Tax compliance and fiscal externalities: Evidence from U.S. diesel taxation

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Abstract

Fiscal externalities across jurisdictions can arise from imperfect tax enforcement and the avoidance behavior of taxpayers. Base shifting to low tax jurisdictions tends to generate positive fiscal externalities, while understating the overall tax liability leads to negative fiscal externalities when the tax base is apportioned across jurisdictions. While much of the literature has focused base shifting and the resulting "race-to-the-bottom" in tax rates, we examine an empirical setting illustrating how negative fiscal externalities can dominate. Truckers in the United States owe state diesel taxes based on diesel consumption, which is apportioned to states based on the miles driven in each state. We document that an increase in the tax rates of other states negatively impacts own-state taxed sales, suggesting that evasion by understating the number of gallons consumed is the predominant source of externalities, since doing so reduces the tax revenues of all states. Our estimates of the tax reaction function indicate that local tax rates respond negatively to tax rates in other states, which is in contrast to the canonical race-to-the-bottom but is consistent with the sign of the estimated fiscal externalities.

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1 Introduction

Tax compliance and enforcement lead to both horizontal and vertical fiscal externalities in multinational tax systems. A transaction in one jurisdiction often generates a tax liability in other jurisdictions or at other levels of government. Examples of this abound. Corporate income is apportioned to states based on the location of a company's sales and capital. A dollar earned abroad leads to a tax bill in the country of residence. A sale over the internet by a company in one state leads to tax liability in the purchaser's state. Income reported on a federal tax form also carries over to state tax forms. Tax evasion and enforcement have effects not only on the tax base of the government where the activity took place but also the tax base of other governments as well.

In this paper, we study how tax compliance leads to fiscal externalities in the context of state diesel taxes in the U.S, and we examine the effect this has on how states set tax rates. This is an environment where individual states are very aware of the fiscal externalities created by differences in state taxes - all of the forty-eight contiguous U.S. states as well as ten Canadian provinces are subject to the International Fuel Tax Agreement that attempts to reduce the incentive for interjurisdictional tax competition, among other objectives. Interstate trucking companies pay diesel taxes to states based on where gallons of diesel are used, not where they are purchased. Much like how corporate income is apportioned to US states based on a company's location of sales and capital, diesel consumption by truckers is apportioned to states based on miles driven. A trucking company reports the total gallons of diesel used and how many miles were driven in each state, from which it is estimated how many gallons were used in each state. The trucker's home state is responsible for collecting the tax on behalf of itself and all other states, and for auditing home-state truckers to ensure compliance.

This approach sharply reduces tax avoidance by dulling the incentive to purchase fuel in response to differences in local tax rates for law-abiding truckers. However, tax evasion could still lead to fiscal externalities through two channels. First, if a state increases its diesel tax rate, truckers may elect to report fewer gallons overall, reducing the revenue of all other states in proportion to miles driven in each state. On the other hand, they may shift reported miles toward other states, increasing the revenue of other states.

We first estimate how the tax rates set by other states affect own-state tax revenues. We find that a weighted average of other states' diesel tax rates is negatively correlated with own-state diesel tax revenue. This is consistent with the hypothesis that an important form of diesel tax non-compliance involves underreporting the number of gallons consumed overall, and that this outweighs any shifting of reported miles into the state from the high tax jurisdiction.

We provide several pieces of evidence in support of this interpretation. First, the negative spillovers result is driven entirely by states where bilateral truck shipments are important, not by neighboring states or states that are economically linked in other ways. Furthermore, conditional on the truck-shipment-weighted tax measure, the tax rates of neighboring states exert a positive influence on own-state revenues. Second, in states where gallons underreporting is difficult, we see no evidence of spillovers. This bolsters the explanation that these fiscal externalities are driven by the method of taxing interstate truckers rather than other unobserved linkages between states, and that gallons underreporting is the likely explanation. We also rule out that the reduction in revenues due to increased tax rates in other states are due to real responses, such as changes in shipping or driving behavior.

