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ABSTRACT

The incidence of taxes on consumers and producers plays a central role in evaluating energy tax policy, yet the literature testing the main predictions of the tax incidence model is sparse. In this paper, we examine the pass-through rate of state gasoline and diesel taxes to retail prices, and importantly we estimate the dependence of pass-through on factors constraining the gasoline and diesel supply chains. We consider several factors that alter the elasticity of supply, including within state heterogeneity in gasoline content requirements, refinery capacity utilization, inventory constraints, and variation in the demand for untaxed uses of diesel. In general, we find that in periods of time when the supply chain is constrained, and the constraint is plausibly unrelated to shifts in demand, the pass-through rate of fuel taxes declines. We describe several potential implications for tax policy, including tax breaks during peak driving season and during times of supply disruptions such as after major hurricanes.

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1 Introduction

Tax incidence plays a central role in current energy policy debates. The extent to which taxes are passed through to retail prices, and on what the pass-through rate depends, determines in part the distributional impact of carbon taxes, the effectiveness of using a tax holiday to ease high fuel prices, and how tax policy can be used to respond to disruptions in the fuel supply chain, such as those caused by natural disasters like hurricane Rita.

While the theory of tax incidence is front and center in the textbook treatment of taxation, the main predictions of the tax incidence model are largely untested. Though it is often assumed that commodity taxes are fully passed through to consumers, this assumption is based on relatively few empirical studies. There is only sparse evidence regarding the extent to which taxes are incorporated into retail prices, as noted by Poterba (1996) and Doyle and Samphantharak (2008), and little work examining the extent to which tax incidence responds to changes in market power or supply elasticity. As a result, the empirical literature on tax incidence is unable to shed much light on the aforementioned policy questions.

In this paper, we examine the pass-through rate of fuel taxes to retail prices by utilizing changes in state gasoline and diesel taxes. Our primary contribution is estimating the dependence of pass-through on factors constraining the gasoline and diesel supply chains. Understanding this dependence provides insight on how tax policy might be conditioned on observed supply conditions. Furthermore, to the extent by which supply chain constraints suggest variation in the elasticity of fuel supply, it provides a test of a fundamental prediction of tax incidence theory.

Consistent with prior literature on gas tax incidence, we find that state gasoline and diesel fuel taxes are on average fully and immediately passed on to consumers. The above result masks important heterogeneity in the rate of pass-through, as we find evidence consistent with the notion that pass-through falls in times of inelastic supply. In particular, the pass-through rate of diesel is low when refinery capacity utilization is at its highest, and when untaxed uses of diesel fuel are less important (which reduces the residual supply elasticity of taxed diesel). We find that the pass-through of gasoline taxes is lower when gasoline content regulations are heterogeneous within a state, which has been found to constrain refiners' ability to adjust production in the short-run. (see for instance Muehlegger, 2006). Moreover, it has been suggested that inventories play a role in constraining the market power of wholesalers – we find that when inventories are constrained from below, the pass-through rate of diesel taxes is greater than one.

Our findings have several implications for current tax policy. First, our work speaks directly to the efficacy of "fuel tax holidays." Like Doyle and Samphantharak (2008), who examine the effects of a gas tax moratorium on prices in Illinois and Indiana, our work suggests that the benefits of a tax holiday will be driven by contemporaneous market conditions. We find that the relationship between capacity utilization and the tax pass-through rate differs between diesel and gasoline. Gasoline taxes are fully passed through to consumers regardless of season or capacity utilization. Consequently, a seasonal state gas tax holiday would apparently provide relief to consumers. In contrast, the pass-through of diesel taxes falls during periods of high capacity utilization. This finding is particularly relevant for fuel tax holidays. Although fuel taxes are passed-through fully under normal circumstances, fuel tax holidays are most attractive to legislators during times of high fuel prices induced by supply chain constraints. We find that at these times, taxes are likely to be shared between consumers and producers - consequently, consumers are unlikely to reap the full benefit of fuel tax moratoria.

Second, our results inform the politics of increasing gasoline taxes. The proposal of the Deficit Reduction Committee recently advocated increasing gasoline prices as part of balancing the federal budget. In addition, several carbon proposal put forth in 2010 implicitly taxed gasoline and diesel by taxing carbon emissions from refinery operations. Our findings inform the distributional consequences of these policies. We find that under most circumstances, gasoline and diesel taxes are fully passed onto consumers. Moreover, since demand for gasoline and diesel fuel are relatively inelastic, our results suggest that refiners, wholesalers and retail station operators likely require little compensation (in the form of tax credits or free carbon permits) to be made whole.

In addition, our work makes several contributions to existing literature on fuel taxes and to the broader literature on tax incidence. To our knowledge ours is the first study to consider the incidence of diesel fuel taxes. Moreover, our work is unique in its examination of how regulations affect tax pass-through. Chouinard and Perloff (2004,2007) and Alm et al (2009) provide evidence regarding the incidence of gasoline taxes on retail prices using state-level variation in taxes and prices. Chouinard and Perloff (2004) tests the response of incidence to residual supply elasticity at the state level, noting that small states should have a greater supply elasticity and therefore a higher rate of consumer incidence. More generally Poterba (1996) examines the incidence of retail sales taxes on clothing prices, Besley and Rosen (1999) consider city-level prices across twelve commodities, and a number of papers including Sung, Hu and Keeler (1994), Barnett et al (1995), Delipalla and O'Donnell (2001), Harding, Lovenheim and Leibtag (2009) and Chiou and Muehlegger (2009) estimate cigarette tax incidence as well as how incidence varies geographically or demographically.[1]

The paper proceeds as follows. Section 2 presents a theoretical discussion of incidence and supply. Section 3 describes the data and empirical methods we will use. Section 4 presents the empirical results, and Section 5 concludes.

2 Model and Industry Background

We consider a quantity tax of t per unit of a good, which is paid by the supplier. A unit mass of firms sell a quantity q of this good to consumers at the tax inclusive price p. Consumers have an aggregate demand for the product given by $D(p)$, while competitive supply can be characterized by the function $S(p,t)$. The textbook approach to characterizing incidence starts from the equilibrium condition $D(p) = S(p,t)$ and perturbs this equilibrium by changing the tax:

$$\frac{dp}{dt} = \frac{S_t(p,t)}{D_p(p) - S_p(p,t)} \tag{1}$$

where S_p, S_t, and D_p represent the derivative of supply with respect to price and tax and the derivative of demand with respect to price, respectively.

Suppose diesel is produced at cost $C(q)$ where $C'(q) > 0$ and $C''(q) > 0$. If firms behave competitively, this yields the profit function

$$\Pi(q) = p(q) - tq - C(q). \tag{2}$$

Firms produce to the point where price is equal to marginal cost, or $q = \phi(p - t)$ where $\phi(p-t) = C'^{-1}(p-t)$. Supply is a function of the price net of tax, so that the supply response to taxes is the same as the response to prices: $S_p = -S_t$. Substituting this into equation (1), multiplying through by p/q, and taking the limit as $t \to 0$, the standard representation of incidence is obtained:

$$\frac{dp}{dt} = \frac{\eta}{\eta - \epsilon} \tag{3}$$

where η and ϵ are the elasticities of supply and demand, respectively. The rate of pass-through goes up as supply is more elastic and demand is less elastic.

A long literature in public finance extends this result to non-competitive markets and shows that tax pass-through in oligopolistic markets can exceed one under certain demand conditions.

[1] Early empirical work on incidence includes Due (1954), Brownlee and Perry (1967), Woodard and Siegelman (1967), and Sidhu (1971).

Following the derivation in Stead (1985), a firm with market power facing consumers with constant demand elasticity will more than fully pass taxes along to consumers. For firm i setting prices with market power, profit maximizing prices are given by

$$p = \frac{mc + \tau}{1 + \frac{1}{\epsilon_i}}$$

where ϵ_i is the residual demand curve faced by the firm. Since the profit maximizing firm will set price on the elastic portion of the demand curve, a change in τ increases tax-inclusive prices by $\frac{1}{1+\frac{1}{\epsilon_i}} > 1$.

2.1 Industry Background

The primary contribution of our paper is to estimate how fuel tax pass-through responds to constraints at various points of the supply curve. We briefly describe the US supply chain for petroleum products. We then present a discussion of factors that shift the elasticity of supply η and empirically examine how these shifts affect the pass-through of gasoline and diesel taxes.

A four-part supply chain (refining, bulk transport, terminal storage, and retail delivery) delivers petroleum products to US consumers. Crude oil is refinery primarily at domestic refineries, with fifty percent of domestic refining capacity located in Texas, Louisiana and California. From 1983 to 2003, 94 percent of national gasoline consumption was refined domestically.[2] Diesel fuel and gasoline are shipped from refineries in bulk by pipelines or barge to wholesale terminals located near most major US metropolitan areas. Wholesale terminals hold gasoline and diesel inventories to smooth local demand shocks - from the wholesale terminals, tanker trucks transport fuel to industrial and commercial customers and to retail stations for sale to individual drivers.

