Differential Effects of Federal and State Gasoline Taxes on Gasoline Consumption*

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Abstract

Previous studies find that gasoline consumption is more responsive to the gasoline tax than the tax-exclusive price. We examine this topic more extensively by considering the differential effects of the tax-exclusive price, federal gasoline excise tax, and total state taxes on gasoline. We find some evidence that the response to changes in the federal excise tax is larger than to changes in state taxes and the tax-exclusive price. We also consider the three specific state taxes and fees on gasoline: excise tax, sales tax, and fees.

Keywords: Excise tax, Gasoline consumption, Tax aversion.

JEL Classification: H21, H25, H31

1. Introduction

Gasoline taxes are used to generate revenue to finance roads and are seen as a tool to reduce gasoline consumption as a means of reducing congestion and pollution. It is thus of policy interest to measure the effect of tax changes on gasoline consumption. Some recent evidence (see below) finds that an increase in the total gasoline excise tax rate reduces gasoline consumption by more than does an increase in the tax-exclusive price of gasoline. We

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extend this line of research by considering whether state taxes on gasoline and the federal tax on gasoline have differential effects on gasoline consumption.

The price of gasoline at the pump is the sum of the tax-exclusive price and various taxes, such as federal and state fuel excise taxes. Traditional economic theory suggests that a consumer’s purchase decision should depend on the tax-inclusive price, and not on the relative composition of the tax-exclusive price and excise taxes. Thus, for example, in estimating labor supply elasticities researchers use the wage rate net of taxes as the independent variable rather than using separate variables for gross wage and taxes (Blundell and MaCurdy 1999), and in estimating the price elasticity of demand for cigarettes researchers use the tax-inclusive price (DeCicca and Kenkel 2015; Tauras et al. 2016).

However, there is empirical evidence, which we summarize below, suggesting that individuals respond differently to taxes than to prices. We extend this literature by considering whether individuals’ responses to taxes differ by the nature of the tax. In particular, we explore whether gasoline consumption responds differentially to changes in the tax-exclusive price of gasoline, in the federal gasoline excise tax, and in state taxes on gasoline.

There are several empirical studies that explore whether consumer responses to changes in taxes differ from their responses to price changes. Rosen (1976), for example, estimated the effect on labor supply of the gross wage separately from taxes and found the effects of the two variables were the same. There are several papers that explore the possibility of a differential response to the tax-exclusive price and the excise tax on gasoline. These papers find that gasoline consumption is more responsive to changes in the gasoline tax than to comparable changes in the tax-exclusive gasoline price. Davis and Kilian (2011), Scott (2012), and Li et al. (2014) employ monthly or annual U.S. state data while Baranzini and Weber (2013) use Swiss quarterly data; each study finds differential effects of changes in price and taxes on gasoline consumption. Rivers and Schaufele (2015) estimate the casual differential effect on gasoline consumption of the tax-exclusive price and a carbon tax adopted by British Columbia in 2000. Using monthly data from British Columbia and Ontario for the period 1990-2011, they estimate a difference-in-differences model and find that the effect of the carbon tax was 4.1 times larger than the effect of a change in the tax-exclusive price.

All of the existing research using U.S. gasoline data to explore the differential effect of price and taxes consider the tax-exclusive price and the aggregate of the taxes on gasoline. There are several taxes on gasoline in the U.S., including the federal excise tax, state excise taxes, state sales taxes in some states, and state tax or fee add-ons in some states. We examine whether gasoline consumption responds differentially to these various taxes, focusing particularly on the difference in responses between federal excise tax and total state taxes on gasoline. We find evidence that the response to changes in the federal excise tax is larger than the response to changes in the tax-exclusive tax. We find that in general the estimated effect of changes in the state total tax is larger than for changes in the tax-exclusive price, although the differences are generally not statistically significant. In most of our regressions the coefficient on the federal excise tax is larger than that on state taxes. However, we find little
difference in responses across the three state taxes: state excise taxes, state sales taxes, and fees on gasoline.

The rest of the paper proceeds as follows. In the Section 2 we discuss how to conceptualize the differential effects of price and taxes and the implications for how regression equations should be specified. In Section 3 we discuss the data and our empirical methodology, while our results are presented in Section 4. A summary section concludes the paper.

2. Specifying the Regression Equation

We posit that a differential effect on consumption means that the effect on the quantity of consumption from a “x” cent increase the tax-exclusive price differs from the change in consumption from a “x” cent increase in the excise tax. An implication of this statement is that one should not use the difference in price and tax elasticities to infer differential effects of price and tax changes. Suppose that the excise tax increases from 30 cents to 60 cents and the tax-exclusive price increases from $2.00 to $2.30. If there is no differential effect, we argue that consumption should change by the same amount for each change since the tax-inclusive price changes by the same amount for each of the two changes. However, if there is no differential effect on consumption, then it must be the case that the elasticities will differ since a 30 cent increase in the excise tax is a much larger percentage change than a 30 cent increase in the tax-exclusive price. Thus, different elasticities do not imply differential effects.

In general, how one specifies the functional form of the demand equation is somewhat arbitrary; for single products demand equations have been specified as linear, semi-log, and log-linear. Consider first the case of a linear or semi-log demand equation

$$ Q = a + b(P_E + T) = a + bP_E + bT \quad [1] $$

where $Q$ is quantity or the log of quantity demanded, $P_E$ is the tax-exclusive price, and $T$ is the excise tax, where income is taken as given. Assume that the consumer responds to a tax as if it equals $T(1+\delta)$, where $\delta$ is assumed to be positive. $\delta$ can be interpreted, for example, as measuring tax salience or the level of tax aversion. Equation [1] can thus be written as

$$ Q = a + b_1P_E + b_2T \quad [2] $$

where $b_1=b$ and $b_2=b(1+\delta)$. If $\delta>0$, than we would expect that if we estimated [2], we would find that $|b_1|<|b_2|$, that is, that $|\frac{\partial Q}{\partial P_E}| < |\frac{\partial Q}{\partial T}|$. Equation [2] can easily be expanded to consider multiple taxes. Most of our empirical specifications are based on the semi-log and linear demand models.
On the other hand, consider the log-linear demand equation given by:

\[ Q = a(P_E + T(1 + \delta))^b \]  