The negative fiscal exernalities that we document may alter the predictions of a model of tax setting by jurisdictions. When fiscal externalities are positive, a race-to-the-bottom is predicted, where states try to undercut competing jurisdictions to gain revenue. In contrast, since diesel taxes exert negative fiscal externalities, tax rates are likely to be strategic complements, and the optimal response to higher tax rates in other states is a high own-state tax rate. To test this, we estimate the tax rate response function, finding that own-state diesel taxes are indeed higher when the tax rates of the state's truck trading partners is high.

Our paper relates to several strands of the tax literature. First, a large literature examines the fiscal externalities and the resulting strategic behavior imposed by interjurisdictional variation in tax rates.[1] Brueckner (2003) provides a excellent overview of both the theoretical literature relating to tax externalities and the empirical literature documenting horizontal tax competition with respect to cigarette, liquor and sales taxes. Most of this work emphasizes the positive horizontal externalities create by local taxes - high local taxes push consumers to lower tax jurisdictions. For example, Lockwood and Migali (2009) find evidence of increased excise tax competition for alcohol after the 2013 introduction of the EU single market. Consequently, the tax rates tend to be too low, as local jurisdictions compete over a mobile tax base.

More recently, several papers have tried to distinguish positive horizontal and negative vertical tax externalities. Brulhart and Jametti (2006) examine personal and corporate tax rates of Swiss cantons and find evidence that the vertical tax externalities dominate the horizontal ones. Devereux et al (2007) test for evidence of horizontal and vertical tax competition in the context of U.S. state cigarette and gasoline taxes and find that horizontal competition is more important

[1] More broadly, a very large literature examines interjurisdictional competition with respect to regulation, tax policy and fiscal policy.

for an easily storable good like cigarettes. Agrawal (2012) examines the sales tax rates set by local jurisdictions near and far from state borders with large state sales tax differentials and finds that local tax rates on the high and low-tax sides of the border smooth the differential in state sales taxes.

Another set of papers examines the relationship between tax enforcement and collections. Trandel (1992) and Lovely (1994) formalize the welfare effects of evasion and enforcement in a world with interjurisdictional tax differentials and cross-border sales. De Paula and Scheinkman (2010) and Pomeranz (2011) examine the self-enforcing nature of the value-added tax and illustrate how enforcement efforts targeting one point in the supply chain can be have effects on evasion up- and down-stream from the targeted firm. More specific to our particular context, several papers examine evasion and enforcement in the context of fuel taxes. Marion and Muehlegger (2008) estimate the effect of a a key regulatory innovation, the dyeing of untaxed diesel, on taxed and untaxed diesel sales in the U.S. Agostini and Martinez (2012) examine the effect of audit threats on tax reporting in Chile.

The existing literature tends to strongly emphasize the positive externalities that local taxes impose on neighboring jurisdictions, due to cross-border sales, tax avoidance, or endogenous firm location decisions. This paper presents an alternative source of fiscal externalities, those arising from tax evasion and enforcement, that we demonstrate in the context of diesel fuel taxes lead to negative externalities and suggest that tax rates may be higher than they would be in the absence of the fiscal externality.

We begin by illustrating theoretically the relevant fiscal externalities. We then present our empirical approach and results. We conclude with a discussion of the implications of our results for other tax policies, such as taxing income from foreign sources, taxing internet transactions, and other excise taxes.

2 Theory discussion

In this paper, we examine the taxation of diesel fuel markets. As we describe in greater detail in next section, jurisdictions are very aware of the potential externalities that might arise from taxation based on point of purchase, especially when attempting to tax a very mobile tax base for which border crossing is part of everyday business. Rather, taxation of diesel fuel is based on point of use – firms report mileage by jurisdiction and are responsible for taxes in the states in which they traveled rather than the states in which they purchased fuel. For tax compliant truckers, this dramatically limits the traditional externalities highlighted in the existing literature; if a firm truthfully reports mileage, selectively purchasing in a low-tax jurisdictions does not provide a tax advantage.