2.2 Refinery Constraints

We examine the effect of four supply chain constraints on fuel tax pass-through. The first constraint we study is when demand for refined products approaches domestic refining capacity. Demand for refined products tends to peak during the summer driving season. On average, domestic refinery capacity is 92 percent utilized during summer months in our study period.

[2]Although regulations do not prevent gasoline and diesel fuel from being refined outside the United States and imported into the country, imports face several barriers to being an effective way to mitigate the effects of supply chain constraints. As Borenstein et al (2004) notes, many arbitrage opportunities (due to unanticipated demand shocks or supply constraints) are relatively short in duration. The lag between refining product to meet US fuel requirements and shipping the product to US markets is often great enough to prevent foreign refineries from acting as a competitive source of peak supply.

During several summers of our sample, though, utilization peaks at over 99 percent. During periods of high capacity utilization, academic studies and government investigations have noted that gasoline prices tend to rise dramatically.[3] Moreover, unanticipated refinery closures often lead to large increases in local prices.

Refinery capacity constraints persist for two reasons. First, siting a new refinery is very difficult. Due to environmental regulations, siting challenges and resistance from local communities, no new domestic refineries have been built since 1976 (although a small refinery (163k bbls/day) is currently proposed in Arizona). Second, expansions of capacity at existing refineries is limited in scope - the growth of domestic refining capacity to approximately 1.0 percent per year between 1995 and 2005, the period during which domestic refining capacity was heavily utilized. Over the same decade, consumption of refined products has increased by 1.7 percent per year.

2.3 Storage constraints

Firms' abilities to store gasoline and diesel fuel at wholesale terminals introduce important complications when considering tax incidence. Storage places restrictions on the intertemporal evolution of prices. Suppose that a change in the tax rate in time $t+1$ is anticipated at time t. Allow firms to store an amount of fuel, S_t, from time t to $t+1$ at a marginal storage cost of k. A wholesale terminal chooses storage to maximize expected profits:

$$E_t[\Pi_{t+1}] = E_t[p_{t+1} - \tau_{t+1}]S_t/(1+r) - (p_t - \tau_t)S_t - kS_t \tag{4}$$

The first-order condition of a competitive storage firm is therefore given by

$$(E[p_{t+1}] - \tau_{t+1})/(1+r) = p_t - \tau_t + k. \tag{5}$$

A simple model of storage predicts that firms will use storage to arbitrage away anticipated differences in prices net of taxes. So long as the no-arbitrage condition holds, prices will rise by the amount of the tax increase and taxes will be fully passed onto consumers. Importantly for our context, the condition (5) should hold even when production is temporarily inelastic, such as when refineries face short-run capacity constraints.

There are several reasons why the simple no-arbitrage condition given by equation (5) may not hold for gasoline or diesel fuel. Borenstein et al (2004) note capacity constraints in the

[3] see e.g. Muehlegger (2006) and the FTC Midwest Gasoline Price Investigation

storage market. If capacity constraints in the storage market are binding, the shadow value of the storage constraint would enter into (5). At the low end, storage obviously cannot fall below zero.

In addition, storage plays an important role in mitigating market power in wholesale fuel markets.[4] Inventories help to mitigate market power concerns that may arise due to short-run mismatches between supply and demand – firms are less able to exercise unilateral market power if other firms hold large inventories. When inventories are low, competitors may be less able to offset a reduction in quantity by a competitor. If inventories act as a hedge against market power in wholesale fuel markets, the residual demand elasticity faced by the firm would be negatively correlated with competitors' inventories. When inventories are low, firms able to exercise temporary market power may more than fully pass the taxes onto consumers.

Consequently, the relationship between inventories and tax incidence is complicated. In a market with no constraints and costless storage, we should expect to estimate full pass-through in a first-differenced specification. However, if storage capacity constraints bind, pass-through may either decrease or decrease. Inventories are unable to respond to changes in price, thereby making supply elasticity, however low inventories may increase market power at wholesale terminals, in which case it is conceivable that wholesalers will be able to more than fully pass taxes along to consumers.

2.4 Residual Supply Elasticity

For diesel, untaxed supplies provide a source of inventories that supplement wholesale terminal inventories. No. 2 distillate can either be sold as diesel or as heating oil, which suggests that the supply of diesel is the residual of No. 2 distillate supply after subtracting the demand for fuel oil. The residual supply of diesel is therefore given by $S^{diesel}(p) = S(p) - D^{oil}(p)$, where $S(p)$ is the supply of No. 2 distillate.[5] Differentiating with respect to p, we obtain the residual supply elasticity of diesel,[6]

$$\eta^{diesel} = \eta/\sigma - \epsilon_{oil}/\sigma^{o} \tag{6}$$

where η^{diesel} is the residual supply elasticity of diesel, η is the supply elasticity of No. 2 distillate, σ is diesel's share of No. 2 distillate, ϵ_{oil} is the demand elasticity for fuel oil, and σ^{o} is the supply

[4] As Borenstein et al (2004) notes, significant barriers to entry exist in the fuel storage market. Consequently, wholesale storage markets tend to be relatively concentrated.

[5] We consider the residual supply rather than residual demand since demand is likely to be largely independent across fuel oil and diesel markets, while supply is interrelated.

[6] Chouinard and Perloff (2004) perform a similar exercise for gasoline, showing how the residual supply elasticity, and therefore pass-through, in a state is higher as its share of national gasoline demand is lower.

of diesel relative to the supply of fuel oil. The supply elasticity is therefore greater when fuel oil demand is high relative to diesel, and a more elastic supply of diesel should increase the pass-through of the diesel tax to consumers. In the empirical section to follow, we utilize variation in weather and households' use of fuel oil as factors that shift σ and σ^o.

2.5 Environmental Regulations

Finally, we consider environmental regulations that complicate the bulk transportation, wholesale storage and local distribution of gasoline. In 1990, the Clean Air Act Amendment mandated special requirements for fuel in regions failing to meet EPA limits for ozone and carbon monoxide pollution. The EPA designed reformulated gasoline (RFG) to reduce mobile-source emissions (cars) in areas in serious or severe ozone non-attainment.[7] For regions in carbon monoxide non-attainment, the EPA designed oxygenated gasoline for winter use.[8]

Special blends complicate the petroleum product supply chain – refiners must determine which blends to produce in advance, pipeline operators must manage the transportation of a larger number of incompatible fuels and wholesale terminal operators may have to manage storage for more than one specification of gasoline at once.[9] Consequently, we anticipate that taxes will be less fully passed-through in states where regulatory heterogeneity is greater.[10]

3 Data and Methods

3.1 Data

We collect a 20-year monthly panel of average state-level prices of gasoline and diesel fuel from the Energy Information Administration (EIA). The EIA reports the monthly average price of

[7]Initially, nine cities with 63 million residents fell into this category: Baltimore, Chicago, Hartford, Houston, Los Angeles, Milwaukee, New York City, Philadelphia and San Diego. Subsequently, Sacramento was reclassified as in severe ozone non-attainment area in the summer of 1995. In addition, many other states, counties and cities chose to voluntarily adopt the new, more stringent reformulated gasoline standards. Between 1995 and 2001, areas containing approximately 35 million people have "opted-in" to the federal RFG program.

[8]Oxygenated gasoline is required in winter months where carbon monoxide emissions are greatest. Thirty-nine areas were in non-attainment initially, containing 86 million people. Of these areas, the majority have since come into attainment and stopped using oxygenated gasoline in winter months.

[9]As an example, following Hurricane Rita, the Missouri Department of Natural Resources received an EPA waiver from local RFG requirements. The EPA determined that "an 'extreme and unusual fuel supply circumstance' exists that will prevent the distribution of an adequate supply of RFG to the St. Louis RFG covered area." The waiver allowed St. Louis retail stations to sell conventional gasoline from Sept 27th until October 7th - since the supply of conventional gasoline to the area outside of the RFG covered area was relatively unaffected.

[10]Special blends may also increase concentration if they are sufficiently costly for refineries to produce. For example, the FTC complaint for the Chevron Texaco merger specifically singles out refining, bulk supply and marketing of California Air Resource Board (CARB) gasoline. We do not find evidence that pass-through varies for conventional gasoline and special blends.

No. 2 distillate separately by the type of end user for twenty-three states.[11] To measure the price of No. 2 diesel for on-highway purposes, we use the price to end users through retail outlets. This price is virtually a perfect match of the low-sulfur diesel price, which is almost exclusively for on-highway use. The EIA publishes average retail gasoline prices for all fifty states monthly from 1983 onwards.