[3]

Totally differentiating [3] and dividing both sides by [3] yields

\[ \frac{dQ}{Q} = b\frac{dP_E}{P_E + T(1 + \delta)} + b(1 + \delta)\frac{dT}{P_E + T(1 + \delta)} = b_1\frac{dP_E}{P_E + T(1 + \delta)} + b_2\frac{dT}{P_E + T(1 + \delta)} \]  

[4]

where \( b_1 = b \) and \( b_2 = b(1 + \delta) \). We could estimate [4] if we knew the value of \((1+\delta)\). Equations [4] can easily be expanded to include multiple taxes. We provide an estimate based on equation [4].

We do not convert the excise tax into an ad valorem tax rate and specify demand as a log-linear equation as some of the existing empirical studies do\(^3\). Consider

\[ Q = a\left(P_E\left(1 + \frac{T}{P_E}\right)\right)^b \]  

[5]

Taking logs and assuming that \( \delta \) is positive, [5] becomes

\[ \ln Q = \ln a + b_1 \ln P_E + b_2 \ln \left(1 + \frac{T}{P_E}\right) \]  

[6]

where \( b_1 = b_2 \). Estimating equation [6] poses a difficulty since it is not possible to express \( b_2 \) as a combination of \( b_1 \) and \( \delta \), as with equation [2]. Of even more relevance to examining the differential effects of multiple taxes is that equation [6] cannot be used to separately estimate the effects of multiple excise taxes. With multiple taxes \( T_1 \) and \( T_2 \), equation [5] would be:

\[ Q = a\left(P_E\left(1 + \frac{T_1}{P_E} + \frac{T_2}{P_E}\right)\right)^b \]  

[7]

Taking the log of equation [7] does not yield an expression similar to [6], \textit{i.e.}, an equation with separate coefficients on \( P_E \) and each of the two tax rates. Thus, we do not estimate a model based on equation [5].

3. Data and Empirical Methodology

We estimate several specifications of the demand for gasoline. Our first equation is specified as:

\[ q_{sy} = \alpha + \beta_1 p_{sy} + \beta_2 t_y^F + \beta_3 t_y^S + X_{sy} \Theta + \lambda_s + Trend_s + e_{sy} \]  

[8]

where \( q_{sy} \) is log of gasoline consumption per adult in state \( s \) and year \( y \); \( p_{sy} \) is the tax-exclusive gasoline price; \( t_y^F \) and \( t_y^S \) are federal and state gasoline excise taxes in cents per gallon,
respectively; $X_s$ is a vector of state-level control variables, $\lambda_s$ are state fixed effects, $\text{Trend}_s$ is a set of state-specific quadratic time trends, and $e_s$ is an error. We closely follow Li et al. (2014) in specifying the trend variables and the selection of control variables. The control variables include average family size, log road miles per adult, log number of registered cars per capita, log number of registered trucks per capita, log number of licensed drivers per capita, log real income per capita, fraction of the population living in metro areas, and fraction of population living in metro areas with rail transport. In addition to the above specification, we also estimate an instrumental variable model, first-differences equations, and specifications that include time fixed effects.

Other than some of the state tax variables, the variables we use were obtained from the online data set constructed by Li et al. (2014)\textsuperscript{4}. We have state level data for the period 1966 to 2008 for all states other than Alaska and Hawaii. All dollar denominated variables are measured in real terms using the consumer price index (1987=100).

We initially assume that $p_s$ does not change if $tF_s$ and $tS_s$ changes. This assumption is consistent with various incidence studies of gasoline excise taxes that find that when the gasoline excise tax increases, the tax-inclusive price increases by the change in the excise tax; see for example, Li et al. (2014), Marion and Muehlegger (2011), Chouinard and Perlo (2004), Alm et al. (2009), and Davis and Kilian (2011). Later, we relax this assumption. Results from Esteller-Moré and Rizzo (2014) suggest that we do not have to be concerned with spatial autocorrelation with respect to tax rates.

We measure $tS_s$ as the sum of the state fuel excise tax, special fees on gasoline, and any sales tax imposed on gasoline. Special fees on gasoline in a state are generally inspection and environmental fees such as an Environmental Assurance Fee and a Groundwater Protection Trust Fee. We obtained information on state special fees imposed on gasoline from the footnotes in Highway Statistics published by the Federal Highway Administration\textsuperscript{5}.

Not all states impose their sales tax on gasoline purchases. Information on state sales tax rates imposed on gasoline after 1979 is available in Highway Statistics. Using various sources, including government websites and contacting individual states, we identified for years prior to 1979 which states applied their sales taxes to gasoline and their sales tax rates. Besides differences in the year the sales tax was first imposed on gasoline and in the sales tax rates, the nature of the tax base (i.e., the applicable price) on which the sales tax is imposed also differs across states. For example, Georgia, Michigan, and New York apply the sales tax to the price inclusive of the federal motor-fuel tax. In California, the tax base is the sales price inclusive of both federal and state motor-fuel taxes. In Illinois, the tax base is the sales price exclusive of federal and state gasoline taxes. We calculate the price on which the sales tax for gasoline is imposed for each state under the assumption that consumers bear the entire tax burden. Using the taxable price and sales tax rate, we calculate the sales tax on a cents-per-gallon scale.

Thus, we have four tax variables: federal fuel excise tax, state fuel excise taxes, special fees on gasoline, and state sales taxes imposed on gasoline; all are measured in real cents-per-gallon terms. We refer to the sum of the three state taxes as the state total tax.
Certain rules for building up the tax data need to be noted. First, there are tax changes within a year for certain states, but we use one tax rate for the entire year, namely the rate as of the end of the year. Second, local government gasoline excise taxes and local government sales taxes are not included. Third, we found typos in Highway Statistics and corrected them by referring to government documents and other data resources such as the American Petroleum Institute’s (API) *Motor Fuel Report*.