We illustrate that a fiscal externality arises as a result of self-reporting of mileage and and fuel consumption. For simplicity, consider a representative trucking firm operating in a high-tax jurisdiction and a low-tax jurisdiction. We further hold the state's choice of audit rate and tax level constant and discuss how these might be relaxed in the next section.

We denote the tax rates in the two jurisdictions as t_1 and t_2 and assume that the high tax jurisdiction is the first, implying $t_1 > t_2$. The firm reports two pieces of data to the tax authority, the total number of gallons of fuel purchased and the miles driven in each jurisdiction. These two pieces of information together determine the tax liability in each jurisdiction. Total miles driven is assumed to be easily verified by examining the odometer. The quantities that can be misreported to the tax authority are therefore total gallons consumed and the miles driven in each jurisdiction, which can be summarized by the portion of miles driven in jurisdiction 1.[2] We denote the true values of the two variables as G and m_1 respectively, and the amounts reported by the firm to the tax authority as $\hat{G}$ and $\hat{m}_1$.

The firm chooses $\hat{G}$ and $\hat{m}_1$ to minimize the value of the tax liability plus the cost of misreporting:

$$T = \hat{m}_1 \hat{G} t_1 + (1 - \hat{m}_1)\hat{G} t_2 + \phi(G - \hat{G}) + \eta(m_1 - \hat{m}_1) \tag{1}$$

where $\phi(.)$ and $\eta(.)$ represent the increasing, convex costs of understating gallons ($G > \hat{G}$) or mis-stating the location of use $m_1 - \hat{m}_1$. [3] Differentiating both sides with respect to the choice variables, we have joint interior first-order conditions:

$$\phi'(G - \hat{G}^*) = \hat{m}_1^* t_1 + (1 - \hat{m}_1^*) t_2 \tag{2}$$

$$\eta'(m_1 - \hat{m}_1^*) = \hat{G}^*(t_1 - t_2). \tag{3}$$

Equation (4) states that at the optimal $\hat{G}$ the marginal cost of underreporting gallons is set equal to the average tax rate faced by the firm, where the tax rate of each state is weighted by the reported mileage in that state. Similarly, equation (4) states that the optimal level of overstating use in low-tax jurisdictions and underreporting use in high-tax jurisdictions equates

[2] In this model, all fuel purchases are made in bulk with tax not included. In practice, truckers may refuel along the route, with the tax of the state in which the refueling occurs included in the price. The trucker would then receive credit for that amount when submitting the tax return.

[3] The cost of understating can represent either real resource costs, or it can represent expected penalties. The distinction is unimportant for the analysis that follows, though would have implications for the welfare consequences of evasion.

the marginal cost of mis-reporting and the magnitude of the tax differential.

Of primary interest is the response of reported taxed gallons used in a state (e.g., $\hat{m}_1\hat{G}$) to changes in the local tax (t_1) and the tax in the neighboring jurisdiction (t_2). The two first order conditions jointly determine the optimal choice(s) of $\hat{G}^*$ and m_1^*. Differentiating both first-order conditions with respect to t_1, we have:

$$-\phi''\frac{\partial \hat{G}^*}{\partial t_1} = \frac{\partial \hat{m}_1^*}{\partial t_1}(t_1 - t_2) + \hat{m}_1^* \tag{4}$$

$$-\eta''\frac{\partial \hat{m}_1^*}{\partial t_1} = \frac{\partial \hat{G}^*}{\partial t_1}(t_1 - t_2) + \hat{G}^*. \tag{5}$$

Intuitively, if enforcement prevents a firm from underreporting taxed gallons, an increase in local taxes induces firms to misreport local use and vice versa. An analogous set of conditions can be derived with respect to the tax rate in neighboring states - in this case, an increase in taxes in neighboring states tends to increase local taxed gallons if the primary means of evasion is misreporting the location of use. If, on the other hand, the primary means of evasion is under-reporting all sales, an increase in taxes in a neighboring state will impose a negative externality on local taxed quantities.