We collect information about the federal and state gasoline and on-road diesel tax rates from 1983 to 2003 from the Federal Highway Administration Annual Highway Statistics.[12] Federal on-road diesel excise taxes were four cents per gallon in 1981, rising to the current level of 24.4 cents per gallon in 1993. State on-road diesel excise taxes also rose throughout the period, from a weighted average excise tax rate of 9.2 cents per gallon in 1981 to 19.4 cents per gallon in 2003.[13] Within-state variation also rose throughout the period. In 1981, state on-road diesel taxes varied from a low of 0 cents per gallon in Wyoming to 13.9 cents per gallon in Nebraska. In 2003, Alaska imposes the lowest state diesel taxes, at 8 cents per gallon, while Pennsylvania imposed the highest taxes of 30.8 cents per gallon. As with diesel taxes, state and federal gasoline taxes increased during this time frame. In 1983, the federal gasoline tax was four cents per gallon and average state gasoline taxes were 11.3 cents per gallon. In 1983, tax rates were lowest in Texas at five cents per gallon and highest in Washington and Minnesota at 16 cents per gallon. By 2003, the federal gasoline tax rose to 18.4 cents per gallon and the average state gasoline tax rose to 20.5 cents per gallon, with a low of 7.5 cents per gallon in Georgia and a high of 30 cents per gallon in Rhode Island.

We also collect data capturing market factors that affect the demand and supply of gasoline and diesel. Our demand shifters for diesel fuel are primarily related to temperature and the prevalence of the use of fuel oil as a home heating source. We obtain monthly heating degree days by state from the National Climate Data Center at the National Oceanic and Atmospheric Administration. The number of heating degree days in a month, commonly used to model heating demand, is defined as the sum of the daily number of degrees the temperature is below 65.[14] We also measure state heating oil prevalence using the fraction of households in a state

[11]The EIA surveys prices for states using No. 2 distillate as a "significant heating source." (source: EIA Form 782b explanatory notes) Price data exists for Alaska, Idaho, Illinois, Indiana, Michigan, Minnesota, Ohio, Oregon, Virginia, Washington, West Virginia, Wisconsin and all states in New England (PADD1a) and the Central Atlantic subdistricts (PADD1b).

[12]Several states in our sample also levy ad-valorem taxes on gasoline or diesel sales. Since the vast majority of the tax changes in our sample are changes to state and federal quantity-based excise taxes, we focus primarily on the pass-through of these taxes. We do not find that the pass-through of quantity based excise taxes differs significantly for states that additionally levy ad-valorem taxes and states that do not levy ad-valorem taxes.

[13]Oregon does not tax diesel sold for trucking, instead taxing the number of weight-miles driven in the state. For this reason, we exclude Oregon from the subsequent analysis.

[14]For example, if the temperature in a state were 55 degrees for each day in the month of January, the number of

reporting in the 1990 census to use fuel oil as the primary energy source for home heating. In addition, we collect state unemployment rates and we calculate the minimum diesel and gasoline tax rates in neighboring states.

To measure capacity constraints at domestic refineries, we obtain national, monthly refinery capacity utilization from the EIA for 1990 to 2003. Capacity utilization is defined as the ratio of total crude oil input to the total available distillation capacity – capacity utilization captures both production constraints arising from both high demand and from unanticipated refinery repairs. In addition, we obtain monthly data on diesel and gasoline inventories at the PADD-level from the EIA for our entire time period. We normalize the inventories by the average daily demand in the prior 12 months in each PADD to measure inventories in terms of number of days of supply.

To measure the effect of environmental regulations, we collect data on within-state variation in gasoline content regulations. For each state, the EIA tracks the proportion of gasoline meeting federal reformulated gasoline requirements, federal oxygenated gasoline requirements and less stringent conventional gasoline requirements.[15] To measure within-state heterogeneity, we sum the squared proportions of RFG, oxygenated and conventional gasoline. A value of one denotes uniform regulation for the entire state; a value of one-third denotes that equal amounts of reformulated, oxygenated and conventional gasoline are sold.

Table 1 reports the summary statistics of our variables. To help interpret the results regarding capacity utilization and incidence, the variable means are also reported separately for months with different rates of US refinery capacity utilization. The average tax inclusive retail price is 120.8 cents per gallon over the course of the series. This price is on average highest when capacity utilization is between 90 and 95 percent, though it is in fact lowest at the highest level of capacity utilization.[16] Over our sample, tax inclusive gasoline prices average 118 cents per gallon. Unlike diesel prices, the average gasoline price rises as refinery capacity utilization increases. The average state diesel tax rate is 18.2 cents per gallon, compared with the average federal tax of 19.8 cents per gallon. Gasoline taxes average 17.1 cents per gallon at the state level and 14.2 cents per gallon at the federal level. The average month has 5.3 heating degree

heating degree days for each day would be 10 and the number of heating degree days for the month would be 310.

[15]The EIA does not report quantities when quantities are small enough to potentially infer the actions of any one company. After first-differencing, EIA redaction causes us to omit twenty-seven percent of the base sample. Redaction varies by region - forty seven percent of the observations in PADD 5 are omitted after first-differencing, while only seventeen percent of the observations in PADD 2 are omitted after first differencing. Importantly, we do not find that our base pass-through results differ significantly when we limit ourselves to this subsample.

[16]Since the capacity utilization series is not available for the entire sample, the means separated by capacity utilization may appear inconsistent with the overall mean.

days. Since cold months tend to have lower demand for gasoline, the average degree days are at their highest when refinery capacity utilization is at its lowest. For the average state, 28 percent of households use fuel oil (diesel) to heat their homes, yet this varies considerably across states as standard deviation of this variable is 0.20.

The average capacity utilization is 91 percent. Low capacity utilization months disproportionately occur in the winter and spring, while 88 percent of high capacity utilization months are in the second and third quarters of the year. Twelve percent of the gasoline sold during the period met federal reformulated gasoline requirements. Approximately two percent of the gasoline sold met federal oxygenated requirements. Content regulations vary substantially both within and across states. Although the mean of the sum of squared content shares is 0.95, the value is less than 0.75 for approximately ten percent of the sample, and less that 0.6 for approximately five percent of the sample.

Tax increases are most likely to come when capacity utilization is low, as there is a 2.7 percent likelihood a state raises its diesel tax in a month with a capacity utilization of less than 85 percent, compared with 1.6 percent overall. This is primarily due to January being a popular month for tax changes. Yet tax increases in high capacity utilization months are not uncommon. States raise taxes in 1.2 percent of months with a capacity utilization above 95 percent, and tax increases are in fact more likely during these months than when capacity utilization is between 85 and 95 percent.

To further illustrate the variation used in this paper, Figure 1 shows the average diesel tax rate over time for the 22 states we use in the analysis, and the number of states per year changing taxes. The average tax per state increases steadily over time, with the growth rate of taxes perhaps slowing somewhat beginning in the nineties. Fewer states changed diesel tax rates during the nineties, yet we still see that several states change taxes in each year of the data. The only exception is 2000, when tax rates were stable for all states. Figure 2 shows a similar series for gasoline taxes. Gas taxes rise over time, with the rate of growth slowing considerably in recent years. Nonetheless, each year saw at least two states increasing gasoline taxes, with most years witnessing between ten and thirty states changing tax rates.

3.2 Methods

The approach taken in this paper is to estimate the effect of federal and state taxes on post-tax (consumer) prices. We assume that the data generating process at the state-month level for prices p_{it} in cents per gallon is given by:

$$p_{it} = \beta_0 + \beta_1 T^S_{it} + \beta_2 T^F_t + BX_{it} + \rho_i + \sigma_t + \epsilon_{it} \tag{7}$$

where T^S_{it} and T^F_t are the state and federal tax rates in cents per gallon, X_{it} is a vector of time-varying state level covariates, ρ_i is a state-level fixed effect meant to capture time-invariant local cost shifters, and σ_t represents time effects. To estimate (7) in the presence of the unobserved state-level heterogeneity described by ρ_i, we will estimate the first-differenced equation

$$\Delta p_{it} = \beta_0 + \beta_1 \Delta T^S_{it} + \beta_2 \Delta T^F_t + B\Delta X_{it} + \sigma_t + \epsilon_{it}. \tag{8}$$

The coefficients β_1 and β_2 are therefore estimated from contemporaneous changes in taxes and prices.[17]

Our approach provides a significant advantage over estimating the relationship in levels. In order for our estimates to be biased, the first-differenced omitted variable must be correlated with state-level tax changes. Thus, demographic trends (or other slow moving variables) are unlikely to bias our results, whereas they are more likely to be correlated with prices in a levels regression. In addition, other variables that change discretely such as transportation policy variables must change contemporaneously with the state-level tax changes in order to bias our results. Furthermore, for the majority of our results, σ_t consists of month*year fixed effects. Although our effects prevent the estimation of the pass-through of federal taxes (β_2), the fixed effects subsume all state-invariant shocks that affect gasoline or diesel prices.