Descriptive statistics for gasoline prices and the various taxes and fees are shown in Table 1. Figure 1 is a plot of U.S. average gasoline consumption per adult, and the U.S. average real state total tax rate, real federal excise tax rate, and the U.S. average real tax-exclusive gas price. One can see the wide swings in the average real tax-exclusive price of gasoline and the general decline in gasoline consumption. To see the pattern of the tax rates more clearly, in Figure 2 we plot just the real average state total tax rate and real federal excise tax rate. Note the general decline in the real state total tax rate, particular pre-1983 and post-1991. Between 1983 and 1994, the federal government increased the federal gas tax, which explains the “stair step” pattern for the federal tax. Also of note is that prior to 1980 and after 1994, both the real federal tax rate and the average real state tax rate declined. These patterns make identifying the separate effects of federal and state gasoline taxes difficult.

| Variables                                | Mean  | Std. Dev. | Min   | Max    |
|------------------------------------------|-------|-----------|-------|--------|
| Gasoline consumption per adult           | 0.657 | 0.100     | 0.355 | 1.195  |
| Log of gasoline consumption per adult     | -0.431| 0.153     | -1.035| 0.178  |
| State total tax rate                     | 0.155 | 0.042     | 0.053 | 0.306  |
| Federal excise tax rate                  | 0.105 | 0.025     | 0.047 | 0.145  |
| Tax-exclusive gas price                  | 0.847 | 0.275     | 0.413 | 1.650  |
| Total federal and state tax rate         | 0.260 | 0.055     | 0.106 | 0.442  |
| State fees rate                          | 0.003 | 0.014     | 0.000 | 0.145  |
| State excise tax rate                    | 0.150 | 0.047     | 0.021 | 0.306  |
| State sales tax rate (cents per gallon)  | 0.002 | 0.009     | 0.000 | 0.065  |
| Tax-inclusive price                      | 1.107 | 0.250     | 0.603 | 1.828  |
| Percent change in tax-exclusive price    | 0.019 | 0.115     | -0.333| 0.362  |
| Percent change in federal tax rate       | -0.001| 0.011     | -0.011| 0.048  |
| Percent change in state total tax rate   | -0.002| 0.011     | -0.050| 0.069  |
| Percent change in gasoline consumption per adult | 0.001 | 0.038 | -0.194 | 0.196 |

*Taxes and prices are in real cents per gallon.*
4. Empirical Results

The results of regressions based on equation [8] are contained in Table 2, for which the dependent variable is log of gasoline consumption per adult, except for column 6 for which it is the level of gasoline consumption per adult. Our full specification includes the covariates listed above, state fixed effects, and state quadratic time trends. However, to show the sensitivity of our basic regression, we also report regressions that use various combinations of state fixed effects and time trends. For all regressions in the paper we report robust standard errors clustered by state.6
Table 2
REGRESSIONS OF LOG GASOLINE CONSUMPTION PER ADULT

| Variables                          | (1)     | (2)     | (3)     | (4)     | (5)     | (6)b    |
|------------------------------------|---------|---------|---------|---------|---------|---------|
| Tax-Exclusive Price                | -0.098*** | -0.125*** | -0.138*** | -0.119*** | -0.120*** | -0.080*** |
|                                   | (0.011) | (0.009) | (0.012) | (0.008) | (0.008) | (0.006) |
| Federal + State Total Tax          | -0.648*** |         |         |         |         |         |
|                                   | (0.093) |         |         |         |         |         |
| Federal Excise Tax                | -1.479*** | -1.694*** | -1.349*** | -1.343*** | -0.975*** |         |
|                                   | (0.110) | (0.139) | (0.130) | (0.121) | (0.073) |         |
| State Total Tax                   | -0.162 | -0.197 | -0.205* | -0.243** | -0.087 |         |
|                                   | (0.147) | (0.191) | (0.120) | (0.120) | (0.106) |         |
| Constant                           | -0.942 | -0.943 | -0.707*** | -0.768*** | 0.861*** | -0.007 |
|                                   | (0.828) | (0.754) | (0.168) | (0.175)*** | (0.140) | (0.662) |
| Covariates                         | X       | X       | X       | X       | X       | X       |
| State Quadratic Trends             | X       | X       | X       |         |         |         |
| State FE                           | X       | X       | X       |         |         |         |
| Observations                       | 2,064   | 2,064   | 2,064   | 2,064   | 2,064   | 2,064   |

Notes: The dependent variable is log of gasoline consumption per adult, except for column 6.

b Dependent variable is level of gasoline consumption per adult.

Robust standard errors in parentheses.

*** p<0.01, ** p<0.05, * p<0.1.

The results from estimating equation [8] using the tax-exclusive price and the sum of federal excise tax and state total taxes per gallon are contain in column 1 of Table 2. As expected, the coefficients on the tax-exclusive price and total taxes are negative and statistically significant. The marginal effect of a price change is -0.098, which is significantly smaller than the marginal effect of a tax change, i.e., -0.648; the difference in the coefficients is statistically significant at better than the one percent level. The result is consistent with the studies discussed above, and in particular with Li et al. (2014), of the differential effect of price and tax on gasoline consumption, although the other studies use a different regression specification.

Our interest is in whether consumers respond differentially to the various taxes. We first separate the total tax on gasoline into the federal excise tax and the state total tax, i.e., the sum of the state excise tax, state sales tax on gasoline, and state fees imposed on gasoline consumption. The regression results are found in column 2 of Table 2.

