ln(P_{jt}^{d})$ is the log of the price of diesel, $ln(P_{jt}^{c})$ is the log of the RAC price of crude in quarter j of year t, D_{jt} are dummy variables for supply disruptions in quarter j of year t, u_j are quarterly fixed effects to control for seasonality, and u_{jt} is the error term. The production disruptions used to identify shifts in supply are discussed in more detail in Section 3.2.

It follows that in equilibrium

$$G_{jt}^{D} = G_{jt}^{S}, \tag{3}$$

where G_{jt}^{D} and G_{jt}^{S} are defined as in Eqs. (1) and (2).

As is well known, OLS regressions are biased and inconsistent when estimating supply and demand models where prices and quantities are jointly determined through shifts in both supply and demand. This is especially important when attempting to estimate supply and demand over a long time period, when many economic forces can affect the supply and demand curves.

Eqs. (1)–(3) are the structural equations of our model while the αs and βs are the structural parameters. In this system of equations, the price and the quantity of gasoline are jointly determined and as such, are endogenous to the system.

The estimated coefficients $\hat{\alpha}_1$ and $\hat{\beta}_1$ are biased under OLS since price is correlated with the error term due to the simultaneity in the determination of supply and demand. In general, it is difficult to determine the direction of the bias. However, in this case the direction of the bias is dependent upon the sign of the difference between the price elasticity of demand and the price elasticity of supply. As long as demand is downward sloping and supply is upward sloping the difference is negative. The result is that both the price elasticity of demand and supply are downward biased.

We address these issues by estimating a simultaneous equations model of the gasoline market using a three-stage least squares

Table 2
Dates and names of supply disruptions, 1990-2009.

Event	Quarters affected
First Gulf War	1990Q3–1991Q1
Hurricane Andrew	1992Q3
Hurricane Bret	1999Q3
Hurricane Lili	2002Q4
Venezuelan Oil Strike	2002Q4–2003Q1
Second Gulf War	2003Q2–2003Q4
Hurricanes Katrina and Rita	2005Q3–2006Q1

approach (Zellner and Theil, 1962). Estimation of the models requires instruments for the price of gasoline. One must find appropriate instrumental variables for both supply and demand. Valid instruments for the demand (supply) function must shift supply (demand) and be uncorrelated with shocks to demand (supply). Only with such instrumental variables can one correct for the endogeneity bias resulting from the joint determination of price and quantity resulting from the market equilibrium.

3.2. Identification

As supply shifters unrelated to demand shocks, we follow Hughes et al., (2008) and use supply disruptions. In addition, both the price of diesel fuel and the refiners cost of crude oil are included in the supply equation, but excluded from the demand equation. Substitution between gasoline and diesel is minimal over short horizons and the prices of gasoline and diesel are highly correlated (correlation coefficient of 0.98), leading to the exclusion of the diesel price variable in the gasoline demand equation. It is difficult to find good instruments for gasoline supply and demand, but there is good reason to believe the supply disruptions we identify are exogenous to market demand. While diesel prices may move with demand shocks that also affect gasoline prices, we believe that the inability of consumers to substitute between gasoline and diesel-powered vehicles in the short run makes the price of diesel a valid instrument. Others, such as Ramsey et al., (1975), and Dahl, (1979), use prices of other refined fuels as instruments for gasoline demand.

The supply disruptions we identify may affect crude oil production or refinery capacity or both. For example, the Iraq Wars and the Venezuelan oil workers strike largely impacted crude oil production. The hurricanes hitting the Gulf coast often resulted in both lower crude oil production (as oil rigs were damaged and workers evacuated) and reduced refinery capacity (as these facilities often sustained damage in the storms). Because the U.S. refines the vast majority of the fuel consumed domestically, these disruptions are likely to have the largest impact on the domestic price of refined fuels. Such disruptions will shift the supply of refined fuels to the left, but are unlikely to be related to the demand for refined fuels. Supply disruptions over our sample period include geopolitical events such as the First and Second Gulf Wars (1990 and 2003) and the Venezuelan Oil Workers Strike (2002). In addition, we account for disruptions due to natural disasters such as major hurricanes with a landfall in Texas and Louisiana, the most recent of which are hurricanes Katrina and Rita that hit the Gulf Coast in 2005. Table 2 lists the supply disruptions and the quarters affected. The weather events we include are limited to hurricanes that made landfall in Texas or Louisiana with 100 mph or stronger winds.[8] The indicator variables are turned on during the quarters of the disruption. Both disruptions to crude oil supply and to refinery capacity affect the supply curve for gasoline, but perhaps in different ways. We have separate dummy variables for each disruption to allow the impact of each to vary.