4 Results

4.1 Basic incidence results

The results of estimating equation (8) for diesel are presented in Table 2. The specifications presented in column 1 control for year and month effects, while the specification shown in column 2 also includes state-level covariates. By separately controlling for state and month effects, we allow for the identification of the effects of both state and federal fuel taxes. Our findings indicate that a one cent increase in the state tax rate increases the retail price by 1.22 cents,

[17] If tax changes are endogenous to prices then this approach will not be valid, a problem shared with other studies of gasoline tax incidence. For instance, if tax increases are not undertaken when prices are increasing, then our estimate of β_1 will not be valid. We have found little relationship between tax changes and factors affecting supply conditions. Furthermore, the lag between the passage of a tax rate increase and its implementation implies that tax increases are unlikely to be related to unexpected changes in supply.

and every one cent increase in federal taxes is estimated to increase the consumer price by 1.1 cents. We are unable to statistically distinguish the pass-through rate of state taxes from that of gasoline taxes. Prior theoretical work on incidence suggest that pass-through of greater than 100 percent is possible. (see Katz and Rosen, 1985; Stern 1987, Besley, 1989; Delipalla and Keen, 1992; and Hamilton 1999) While the estimates for the incidence of state taxes suggest more than full pass-through, we cannot reject a null hypothesis of merely full pass-through. It is worth noting that there are few tax changes from which to estimate the pass-through rate of federal taxes. One of these tax changes occurs in October of 1993, coinciding with more stringent content regulations for diesel fuel. In these and future specifications, we will include a separate regressor controlling for the change in prices in October of 1993.

We next account for a richer set of time effects by controlling for year*month effects. Since federal taxes vary only at the year*month level, this precludes the estimation of β_2. In column 3, we present the results. Including the finer time effects has a noticeable effect on the estimates of β_1. We estimate a pass-through rate for state taxes of 1.09, which as before is not statistically distinguishable from one, but is more precisely estimated.[18]

Changes in taxes are not necessarily immediately reflected in the retail price of diesel. Lags in adjustment by both suppliers and demanders could make short-run elasticities differ from longer-horizon elasticities. To account for the dynamic adjustment of taxes into prices, we follow Alm et al (2009) by including the lagged tax rate in the specification shown in column 4 of Table 2. The coefficient on the interaction term is estimated to be 0.071 and statistically insignificant. Therefore, almost the entire effect of changes in tax rates are immediately realized in prices.[19]

We next investigate whether the price response is linear in the size of the tax change. We divide tax changes into 24 evenly sized bins 0.5 cents wide. We then find the average change in price by bin. The results of this exercise are presented in Figure 3, where we see that the relationship in the data between price and tax changes appears linear.

In Table 3, we display the basic incidence results for gasoline. These results are not new,

[18]One drawback to using state-level price data is that the EIA only reports these data for 23 states. It is desirable to provide incidence estimates for the entire US, as the states for which we have price data may not be representative. We perform a similar analysis aggregating state taxes and covariates up to the PADD-level, at which the EIA reports data for all states. We present the results in Appendix Table A2. With PADD-level covariates and month and year fixed effects, we estimate the pass-through rate of the average state tax rate of 1.01, while the pass-through rate of the federal tax rate is 0.98. Using year*month effects, we estimate pass-through of 1.04, very close to the analogous state-level estimate of 1.09. Similarly, we find that taxes seem to be immediately reflected in the retail price of diesel.

[19]It is unlikely that controlling for the lagged tax rate will have the power to account for longer horizon adjustments by demanders. For instance, if higher prices leads to the take up of more efficient vehicles by drivers, even a relatively swift adjustment in the flow of vehicles purchased will only alter the fuel efficiency of the stock of existing vehicles very slowly.

as they have been documented using similar variation in Alm et al (2009) and Chouinard and Perloff (2004). Consistent with these papers, we find full pass-through of state taxes. Unlike Chouinard and Perloff, we also find full pass-through of federal gasoline taxes. We employ a specification of the changes of gasoline prices and taxes, a source of difference with Chouinard and Perloff, who estimate a specification in levels.[20] We also find that the gasoline tax is fully incorporated into gasoline prices in the month of the tax change, as the lagged tax rate is small and statistically insignificant. These findings are robust to the inclusion of covariates and year*month effects.

We again examine the linearity of the relationship between tax changes and prices by dividing gasoline tax changes into 24 evenly spaced bins 0.5 cents wide. The average price change in each of these bins is shown in Figure 4. As with diesel, there appears to be a linear relationship between changes in taxes and changes in prices.

4.2 Supply Conditions and Tax Incidence

4.2.1 Untaxed diesel and supply elasticity

We next examine whether the incidence of diesel and gasoline taxes varies with three changes in supply conditions – changes in the residual supply elasticity arising the demand for untaxed uses of diesel, supply inelasticity arising from refinery capacity constraints, and supply conditions related to varying inventory levels. To test the first, we will include a triple interaction between the state tax rate, the heating degree days in a state-month, and the prevalence of fuel oil's use to heat homes in the state. In cold weather, demand for untaxed diesel fuel increases with the proportion of households using oil for residential heating. As shown in equation (6), substantial demand for an untaxed alternative will increase the residual supply elasticity of taxed diesel in a state.[21] While cold weather may directly influence the price due to delivery cost or cold-weather

[20]Under certain assumptions, estimating a specification of the level of gasoline prices, controlling for state fixed effects, and estimating a model in first-differences should both yield consistent estimates of the pass-through parameter. Given the serial correlation in tax rates, we are concerned that unobserved factors that shift over time will be correlated with both price and taxes, and therefore the specification in levels will be more prone to bias than the first-differenced specification, which estimates the pass-through parameter using only contemporaneous changes in taxes and prices. If this is true, the levels specification is likely to be particularly sensitive to misspecification of the time trend. In the Appendix Table A1, we estimate a levels specification similar to that of Chouinard and Perloff (2004) using different specifications of the time trend. In column (1), we control only for seasonal dummies. In the specification showin in Column (2) year enters linearly, while in column (3) year enters quadratically. Finally in the specification shown in column (4) we allow for a full set of year and month effects. The estimate of the pass-through of the federal tax varies wildly across the specifications. On the other hand, the estimated pass-through rate is stable across different forms of the time trend in the first-differences specifications, as shown in columns (5)-(8)

[21]We choose not to use a direct measure of σ_o for two reasons. First, at least in the pre-dye period, sales of distillate intended for on-highway use comprised a significant share of reported fuel oil sales. Second, the fuel oil series is often missing.

additives, this specification will control for state degree days directly so that the effect of tax changes in cold weather is compared between states with differing levels of household fuel oil use. Furthermore, it is conceivable that fuel oil demand could directly influence the price of diesel in a state. We condition on the interaction of degree days and fuel oil use by households, which should capture any demand effects on price, and focus instead on the coefficient on the triple interaction between diesel taxes, degree days, and fuel oil. Finally, our measure of household use of heating oil is a snapshot from the 1990 census and therefore on its own will not be directly correlated with month-to-month variation in prices.

The last column of Table 2 presents the relationship between residual supply elasticity of taxed diesel and tax pass-through. To make reading the table easier, degree days have been divided by 100. The coefficient on the interaction between degree days/100, the state tax rate, and the fraction of households using fuel oil to heat their homes is 0.055. This implies that a state with a one standard deviation greater fraction of households using heating oil (20 percent), in a month with 1000 degree days (approximately equal to February in Chicago), has a pass-through rate 11.0 percentage points higher than a month with zero degree days.

4.2.2 Capacity Utilization

To examine how incidence varies with domestic refinery capacity utilization, we separately estimate the incidence of state taxes for months with high and low levels of capacity utilization. Capacity utilization is measured at the national level in our data, and therefore we are not exploiting cross-state variation in supply constraints. Instead, we are examining how the pass-through rate of a state's tax depends on the prevailing national supply constraints. If refiners are operating at full capacity, there is little scope to alter production in the short-run in response to changes in taxes. For gasoline, periods of high capacity utilization may also indicate particularly strong demand, which could be associated with more inelastic demand. Capacity constraints may therefore be associated with two conflicting effects on gas tax incidence, as both demand and supply are less elastic. It is worth noting that diesel demand does not appear to drive capacity constraints, and therefore diesel tax incidence may provide a clearer view of the effect of supply elasticity on pass-through.

Since supply may only be truly constrained for high levels of capacity utilization, we will allow for the effect to enter nonlinearly. We estimate incidence separately for months with less than 85 percent capacity utilization, between 85 and 90, between 90 and 95, and above 95 percent. Since capacity utilization tends to be higher in the summer months, we also perform the estimation separately for the four quarters of the year to investigate the possibility that the effect depends on the season.

The results for diesel are presented in Table 4. In Panel A, we show the results for capacity utilization. We find that there is virtually no difference in incidence between 80 and 95 percent capacity utilization. The incidence parameter for less than 85 percent capacity utilization is estimated to be 1.29, 1.00 for 85-90 percent capacity utilization, and 1.06 for between 90 and 95 percent capacity utilization. None of these coefficients are statistically distinguishable from one. However, there is a noticeable difference in the estimated incidence for tax changes occurring in months with greater than 95 percent capacity utilization. For these months, only 41 percent of the diesel tax is passed through to consumers. Therefore, we find that the effect of capacity utilization on incidence is highly nonlinear, as it is only noticeable for the most capacity constrained months. However, it is worth noting that even in these extreme situations, almost half of the tax is born by consumers. In Panel B, we present the diesel incidence parameter separately by season. We find that the rate of diesel pass-through is statistically indistinguishable from one regardless of quarter.