The coefficients on the tax-exclusive price and the two tax rate variables are negative, and in the case of the price and federal tax are very precisely measured. However, the coefficient on the state total tax is not statistically significant. The coefficient on the federal excise tax is much larger than the coefficients on the tax-exclusive price and the state total tax;
these differences are statistically significant at better than the one percent level. The coefficient on the state total tax rate is larger than the coefficient on the tax-exclusive price, but the difference is not statistically significant. Column 6 contains the results using the level of gasoline consumption per adult; as expected, the results are qualitatively equivalent to those in column 2.

We obtain equivalent results if we estimate more parsimonious regressions. Columns 3-5 report the results from dropping various combinations of the state quadratic time trends and state fixed effects. The magnitudes of the coefficients for these three regressions are similar to those in column 2, and in particular, the relative rankings of the size of the coefficients remain the same. While the coefficients on state total tax is statistically significant in columns 4 and 5, these coefficients are not statistically significantly different from the coefficients on price.

The results reported in Table 2 imply that consumer response to a change in the federal tax is larger than the response to a change in price. Furthermore, the results suggest that the response to a change in the federal gasoline excise tax is larger than the response to a change in state taxes on gasoline. In other words, changes in the two taxes appear to have differential effects on gasoline consumption.

One concern with our results is the possibility of simultaneity between price and gasoline consumption. Li et al. (2014) consider this possibility and use oil prices as an instrument for the tax-exclusive price. They find little change in their coefficients when they account for the simultaneity. We follow their method and construct the instrumental variable (IV) by interacting the tax-exclusive price in 1966 with the average annual real price of imported crude oil. As do Li et al. (2014), we drop the observations for 1966 and 1967 and use data from 1968 to 2008 to estimate the IV regression. The validity of the instrument depends on the assumptions that the demand shock after 1967 is not correlated with the shocks in 1966 and the state-level shocks are not correlated with the national average of the imported oil prices. We find the coefficients for the models presented in columns 1 and 2 in Table 2 are just slightly smaller when we use IV to account for simultaneity.

The regressions reported in Table 2 include state-quadratic time trends, but do not include year fixed effects. Given that the federal gas tax rate does not vary across states in a given year, the federal gas tax and year fixed effects are perfectly correlated. Thus, one cannot include both the federal gas tax and year fixed effects. Devereux et al. (2008) faced an equivalent issue in an international setting and argue that including country-specific time trends does allow, as far as possible, for unobserved factors that vary over time. Their argument applies to the results we report in Table 2.

However, to address more directly the collinearity between year fixed effect and the federal gas tax we estimate first-difference regressions. Table 3 reports the results using a first-difference equation; the results in columns 1 and 2 use change in log of gasoline consumption per adult, while those in columns 3 and 4 use the change in the level of gasoline
consumption per adult. These results are qualitatively consistent with the results presented in Tables 2. All of the coefficients in Table 3 are negative and statistically significant. First, consider columns 1 and 2 of Table 3, which use the log of gasoline consumption per adult. The coefficient on the total federal and state tax is statistically significantly larger than the coefficient on the tax-exclusive price (column 1). The coefficient on the tax-exclusive price is very similar to that in column 1 of Table 2, but the coefficient on the total federal and state tax is smaller in Table 3 than in column 1 of Table 2.

### Table 3

**FIRST DIFFERENCE REGRESSIONS**

| Variables: Change in log gas consumption |  | Change in level gas consumption |  |
|----------------------------------------|---|---------------------------------|---|
| First Differences of:                  |  |                                 |  |
| Tax-Exclusive Price                     | -0.104*** | -0.105*** | -0.071*** | -0.072*** |
|                                         | (0.005)    | (0.005)    | (0.004)    | (0.004)    |
| Federal + State Total Tax              | -0.216***  | 0.141***   |             |             |
|                                         | (0.034)    | (0.024)    |             |             |
| Federal Excise Tax                     | -0.308***  |             | -0.208***   |
|                                         | (0.059)    |             | (0.041)    |
| State Total Tax                        | -0.132**   | -0.079**    |             |
|                                         | (0.055)**  | (0.039)    |             |
| Constant                               | -0.006***  | -0.004***   | -0.004***   |
|                                         | (0.001)    | (0.001)    | (0.001)    |
| Covariates                             | X          | X          | X          | X          |
| Observations                           | 2,016      | 2,016      | 2,016      | 2,016      |

**Notes:** The dependent variable is change in the log of gasoline consumption per adult (columns 1 and 2), or the change in level gasoline consumption per adult (columns 3 and 4). Robust standard errors in parentheses.

*** p<0.01, ** p<0.05, * p<0.1.

In column 2 of Table 3 the coefficient on federal excise tax is larger than the coefficient on state total tax, and both are larger than the coefficient on the tax-exclusive price. The difference in the coefficients on the two tax variables in column 2 is statistically significant at the five percent level. However, the difference in the coefficients on price and state total tax is not statistically significant. The results for the level of gasoline consumption per adult (columns 3 and 4) are consistent with those in columns 1 and 2. The results in Table 3 suggest that changes in the federal tax have a larger effect on consumption than changes in tax-exclusive price or state total tax, and while the effect of changes in the state total tax is larger than the effect of the change in the tax-exclusive price, the difference is not statistically significant.
We explore the effect of changes in the federal tax more specifically by considering just the 4 years in which the nominal federal excise tax rate changed. Using the data for just those 4 years, we estimate regressions equivalent to those in Table 3. The results are reported in Table 4. While the coefficients are, with one exception, larger in Table 4 than in Table 3, the qualitative results are similar. The coefficients on the total federal and state excise tax (columns 1 and 3) are larger than the coefficients on the tax-exclusive price, as in Table 3. Of greater relevance, in both columns 2 and 4 the coefficient on the federal tax variable is statistically significantly larger (at the one percent level) than the coefficient on the tax-exclusive price, while the coefficient on state total tax is larger than the coefficient on the tax-exclusive price, but the difference is not statistically significant. These results support the conclusions drawn from the results in Table 3.

