Fuel Tax Incidence, Supply Conditions and Tax Evasion

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Abstract

In this paper, we provide new evidence regarding the pass-through of diesel and gasoline taxes to prices, and how the estimated pass-through depends on a variety of supply conditions including a measure of state residual supply elasticity, refinery and inventory constraints. In addition, we estimate the response of tax incidence to two regulatory changes in fuel markets - diesel dye regulations, which decreased fuel tax evasion, and gasoline content regulations, which complicated the supply chain by increasing product differentiation. We find that state gasoline taxes, and both state and federal diesel taxes, are fully passed on to consumers, while 65 percent of federal gas taxes are incurred by consumers. We also find that the pass-through of diesel taxes is greater in settings where untaxed uses of diesel are more important, which corresponds to times when residual supply is more elastic. Finally, we find that only half of the diesel tax is passed on to consumers when U.S. refinery capacity utilization is above 95 percent. Gasoline taxes, on the other hand, are fully passed through regardless of season or capacity utilization, indicating that a gas tax holiday would provide price relief to consumers. Improvements in diesel tax compliance do not significantly affect incidence, although we find evidence consistent with a change in the method of evasion following the introduction of fuel dye. We find that regional gasoline content regulations affect pass-through - we estimate tax pass-through is 23 percentage points lower in a state using two blends of gasoline than a state using one blend of gasoline.

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1 Introduction

Over the past twenty-five years, fuel taxes have represented close to thirty percent of the retail price of diesel and gasoline, on average. The incidence of fuel taxes, and specifically how they respond to market conditions, play a central role in current energy policy debates. Concern over the incidence of taxes was the first argument offered in an open letter signed by 150 prominent economists against the tax moratorium proposed by Sens. Clinton and McCain last Spring. Whether the proposed "gas tax holiday," which would suspend the gasoline tax during the peak driving season, would provide relief to consumers depends crucially on the extent to which lowering taxes reduces the tax-inclusive retail price. Furthermore, recent proposals have suggested that taxing carbon emissions, from both stationary and mobile sources, will play an important part in climate policy. The extent to which a carbon-based fuel tax reduces mobile-source emissions hinges on the degree to which the taxes are passed onto the consumer.

In addition to the central importance of incidence in current policy debates, the topic of tax incidence is front and center in the textbook treatment of taxation. Despite its central role in public finance, the main predictions of the tax incidence model are largely untested, and 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). There is to our knowledge no prior empirical work on the incidence of diesel taxes and sparse empirical work examining the relationship between incidence of taxes and supply conditions.

Moreover, fuel taxes provide two interesting settings in which to examine how regulations interact with tax incidence. Beginning in October 1993, federal regulations required red dye be added to untaxed diesel to distinguish it from diesel intended for taxed, on-road use. Marion and Muehlegger (2008) show that the introduction of fuel dye resulted in a marked improvement in tax compliance - sales of taxed gallons rose by 25 percent in the month of the implementation, while sales of untaxed gallons fell by a similar amount. Using the discontinuous change in illegal activity created by the introduction of diesel fuel dye, we examine the relationship between incidence and tax evasion.

In addition to examining tax evasion, gasoline markets allows us to examine how regional environmental regulations interact with tax incidence - in 1990, the Clean Air Act Amendment mandated that regions failing to meet EPA air emissions limits must begin using specially-designed gasoline blends, called oxygenated gasoline and reformulated gasoline, to reduce urban air pollution. States supplemented the federal requirements with unique blends of their own - increasing heterogeneity of gasoline in the US supply chain. Muehlegger (2006) finds that the increase in regulatory heterogeneity increased price levels as well as price volatility - we use changes in gasoline content regulation during the period to examine the effect of exogenously-imposed product differentiation on tax incidence.

The first objective of this paper is to estimate the rate of pass-through for gasoline and diesel excise taxes using state-level variation in taxes and prices. In addition, we examine how pass-through varies with three factors which affect the elasticity of supply - variation in the demand for untaxed uses of fuel, domestic refining constraints and regional inventory constraints. Our findings indicate that diesel taxes are fully passed on to consumers. Increases in state diesel taxes of one cent per gallon lead to an increase in the state retail price of 1.08 cents. Furthermore, the tax is fully realized in the price of diesel in the month of the tax change. This identification strategy will be biased if tax changes are correlated with supply conditions such as capacity utilization. However, we find that these factors are generally unsuccessful at explaining state tax changes.[1] Consistent with prior literature using a similar identification strategy (see Chouinard and Perloff, 2004), we find that state gasoline taxes are born fully by consumers while 65 percent of federal taxes are passed on to consumers.

Consistent with the theory of tax incidence, we find that more of the diesel tax is passed through to consumers when the residual supply of diesel is more elastic. Number 2 distillate can either be sold as diesel fuel or as heating oil. When demand for untaxed uses of diesel are high relative to demand for taxed uses, the residual supply of taxed diesel is more elastic. We find that pass-through is greater during times when heating oil demand is higher, such as in cold months in states where a greater fraction of households use heating oil to heat their homes.

We find less strong evidence that very high capacity utilization or low fuel inventories, both of which would tend to make supply more inelastic, are associated with less pass-through of fuel taxes. While taxes are fully passed through in months where refinery capacity utilization is below 95 percent, pass-through falls to 56 percent in months in which refinery utilization is above 95 percent. In constrast, state gasoline taxes are fully passed on to consumers regardless of refinery capacity utilization and season. This suggests that a summer tax holiday for gasoline would likely provide relief to consumers. For both diesel and gasoline, increases in lagged inventories are associated with lower tax-inclusive fuel prices. For gasoline, larger inventories are also associated with greater tax pass-through to consumers - a one standard deviation increase in gasoline inventories is associated with 8 percent greater tax pass-through.

[1] Decker and Wohar (2006) also consider factors shaping state diesel taxes. However they do not examine capacity conditions or neighbor's tax rates, two factors of particular interest to our study. Devereux et al (2007) considers the response of state gasoline taxes to the taxes of other states and the federal government, and Besley and Rosen (1998) consider the tax competition between states and the federal government.

The second objectives of this paper examines how tax incidence varies with tax evasion. We begin by incorporating tax evasion into the standard specific quantity tax model. Due to the potential for misreporting the sale of gallons intended for on-highway travel, for which diesel taxes are owed, as intended for non-taxed uses such as home heating, there has traditionally been a significant degree of tax evasion in this market. As Slemrod and Yitzhaki (2000) note, evasion could significantly alter the distributional consequences of a tax. In our model, there is a quantity tax paid by suppliers, who can underreport the amount of taxable gallons sold by incurring an evasion cost. We distinguish firms by their marginal cost of tax evasion. If all firms report at least some taxed sales, the incidence of the tax on the consumer price is identical to the case absent evasion. "Partially-evading" firms evade until the marginal cost of evasion is equal to the tax rate - thus, in equilibrium, firms' marginal cost is identical with or without evasion. Therefore, evasion merely shifts surplus from the government to producers, leaving consumer surplus unchanged. Conversely, if the cost of evasion is sufficiently disperse, some firms will find it in their interest to report no taxable diesel sales. For these firms, the constraint that they report nonnegative taxed sales is binding, which drives a wedge between the marginal cost of evasion and the tax rate. As a result, full-evaders will respond less to a change in taxes - leading supply to be more tax inelastic. The degree to which taxes are passed through to consumers will be affected by evasion depending on the prevalence of full-evaders in the market.

We also consider a second form of evasion, whereby interjurisdictional tax differences allow producers to misreport sales to a high tax jurisdiction as sales to a nearby low-tax jurisdiction. Like our analysis of traditional evasion, a firm purchasing solely from a lower tax jurisdiction will base her decision on the tax rate in the neighboring jurisdiction rather than the local tax rate - consequently, they will not respond to a change in the in-state tax rate. As the size of the jurisdiction increases, the expected cost of misreporting out-of-state sales increases. The tax elasticity of supply should be positively correlated with the size of the jurisdiction.[2]

We then proceed to empirically examine whether diesel tax incidence varied following the introduction of fuel dye. Although we find that the point estimate is of the correct sign, the pre-dye and post-dye tax incidences are statistically indistiguishable. We do find a noticeable effect of state size on the incidence of diesel taxes, as a one standard deviation increase in state size increases the pass-through by seven percentage points. Moreover, this effect is entirely concentrated in the post-diesel dye period. After the dye program was implemented, the same

[2] We also allow consumers to avoid taxes by crossing into the low-tax jurisdiction. As the size of the jurisdiction decreases, consumers' cost of avoidance declines - as a result, the instate demand becomes more elastic with respect to taxes as the size of the jurisdiction declines. Border-crossing by consumers will also tend to shift the burden of taxation more heavily towards producers, especially in small jurisdictions where cross-border travel is less costly.

one standard deviation increase in state size is associated with a 13 percentage point increase in diesel tax pass-through.