In Table 4 we present similar results for gasoline. Unlike diesel, we find that gasoline incidence is largely independent of capacity utilization. We estimate that consumer incidence is 90 percent of the gasoline tax in the highest capacity utilization months, which is indistinguishable from one. This differs from the diesel result, likely due to the fact that capacity constraints are driven by a large extent by demand for gasoline. In Panel B, we present results indicating that the pass-through rate of the gas tax is virtually one for the first, second, and third quarters of the year. This suggests that a state tax holiday occurring during the summer would be fully passed to consumers.

4.2.3 Inventories

Next, we estimate the association between incidence and inventories, as measured at the PADD level by the days of supply of gasoline and diesel stored at the wholesale level. Inventories are constrained by storage capacity since there are significant barriers to entry in the storage market. Storage is also likely to be constrained at the low end as well due to marketing costs, which are suspected to be highly nonlinear at low levels of inventory (see Pindyck, 1994). Storage constraints could indicate a less elastic supply curve, in which case less of the tax is passed on to consumers. On the other hand, stored gallons could represent competition for producers. Low inventory levels could therefore exacerbate any regional market power, and market power could in fact lead to over-shifting of taxes to consumers.

To examine the effect of inventories, we include wholesale inventory levels (measured in terms of days of supply), lagged inventory levels to capture dynamic adjustment, and the interaction between inventory levels and the state tax rate. The former term captures the effect of inventories on price levels, while the interaction term captures the association between inventories and tax incidence. We also consider periods of time where inventories are likely to be constrained, interacting changes in the fuel tax rate with indicators for the monthly inventory lying in the bottom 10 percent and top 10 percent of all monthly inventories in the sample.

In Table 6, we present the results for diesel in panel A and gasoline in panel B. Each specification includes the full set of covariates, as well as month*year fixed effects. We find that, for both gasoline and diesel, the inventories are negatively correlated with the tax-inclusive price. When considering the interaction between inventories and taxes, we find that lower inventory levels are associated with a significant decrease in pass-through for gasoline, but not for diesel. We estimate that a one standard deviation decrease in inventories is associated with approximately 13.1 percentage point greater pass-through of gasoline prices.

Interestingly, pass-through spikes substantially in months where diesel inventories are particularly low. In the bottom ten percent of inventory months, approximately 159 percent of diesel taxes are passed through to consumers. In the absence of market power, pass-through must be between zero and 100 percent regardless of the elasticities of supply and demand. Therefore, rather than indicating a particularly inelastic supply curve during those months, this over-shifting suggests that low inventories are associated with market power on the part of suppliers.

The same does not hold for gasoline. While pass-through is estimated to be higher during the low gasoline inventory months, this effect is not statistically significant. On the other hand, when gasoline inventories are unusually high – in the top ten percent of inventory months – pass-through is estimated to be substantially lower. This is consistent with inelastic supply when inventories are constrained.

4.2.4 Regional Content Regulations

Finally, we examine the introduction of regional gasoline content regulations and estimate the relationship between regulatory heterogeneity and pass-through of gasoline taxes. Although the particular example is specific to gasoline, interaction between regulations and taxes is common – many industries face both taxes on inputs or products as well as regulatory standards their processes or products must meet. Moreover, examining environmental regulations present a potentially cleaner test of supply constraints than examining refinery capacity constraints or inventory constraints. Both high refinery utilization and low inventories are at least partially driven by demand. The fraction of a state's gasoline required to meet content regulations, on the other hand, is largely set exogenously to monthly supply and demand conditions.

We control for changes in the composition of a state's gasoline sales by including the percent of gasoline sold within the state meeting federal Reformulated and Oxygenated requirements. As a measure of the complexity of wholesale storage and distribution, we sum the squared market shares of Conventional, Reformulated and Oxygenated gasoline in each state. A value of one denotes a state using a consistent blend of gasoline state-wide. Importantly, a value of one does not differentiate between a state using all conventional gasoline or all reformulated gasoline - in each case, the wholesale storage and distribution of gasoline is uncomplicated. In contrast, a value of one-third would denote a state that uses all three types of gasoline in equal proportion and requires the most complex supply chain. The most heterogeneous state in our sample period is Nevada (0.37), which uses roughly equal quantities of all three formulations during the winter. We then interact our measure of regulatory homogeneity with the state's gasoline tax rate to test if incidence is correlated with variation in a state's gasoline regulations.[22]

The estimates are presented in Table 7. All of the specifications include first-differenced control variables as well as month*year fixed effect. In column 1, we present the results from estimation our baseline gasoline specification (column 3 from Table 3) including only the seventy-three percent of the data for which we observe content shares. We estimate a very similar pass-through rate for the subsample – the point estimate is 1.067 (in comparison to a point estimate of 1.053). As with the full sample, we cannot statistically distinguish our estimate from full pass-through. In the specification shown in column 2, we include the percent of gasoline sold as reformulated and as oxygenated are added as additional covariates to the base specification. While both are positively correlated with price as we expect, neither coefficient is statistically significant.

In column 3, we include the sum of squared content shares as well as the interaction term. Consistent with our prediction, we find reduced pass-through of gasoline taxes in states requiring more heterogeneous gasoline supply. We estimate that pass-through is approximately 22 percentage points higher in states with uniform regulations (eg. California or Massachusetts)

[22] Special blends may also increase concentration if they are sufficiently costly for refineries to produce. For example, the FTC complaint for the Chevron Texaco merger specifically singled out refining, bulk supply and marketing of California Air Resource Board (CARB) gasoline, a more stringent version of RFG used in California. We do not find evidence that pass-through varies significantly for conventional gasoline and special blends.

than a state that uses two gasoline formulations in roughly equal proportion (eg. Illinois). All else equal, shifting from using conventional gasoline to using reformulated gasoline exclusively is associated with a 2.2 cent per gallon increase in the tax inclusive retail price. While the point estimate on the percent of gasoline meeting oxygenated requirements is positive, it is still imprecisely estimated.

5 Conclusion

In this paper, we examine the effect of diesel and gasoline taxes on retail prices. We find at least full, and potentially more than full, pass-through of both federal and state diesel and gasoline taxes to consumers. The pass-through effects are immediately reflected in prices. For diesel, the pass-through rate is amplified in cold months, particularly in states with a high fraction of households using heating oil. Since heating oil and diesel are chemically equivalent, this is consistent with heating oil use increasing the residual supply elasticity of diesel. We also consider the effect of refinery capacity constraints and wholesale inventory levels on the pass-through of diesel and gasoline taxes. We provide support for the notion that pass-through is considerably less-than 100 percent if tax changes occur when U.S. refinery capacity utilization is high. This holds for diesel taxes but not for gasoline taxes. This could be due to differences in gasoline demand during high capacity utilization months. We find that low inventory levels are associated with higher tax inclusive prices for both gasoline and diesel fuel, and are associated with greater tax pass-through for gasoline.

Finally, we examine the interaction between gasoline content regulations and tax incidence. We find a positive and significant relationship between the consistency of a state's gasoline regulations and tax pass-through. We estimate that tax pass-through in a state with consistent regulations (like California) is 22 percentage points higher than pass-through in a state using two blends in equal proportions (like Illinois). This suggests that the interaction between taxes and other forms of regulation is likely to have important implications for tax incidence.

Our results inform two current policy debates. First, our results suggest that the benefits of fuel tax holidays are likely to accrue to consumers during under normal market conditions, but are likely to be shared by consumers and producers during times at which supply chain constraints exist. This distinction is important for policy, since tax holidays are most attractive during time of supply chain constraints and associated high fuel prices. Second, since the burden on fuel taxes falls primarily on consumers and demand for diesel and gasoline are inelastic, producer profits are unlikely to fall as taxes rise. Consequently, tax credits or free permits (in the case of carbon policy) are unlikely to be necessary to compensate producers.

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Appendix

Table A1: Gasoline Incidence Sensitivity to Time Trend Specification

Dependent variable: Real gasoline price

	Levels, state FE				First-differences			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Real gas tax	1.190	1.067	1.024	1.016	1.056	1.068	1.069	1.066
	(0.054)***	(0.042)***	(0.026)***	(0.018)***	(0.096)***	(0.094)***	(0.094)***	(0.086)***
Real federal gas tax	0.266	0.488	0.428	1.108	1.092	1.116	1.119	1.056
	(0.159)*	(0.150)***	(0.156)***	(0.186)***	(0.086)***	(0.092)***	(0.094)***	(0.122)***
Linear time trend		X				X		
Quadratic time trend			X				X	
Year dummies				X				X
Observations	10665	10665	10665	10665	10560	10560	10560	10560
R-squared	0.94	0.95	0.95	0.95	0.51	0.51	0.51	0.52

Standard errors clustered by year*month are in parentheses.