Table 4
FIRST DIFFERENCE REGRESSIONS FOR YEARS FEDERAL EXCISE TAX RATE CHANGED

| Variables: First Differences of: | Dependent Variable | | |
|----------------------------------|--------------------|---|---|
|                                  | Change in log gas consumption | Change in level gas consumption |
|                                  | (1) | (2) | (3) | (4) |
| Tax-Exclusive Price              | -0.110*** | -0.144*** | -0.065*** | -0.086*** |
|                                  | (0.031) | (0.032) | (0.020) | (0.021) |
| Federal + State Total Tax        | -0.496*** | -0.309*** |          |          |
|                                  | (0.102) | (0.065) |          |          |
| Federal Excise Tax               |          | -0.726*** |          | -0.452*** |
|                                  |          | (0.133) |          | (0.086) |
| State Total Tax                  |          | -0.261* |          | -0.163* |
|                                  |          | (0.134) |          | (0.086) |
| Constant                         | -0.392 | -0.567 | -0.248 | -0.327 |
|                                  | (0.356) | (0.355) | (0.228) | (0.227) |
| Covariates                       | X | X | X | X |
| Observations                     | 192 | 192 | 192 | 192 |

Notes: The dependent variable is change in the log of gasoline consumption per adult (columns 1 and 2). or the change in level gasoline consumption per adult (columns 3 and 4). Robust standard errors in parentheses.
*** p<0.01, ** p<0.05, * p<0.1.

Table 5, columns 1 and 3, contain the results for models that are equivalent to the models in columns 1 and 2 of Table 2, except that we include year fixed effects. Comparing column 1 in Table 5 to column 1 in Table 2, we find that when including year fixed effects, the coefficient on price is smaller and is no longer statistically significant. We suspect that this result is due to collinearity between the tax-exclusive gas price and the year dummies.
The coefficient on total federal and state taxes is substantially smaller in column 1 of Table 5 than in column 1 of Table 2, but still statistically significant. To include year fixed effects in the model shown in column 2 of Table 2, we omit federal gas tax (column 3 of Table 5). As expected, the coefficients on the tax-exclusive price and the tax variables (total federal and state taxes in column 1 and state total tax in column 3) are equal for the regressions reported in columns 1 and 3 of Table 5, and the coefficient on total federal and state tax in column 1 equals the coefficient on state tax in column 3.

Table 5
REGRESSIONS OF LOG GASOLINE CONSUMPTION PER ADULT WITH PERIOD FIXED EFFECTS

| Variables                  | (1)          | (2)          | (3)          | (4)          | (5)          |
|----------------------------|--------------|--------------|--------------|--------------|--------------|
| Tax-Exclusive Price        | -0.045       | -0.118***    | -0.045       | -0.104***    | -0.134***    |
| (0.033)                    |              | 0.005        | (0.033)      | (0.013)      | (0.006)      |
| Federal + State Total Tax  | -0.377***    | -0.385***    |              |              |              |
| (0.068)                    |              | 0.054        |              |              |              |
| Federal Excise Tax         | Omitted      |              | -0.282***    | -0.889***    |
|                            |              |              | (0.091)      | (0.094)      |
| State Total Tax            | -0.377***    | -0.370***    | -0.281***    |
| (0.068)                    |              | (0.067)      | (0.065)      |
| Constant                   | -1.074***    | -1.156***    | -1.127***    | -1.086***    | -1.085***    |
| (0.372)                    |              | (0.338)      | (0.370)      | (0.351)      | (0.333)      |
| Covariates                 | X            | X            | X            | X            | X            |
| State Quadratic Trends     | X            | X            | X            | X            | X            |
| State FE                   | X            | X            | X            | X            | X            |
| Year FE                    | 1-year       | 3-year       | 1-year       | 2-year       | 3-year       |
| Observations               | 2,064        | 2,064        | 2,064        | 2,064        | 2,064        |

Notes: The dependent variable is log gasoline consumption per adult. Robust standard errors in parentheses.

*** p<0.01, ** p<0.05, * p<0.1.

Since we cannot use year fixed effects because of their collinearity with the federal excise tax but still estimate a coefficient for the federal gas tax, we construct two-year and three-year fixed effects. Davies and Vadlamannati (2013) face a similar issue and address it by using three-year fixed effects. To construct these period fixed effects, we create dummy variables that equal one for two (or three) consecutive years. Thus, for example, the first two-year dummy equals one for both 1966 and 1967. While not a perfect substitute of year fixed effects, two-year and three-year fixed effects do reflect unmeasured factors that differ over time. Recall that we still include state quadratic trends, which also account for variations over time. Two-year and three-year fixed effects remove the perfect collinearity between the year fixed effects and federal gas tax,
allowing the remaining variation in the federal gas tax to identify some of the variation in gasoline consumption.

Column 2 of Table 5 contains the results when three-year fixed effects are used and the tax is the total federal and state tax. (Since the basic results for column 2 are equivalent when we use two-year fixed effects, we report the results using just the three-year fixed effects). The difference in the coefficients on the tax-exclusive price and federal plus state tax is statistically significant at better than the one percent level for both columns 1 (one-year fixed effects) and 2 (three-year fixed effects) of Table 5. Compared to the results in column 1 of Table 5, the coefficient on the tax-exclusive price in column 2 is larger and statistically significant. We believe the change in the coefficient is due to the fact that three-year fixed effects are not as correlated with the tax-exclusive price as one-year fixed effects. The coefficient on total federal and state taxes changes from -0.648 with no year fixed effects (column 1 of Table 2) to -0.377 with one-year fixed effect (column 2 of Table 5), but essentially does not change when we use three-year fixed effects rather than one-year fixed effects (column 2 versus column 1 of Table 5). Note that the results in column 2 of Table 5 are similar to those in column 1 of Table 3.