Whether the tax rates in neighboring states act as strategic complements or substitutes depend on the ease with which firms can underreport gallons relative to the ease with which firms can misreport the location of sale. A revenue-maximizing state sets t_1 to maximize tax revenues, $TR_1 = \hat{G}\hat{m}_1 t_1$. Following the canonical result in Bulow et al (1985), whether taxes are strategic complements or substitutes depends on the sign of the second-order of the state's objective function with respect to own- and neighboring-tax.

Taking the derivative of tax revenues with respect to t_1 and t_2, we have:

$$\frac{\partial^2 TR_1}{\partial t_1 \partial t_2} = \frac{\partial^2 \hat{G}}{\partial t_1 \partial t_2}\hat{m}_1 t_1 + \frac{\partial^2 \hat{m}_1}{\partial t_1 \partial t_2}\hat{G} t_1 + \frac{\partial \hat{G}}{\partial t_1}\frac{\partial \hat{m}_1}{\partial t_2} t_1 + \frac{\partial \hat{m}_1}{\partial t_1}\frac{\partial \hat{G}}{\partial t_2} t_1 + \frac{\partial \hat{G}}{\partial t_2}\hat{m}_1 + \frac{\partial \hat{m}_1}{\partial t_2}\hat{G} \tag{6}$$

Multiplying by $\frac{t_2}{\hat{G}\hat{m}_1}$, we can represent the sign of $\frac{\partial^2 TR_1}{\partial t_1 \partial t_2}$ as:

$$sign(\frac{\partial^2 TR_1}{\partial t_1 \partial t_2}) = sign\left(\frac{\partial^2 \hat{G}}{\partial t_1 \partial t_2}\frac{t_1 t_2}{\hat{G}} + \epsilon_{t_2}^G\left[1 + \epsilon_{t_1}^m\right] + \frac{\partial^2 \hat{m}_1}{\partial t_1 \partial t_2}\frac{t_1 t_2}{\hat{m}_1} + \epsilon_{t_2}^m\left[1 + \epsilon_{t_1}^G\right]\right) \tag{7}$$

where $\epsilon_{t_i}^m$ and $\epsilon_{t_i}^G$ denote the elasticities of misreporting and underreporting with respect to state i.

The sign of the expression depends on the relative magnitude of the two channels by which evasion might occur. Two benchmarks, in which evasion occurs solely through one of the channels, are particularly instructive. If the technology of evasion only allows firms to misreport the total quantities of diesel ($\hat{G} < G$) but not the state in which the gallons were consumed, the second order and elasticity terms related to m drop out of equation (7). The remaining expression is negative.[4] In this case, taxes are strategic substitutes and the slope of the reaction function is negative. In contrast, if the technology of evasion only allows firms to misreport the location of use ($\hat{m} \neq m$), taxes are strategic complements and the slope of the reaction function is positive.

3 Background

Our context is the U.S. market for diesel fuel. Diesel taxes are levied on fuel intended for on-highway use by the federal, state, and some local governments. The federal tax is 24.4 cents per gallon. State diesel taxes vary substantially, from a low of 8 cents per gallon in 2011 to a high of 35.1 cents per gallon. Marion and Muehlegger (2011) find that the burden of diesel taxes falls entirely on consumers, in this case, large trucking companies and users of commercial diesel vehicles.