*,**,*** denote significance at the 90%, 95%, and 99% level, respectively.

In specifications (1)-(4), each variable in the model is the level of the stated variable, while in specifications (5)-(8) each variable has been first-differenced. Additional controls include the WTI crude oil spot price, the lagged WTI price, month dummies, the minimum of neighboring states' tax rates, and a dummy indicating Oct 1993. Specifications (1)-(4) also include state fixed effects.

Table A2: Diesel Tax Incidence, PADD level

	(1)	(2)	(3)	(4)
State diesel tax	0.960	1.009	1.037	1.051
	(0.169)***	(0.175)***	(0.133)***	(0.158)***
Federal diesel tax	0.979	0.983		
	(0.178)***	(0.178)***		
State tax t -1				0.032
				(0.187)
Covariates		X	X	X
Year, month effects	X	X		
Year*month effects			X	X
Observations	1747	1698	1706	1698
R-squared	0.56	0.60	0.85	0.85

Standard errors clustered by year*month are in parentheses.
*,**,*** denote significance at the 90%, 95%, and 99% level, respectively.
The dependent variable is the one month change in the PADD-level tax inclusive price. The PADD level tax rate is obtained by taking a weighted average of the tax rates across states within the PADD. The weights used are the average monthly quantity of No. 2 distillate consumed in the state.
Other controls in the specification shown in column 2 include WTI Crude Spot Price and its lag. The specifications shown in columns 3 and 4 have controls for degree days, degree days interacted with prevalence of household fuel oil use for home heating, and the unemployment rate. As with the state tax rate, these controls are obtained by taking a weighted average of the values across states within the PADD. Each independent variable has been first-differenced.