[8] We were able to find news reports documenting significant supply disruptions for each of the hurricanes we include in our analysis.

Table 3
3SLS estimates: gasoline demand, 1990–2009.

	ln(Gallons per Capita)
ln(Gasoline Price)	-0.0752^{***}
	(0.018)
ln(Disp. Inc)	0.413^{***}
	(0.050)
Inflation	0.167^{**}
	(0.072)
ln(1yr Rate)	0.007^{**}
	(0.003)
Quarter Fixed Effects	Yes
N	79

[a] $^{*}p<0.10$, $^{**}p<0.05$, $^{***}p<0.01$.
[b] Standard errors in parentheses below parameter estimates.

We use disposable income as a demand shifter unrelated to supply. Supplier decisions depend upon the costs of production and the revenue from sales of output, which are determined by the price of crude oil and the prices of gasoline, respectively. Disposable income affects supply only indirectly, through demand and thus prices. In addition, macroeconomic fluctuations have a significant impact on the demand for gasoline. These variables are excluded from the supply equation and provide additional instrumental variables for the identification of gasoline supply.

The simultaneous equations model uses three-stage least squares (3SLS) to estimate Eqs. (5) and (6), using the instrumental variables discussed to identify the supply and demand curves.

3.3. Results

Three-stage least squares estimates for the demand equation are presented in Table 3. Table 4 contains the estimates for the supply equation. The price and income elasticities in the demand function have the expected sign and are similar to what we find in simple OLS.[9] As we discuss in Section 3, OLS estimates of the price elasticities are biased downward. The results from three-stage least squares estimation confirm this. The own price elasticity for gasoline supply increases; rising from 0.21 to 0.29. The demand elasticity also increases, rising from −0.08 to −0.07. As one would expect, both the cross price elasticity and the coefficient on the RAC price are negative, with point estimates of −0.19 and −0.09, respectively. That is, gasoline supplied decreases as the price of substitutes increases or as input costs increase.

4. Discussion

The price and income elasticities of gasoline demand we find are consistent with the estimates of others who use aggregate models to estimate gasoline demand. Using an original data source, we confirm, and find further evidence of, the relatively price inelastic demand for gasoline found by others.

It has been documented that increases in gasoline prices drive increases in fleet fuel efficiency through new vehicle purchases and the scrapping of older, less efficient vehicles (e.g., Li et al., (2011)). In theory, the availability of more efficient vehicles can affect measured demand elasticities in two opposing ways. First, consumers may be able to switch to more efficient vehicles when gasoline prices increase, decreasing (making more negative) the price elasticity of demand. On the other hand, once more efficient vehicles are adopted, the price elasticity of demand may increase (become less negative) because the increase in gasoline prices have less of an impact on the cost of miles traveled. In practice, the effect of fuel economy on estimates of demand elasticities is negligible over the 1990–2009 period. During these years, average fuel

[9] Results from the OLS estimation are presented in Appendix 5.

Table 4
3SLS estimates: gasoline supply, 1990–2009.

	ln(Gallons per Capita)
ln(Gasoline Price)	0.289***
	(0.042)
ln(Diesel Price)	−0.196***
	(0.044)
ln(RAC Price)	−0.093***
	(0.030)
Iraq1	0.017
	(0.011)
Ven	0.000
	(0.019)
Iraq2	−0.009
	(0.010)
Andrew	0.008
	(0.017)
Bret	0.005
	(0.017)
Lili	−0.010
	(0.026)
Katrina-Rita	−0.004
	(0.010)
Quarter Fixed Effects	Yes
N	79

[a] *$p<0.10$, **$p<0.05$, ***$p<0.01$.
[b] Standard errors in parentheses below parameter estimates.

economy of new, light vehicles rose from 25.4 to 29.1 miles per gallon (an increase of 14.7%, less than 1% per year),according the the EIAs *Annual Energy Outlook 2011*. Between 1990 and 2008, fuel economy for all vehicles in service rose from 16.4 to 17 miles per gallon (less than 0.2% per year).[10] These increases in fuel economy are very small, suggesting little bias in the measured elasticities. Controlling for fleet fuel economy in our most preferred specification (3SLS) shows no statistical difference in the elasticities we measure, confirming what the data on fuel economy suggest.