Diesel tax liability for interstate truckers is based on the state of use rather than the state of purchase. This more closely connects highway funding for road repair and construction with driving. It also mitigates, though perhaps not eliminates, the strategic location of purchase by truckers, a likely source of fiscal externalities. Truckers cannot simply wait to refuel at a low tax state to reduce their ultimate diesel tax burden. There may still be some incentive to alter the location of purchase in response to taxation. Due to the lag between when fuel is purchased and when the tax bill is settled, the present value of taxes owed could be lower. On the other hand, if the tax pass-through rate is less than 100 percent, purchasing in a high tax state may actually be desirable.

To ease the burden of collection, in the late 1980's, state tax authorities adopted the International Fuel Tax Agreement (IFTA). The IFTA coordinates tax collection, enforcement and licensing across the 48 contiguous U.S. states and 10 Canadian provinces. The IFTA began in 1983 as an agreement between Arizona, Iowa and Washington. Gradually, over the subsequent two decades, all of the remaining contiguous states and ten Canadian provinces chose to join.[5]

Prior to the IFTA, the system of licensing and tax collection was decentralized. Each state

[4] If m is fixed, equation (7) simplifies to $\frac{\partial^2 \hat{G}}{\partial t_1 \partial t_2} \frac{t_1 t_2}{\hat{G}} + \epsilon^{G}_{t_2}$. Again holding m fixed, both terms are negative; the first from differentiating (5) with respect to t_2 and the second from differentiating () with respect to t_2. The result for the case in which G is held fixed is derived analogously.

[5] Denison and Facer (2005) discuss the history of the IFTA in greater detail.

defined the allowed set of vehicles and licensing requirements – trucks with national routes were required to license in each state in which they operated and may be regulated in some jurisdictions but not others. Further, truckers reported to each state the number of in-state miles driven, taxes paid on fuel and had to apply to each state to collect tax rebates (if any).

The IFTA simplified licensing and tax collection by playing two important coordinating roles. The IFTA unifies the definition of a regulated vehicle and simplifies vehicle licensing, by requiring operators to register in a single base jurisdiction. Registration in the base jurisdiction allows a truck to operate in any of the IFTA member jurisdictions.

Second, the IFTA coordinates state-level diesel tax collection by formalizing a system of inter-state fuel tax transfers. Each quarter, operators submit a single tax return to their base jurisdiction. In this tax return, they report fuel taxes paid, total fuel consumed and road distance traveled, in each member jurisdiction. The latter is derived from detailed log books where the operator records odometer readings at each state line crossing. Total gallons consumed by the trucker are then allocated to each jurisdiction in proportion to the miles driven in that state, and the tax owed each jurisdiction is based on these allocated gallons. The net tax payment due to each state is calculated as the difference between taxes paid and taxes due. Each licensed operator receives one bill (or rebate) to cover the overall difference between taxes owed and taxes already paid. IFTA then facilitates the settlement of any aggregate discrepancies between states – the overall taxes paid in one state that are owed in another.

The IFTA also specifies and monitors the tax enforcement activities of member jurisdictions. The responsibility for auditing operators lies solely with the base jurisdiction in which the operator is licensed. The IFTA requires states to audit 3 percent of tax returns, with a minimum of 25 percent of audited carriers in the top quartile of the mileage distribution and 15 percent in the bottom quartile. States often elect to audit more than 3 percent of returns, and as we document in Marion and Muehlegger (2014), the audit rate requirement is not perfectly enforced, as states often choose lower rates of audit.

Figure 1 maps the date at which each state adopted IFTA (and became a member of the International Fuel Tax Association). The earliest adopters were states in the Upper Midwest and Rocky Mountain states for which interstate trucking likely represents a higher fraction of taxed diesel consumption. The remaining states gradually adopted IFTA, until the 1996 deadline set by the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA).