Figure 1: Average State Diesel Tax Rates by Year

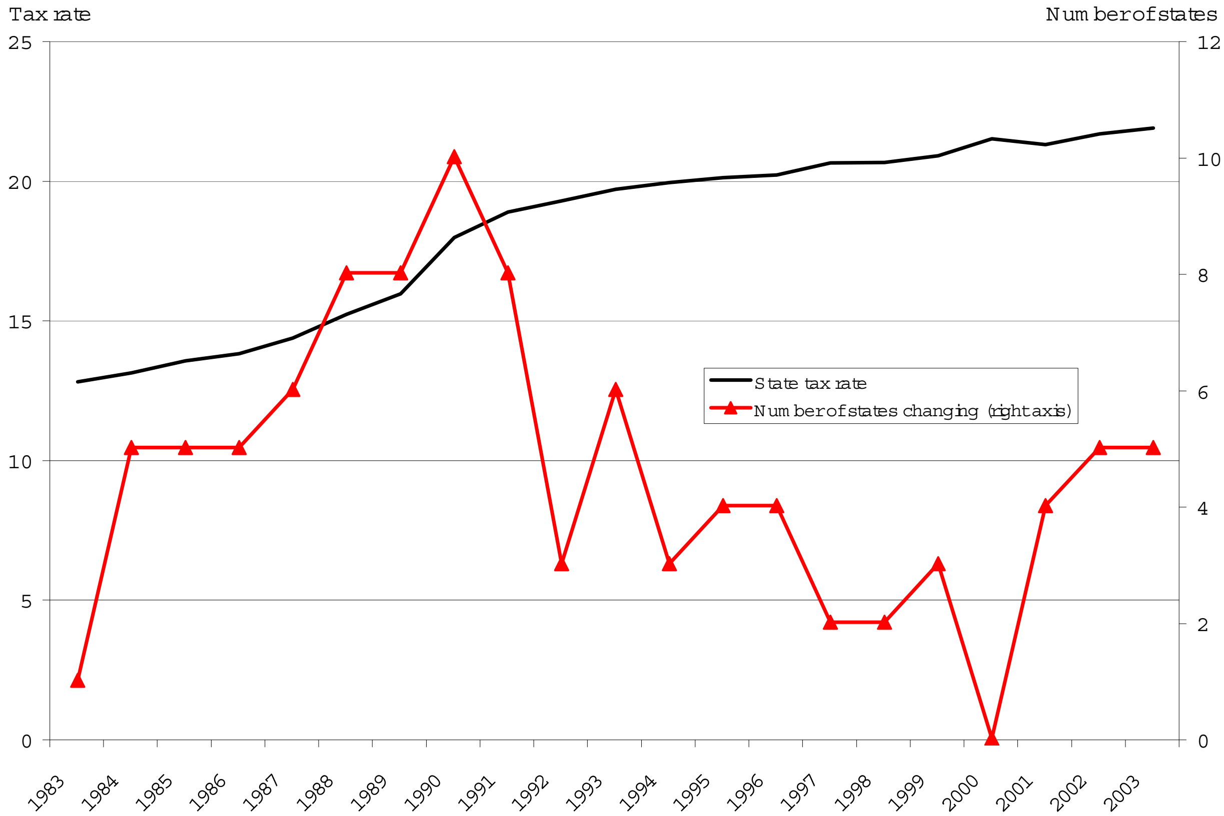

Figure 2: Average State Gasoline Tax Rates by Year

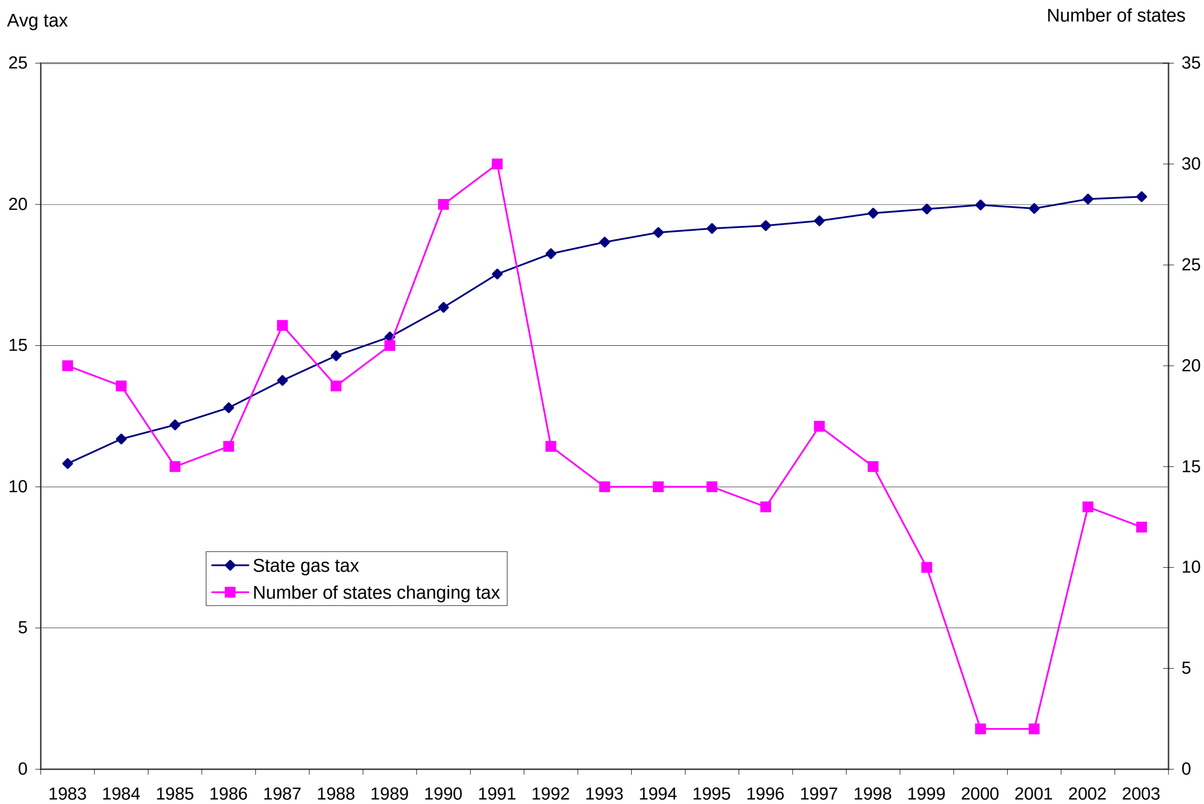

Figure 3: Diesel Price and Tax Changes

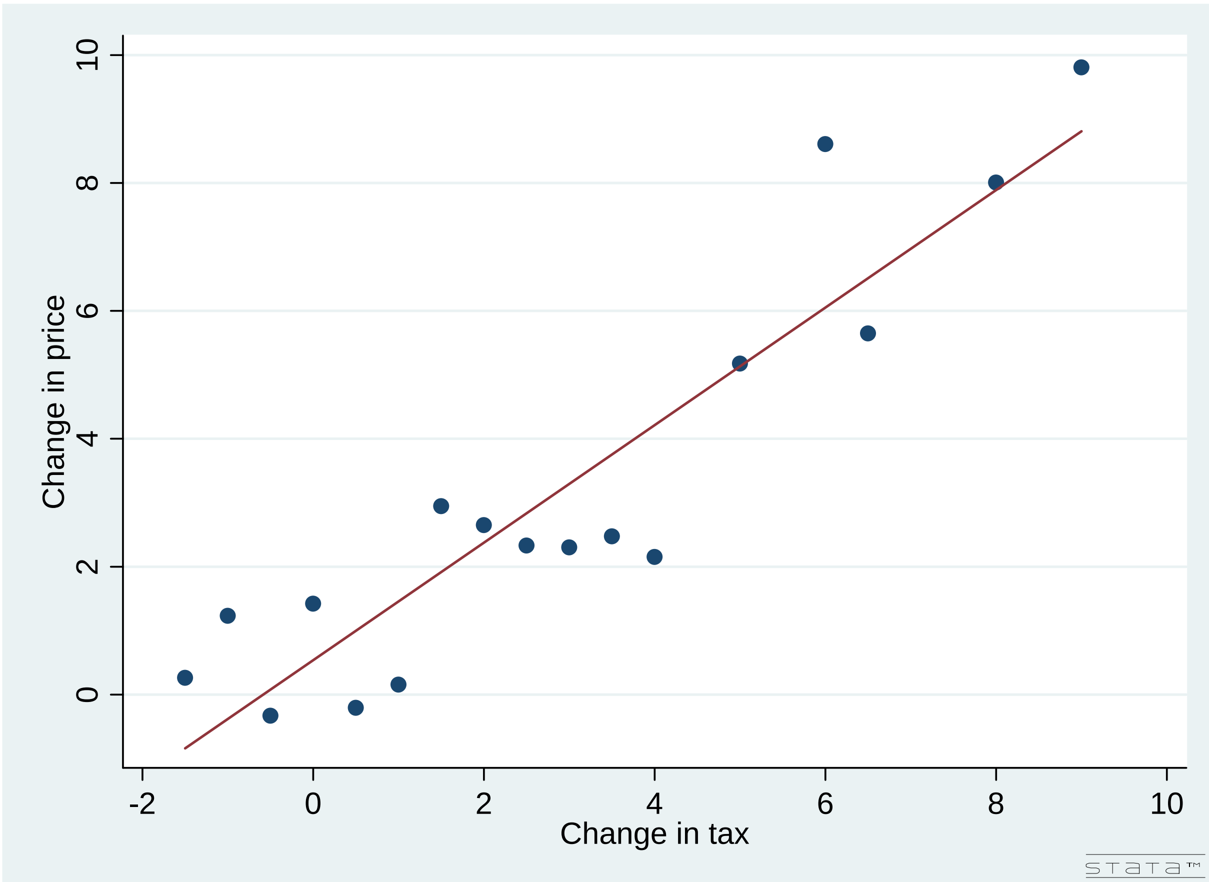

Figure 4: Gasoline Price and Tax Changes

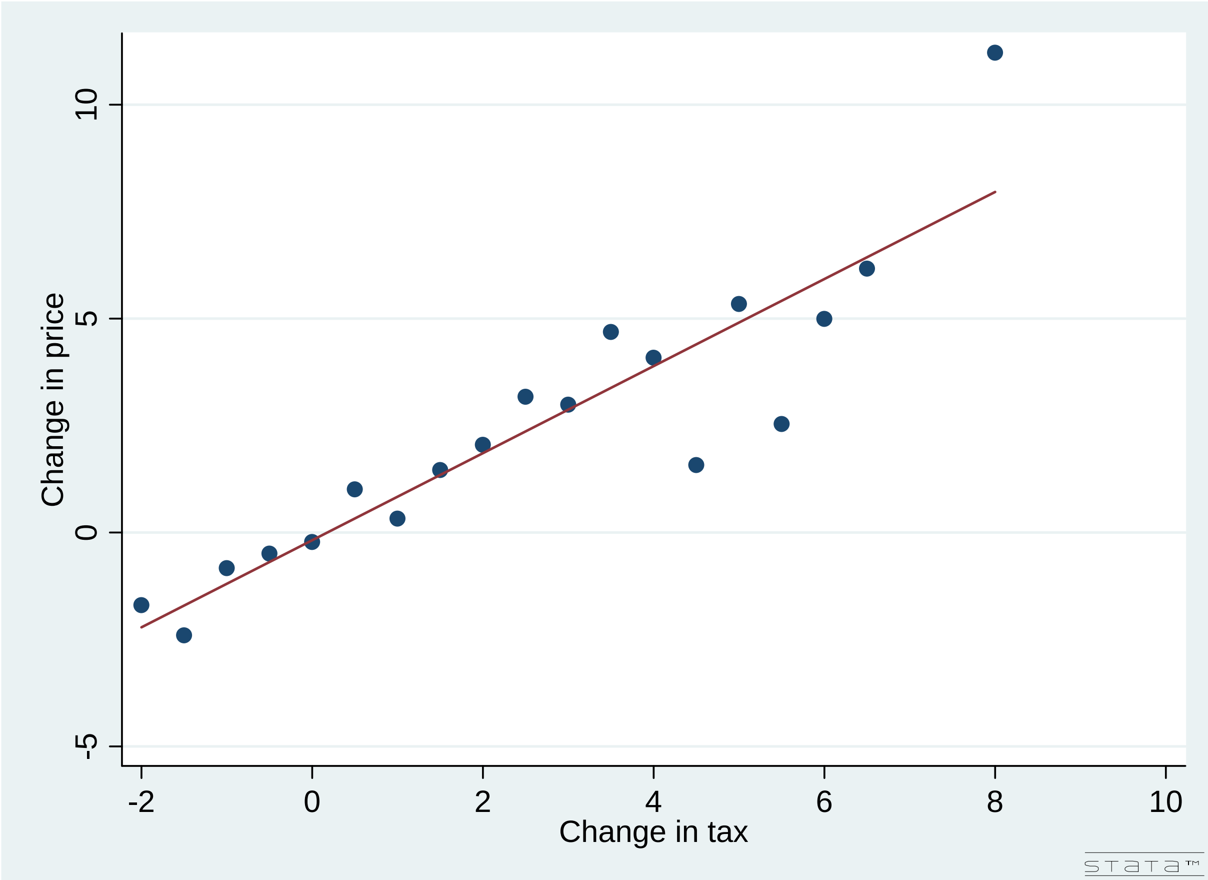

Table 1: Summary Statistics by Capacity Utilization

	(1) Overall	(2) < 85%	(3) 85-90%	(4) 90-95%	(5) >95%
Diesel tax inclusive retail price (c/gall)	120.83	126.21	126.15	129.43	125.76
	(19.31)	(15.12)	(20.10)	(18.68)	(18.00)
Gasoline tax inclusive retail price (c/gall)	118.15	105.23	112.88	125.98	119.22
	(19.03)	(16.09)	(17.69)	(18.40)	(15.38)
State diesel quantity tax (c/gall)	18.22	19.00	20.19	20.72	20.64
	(5.23)	(4.02)	(4.73)	(5.07)	(5.00)
Federal diesel quantity tax (c/gall)	19.79	20.04	22.59	24.00	24.23
	(5.24)	(1.91)	(2.12)	(1.22)	(0.77)
State gas quantity tax (c/gall)	17.08	14.25	17.14	19.38	16.13
	(5.21)	(3.85)	(4.74)	(4.83)	(5.77)
Federal gas quantity tax (c/gall)	14.23	9.94	13.29	17.55	14.15
	(4.41)	(1.93)	(4.07)	(2.29)	(4.96)
Minimum neighboring state diesel tax	14.27	15.22	16.03	16.39	16.37
	(4.33)	(3.43)	(3.87)	(4.00)	(4.06)
Minimum neighboring state gas tax	13.03	10.53	13.00	15.14	12.21
	(4.51)	(3.08)	(4.21)	(4.30)	(4.79)
Heating degree days	5.33	8.52	7.48	5.26	1.63
	(4.49)	(3.21)	(4.32)	(4.26)	(2.30)
Fraction of HH using heating oil	0.28				
	(0.20)				
Diesel Inventories (days)	51.5	54.0	49.2	48.7	48.1
	(16.1)	(15.2)	(13.9)	(14.7)	(14.8)
Gasoline Inventories (days)	38.8	43.0	39.4	34.8	34.8
	(14.6)	(13.4)	(13.4)	(13.7)	(14.1)
Unemployment rate	5.71	6.73	5.89	5.06	4.73
	(2.08)	(1.50)	(1.69)	(1.41)	(1.30)
US Refinery capacity utilization	91.36				
	(3.89)				
Percent Reformulated Gasoline	0.12				
	(0.29)				
Percent Oxygenated Gasoline	0.02				
	(0.10)				
Sum of Squared Content Shares	0.95				
	(0.14)				
Diesel tax raised	0.016	0.027	0.007	0.012	0.012
Gas tax raised	0.022	0.027	0.032	0.014	0.010
Quarter 1		0.39	0.39	0.16	0
Quarter 2		0.18	0.23	0.23	0.44
Quarter 3		0.10	0.23	0.28	0.44
Quarter 4		0.33	0.15	0.34	0.11
Number of months		51	61	80	36

Standard errors are in parentheses.
Each row reports the mean of the stated variable separately for months with the U.S. refinery capacity utilization stated in the column heading. The exception is the number of months, which simply reports the number of months that experienced the given capacity utilization.
The samples used to compute the means differ between column 1 and columns 2-5. The former uses the entire series, while the latter is based only on those months for which capacity utilization data is available.