The final objective of this paper is to examine the relationship between gasoline content regulations and gasoline tax incidence. Although little work examines the interaction between regulation and taxes, regulatory-standards and taxes often apply concurrently to industries. Although gasoline content regulations and fuel taxes achieve similar environmental goals by reducing air pollution (directly in the case of content regulations, and indirectly, by increasing gasoline prices), content regulations themselves affect the supply chain by limiting the ability of suppliers to respond to market shocks. Consequently, the regulations may reduce the passthrough of gasoline taxes, thereby reducing the degree to which gasoline taxes reduce fuel consumption. We examine the interaction between tax incidence and regional content regulations. We use within-state variation in the mix of special gasoline blends required by changes in environmental regulation and estimate how heterogeneous content requirements affect the incidence of taxes. We find a relatively large effect - we estimate that tax pass-through in a state like California (which has one uniform, although stringent, blend of gasoline) is approximately 23 percentage points higher than tax pass-through in a state like Illinois (which uses two blends of gasoline in roughly equal proportion).

Little empirical evidence exists considering the incidence of commodity taxes on prices in general, and specifically in the fuel markets. To our knowledge ours is the first study to consider the incidence of diesel fuel taxes. Moreover, our work in unique in its estimation of both the effect of illegal activity on tax incidence, as well as its examination of how other regulations affect the incidence of fuel taxes. Chouinard and Perloff (2004,2007), and Alm et al (forthcoming) 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. Doyle and Samphantharak (2008) examine the effects of a gas tax moratorium on prices at the gas station level in Illinois and Indiana. 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 Barnett et al (1995) examines the incidence of cigarette excise taxes.

The paper proceeds as follows. Section 2 presents the model and derives the relevant incidence results. Section 3 provides background details regarding the regulation of diesel and gasoline markets and Section 4 describes the data and empirical methods we will use. Section

5 presents the empirical results, and Section 6 concludes.

2 Model

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 supply can be characterized by the function $S(p,t)$. The textbook approach to characterizing incidence starts from the equilibrium, $D(p) = S(p,t)$ 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.

One objective of this paper is to consider factors that shift the elasticity of supply η and empirically examine how these shifts affect the pass-through of diesel taxes. Below we describe one way in which we will identify shifts in η related to the effect of shifts in demand for fuel oil, which is chemically equivalent to diesel yet is used for a distinct purpose. Additionally, tax evasion and avoidance may work to drive a wedge between suppliers' response to taxes versus their response to prices, which has implications for the rate of pass-through of fuel taxes. Below we derive predictions for how evasion and avoidance behavior will affect tax incidence.

2.1 Residual supply elasticity and fuel oil demand

In the standard incidence equation derived above, the rate of pass-through depends on the relative elasticities of supply and demand. Characteristics of the market for diesel allow for an investigation into the impact of supply elasticity on the pass-through of diesel taxes. 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. Differentiating with respect to p, we obtain the residual supply elasticity of diesel,[3]

$$\eta^{diesel} = \eta/\sigma - \epsilon_{oil}/\sigma^{o} \tag{4}$$

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 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}.

2.2 Tax Evasion

Firms are able to evade the tax by underreporting the quantity of the taxable good sold to consumers. Denote the level of underreporting by q_u and the amount of good for which the tax is paid by q_t, so that total diesel production is given by $q = q_u + q_t$. The misreporting comes at a heterogenous evasion cost of $C_e(q_u, \gamma)$, which can be thought of as the resource cost to the firm of hiding underreported quantities, as well as penalties the firm incurs in the event it is caught by the tax authorities. Firms differ according to their evasion cost parameter, γ, which is distributed $F(\gamma)$. We assume the cost of evasion is convex and increasing in the amount of misreporting, $\frac{\partial C_e}{\partial q_u} > 0$, $\frac{\partial^2 C_e}{\partial q_u^2} > 0$. Furthermore, we assume that $\frac{\partial^2 C_e}{\partial q_u \partial \gamma} > 0$, the marginal cost of misreporting is increasing in γ.

Firms maximize the profit function

$$p(q_u + q_t) - tq_t - C(q_u + q_t) - C_e(q_u, \gamma) \tag{5}$$

[3] 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.

subject to the constraints $q_u, q_t \geq 0$, which have multipliers λ and ζ.

The first-order conditions for a firm's problem are given by

$$p - C'(q_u + q_t) - \frac{\partial C_e}{\partial q_u} - \lambda = 0 \tag{6}$$

and

$$p - t - C'(q_u + q_t) - \zeta = 0. \tag{7}$$

At an interior solution, equation (7) implies that total supply of diesel is given by

$$q_u + q_t = \phi(p - t) \tag{8}$$

where $\phi(p-t) = C'^{-1}(p-t)$, the inverse of the marginal cost function. It is important to note that supply does not depend on the cost of evasion parameter, γ, for those firms at an interior solution. With the assumed increasing marginal cost of evasion, the first-order condition (6) can be solved to yield a unique solution for the level of underreporting, $q_u^*(p, t, \gamma) = {C'}_e^{-1}(t)$.

The necessary condition for non-evasion is given by comparing the profits a firm earns when choosing $q_u^*(p, \gamma)$ and the profit a firm earns when choosing $q_u = 0$,

$$tq_u^*(p, \gamma) \leq C_e(q_u^*(p, \gamma)) - C_e(0) = FC_e + \int_0^{q_u^*} C_e'(q)dq. \tag{9}$$

Absent a fixed cost of evasion (FC_e) or a marginal cost of evasion greater than t for the first incremental unit of evasion, the constraint $q_u \geq 0$ never binds. Without a fixed cost of evasion, if the marginal cost of evasion at $q_u = 0$ is below the strictly positive tax rate, a firm will choose to at least partially evade.[4]

We also define the condition under which $q_t \geq 0$ binds given a positive tax rate. Firms with sufficiently low evasion costs of evasion will find it optimal to fully evade. The cutoff value of the evasion parameter, $\hat{\gamma}(p, t)$, is defined by the unique[5] solution to

$$\frac{\partial C_e'(\phi(p - t))}{\partial \gamma} = t. \tag{10}$$

For example, with a quadratic cost of evasion, $C_e(q_u, \gamma) = \gamma q_u^2$, the unique solution for $\hat{\gamma} = \frac{t}{\phi(p-t)}$.

[4] For example, all firms will choose to at least partially evade for quadratic evasion costs given by $C_e(q_u, \gamma) = \gamma q_u^2$.
[5] Uniqueness follows from our assumption that the marginal cost of evasion is strictly increasing in γ.

2.2.1 Absent Fully-Evading Firms

First, we assume that the lower bound for the support of γ is greater than the full-evasion cutoff. In this case, firms either partially evade taxes or fully comply - in both groups, firms choose to supply diesel up until the point at which the marginal cost of increasing total output is exactly equal to the tax inclusive price. Thus, aggregate supply is given by $S(p,t) = \phi(p-t)$. This is identical to the supply of diesel without allowing for evasion. The market equilibrium equates supply and demand, $D(p) = S(p,t)$. To obtain the tax incidence, we perturb this equilibrium:

$$\frac{dp}{dt} = \frac{\phi'(p-t)}{\phi'(p-t) - D'(p)}. \tag{11}$$

Hence, the presence of firms partially evading taxes does not alter the supply elasticity nor does supply depend on the marginal cost of evasion. In this case would expect incidence to remain the same even if enforcement policies altered evasion incentives.

2.2.2 With Fully-Evading Firms

We now allow the support of γ to be $[0,\infty]$. Let $\widehat{\gamma}(p,t)$ denote the full-evasion cutoff. Any firm with a cost of evasion parameter γ below this cutoff fully evades the tax. To find aggregate supply, we integrate individual firm supply over the support of γ:

$$S(p,t) = \int_0^{\widehat{\gamma}(p,t)} q_u^*(p,\gamma) f(\gamma) d\gamma + (1 - F(\widehat{\gamma}))\phi(p-t). \tag{12}$$

The first and second terms in equation (12) are the supply provided by firms fully evading the tax, plus supply provided by partial-evaders and non-evaders. The equilibrium condition $D(p) = S(p,t)$ can be perturbed to obtain the incidence of taxes on post-tax prices:

$$\frac{dp}{dt} = \frac{\phi'(p-t)}{\phi'(p-t) - \frac{1}{1-F(\widehat{\gamma}(p,t))}(D'(p) - \zeta)} \tag{13}$$

where $\zeta = \int_0^{\widehat{\gamma}} \frac{dq_u^*}{dp} f(\gamma) d\gamma$. Since ζ is strictly positive, the incidence of taxes are lower when fully-evading firms are present. For the full evaders there is a wedge between the marginal cost of evasion and the tax rate. This wedge leads fully-evading firms not to change sales in response to a tax change, thereby reducing the tax elasticity of supply. In addition, an increase in the tax rate may increase the measure of firms fully evading, which further reduces the response of the aggregate supply curve to a change in taxes.