The only benchmark to which we can compare our estimate of the price elasticity of gasoline supply is an EIA report cited by Austin and Dinan, (2005), and CBO, (2003). The EIA report suggests a long-run price elasticity of supply of 2. Our results suggest a short-run elasticity of 0.29. As one would expect, this is much lower than the assumed long-run elasticity of 2. A lower elasticity of supply has important implications for tax policy. First, a less elastic supply curve implies that more of the tax incidence will fall on producers. In the case of a short run policy such as a gas tax holiday, the smaller short-run supply elasticity would result in more of the benefits of a gasoline tax holiday flowing to producers. Second, the size of the long-run responses to changes in policy are related to this short-run elasticity. The long-run changes are the sum of the short-run responses we measure and longer-run changes, such as increases in refinery capacity. While we don't know how large these longer-run responses are, we can speculate about what a smaller long-run elasticity means for the long-term effect of policy. In particular, a smaller price elasticity of supply implies that a tax of a given amount will move the equilibrium quantity less due to the more inelastic supply. Thus taxes that are intended to correct for externalities, such as carbon emissions, need to be higher when the supply elasticity is more inelastic in order to achieve the same reduction in emissions. A corollary is that, in the absence of consumption externalities, the efficiency costs of taxes will be smaller. Finally, because the equilibrium quantity moves less for a given change in taxes, government can achieve the same increase in tax revenue for a smaller change in tax rates.

IRS data on gallons of gasoline sold are very close to the amounts reported by EIA (see Fig. 1). Still, the estimation of gasoline supply and demand using the IRS data was useful in two respects. It adds robustness to the studies using EIA data to estimate gasoline demand, as our results are largely similar to the estimates produced with EIA data over a similar time period. In light of the potential errors in the export and inventory data used by EIA, this is an important service. In addition, to the extent that the two data sources differ, one might argue that the IRS data does a better job of measuring taxable gasoline sales. Taxable gasoline sales are the object of interest for many of the analyses of the gasoline market, since tax policy is often the intended consumer of such analysis.

There are disadvantages to using tax data. Excise taxes are remitted quarterly, whereas the EIA provides monthly data. Quarterly data obscure very short run fluctuations in supply or demand and result in fewer time series observations. The result is the loss of observations and very short run variations in consumption. Furthermore, IRS data does not allow us to make use of regional variation in gasoline consumption. Because taxes are remitted by the refinery, we are unable to identify the location at which the gasoline was consumed.

Aggregate analysis such as ours is helpful in guiding policy, but does lack the detail of micro-econometric studies. For example, both West, March (2004) and West and Williams, (2004) study the tax incidence of pollution controls such as gasoline taxes. These and others suggest that the tax incidence is not equally distributed over the population. Wadud et al., (2010) do not talk about the tax incidence per se, but do estimate price elasticities of demand for those with different levels of income and other household characteristics. They find significant variation in price elasticities between different types of households. Studies such as this, making use of micro-level data are especially useful in understanding the who bears the burden of gasoline taxes.

5. Conclusion

We estimate the supply and demand for gasoline using data provided by the IRS. We find demand elasticities (price and income) in-line with the existing literature. We find a price elasticity of supply of 0.29, which differs from the common assumption of a perfectly inelastic short-run supply curve. In doing so, we provide a robustness check on aggregate studies of gasoline demand and a consistent, econometric estimate of the price elasticity of gasoline supply. These results will be useful in light of current and future debate on tax and regulatory policies regarding gasoline consumption.

In December of 2010, the Obama administration's National Commission on Fiscal Responsibility and Reform released a plan to achieve roughly $4 trillion in deficit reduction through 2020. Part of the plan includes gradually increasing the federal gas tax by 15 cents per gallon between 2013 and 2015 and dedicating the increase to the Transportation Trust Fund (which is proposed to replace the Highway Trust Fund). This increase, combined with proposed spending limits for the Fund, would in turn assist in deficit reduction by alleviating the need for continued bailouts of the Fund through deficit spending.

The low elasticities of supply and demand for gasoline found in this paper suggest that, at least in the short-run, raising fuel taxes will generate significant amounts of revenue with relatively low efficiency costs. Given these results, and the historic recent deficits for both the Highway Trust Fund and the overall federal budget, policymakers should give careful consideration to the Commission's recommendation of increasing the federal gas tax. In addition to raising revenue and reducing deficits, many have made an argument for increasing fuel taxes for environmental purposes. Hsing, (1994), Morrow et al., (2010), and several others have found fuel taxes to be effective mechanism for reducing gasoline consumption and in turn carbon emissions. The elasticities found in this paper indicate that consumption of gasoline and resulting carbon emissions will be largely unaffected by marginal fuel tax increases, at least in the short-run.

Finally, while not a micro-econometric study like West, (2004), (West and Williams, May, 2004), and (Wadud et al., (2010), by providing a short-run supply elasticity our study is able to provide

[10] See the EIA's Annual Energy Review Table 2.8 at: http://www.eia.doe.gov/totalenergy/data/annual/txt/ptb0208.html

Table 5
OLS estimates: gasoline demand, 1990–2009.