Columns 4 and 5 of Table 5 are regressions that consider the separate federal and state taxes, with two-year and three-year fixed effects. For both regressions the coefficients on the tax-exclusive price and the two taxes are negative and statistically significant. For column 4, the differences between the coefficients on price and each of the two tax rates are statistically significantly at better than the five percent level, but the coefficients on the two tax rates are not statistically significantly different. For column 5 the coefficients are all statistically significantly different from each other at better than the five percent level. The magnitude of the coefficient on the federal tax is larger in column 5 than in column 4, and in column 5 it is also larger than the coefficient on state taxes. (We also created five-year fixed effect dummies; the results are similar to those in Table 3, except that the size of the coefficient on the federal tax increases to -1.003, approaching the value of the coefficient in column 2 of Table 2, i.e., the case with no period fixed effects. The coefficient on state total tax is somewhat smaller with five-year fixed effects.)

The results reported in columns 4 and 5 of Table 5 and column 2 of Table 3 and Table 4 do differ. Nonetheless, we suggest that the results provide evidence in support of the position that taxes have a larger effect on gasoline consumption than price and are generally consistent with the position that the effect of the federal tax is larger than that of the state tax.

The above results are based on a semi-log and linear demand function, \( i.e., \) equation [8]. An alternative demand equation is equation [4] (after expanding \( T(1+\delta) \) into \( t_F (1+\delta_F)+t_S (1+\delta_S) \)), in which the dependent variable is the percentage change in consumption and the relevant independent variables are the change in price or tax divided by \( P_t t_t (1+\delta_F) \) and \( (1+\delta_S) \). Table 6 reports the results. We make use of the equation \( b_2=b(1+\delta) \) (where the value of \( b \) is assumed to be the coefficient on the tax-exclusive price) and use the coefficients in column 2 of Table 2 to develop estimates of \( (1+\delta_F) \) and \( (1+\delta_S) \). The results of the regression
are reported in column 1 of Table 6. The coefficients on price and the two tax variables are negative and statistically significant. As in Tables 3 and 4, the coefficient on the federal tax variable is statistically significantly larger than the coefficient on the tax-exclusive price at the one percent level, but the difference between the coefficients on the tax-exclusive price and on the state total tax is not statistically significant. In column 2 of Table 6 we report the results when we assume that $\delta=0$ and thus simply divide through equation [4] by $P + t_F + t_S$. These results are qualitatively equivalent to those in column 1.

### Table 6
REGRESSIONS OF PERCENT CHANGE IN LOG GASOLINE CONSUMPTION

| Variables                                   | (1)       | (2)       |
|---------------------------------------------|-----------|-----------|
| Change in Tax-Exclusive Price/Adjusted Tax-Inclusive Price | -0.301*** | -0.146*** |
|                                              | (0.012)   | (0.011)   |
| Change in Federal Excise Tax/Adjusted Tax-Inclusive Price | -0.741*** | -0.276*** |
|                                              | (0.111)   | (0.062)** |
| Change in State Total Tax/Adjusted Tax-Inclusive Price | -0.259*   | -0.150    |
|                                              | (0.138)   | (0.066)   |
| Constant                                    | -0.149*** | -0.149*** |
|                                              | (0.022)   | (0.022)   |
| Covariates                                  | X         | X         |
| Observations                                | 2,016     | 2,016     |

Notes: The dependent variable is percent change in log gasoline consumption per adult. In column 1, changes in price and taxes are divided by tax-inclusive price adjusted for estimated tax aversion, while in column 2 we assume no tax aversion. See text for explanation. Robust standard errors in parentheses.

*** $p<0.01$, ** $p<0.05$, * $p<0.1$.

As we noted above, the state total tax is comprised of three separate taxes and fees, namely the state excise tax, fees, and state sales tax. Table 7 considers the separate effect of these three state components using the log of gasoline consumption (column 1) and level of gasoline consumption (column 2). All of the coefficients are negative, as expected, and with the exception of the coefficient on the state excise tax and the sales tax, the coefficients are statistically significant. The value of the coefficients on price and the federal excise tax are very similar to those reported in column 2 of Table 2. The coefficients on the three state taxes are smaller than the coefficients on the federal excise tax, and all are larger than the coefficients on price, as was the case for total state tax in Table 2. However, many of the differences are not statistically significant. In column 1, none of the differences among the three state taxes is statistically significant. It is of interest that all three of the state tax variables have similar effects, suggesting it may be the level of government imposing the tax and not the specific nature of the tax that causes the differential effect. The only differences that are statistically significant are between the price and the federal tax and state fees, and between the federal tax and all three of the state taxes. The results are similar for the coefficients in column 2.
### Table 7
REGRESSIONS WITH DETAILED STATE TAXES AND FEES

| Variables                  | (1) Log of Gas Consumption per Adult | (2) Level of Gas Consumption per Adult |
|----------------------------|--------------------------------------|----------------------------------------|
| Tax-Exclusive Price        | -0.118***                            | -0.077***                              |
|                            | (0.008)                              | (0.005)                                |
| Federal Excise Tax         | -1.327***                            | -0.897***                              |
|                            | (0.125)                              | (0.089)                                |
| State Excise Tax           | -0.160                               | -0.078                                 |
|                            | (0.126)                              | (0.101)                                |
| State Other Fees           | -0.721**                             | -0.387**                               |
|                            | (0.343)                              | (0.177)                                |
| State Sales Tax            | -0.325                               | -0.115                                 |
|                            | (0.411)                              | (0.270)                                |
| Constant                   | -0.759***                            | 0.430***                               |
|                            | (0.173)                              | (0.134)                                |
| Covariates                 | X                                    | X                                      |
| State Quadratic Trend      | X                                    | X                                      |
| State FE                   | X                                    | X                                      |
| Observations               | 2,016                                | 2,016                                  |

Notes: The dependent variable is log of gasoline consumption per adult (column 1), or gasoline consumption per adult (column 2). Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

At most there were 9 states with a sales tax that applied to gasoline purchases, and the average sales tax over the entire period for those states with a sales tax that applied to gasoline was 1.7 cents per gallon. We thought this might be an explanation for the statistical insignificance of the coefficient on the state sales tax. However, the coefficient on fees is statistically significant even though there were no states with a fee until 1979, only one state until 1983, just 16 states in 2008, and, with the exception of Pennsylvania and New York, the fees for the other 14 states averaged less than 1.4 cents per gallon. Thus, we are unable to explain the statistical insignificant of the coefficient on sales tax.