The effect of evasion on incidence therefore depends on the importance of full evaders. As

$F(\widehat{\gamma})$ goes to zero, the effects of evasion on incidence disappear.[6] In the empirical section of the paper, we will consider the effects on incidence of a large reduction in the cost of monitoring tax evaders. Reducing monitoring costs, and therefore the likelihood of an evading firm being detected, raises the cost of evasion. Either greater resource costs must be incurred to achieve a given level of evasion, or the expected penalties associated with a given level of evasion are higher. We therefore treat a reduction in the cost of monitoring as a rightward shift in the distribution of the evasion cost parameter, γ. This reduces the measure of firms for whom $\gamma < \widehat{\gamma}$, which moves the tax incidence effects closer to the no evasion case.

2.3 Interjurisdictional Tax Differences

Finally, we consider the effect of differential state taxes. Interjurisdictional tax differences allow producers to avoid taxes in the high-tax jurisdiction by misreporting sales in the high-tax jurisdiction as sales in the low-tax jurisdiction. While the evasion we consider does not require a firm to move product interjurisdictionally, the impact of evasion requiring physical movement (such as "carousel" evasion of VAT) would follow analogously. Consumers may also respond - travelling from high-tax to low-tax jurisdictions to make their purchases. In this section, we first generalize the model of firm evasion and then consider cross-border consumer purchases.

Extending the previous model for firms, we now allow firms to report out-of-state sales, q_o, in addition to untaxed quantities, q_u, and taxed quantities, q_t.[7] We denote the in-state tax rate as t_i and the out-of-state tax rate as t_o where $t_o < t_i$. As with overreporting untaxed quantities, firms also vary in their cost of overreporting out-of-state sales (related to, for example, the distance to a lower-tax border or the plausibility of out-of-state sales). A firm choosing to overreport out-of-state sales q_o units of diesel fuel incurs cost $C_o(q_o, \rho)$ and maximizes profits given by

$$p(q_u + q_t + q_o) - t_i q_t - t_o q_o - C(q_u + q_t + q_o) - C_e(q_u, \gamma) - C_o(q_o, \rho) \tag{14}$$

subject to the constraints $q_u, q_t, q_o \geq 0$.

Letting ν denote the multiplier on the non-negativity constraint for q_o, the first-order condition for q_o is given by

$$p - t_o - C'(q) - \frac{\partial C_o}{\partial q_o} - \nu = 0. \tag{15}$$

[6]It is also instructive to note that if all firms fully evaded the tax, the price consumers face is unaffected by the tax rate, $\frac{dp}{dt} = 0$. In this case, the incidence of taxation falls entirely on producers and none of them remit taxes to the government.

[7]We exclude the final option - purchasing untaxed diesel in nearby jurisdictions. Assuming that the costs of evasion instate and out of state are equivalent, instate evasion strictly dominates out-of-state evasion.

For an interior solution, optimal reporting of taxed, untaxed and out-of-state sales solve

$$\frac{\partial C_e}{\partial q_u} = t_i, \qquad \frac{\partial C_o}{\partial q_o} = t_i - t_o, p - t_i = \frac{\partial C}{\partial q_t} \tag{16}$$

When the non-negativity constraints do not bind, the firm equates the marginal cost of out-of-state overreporting with the difference between the in-state and out-of-state tax rates (to equate the marginal profits of out-of-state reporting with legal reporting) and the difference between the neighboring tax rate and the marginal cost of reporting untaxed quantities (to equate marginal profits of the two forms of illegal reporting).

Although the method of evasion differs, the effect of overreporting out-of-state sales on incidence is similar to that of overreporting untaxed sales. A firm partially evading taxes (through either untaxed or out-of-state overreporting) will purchase a total quantity of diesel fuel identical to that of a firm fully complying with local fuel taxes. If a firm's cost of overreporting either untaxed or out-of-state sales is sufficiently low, the firm will opt to report no instate taxed sales. As before, a binding non-negativity constraint drives a wedge between the tax rate and the marginal cost overreporting. As a result, supply becomes more tax inelastic. While the size of the state, does not affect untaxed overreporting, it plausibly affects the ease with which a firm can misrepresent in-state sales as out-of-state sales. Specifically, as the size of the home state rises, the costs associated with legal out-of-state sales also rise. As a result, reporting substantial out-of-state sales tends to become less credible and more likely to be scrutinized by regulators. Thus, home state area should be negatively correlated with out-of-state overreporting. Consequently, as state size rises, we should expect in-state supply to become more elastic and the state taxes to be more heavily borne by consumers.

Unlike firms, consumers (specifically, interstate trucking) can legally shift purchases from higher tax to lower tax jurisdictions. Consumers will choose to purchase in lower-tax jurisdiction if the utility they receive from purchasing out of state exceeds the utility associated with purchasing at a higher tax rate instate. Denoting the utility of diesel consumption as $v(p)$, quantity demanded as $q(p)$ and the instate and out-of-state tax-inclusive prices as $p_i = p + t_i$ and $p_o = p + t_o$, a consumer located at location $d \in [0, \bar{\theta}]$ will choose to purchase instate if

$$d > \frac{v(q(p_o)) - q(p_o)p_o - v(q(p_i)) - q(p_i)p_i}{\delta}. \tag{17}$$

where δ denotes the cost of travel. Using $\hat{\theta}$ to denote threshold distance, total instate demand is given by

$$Q_d^i = q(p_o) \int_{\hat{\theta}}^{\bar{\theta}} f(d)\partial d \tag{18}$$

It is straightforward to derive that tax elasticity of demand will fall, as the size of the jurisdiction rises.[8]

Both consumer border-crossing and producer overreporting of out-of-state sales reduce the tax pass-through. Border-crossing leads demand to be more elastic and supply to be less elastic - shifting the incidence of taxation towards producers. As the size of the jurisdiction rises, though, firms find it more costly to credibly misrepresent instate taxed sales as out-of-state sales and consumers find it more costly to make cross-border transactions. Thus, as the size of the home jurisdiction rises, we predict that the incidence of taxation will fall more heavily on consumers. [9]

In addition, the first-order conditions for the firm suggest that overreporting untaxed sales may act as a substitute for overreporting out-of-state sales. If the costs of misrepresenting taxed sales as untaxed and out-of-state are roughly comparable, a firm will likely prefer to report overreport illegal sales as untaxed, rather than out-of-state. Out-of-state sales are subject to both the federal tax rate, as well as the state tax rate in the neighboring jurisdiction. In our empirical analysis, we consider the introduction of fuel dye - which substantially increased the cost of representing untaxed sales as taxed sales. Interestingly, the introduction of fuel dye did not affect the cost of overreporting out-of-state sales. By paying the federal taxes (even if the firm misrepresents the ultimate destination), the firm receives undyed diesel. Thus, we hypothesize that "out-of-state evasion" may not have been a large source of evasion in the pre-dye period, but may have become a larger source of evasion in the post-dye period.

3 Regulatory Background

3.1 Fuel Tax Evasion and Diesel Dye

Diesel fuel (technically, No. 2 Distillate) has a wide variety of uses. While the majority of diesel fuel is used on-highway in truck engines, substantial amounts of diesel is used "off-highway" for agriculture, residential heating, marine, commercial and industrial use.[10] Diesel fuel used

[8]An alternative specification allows consumers to vary by travel cost - the conclusions are identical.

[9]Interestingly, Chouinard and Perloff (2004) predict that consumer incidence should be negatively correlated with the state's share of national demand. If state size is positively correlated with total in-state demand, our results suggest the opposite relationship.

[10]In 2004, approximately 60 percent of diesel sales were for on-highway use.

on-highway is subject to federal highway taxes of 18.4 cents per gallon and state highway taxes ranging from 9 to 32.1 cents per gallon. In addition, environmental regulations limit the amount of allowable sulfur content of on-road diesel fuel.[11] Diesel fuel consumed for agriculture or marine use, or as fuel oil for residential, commercial or industrial boilers is untaxed and does not meet similar sulfur limits.

Variation in taxation and environmental stringency by use create strong incentives for firms to evade taxation. Evaders purchase diesel fuel meant for off-road use and use or resell it for on-road use without paying or collecting the appropriate highway taxes. In the 1980's, the canonical method of evasion was the "daisy chain", in which a licensed company would purchase untaxed diesel fuel and resell the diesel fuel internally or to another company several times to make it more difficult to audit the transaction. Eventually, a distributor would sell the untaxed fuel to retail stations as fuel on which taxes had already been collected.[12] In 1992, the Federal Highway Adminstration estimated the "daisy chain" and other evasion schemes, allowed firms to evade between seven and twelve percent of on-road diesel taxes, approaching $1.2 billion dollars of federal and state tax revenue annually.