	(1)	(2)
ln(Gasoline Price)	−0.063***	−0.082***
	(0.019)	(0.019)
ln(Disp. Inc)	0.357***	0.455***
	(0.048)	(0.057)
Inflation		0.197
		(0.133)
ln(1yr Rate)		0.015**
		(0.006)
Quarter Fixed Effects	Yes	Yes
R-squared	0.664	0.694
N	79	79

[a]*$p<0.10$, **$p<0.05$, ***$p<0.01$.
[b]Standard errors in parentheses below parameter estimates.

greater insight into fuel tax incidence. While the entire statutory burden of fuel taxes fall on suppliers, the economic burden for consumers can be found by dividing the price elasticity of supply by the difference of the price elasticity of supply and the price elasticity of demand. Using our result of 0.07 for the price elasticity of demand and 0.28 for the price elasticity of supply, we find that in the short-run 80% of a fuel tax increase would fall on consumers.

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Appendix A

Table 5 presents the parameter estimates for the Ordinary Least Squares gasoline demand model in column 1. Column 2 shows the basic gasoline model with the addition of two macroeconomic indicators, the inflation rate and the interest rate on one-year Treasury bills, which control for business cycle fluctuations over the sample period. The price elasticity of demand is −0.06 in the model with no economic controls and −0.08 in the model with macroeconomic controls. The income elasticity is 0.36 in the basic model and 0.46 in the model with macro variables. These price and income elasticities have the expected signs and are well within the magnitudes found in the literature. The coefficients on the macroeconomics indicators have the expected sign. Both suggest that a growing economy (characterized by higher interest rates and inflation) is associated with increases in demand for gasoline.

OLS estimates of the supply function for gasoline are shown in Table 6. The first column shows the results for the simplest specification; gasoline supply as a function of the retail price of gasoline and the cost of crude oil, plus seasonal dummy variables. The second column adds the cross price elasticity with the price of diesel fuel. The prices of other refined fuels (particularly diesel) are important covariates to control for as refineries can, relatively easily, shift the amount of capacity devoted to gasoline or diesel or other refined fuels. The third and fourth columns add indicator variables that account for a supply disruption due to either a change in the supply or crude oil or refinery capacity.[11] Such disruptions will shift the supply of refined fuels to the left, but are unlikely to be related to the demand for refined fuels.

In all specifications, the price elasticity of supply is positive and statistically different from zero, ranging from 0.12 to 0.21. The cross price elasticity has the expected negative sign and is −0.17 and −0.19 in the two specifications that include diesel prices. Interestingly, the cost of crude oil has a coefficient that is statistically insignificant when the price

Table 6
OLS estimates: gasoline supply, 1990–2009.

	(1)	(2)	(3)	(4)
ln(Gasoline Price)	0.123***	0.185***	0.153***	0.210***
	(0.039)	(0.045)	(0.033)	(0.036)
ln(Diesel Price)		−0.172**		−0.197***
		(0.069)		(0.062)
ln(RAC Price)	−0.107**	−0.010	−0.137***	−0.010
	(0.041)	(0.055)	(0.035)	(0.052)
Iraq1			−0.009	0.001
			(0.023)	(0.022)
Ven			−0.008	−0.001
			(0.040)	(0.039)
Iraq2			0.038*	0.025
			(0.020)	(0.020)
Andrew			−0.035	−0.030
			(0.036)	(0.034)
Bret			0.029	0.017
			(0.035)	(0.034)
Lili			0.039	0.017
			(0.054)	(0.053)
Katrina-Rita			0.017	0.023
			(0.021)	(0.020)
Quarter Fixed Effects	Yes	Yes	Yes	Yes
R-squared	0.551	0.584	0.551	0.601

[a]*$p<0.10$, **$p<0.05$, ***$p<0.01$.
[b]Standard errors in parentheses below parameter estimates.

of diesel is included in the model. RAC prices and the price of gasoline and diesel fuel move very much together and the positive, insignificant coefficient is likely the result of demand shocks that increase demand for gasoline and other petroleum products. Driving up the price of crude and the price of fuels simultaneously, leading to a positive correlation between gasoline supply and crude prices. Such simultaneity needs to be accounted for to produce accurate estimates, which is why we present the results from the simultaneous equations model in the main text.

[11] Specifically, we focus on disruptions to U.S. refineries. Because the U.S. refines the vast majority of the fuel consumed domestically, these disruptions are likely to have the largest impact on the domestic price of refined fuels.

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