Table 2: Diesel Tax Incidence

	(1)	(2)	(3)	(4)	(5)
State diesel tax	1.262	1.218	1.087	1.087	1.071
	(0.176)***	(0.124)***	(0.083)***	(0.083)***	(0.086)***
Federal diesel tax	1.081	1.110			
	(0.252)***	(0.262)***			
State tax t -1				0.071	
				(0.083)	
State tax * degree days * HH fuel oil frac					0.055
					(0.022)**
Diesel tax * degree days					0.000
					(0.004)
State tax * HH fuel oil frac					0.116
					(0.513)
WTI Crude Oil Price	1.285	1.232			
	(0.160)***	(0.172)***			
WTI Price t-1	0.831	0.899			
	(0.127)***	(0.128)***			
Oct 1993	3.673	3.613			
	(1.258)***	(1.299)***			
Minimum neighbor tax		1.177	0.739	0.741	0.723
		(0.499)**	(0.456)	(0.456)	(0.438)
Degree days		-0.021	-0.051	-0.050	0.226
		(0.120)	(0.076)	(0.078)	(0.130)*
Degree days * HH Oil Frac.		0.507	0.512	0.506	-0.502
		(0.151)***	(0.135)***	(0.138)***	(0.386)
Unemployment rate		0.481	0.446	0.339	0.424
		(0.822)	(0.498)	(0.506)	(0.495)
Year, month effects	X	X			
Year*month effects			X	X	X
Observations	5272	5133	5200	5133	5200
R-squared	0.46	0.51	0.77	0.77	0.77

Standard errors clustered by year*month are in parentheses.
*,**,*** denote significance at the 90%, 95%, and 99% level, respectively.
The dependent variable is the one month change in the tax inclusive retail price of No. 2 diesel. Each independent variable has been first-differenced.

Table 3: Gasoline Tax Incidence

	(1)	(2)	(3)	(4)
State gas tax	1.066	1.069	1.053	1.054
	(0.089)***	(0.088)***	(0.054)***	(0.054)***
Federal gas tax	1.034	1.038		
	(0.192)***	(0.190)***		
State tax t -1				0.038
				(0.046)
WTI Crude Oil Price	1.125	1.125		
	(0.146)***	(0.145)***		
WTI Price t-1	1.037	1.037		
	(0.148)***	(0.148)***		
Oct 1993	2.705	2.688		
	(1.186)**	(1.175)**		
Minimum neighbor tax		-0.302	-0.029	-0.030
		(0.162)*	(0.124)	(0.124)
Unemployment rate		-0.271	0.011	0.016
		(0.727)	(0.246)	(0.248)
Year, month effects	X	X		
Year*month effects			X	X
Observations	10560	10560	10606	10560
R-squared	0.47	0.47	0.77	0.77

Standard errors clustered by year*month are in parentheses.
*,**,*** denote significance at the 90%, 95%, and 99% level, respectively.
The dependent variable is the one month change in the tax inclusive retail price of gasoline. Each independent variable has been first-differenced.

Table 4: Diesel Incidence and U.S. Refinery Capacity Utilization

Dependent variable: Change in tax inclusive diesel price

	Panel A: Split by lagged capacity utilization			
	<85%	85-90%	90-95%	>95%
State diesel tax	1.290	0.995	1.059	0.414
	(0.164)***	(0.204)***	(0.076)***	(0.150)***
Observations	1111	1247	1682	660
R-squared	0.71	0.79	0.82	0.79
	Panel B: Split by quarter			
	Quarter 1	Quarter 2	Quarter 3	Quarter 4
State diesel tax	1.057	1.261	0.953	1.197
	(0.184)***	(0.155)***	(0.104)***	(0.036)***
Observations	1257	1268	1323	1352
R-squared	0.79	0.75	0.76	0.75

Standard errors clustered by year*month are in parentheses.
*,**,*** denote significance at the 90%, 95%, and 99% level, respectively.
Other controls include month*year effects, the minimum of the neighboring states' tax, the number of heating degree days, heating degree days interacted with household use fuel oil for home heating, and the state unemployment rate. Each independent variable has been first-differenced.

Table 5: Gasoline Incidence and U.S. Refinery Capacity Utilization

Dependent variable: Change in tax inclusive gas price

	Panel A: Split by lagged capacity utilization			
	<85%	85-90%	90-95%	>95%
State gas tax	1.036	1.007	1.205	0.898
	(0.115)***	(0.108)***	(0.109)***	(0.116)***
Observations	1840	2394	3619	1653
R-squared	0.84	0.82	0.77	0.65
	Panel B: Split by quarter			
	Quarter 1	Quarter 2	Quarter 3	Quarter 4
State gas tax	1.008	0.988	1.065	1.394
	(0.117)***	(0.115)***	(0.077)***	(0.048)***
Observations	2663	2702	2620	2621
R-squared	0.83	0.76	0.71	0.73

Standard errors clustered by year*month level are in parentheses.
*,**,*** denote significance at the 90%, 95%, and 99% level, respectively.
Other controls include month*year effects, the minimum of the neighboring states' tax, and the state unemployment rate.

Table 6: Fuel Tax Incidence and Wholesale Inventories

Dependent variable: Change in tax inclusive fuel price

	Panel A: Diesel				Panel B: Gasoline			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
State fuel tax	1.092	1.082	1.042	1.013	1.051	0.636	0.565	0.565
	(0.081)***	(0.137)***	(0.141)***	(0.133)***	(0.056)***	(0.155)***	(0.170)***	(0.172)***
Inventories	-0.045	-0.048	-0.048	-0.006	0.096	-0.057	-0.099	-0.090
	(0.020)**	(0.039)	(0.040)	(0.037)	(0.039)**	(0.031)*	(0.043)**	(0.045)**
Lagged inventories				-0.112				-0.224
				(0.021)***				(0.045)***
State tax * Inventories		0.000	0.000	0.001		0.009	0.012	0.012
		(0.002)	(0.002)	(0.002)		(0.003)***	(0.004)***	(0.004)***
State tax * Bottom 10% Inventories			0.594	0.564			0.194	0.177
			(0.297)**	(0.320)*			(0.243)	(0.225)
Bottom 10% Inventories			0.021	-0.056			0.139	0.000
			(0.354)	(0.352)			(0.527)	(0.498)
State tax * Top 10% Inventories			0.126	0.106			-0.330	-0.382
			(0.259)	(0.258)			(0.192)*	(0.194)**
Top 10% Inventories			-0.422	-0.056			-0.083	-0.067
			(0.355)	(0.366)			(0.074)	(0.096)
Observations	5114	5114	5114	5029	10606	10606	10606	10560
R-squared	0.77	0.77	0.78	0.78	0.78	0.78	0.78	0.78

Standard errors clustered by year*month are in parentheses.

*,**,*** denote significance at the 90%, 95%, and 99% level, respectively.

Inventories are measured as days of supply, where supply is a moving average of quantities sold in the prior 12 months. The variable bottom 10% inventories is an indicator for the level of the days supply measure for that month being in the bottom ten percent of months in the sample. The variable “top 10% inventories” is similarly defined. All variables have been first-differenced. Other controls for both diesel and gasoline include month*year effects, the minimum of the neighboring states’ tax, and the state unemployment rate. In addition, for the diesel regressions, we include the number of heating degree days, fuel oil for home heating, and heating degree days interacted with household use.

Table 7: Gasoline Tax Incidence and Content Regulations

Dependent variable: Change in tax inclusive gasoline retail price

	(1)	(2)	(3)
State gas tax	1.067***	1.069***	0.629**
	(0.0598)	(0.0598)	(0.250)
Percent Reformulated Gas		1.593	2.189**
		(1.120)	(1.046)
Percent Oxygenated Gas		0.404	1.577
		(0.908)	(0.975)
Sum of Squared Content Shares			-6.047
			(5.289)
Sum of Sq. Cont. Shares *			0.451*
State Gas Tax			(0.255)
Observations	8148	7977	7977
R-squared	0.788	0.789	0.789

Standard errors, clustered at the state-level, are in parentheses. *,**,*** denote significance at the 90%, 95%, and 99% level, respectively. All variables have been first differenced. Other controls include month*year fixed effects, the minimum of the neighboring states' tax, and the state unemployment rate.