On October 1, 1993, Environmental Protection Agency (EPA) began requiring that all diesel fuel failing to meet the low-sulfur on-road requirements be dyed to distinguish it from fuel meeting on-road sulfur limits. The IRS regulations, enacted as part of the Omnibus Budget Reconciliation Act of 1993 and put into effect on January 1, 1994, place similar dyeing requirements on diesel fuel on which taxes had not been collected. The IRS and EPA regulations have two effects on fuel tax evasion: (1) the regulations reduce the cost of regulatory enforcement, and (2) the regulations increase the cost of common evasion schemes like the "daisy chain." The use of fuel dye primarily decreases the cost of regulatory monitoring. Dyeing diesel fuel for which on-road taxes have not been collected or which fails to meet on-road sulfur requirements allows regulators to more easily monitor and enforce on-road regulations through random testing of trucks. In conjunction with lower enforcement costs, IRS monitoring intensity rose following the introduction of fuel dye into diesel fuel. Baluch (1996) tabulates IRS staff hours related to audits and enforcement of diesel fuel taxes and finds that staff hours rose approximately three and a half times, from 151,190 hours in 1992 to 516,074 hours in 1994.

The compliance effects of the diesel dye program were studied by Marion and Muehlegger

[11] From October 1993 to August 2006, the allowable sulfur content for on-highway diesel fuel was 500 parts per million. Regulations did not constrain the sulfur content of diesel intended for other uses. Beginning September 1, 2006, diesel sold for on-highway use must meet new Ultra Low Sulfur Diesel Fuel requirements, with sulfur content not exceed 15 ppm.

[12] For documented examples of evasion, see the Federal Highway Administration Tax Evasion Highlights.

(2008), who find substantial evidence that the dye program reduced tax evasion in the short-run. Sales of diesel fuel, which is almost entirely taxed for on-highway use, rose by an estimated 26 percent in the month that suppliers were required to begin dyeing. Sales of fuel oil, which is entirely untaxed, fell by a similar amount, leaving overall sales of No. 2 distillate virtually unchanged. The response by state matches economic incentives, as the jump in reported diesel sales was higher in high tax states and states with more legitimate users of fuel oil (and therefore higher costs of monitoring). Furthermore, a greater fraction of fuel oil sales seem to be legitimate in the post-dye period, as seasonal factors, temperature, and the fraction of households using fuel oil to heat their homes explain nearly three times the variation in the post-dye period compared to the pre-dye period. Finally, state fuel oil sales have a significantly positive diesel tax elasticity pre-dye, yet are unresponsive to taxes in the post-dye period. This all points to a significant reduction in firms' ability to evade diesel taxes after the the implementation of the dye program, and in total, the dye program raised federal fuel tax revenue by approximately 1.7 billion dollars per year.

3.2 Gasoline Content Regulation

In addition to examining the effect of the diesel dye program (and subsequent reduction in evasion) on tax incidence, we also estimate the effect of regional gasoline content regulations on tax incidence. Content regulations specify the chemical composition of fuel, defining what refiners must add or remove from gasoline prior to retail sale. In 1990, the Clean Air Act Amendment mandated federal content regulations for use in regions failing to meet EPA limits for ozone and carbon monoxide pollution. The amendment mandated three broad regional classes of gasoline: conventional, oxygenated and reformulated gasoline (RFG), designing oxygenated gasoline to reduce carbon emissions and RFG to limit ground-level ozone pollution. Subsequent to the federal regulation, many states chose to supplement the federal regulations either by voluntarily adopting the federal requirements or by mandating more strict regulations. As a result of state-level regulation, fifteen distinct gasoline blends were sold domestically in 2001.

Muehlegger (2006) studies regional content regulations and finds that specialty blends increased the price of gasoline as well as the price volatility. The introduction of specialty blends complicates the petroleum product supply chain - refinery 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. As the number of fuels increases, the ability of producers to respond to market shocks becomes more difficult - locations which special fuels experience more dramatic price spikes after experiencing a local supply shock, like a refinery fire.

4 Data and Methods

4.1 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 monthly average price of No. 2 distillate separately by the type of end user for twenty-three states.[13] 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 in the post-dye period. 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. Federal on-road diesel 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 taxes rise throughout the period as well, from a weighted average tax rate of 9.2 cents per gallon in 1981 to 19.4 cents per gallon in 2003.[14] Within-state variation also rises throughout the period. In 1981, state on-road diesel taxes vary 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. State and federal gasoline taxes rose throughout the period as well. 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 preva-

[13] 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 subdististricts (PADD1b).

[14] 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.

lence 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.[15] We also measure state heating oil prevalence using the fraction of households in a state reporting to use fuel oil as the primary energy source used for home heating from the 1990 census. In addition, we collect state-level gross state product, unemployment rate, state land area and calculate the minimum of the diesel and gasoline tax rate in neighboring states as additional covariates.

As factors affecting the elasticity of supply, 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 average seasonal demand in each PADD to measure inventories in terms of number of months of supply.

Table 1 reports the summary statistics of the each series employed in the regression analysis to follow. 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] Gasoline prices average 118 cents per gallon. Unlike diesel prices, the average gasoline prices 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 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.

[15] For example, if the temperature in a state were 55 degrees for each day in the month of January, the number of heating degree days for each day would be 10 and the number of heating degree days for the month would be 310.

[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.

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. Finally, 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 when capacity utilization is high is not unlikely. 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.

4.2 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} cents per gallon is given by:

$$p_{it} = \beta_0 + \beta_1 T_{it}^S + \beta_2 T_t^F + BX_{it} + \rho_i + \sigma_t + \epsilon_{it} \tag{19}$$

where T_{it}^S and T_t^F 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 time effects. To estimate (19) in the presence of the unobserved state-level heterogeneity described by ρ_i, we will estimate the first-differenced equation

$$\Delta p_{it} = \beta_0 + \beta_1 \Delta T_{it}^S + \beta_2 \Delta T_t^F + B\Delta X_{it} + \sigma_t + \epsilon_{it}. \tag{20}$$

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

We perform four sets of analysis. First, we estimate the incidence of state and federal fuel taxes and test whether the tax-inclusive price adjusts immediately to a change in taxes, by including the lagged value of the per unit excise tax. Second, we examine whether the incidence of diesel and gasoline taxes varies with three changes in supply conditions - changes in the residual supply elasticity arising from changes in the demand for untaxed uses of diesel, supply inelasticity arising from refinery capacity constraints, and supply inelasticity arising from low inventory levels. Third, we test whether the effect of the introduction of diesel fuel dye (and the contemporaneous reduction in tax evasion) is consistent with the predictions of our theoretical model. Finally, we examine the introduction of regional gasoline content regulations and estimate the relationship between regulatory heterogeneity of gasoline content and pass-through of gasoline taxes.

5 Results

5.1 Basic incidence results

The results of estimating equation (20) 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 1.2 cents, and every one cent increase in federal taxes is estimated increase the consumer price by 0.94 cents. Consistent with prior estimates from gasoline markets, there appears to be a greater degree of pass-through of state taxes than federal taxes. This is consistent with demand being more responsive to state taxes, perhaps through cross-border purchases, than to federal taxes, where cross-border sales are not a way to avoid the tax. 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.

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. Column 3 presents 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 1.08, which as before is not statistically distinguishable from one, but is more precisely estimated.

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 (forthcoming) 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.

One drawback to using state-level price data is that the EIA only reports these data for 23 states.[17] It is desirable to provide incidence estimates for the US, as the states for which we have price data may not be representative. The U.S. is divided into five petroleum districts referred to as PADDs and the Northeast states are further divided into three sub-PADDS. The EIA reports a complete monthly retail diesel price series for each PADD. We form series of tax rates for the three northeast sub-PADDs and the four PADDs comprising the rest of the U.S. To do so, we take a weighted average of the state tax rates of the states comprising the PADD, weighted by the average monthly consumption of No. 2 distillate consumed by the state. The series of covariates are similarly formed.

Table 3 reports the results of regressing the PADD price on the weighted average PADD tax rate and covariates. In Columns 1 and 2, we include state and month effects separately to allow for the identification of the effect of the federal tax rate. These results indicate somewhat lower pass-through of taxes. In the specification with PADD-level covariates, we estimate the pass-through rate of the average state tax rate of 0.87, while the pass-through rate of the federal tax rate is 0.86.