Until this point, we have assumed that the burden of excise taxes on gasoline falls entirely on consumers. However, Chouinard and Perloff (2004) find that this is the case for state excise tax on gasoline but not for the federal excise tax on gasoline. Their empirical analysis suggests that 47 percent of the federal excise tax is born by the consumer in the form of higher retail price and 53 percent is born by wholesalers in reduced whole-
sale price. These incidence results imply that if the federal excise tax increased by 10 cents, the tax-inclusive price will go up by only 4.7 cents. Since the tax-inclusive price equals the tax-exclusive price plus state tax and federal tax, it follows that a 10 cent increase in the federal tax will cause the tax-exclusive price to fall by 5.3 cents. To account for this, we deducted 53 percent of the federal excise tax from the tax-exclusive price and re-estimated equation 2 of Table 2. The only changes in the results reported in column 2 of Table 2 are that coefficient on the federal excise tax increases slightly to -1.545 and the coefficient on total state tax increases to -0.162. Alternatively, we could assume that consumers believe that a 10 cent increase in the federal excise tax will only increase the tax by 4.7 cents. Re-estimating equation 2 of Table 2 but reducing the federal excise tax by 47 percent simply increases the value of the coefficient on the federal tax to -3.288, with no other changes.

5. Summary and Conclusions

In this paper, we examine whether gasoline consumption responds differentially to various taxes, in particular to the federal excise tax and total state taxes on gasoline. We extend the existing literature by estimating the relationship between gasoline consumption and the tax-exclusive price and the different taxes using several different regression specifications. As one would expect, we find that gasoline consumption is negatively and generally statistically significantly related to the tax-exclusive price and to both federal and state taxes on gasoline. However, regarding the basic question of interest, i.e., are there differential effects across taxes, we find that changes in federal excise tax have a larger effect on gasoline consumption than changes in the tax-exclusive price or in the state total tax. While we generally find that the coefficients on state total tax are larger than the coefficient on the tax-exclusive price, the differences are not usually statistically significant.

There are several possible explanations for a differential response by tax. One explanation is what behavioral economists refer to “tax aversion bias,” that is, an individual perceives that a tax has an additional burden beyond its monetary value; see for example, Kirchler (1998), Schmölders (1959), Alm and Bourdeaux (2013), and Hill (2010). Tax aversion, also referred to as a labeling effect, has been studied using survey responses and laboratory experiment. Sussman and Olivola (2011), for example, use a survey to ask subjects to choose between buying a television at a local store at a price discount or at a store that required a 30-minute drive but did not charge the sales tax (which is less than the price discount). They find that more subjects choose to drive the longer distance in the tax free, but more expensive situation. Other surveys have been conducted by McCaffrey and Baron (2004), Löfgren and Nordblom (2009), and Hardisty et al. (2010).

Others have used laboratory experiments to explore tax aversion, with mixed results. Kallbekken et al. (2011), for example, asked subjects to vote on a choice between a (Pigouvian) “tax” and a (Pigouvian) “fee”, and find no evidence of tax aversion when the revenue
is distributed to the victims or polluters. In their experiment Ackermann et al. (2013) find tax aversion, while Blaufus and Möhlmann (2014) do not.

Tax aversion would explain the larger effect of taxes than for the tax-exclusive price. But it might be argued that the aversion to a particular tax depends on any perceived benefit the individual receives from expenditures associated with the tax, which might include better roads in the case of the taxes on gasoline. If individuals believe that a dollar of revenue generated by the state excise tax will generate greater benefits than will the federal excise tax, the size of tax aversion effect would be smaller for the state tax on gasoline. All of the revenue from the state tax will be spent in the individual’s state, while the revenue from the federal excise tax could be allocated to other states. Furthermore, to the extent that voters in a state have greater say as to the size of the state tax than the federal tax, consumers might be less averse to the state tax. This suggests that the effect of a change in the state gasoline tax would be smaller than a change in the federal excise tax.

An alternative explanation for why consumers may respond differentially to taxes than prices is related to salience of prices and taxes (see Chetty et al. 2009; Finkelstein 2009; Congdon et al. 2009; Gallagher and Muehlegger 2011; Goldin and Homonoff 2013). Chetty et al. (2009), for example, find that the response to a sales tax is larger if the sales tax is more salient; in particular, if the tax is posted on grocery store shelves than if the tax is imposed at checkout. Li et al. (2014) present evidence that gasoline tax changes are more salient than price changes, which is consistent with larger responses to tax changes then price changes. If the federal excise tax is more salient than the state tax on gasoline, we would expect a larger response to the federal excise tax than the state tax on gasoline. The federal excise tax is certainly larger than most state taxes on gasoline, which would be expected to make the federal excise tax more salient. But the federal excise tax did not change often over the period, while many states changed their state tax on gasoline. That would suggest that state taxes could be more salient. As far as we can determine, there is no measure of the relative tax salience of federal and state gasoline taxes, although Fisher and Wassmer (2017) report that consumers substantially overestimate the state gas tax they pay.

A third possible explanation for the finding of differential effects of the two taxes is that federal excise taxes are more persistent than state taxes and prices. Consumer decisions regarding automobile purchases, and thus the choice of fuel economy, could be affected by the perceived persistence of the federal excise tax. If federal taxes are more persistent than state taxes, this could affect consumers’ long-run automobile purchase decisions, which in turn would affect the consumers’ ability to make short-run changes in gasoline consumer (Scott 2012; Li et al. 2014.) Over the period we consider, the nominal federal excise tax changed 4 times, but there are only 3 states that changed their excise tax 4 or fewer times. The average number of state excise tax changes was 8.7 times.