The lower pass-through rate of the average state tax in the PADD-level regression appears to be largely accounted for by time controls. In column 3, we display the results of estimating a specification controlling for year*month effects. With the addition of these controls, the estimated pass-through of the average state tax is 1.13, very close to the analogous state-level estimate of 1.08. Finally, we include the lagged value of the state-tax rate, as shown in column 4. As with the state-level estimates, the effects of prices on taxes seem to be immediately reflected in the retail price of diesel.

[17]This includes Oregon, which we do not include due to a large proportion of its diesel tax revenues derive from a weight-mile tax assessed on diesel trucks.

In Table 4, we display the basic incidence results for gasoline. These results are not new, as they have been documented using similar variation in Alm et al (forthcoming) and Chouinard and Perloff (2004). Consistent with these papers, we find full pass-through of state taxes, and we find that 65 percent of federal taxes are passed through to consumers. Furthermore, 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.

5.2 Supply Conditions and Tax Incidence

In our second extension, we 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 inelasticity arising from low 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 (4), substantial demand for an untaxed alternative will increase the residual supply elasticity of taxed diesel in a state. [18] While cold weather may directly influence the price due to delivery cost or cold-weather 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.

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 0.053. 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 10.6 percentage points higher than a month with zero degree days.

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. If refiners are operating at full capacity, there is little scope to alter production in the short-

[18] 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.

run in response to changes in taxes. Also, periods of high capacity utilization may indicate particularly strong demand, which could be associated with more inelastic supply. 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 5. 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 1.28, 0.99 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 56 percent of the 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, over half of the tax is born by consumers. In Panel B, we present the diesel incidence parameter separately by season. We find that diesel incidence is statistically indistinguishable from one regardless of quarter.

In Table 5 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 93 percent of the gasoline tax in the highest capacity utilization months, which is indistinguishable from one. 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.

Finally, we estimate the association between incidence and inventory levels. We predict low inventories to have a similar effect as high refinery capacity utilization - if inventories are sufficiently low, the elasticity of supply will be reduced and tax pass-through will decline. To examine the effect of inventories, we include wholesale inventory levels (measured in terms of months 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.

In Table 7, 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 effect. We find that, for both gasoline and diesel, the level of inventories is negatively correlated with the tax-inclusive price - a one-standard deviation decrease in lagged inventories is associated with one cent per gallon increase in gasoline and diesel fuel. Unlike our results for refinery capacity, 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 seven percentage point greater pass-through of gasoline prices.

5.3 Evasion, Fuel Dye and Tax Incidence

Next, we examine the effect of increased diesel tax compliance, as induced by the diesel dye program, on tax incidence and test the predictions of our model in Sections 2.2 and 2.3. The first prediction of our model is that tax pass-through should decrease with the prevalence of full evaders. Although we do not know the prevalence of full-evaders and partial-evaders in the pre-dye period, Marion and Muehlegger (2008) find that the diesel dye substantially reduced evasion. To test the prediction, we allow the parameter β_1 to differ in the pre- and post-dye periods.[19] We therefore extend the full specification including covariates and year*month effects, as shown in column 1 of Table 8 to include an interaction between the state tax rate in cents per gallon and a post-dye indicator. We estimate a modest increase in pass-through post-dye of 0.092. The sign of the point estimate is consistent with our theoretical prediction, that reducing the prevalence of full evaders should increase the incidence of fuel taxes on consumers, though the estimated effect that we obtain is statistically insignificant.

In addition, we test two hypotheses related to the relationship between incidence and interjurisdictional tax differences. First, our model predicts that if border-crossing by consumers or producers exists, incidence should increase with state size. We test this hypothesis in specification (2), by extending the theoretical model to include an interaction term between the state tax rate and the log of state size. In addition, our model makes a prediction about the substitution between types of tax evasion. Specifically, if the costs of overreporting untaxed and out-of-state sales are roughly comparable, firms evading taxes will tend to prefer to over-

[19] Federal taxes were virtually unchanged in the post-dye period, so separately estimating β_2 pre- and post-dye is not possible. The federal highway tax on diesel fuel was 24.4 cents per gallon for the entire duration of the post-dye period, with the exception of January 1, 1996 to September 30, 1997. The 0.1 cent per gallon tax for the Leaking Underground Storage Tank Trust Fund expired in January 1996 and was reinstated in October 1997, lowering the federal tax rate during this period to 24.3 cents per gallon.

report untaxed sales, since the benefits from overreporting untaxed sales are greater than then benefits from overreporting out-of-state sales. Following the introduction of fuel dye, the cost of overreporting untaxed sales increased substantially. If firms substituted away from "untaxed evasion" to "out-of-state" evasion, we would expect to see a stronger correlation between state size and incidence in the post-dye period than in the pre-dye period. We test this hypothesis in specification (3) by including an additional interaction term, which separately estimates the interaction between state tax rate and the log of state size in the pre- and post-dye periods.[20]

Consistent with our predictions, we estimate that the incidence of state taxes falls more heavily on consumers in large states and falls more heavily on producers in small states. We find that a one standard deviation increase in state size (corresponding roughly to the relative size difference between Massachusetts and Maine) is associated with consumers bearing approximately 8 percent more of the tax. When we separately estimate the coefficient for the interaction term for the pre- and post-dye periods, we find no significant effect of state size in the pre-dye period, and a positive and significant relationship in the post-dye periods. This result is consistent with the hypothesis that in the pre-dye period, overreporting untaxed sales was a more profitable form of evasion than overreporting out-of-state sales. After the introduction of fuel dye, it became much easier for retail stations, consumers and regulators to distinguish fuel on which federal tax had been paid from fuel which had not been taxed federally. Our estimates provide suggestive evidence that, in the post-dye period, firms in small states participated in "out-of-state" evasion to a greater degree than firms in large states. In addition, the absence of an effect in the pre-dye period suggests that consumer border-crossing was not a large factor in the pre-dye period.

It is important to note that the pre- and post-dye results are also consistent with an increase in the tax elasticity of demand in the post-dye period. If, for example, new technology introduced after the introduction of fuel dye made it easier for interstate truckers to avoid purchasing diesel in high-tax jurisdictions, we would expect to see similar difference between the pre- and post-dye interaction terms. As a test to partially distinguish between the two explanations, we separately estimate the interaction term between tax rates and state size for 1994 - 1998 and 1999 - 2003. We find that the coefficient is constant across the two periods, suggestive of a quick change in tax incidence shortly after the introduction of fuel dye. If the result were primarily consumer driven, we would expect a more gradual effect as technology penetrated the trucking industry, rather than the discontinuous change in incidence we observe.

[20] We limit our sample to the lower 48 states - this effectively excludes Alaska which is both substantially larger that other states and lacks viable options for cross-border activity.

5.4 Regional Content Regulations and Tax Incidence

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.

Regional content regulations specify the criteria gasoline must meet prior to retail sale in each jurisdiction.[21] During the early 1990's many states and even cities enacted more stringent regulations than the Reformulated and Oxygenated blends specified by the EPA. Anecdotally, industry complained that the proliferation of "boutique" fuels placed substantial constraints on refiners, pipeline operators and wholesale storage facilities.

We control for changes the composition of gasoline sold within a state by including the percent of gasoline sold within the state meeting federal Reformulated and Oxygenated requirements. To test whether heterogeneity in the types of gasoline required in a state constrain suppliers and thereby reduce tax pass-through to consumers, we include two additional terms. As a measure of the homogeneity of regulation within a particular state, we sum the squared market shares of Conventional, Reformulated and Oxygenated gasoline in each state.[22] A state using only one type of gasoline (regardless of specification) would receive the maximum value of 1. 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.

The estimates are presented in Table 9. In specification (4), which includes all four variables, as well as the standard covariates and month*year fixed effects, we find results consistent with previous literature finding that content regulations modestly increase the retail price of fuel. We find that the percent of gasoline meeting reformulated requirements is positively correlated with the tax-inclusive price - all else equal, shifting from only using conventional gasoline to only using reformulated gasoline 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 imprecisely estimated. Furthermore, the interaction term between

[21] Diesel must also meet content criteria related to sulfur content. Unfortunately, diesel regulations changed nationally - no local variation exists with which to estimate the effect of diesel content regulations on taxes.

[22] The mathematical approach is identical to the Hirschman-Herfindahl Index for measuring industry concentration. For example, if half of the gasoline sold in a state meets Reformulated requirements and half meets Conventional requirements, our measure of homogeneity would be equal to 0.5.

gasoline taxes and our measure of regulatory homogeneity is positive and significant - consistent with our prediction, we find that pass-through is approximately 22 percentage points higher in a state with uniform regulations (eg. California or Massachusetts) than a state which uses two gasoline formulations in equal proportion (eg. Illinois). [23]

5.5 Drivers of Fuel Tax Changes

As noted by Doyle and Samphantharak (2008), one concern with regressing price changes on contemporaneous tax changes, as we do in this paper, is the possibility that taxes are set with current demand and supply conditions in mind. If tax changes are more or less likely when prices or capacity utilization are high, then this will tend to bias our estimates of the pass through of diesel taxes.

In this section, we investigate the factors that are correlated with tax changes. We begin by estimating a regression of the change of the state tax rate on a host of covariates, including the federal tax rate, the minimum of the neighboring state's tax rate, recent prices, and current and past capacity utilization. We also consider the effect of these factors on the likelihood that a state raises its tax in a given month.

In Table 10, we present estimates of the determinants of the level of the month-to-month change in the state diesel tax rate. In column 1, we begin by examining the month-to-month changes in the explanatory variables. In general, we have little success in explaining changes in states' tax rates. We see that the change in the federal tax rate and the minimum of the neighbor's tax rate are both negatively correlated with changes in a state's taxes, though neither of these coefficients are statistically significant. Changes in capacity utilization similarly bear little relationship with changes in state tax rates.

Due to policy lags, a contemporaneous correlation is unlikely to exist between explanatory factors and state diesel tax rates. In column 2, we allow for a lagged response to changes in capacity utilization and the minimum of the neighbor's tax. We again see no relationship between lagged capacity utilization and the tax rate, however with this specification, we do observe a significant negative relationship between a state's tax rate and the lagged change in the minimum of the neighboring state's tax rate. It is worth noting that this is the only significant coefficient reported in the entire table.

Finally, in column 3 we allow for the state tax rate to depend not on changes in the covariates but instead on their levels. This may be a more sensible model, since the level of capacity

[23] Importantly, this suggests that a naive empirical approach which examines the effect of a regulation on retail prices may understate the true impact if the regulations make supply more inelastic.

utilization, for instance, may be more relevant than its change. Again, however, we see that no covariate is a statistically significant determinant of the change in the state tax rate. These results ameliorate to some degree the concern that important unobserved factors are correlated with both the tax rate and the price.

Specifications involving the change in the tax rate have several disadvantages. In Table 11, we present the results of estimating specifications involving an indicator for whether a state raised its tax rate in a given month as the dependent variable. Whether federal taxes or the minimum tax of neighboring states were raised has no bearing on a state's likelihood of raising the tax in a given period. Similarly, neither current or lagged capacity utilization has an effect on the likelihood of a state raising its taxes. Due to policy lags, the response to actions of other jurisdictions may take time to affect current taxes. We therefore examine tax changes in other jurisdictions occurring within the preceding 12 months. We find that the likelihood a state raises its diesel tax declines both when the federal government has raised its tax in the past 12 months and when the minimum neighboring state's tax rate has increased in the last 12 months.

6 Conclusion

In this paper, we examine the incidence of diesel taxes on retail prices, a previously unexplored topic. We find at least full, and potentially more than full, pass-through of both federal and state diesel taxes to consumers. The pass-through effects are immediately reflected in prices and are 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 raising 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.

Further, we used a simple competitive model to derive a testable hypothesis regarding the effects of evasion on pass-through. After the implementation of the diesel dye program, which significantly improved tax compliance, we see a small but statistically significant increase in tax incidence. The timing of this increase also roughly corresponds to the implementation of the dye program. This suggests that prior to the dye program, a significant fraction of diesel consumers were fully evading the tax, for whom there is a wedge between the marginal cost of evasion and the tax rate. We find evidence that inter-jurisdictional tax effects are important for diesel, though not for gasoline. Diesel prices in a state increase when neighboring state's taxes are raised. Furthermore, a state's size has a noticeable effect on diesel tax incidence in the post-dye period, consistent with criminal substitution to alternative methods of evasion following the introduction of fuel dye.

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 23 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 be important if regulators care about whether the incidence of taxes fall on consumers or producers.

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Figure 1: Average State Diesel Tax Rates by Year