Anderson et al. (2013) find consumers do not readily distinguish between tax and non-tax changes in making future gasoline price forecasts. So their forecast data do not provide support for the hypothesis that excess sensitivity of forecasts of tax changes is likely to ex-
plain the finding that current gasoline consumption is more sensitive to tax policy than to pre-tax price changes.

Cross-border shopping will cause a larger reduction in the state’s gasoline consumption as a result of an increase in state gasoline tax than an increase in the federal excise tax. This is a reason to expect the coefficient on the state gasoline tax to be larger than the coefficient on the federal excise tax. There is an extensive literature that finds that differential sales taxes along a state’s border results in larger sales along the border of the state with the lower tax sales rate (see Fox 1986; Walsh and Jones 1988; Tosun and Skidmore 2007; Leal et al. 2010). Regarding the effect of state fuel tax differential on cross-border shopping for gasoline, there is some evidence from Europe regarding the effect of gasoline tax differentials; see Banfi et al. (2005); Rietveld et al. (2001); and Leal et al. (2009). However, we found only one article that focuses on the U.S. Manuszak and Moul (2009) consider gasoline tax rate differentials across northern Illinois and Indiana, and find that a typical consumer’s willingness to pay to travel an additional mile to buy gasoline is about $0.065 to $0.085 per gallon. There is other research that finds that a state’s gasoline price near its border will increase when the neighboring state increases its gasoline tax rate (Doyle and Samphantharak 2008 and Coyne 2017). For example, Coyne finds that the price increase along the border equals roughly 35 percent of the price increase in the state that increased its gasoline tax. Therefore, the tax increase would have to be $0.092 to $0.131 per gallon to provide an incentive to travel an additional mile to buy gasoline. Considering that the average state gasoline taxes in 2008 is only $0.217, we presume that the cross-border shopping behavior in gasoline is limited. The total size of the cross-border shopping effect will depend on the number of people who live along the state’s border. While cross-border shopping means that an increase in the state gasoline tax will have a larger effect, our results imply that the effect is not large enough to result in the state gasoline tax having a larger effect than the federal excise tax.

Our results have obvious policy implications. One implication is the estimate of the effect of a tax increase on tax revenue. Our results suggest that the effect on gasoline consumption from a tax increase will be larger than from an increase in the tax-inclusive price. This implies that a predicted change in revenue using changes in the tax-inclusive price to estimate the effect on consumption will be smaller than if the estimated effect is based on the effect of changes in the tax rate. The results also imply that the revenue effect will be smaller for a given change in the federal excise tax than for a change in the state tax. A second, and related implication is the effect on miles driven and pollution levels. Our results imply that an increase in the federal excise tax will have a larger reduction in miles driven, and thus a larger reduction in the level of congestion and pollution, than an increase in state gasoline tax.

Related to this is the determination of the optimal tax for addressing the externalities from miles driven. The optimal Pigouvian tax is based on how gasoline consumption (and thus miles travelled) changes due to a tax increases and how the externality changes as miles driven changes. The estimated change in gasoline consumption based on changes in the price will be smaller than if the estimate is based on changes in the federal tax; this will lead to
different estimates of the optimal tax, and in particular to a larger Pigouvian tax using the
former. Further, the response to a federal gas tax change is larger than for an increase in the
state tax on gasoline, and therefore the increase in the federal excise tax necessary to obtain
a given reduction in miles driven will be smaller than for an increase in the state tax on
gasoline. Thus, the welfare loss from a federal gas tax increase for a given reduction in miles
driven will be smaller than for an increase in the state gas tax. This implies that the federal
excise tax should be used to reduce the externalities. However, it is unlikely that the optimal
decrease in miles driven should be the same in all states. Thus, there is a tradeoff between
higher net social benefit on average from an increase in the federal excise tax and the welfare
gain from a more geographically tailored tax policy that requires a larger average increase in
state taxes.

Notes
1. Goodwin et al. (2004) provide a recent survey of the estimation of the price elasticity of demand for gasoline.
2. The only empirical paper, besides Rosen (1976), we identified that does not find a differential effect between
the tax-exclusive price and the tax is Ghalwash (2007), who uses Swedish aggregate data for the period 1980-
2002 on consumption of various non-durables to examine the differences in consumer reaction to environmen-
tal taxes.
3. Rivers and Schaafele (2015) is an exception. They specify a linear demand equation equivalent to [2], but use
log of Q.
4. The Li et al. (2014) data are available at https://www.aeaweb.org/articles.php?doi=10.1257/pol.6.4.302.
5. In some, but not all cases, these fees are included in the state excise tax reported by Li et al. (2014), but were
not separately reported.
6. Regressions were estimated using Stata’s xtreg option.
7. The number of years in our sample is not evenly divisible by two or three. We experimented with how to treat
or assign the extra year, but obtained similar results regardless of how it is assigned.

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**Resumen**

Los estudios previos demuestran que el consumo de gasolina es más sensible a los cambios en los impuestos que a los cambios en precio de la gasolina sin impuestos. Este trabajo analiza por separado los efectos sobre el consumo de gasolina de las variaciones en el precio sin impuestos, de los cambios en el impuesto especial federal y de las alteraciones en los impuestos estatales que gravan la gasolina. Los resultados indican que el consumo de gasolina se ve afectado en mayor medida por los cambios en el impuesto especial federal que por las variaciones en los impuestos estatales o en el precio sin impuestos. A su vez también analizamos el efecto sobre el consumo de gasolina de determinados impuestos estatales y tasas: el impuesto especial sobre el consumo, el impuesto sobre las ventas y las tasas.

*Palabras clave:* impuestos especiales, consumo de gasolina, aversión a los impuestos.

*Clasificación JEL:* H21, H25, H31