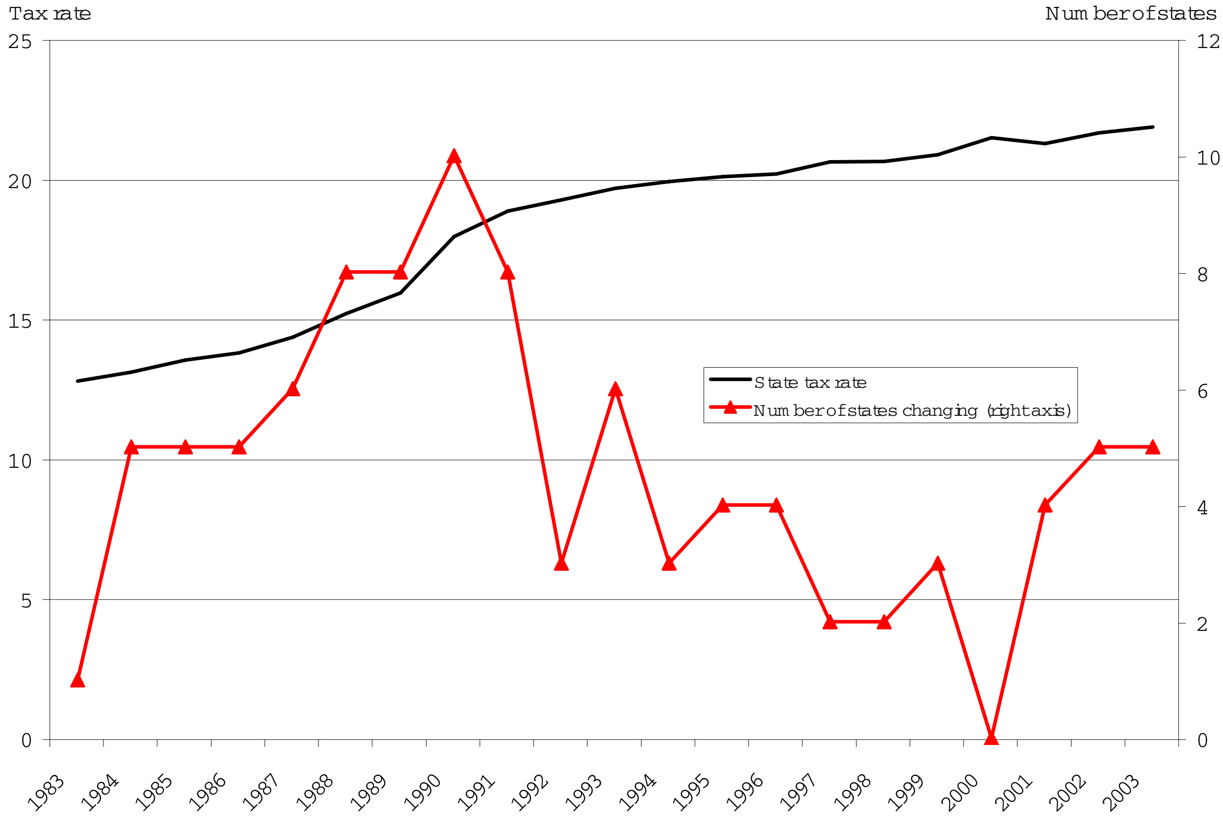

Figure 2: Average State Gasoline Tax Rates by Year

Figure 3: Diesel Price and Tax Changes

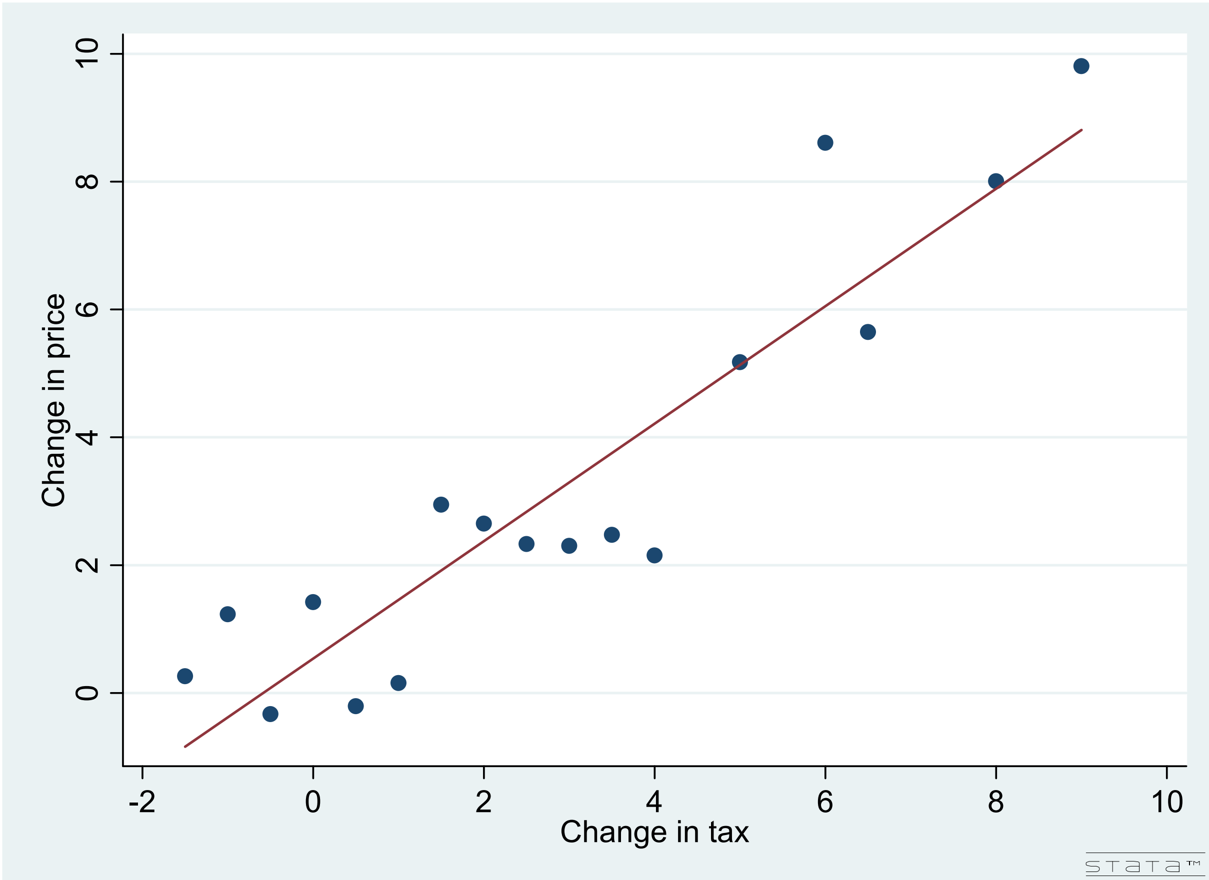

Figure 4: Gasoline Price and Tax Changes

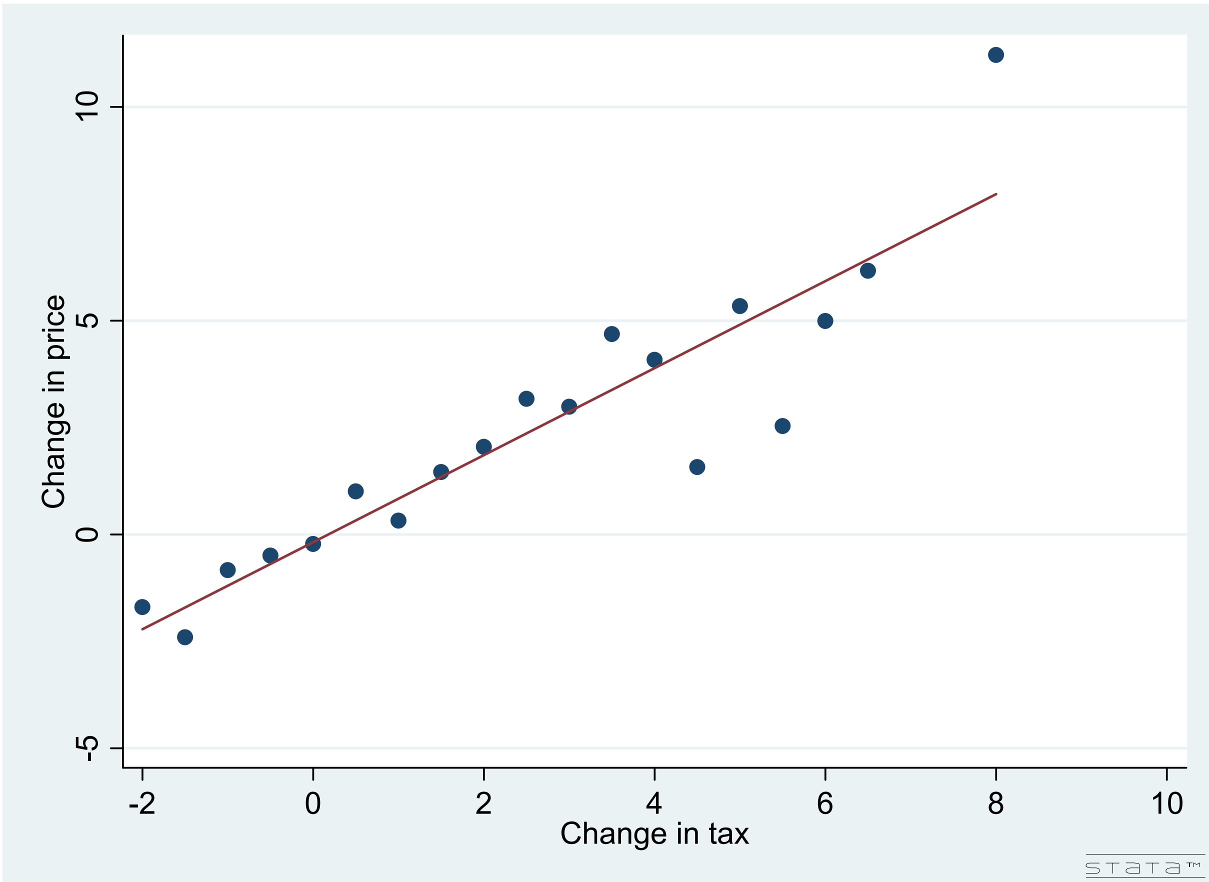

Table 1: Summary Statistics by Capacity Utilization

	(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 (months)	1.14	1.26	1.17	0.99	1.22
	(0.46)	(0.42)	(0.44)	(0.38)	(0.56)
Gasoline Inventories (months)	0.92	1.04	0.94	0.82	0.94
	(0.36)	(0.33)	(0.33)	(0.33)	(0.41)
Log state GSP	11.36	11.33	11.50	11.60	11.60
	(1.12)	(1.09)	(1.10)	(1.09)	(1.09)
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)				
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: Incidence of Diesel Taxes on Prices

	(1)	(2)	(3)	(4)	(5)
State diesel tax	1.250	1.222	1.084	1.083	1.071
	(0.195)***	(0.188)***	(0.074)***	(0.073)***	(0.089)***
Federal diesel tax	0.947	0.944			
	(0.139)***	(0.136)***			
State tax t-1				0.071	
				(0.087)	
State tax*deg. days*HH oil frac					0.053
					(0.020)**
Diesel tax * degree days					0.000
					(0.005)
State tax * HH fuel oil frac					0.090
					(0.383)
Minimum neighbor tax		1.259	0.690	0.692	0.677
		(0.354)***	(0.202)***	(0.203)***	(0.196)***
Degree days		-0.031	-0.052	-0.044	0.216
		(0.044)	(0.022)**	(0.027)	(0.141)
Degree days * HH Oil Frac.		0.481	0.522	0.516	-0.449
		(0.054)***	(0.072)***	(0.073)***	(0.371)
Log state GSP		-5.677	-19.442	-19.557	-19.169
		(10.318)	(7.454)**	(7.402)**	(7.612)**
Unemployment rate		-0.798	0.086	0.087	0.062
		(0.335)**	(0.400)	(0.401)	(0.404)
Year, month effects	X	X			
Year*month effects			X	X	X
Observations	5297	5156	5156	5067	5156
R-squared	0.18	0.21	0.77	0.77	0.77

Standard errors clustered by state 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: Incidence of Diesel Taxes on Prices, PADD level

	(1)	(2)	(3)	(4)
State diesel tax	0.838	0.867	1.131	1.131
	(0.250)***	(0.373)**	(0.145)***	(0.160)***
Federal diesel tax	0.889	0.857		
	(0.814)	(0.813)		
State tax t-1				-0.000
				(0.185)
Covariates		X	X	X
Year, month effects	X	X		
Year*month effects			X	X
Observations	1741	1692	1692	1677
R-squared	0.21	0.23	0.85	0.85

Standard errors clustered by PADD 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 include degree days, degree days interacted with prevalence of household fuel oil use for home heating, log GSP, 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.

Table 4: Incidence of Gasoline Taxes on Prices

	(1)	(2)	(3)	(4)
State gas tax	1.092	1.102	1.063	1.064
	(0.105)***	(0.103)***	(0.057)***	(0.058)***
Federal gas tax	0.649	0.648		
	(0.037)***	(0.037)***		
State tax t -1				0.038
				(0.045)
Minimum neighbor tax		0.065	0.035	0.035
		(0.078)	(0.084)	(0.084)
Log state GSP		-23.352	-10.902	-10.902
		(4.680)***	(5.297)**	(5.297)**
Unemployment rate		-0.816	-0.161	-0.161
		(0.160)***	(0.187)	(0.188)
Year, month effects	X	X		
Year*month effects			X	X
Observations	11058	11058	11058	11010
R-squared	0.19	0.20	0.75	0.75

Standard errors clustered by state 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 5: 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%
Δ State diesel tax	1.276	0.994	1.060	0.564
	(0.175)***	(0.208)***	(0.062)***	(0.121)***
Observations	1111	1247	1682	660
R-squared	0.71	0.79	0.82	0.80
	Panel B: Split by quarter			
	Quarter 1	Quarter 2	Quarter 3	Quarter 4
Δ State diesel tax	1.040	1.261	0.960	1.191
	(0.168)***	(0.180)***	(0.091)***	(0.048)***
Observations	1257	1268	1279	1352
R-squared	0.79	0.75	0.76	0.75

Standard errors, clustered at the state-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, the number of heating degree days, heating degree days interacted with household use fuel oil for home heating, the log of the state GSP, and the state unemployment rate.

Table 6: 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%
Δ State gas tax	1.068	1.009	1.206	0.934
	(0.141)***	(0.086)***	(0.075)***	(0.130)***
Observations	1920	2497	3773	1724
R-squared	0.79	0.79	0.75	0.63
	Panel B: Split by quarter			
	Quarter 1	Quarter 2	Quarter 3	Quarter 4
Δ State gas tax	1.010	1.011	1.063	1.368
	(0.131)***	(0.111)***	(0.074)***	(0.152)***
Observations	2777	2816	2731	2734
R-squared	0.80	0.73	0.69	0.70

Standard errors, clustered at the state-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, the log of the state GSP, and the state unemployment rate.

Table 7: Fuel Tax Incidence and Fuel Inventories

Dependent variable: Change in tax inclusive fuel price

	Panel A: Diesel			Panel B: Gasoline		
	(1)	(2)	(3)	(4)	(5)	(6)
State fuel tax	1.088***	1.075***	1.080***	1.039***	0.839***	0.845***
	(0.0754)	(0.0915)	(0.0848)	(0.0584)	(0.0858)	(0.0824)
Inventories	-0.474**	-0.668	-0.132	2.837***	-0.485	-1.035
	(0.214)	(0.537)	(0.584)	(0.928)	(1.205)	(1.140)
Lagged Inventories			-2.536***			-3.068***
			(0.273)			(1.001)
State Tax * Inventories		0.0120	0.00886		0.199***	0.189***
		(0.0302)	(0.0307)		(0.0721)	(0.0681)
Observations	5146	5146	5125	10375	10375	10330
R-squared	0.775	0.775	0.784	0.773	0.774	0.775

Standard errors, clustered at the padd-level, are in parentheses.
*,**,*** denote significance at the 90%, 95%, and 99% level, respectively.
All variables have been first-differenced. Other controls for both diesel and gasoline include month*year effects, the minimum of the neighboring states' tax, the log of the state GSP, 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 8: Evasion, Border Crossing and Diesel Tax Incidence

Dependent variable: Change in tax inclusive diesel retail price

	(1)	(2)	(3)
State tax (cpg)	1.037	0.907	1.129
	(0.111)***	(0.085)***	(0.202)***
Post-dye*State tax (X100)	0.092		-0.344
	(0.170)		(0.236)
State tax*Log(Area)		0.066	-0.014
		(0.035)*	(0.048)
Post-dye*State tax*Log(Area)			0.137
			(0.038)***
Min. Neighbor tax (cpg)	0.690	0.707	0.702
	(0.196)***	(0.192)***	(0.190)***
Degree days (X100)	-0.051	-0.045	-0.044
	(0.022)**	(0.031)	(0.031)
Degree days*HH fuel oil use	0.521	0.498	0.518
	(0.072)***	(0.086)***	(0.092)***
Log(GSP)	-19.427	-5.208	-5.316
	(7.427)**	(6.422)	(6.405)
Unemp. Rate	0.090	0.338	0.308
	(0.397)	(0.268)	(0.268)
Year*Month effects	x	x	x
Observations	5156	4991	4991
R-squared	0.77	0.79	0.79

Standard errors, clustered at the state-level, are in parentheses.
*,**,*** denote significance at the 90%, 95%, and 99% level, respectively.
All variables in the regression have been first-differenced. The dependent variable is the change in the tax inclusive retail price of No. 2 diesel.

Table 9: Gasoline Content Regulations and Tax Incidence

Dependent variable: Change in tax inclusive gasoline retail price

	(1)	(2)	(3)	(4)	(5)
State gas tax	1.063***	1.064***	0.893***	0.639**	0.441
	(0.0597)	(0.0597)	(0.0877)	(0.239)	(0.282)
Percent Reformulated	1.643	2.408**	2.405**	2.230**	3.421***
	(1.131)	(1.010)	(0.978)	(1.062)	(1.220)
Percent Oxygenated	0.362	1.633*	1.702**	1.520	1.413
	(0.881)	(0.904)	(0.839)	(0.960)	(0.973)
Sum of Squared Content Shares		3.383***		-5.767	-5.924
		(1.135)		(5.142)	(5.525)
SSCS * State Gas Tax			0.175***	0.435*	0.436
			(0.0533)	(0.245)	(0.269)
Inventories					-1.167
					(1.085)
Lagged Inventories					-3.082***
					(1.043)
State Tax * Inventories					0.193***
					(0.0679)
Observations	7761	7761	7761	7761	7761
R-squared	0.786	0.786	0.786	0.786	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 effects, the minimum of the neighboring states' tax, the log of the state GSP, and the state unemployment rate.

Table 10: Determinants of diesel tax changes

Dependent variable: Change in state diesel tax

	(1)	(2)	(3)
Change in federal tax	-0.009	-0.011	-0.008
	(0.008)	(0.008)	(0.009)
Change in capacity utilization	-0.001	-0.003	
	(0.004)	(0.005)	
Lagged change in cap. Utilization		-0.007	
		(0.005)	
Change in minimum neighbor's tax	-0.019	-0.021	
	(0.019)	(0.019)	
Lagged change in minimum neighbor's tax		-0.018	
		(0.007)**	
Change in degree days	0.003	-0.000	
	(0.008)	(0.008)	
Change in degree days * HH fuel oil frac	0.015	0.019	
	(0.016)	(0.016)	
Capacity utilization			-0.003
			(0.006)
Lagged capacity utilization			-0.001
			(0.004)
Minimum neighbor's tax			0.000
			(0.002)
Degree days			0.000
			(0.004)
Degree days * HH fuel oil frac			-0.000
			(0.007)
Change in GSP	1.107	1.246	1.013
	(1.224)	(1.267)	(1.229)
Change in unemp. Rate	0.143	0.142	0.137
	(0.096)	(0.094)	(0.093)
Constant	0.014	0.094	0.194
	(0.048)	(0.055)*	(0.537)
Year, month effects	X	X	X
Observations	3267	3231	3289
R-squared	0.02	0.02	0.01

Standard errors, clustered at the state-level, are in parentheses.
*,**,*** denote significance at the 90%, 95%, and 99% level, respectively.

Table 11: Determinants of likelihood of diesel tax increase

Dependent variable: Indicator for increasing state tax rate

	(1)	(2)	(3)	(4)
Federal tax raised	-0.010			
	(0.009)			
Federal tax raised last 12 months		-0.009		
		(0.005)*		
Neighboring state's tax raised	0.006		-0.018	
	(0.032)		(0.033)	
Neighbor raised last 12 months		-0.007		-0.009
		(0.005)		(0.005)*
Log of lagged price	0.021		-0.009	
	(0.016)		(0.017)	
Log average price last 12 months		0.021		0.010
		(0.015)		(0.016)
US Refinery Capacity utilization	-0.000	-0.000	0.000	0.000
	(0.001)	(0.001)	(0.001)	(0.001)
Lag Capacity utilization	0.001	0.001	-0.000	-0.000
	(0.001)	(0.001)	(0.001)	(0.001)
Change in degree days	-0.002	-0.002	-0.002	-0.001
	(0.002)	(0.002)	(0.002)	(0.002)
Change in degree days*HH fuel oil use	0.007	0.007	0.007	0.007
	(0.003)**	(0.003)**	(0.003)**	(0.003)**
Change in log GSP	0.082	0.084	0.050	0.076
	(0.516)	(0.495)	(0.457)	(0.437)
Change in Unemp. Rate	0.046	0.047	0.090	0.087
	(0.023)**	(0.023)**	(0.050)*	(0.049)*
Year,month effects	X	X		
Month*year effects			X	X
Observations	3232	3290	3232	3290
R-squared	0.03	0.03	0.08	0.08

Standard errors, clustered at the state-level, are in parentheses.
*,**,*** denote significance at the 90%, 95%, and 99% level, respectively.
The reported results are from a linear probability model estimated using OLS, where the dependent variable takes on a value of 1 if the state's diesel tax rate was increased in that particular month.