With perfect compliance, taxing the location of usage rather than sales should significantly mitigate the horizontal externality created by a levying local taxes on a mobile tax base. Yet self-reporting creates two potential strategies for tax evasion by truckers. First, operators could choose to under-report the total number of purchased gallons of diesel fuel. Underreporting might arise since commercial truckers can purchase bulk fuel pre-tax and legally use it on-highway, so long as they pay the appropriate taxes as part of the quarterly IFTA tax settlement process. Second, an operator could accurately report gallonage, but over-report mileage in low-tax states and underreport mileage in high-tax states, lowering the average tax rate they face.

In principle, a horizontal externality still may exist if long-haul truckers select cross-country routes to minimize tax costs. Given the relative tax rates, we think this unlikely. A 5 cent per gallon average tax differential on a New York to Los Angeles route translates into roughly twenty dollars (assuming the fleet average of 6.5 miles per gallon) and is likely outweighed by other considerations like minimizing travel time, distance or delays related to weather, terrain, construction or traffic.

It is important to note that we focus on a different evasion pathway than the previous literature examining tax evasion in diesel markets. Marion and Muehlegger (2008) and Kopczuk et al. (2013) study tax evasion by the parties in the diesel fuel supply chain responsible for initially remitting on-highway taxes to the federal and state governments. Since diesel used for off-highway uses, such as farming, home heating, and industrial use, is exempt from highway use taxes, firms supplying diesel to retail stations have the incentive to divert untaxed fuel for taxed use. The previous literature find evidence of substantial tax evasion and find that government policies that increase the cost of evasion or change the identify of the remitting party reduce tax evasion.

4 Data

We use annual, state-level data on taxed diesel quantities for 1983-2007 from the Federal Highway Statistics Annual, published by the Federal Highway Administration (FHA). The FHA solicits reports from each state that contain the total gallons on which taxes were collected after any rebates, collections, or inter-jurisdictional tax transfers as per IFTA.

To measure diesel prices, we use data from the Energy Information Administration, which provides information on the tax-exclusive price of No. 2 distillate sold to end users through retail outlets for select states from 1983 onward. The states for which diesel prices are collected are mostly located in the Northeast, Mid-Atlantic, Upper Midwest, and a handful of Northwestern states with relatively high use of home heating oil. While this EIA series does not attempt to distinguish between taxed and untaxed uses of diesel, it is likely that most purchases made by end-users through retail outlets are for on-road use, with a smaller portion intended for agriculture. Diesel used for home heating, industrial processes, to power trains, or for other common untaxed uses is not sold through retail outlets.

State per-gallon taxes are from the Highway Statistics Annual. We obtain retail diesel prices are from the Energy Information Adminstration, who survey . Where available we use state-specific data. If state-level data is unavailable, we assign the state the regional average diesel price.[6] Over our study period, nominal diesel prices average 98.6 cents per gallon, of which on average 38.6 cents per gallon are accounted for by combined state and federal nominal tax rates.

An important choice when estimating an empirical model of fiscal externalities is properly weighting the tax rates of the other states. We consider several possible candidates for weighting. One candidate variable is the value, or alternatively the weight, of bilateral truck shipments between states. This weighting scheme is more directly related to our hypothesized source of the fiscal externality than commonly used measures such as an equal weighting of neighboring states. Neighboring states are often, but not always, trading partners, and states that see little in the way of bilateral truck flows will have fewer opportunities to take advantage of interstate tax differences.

To form the measure of bilateral truck shipping, we obtain bilateral values and weights of truck and non-truck shipments between states from the Commodity Flow Survey collected through a partnership between the Bureau of Transportation Statistics and the Census Bureau. Usually collected at five-year intervals, these data are based on survey data from thousands of firms in mining, manufacturing, wholesale, and select retail industries. Respondents are asked about the weight and value of a sample of outgoing shipments by destination, mode of transportation, and commodity category. Shipments to and from the fifty US states and the District of Columbia are covered, though shipments passing through the US from a foreign origin and heading to a foreign destination are not included. Industries not covered by the survey include transportation, construction, agriculture, and most retail sectors.[7]

We base our weights on shipments from the 2007 Commodity Flow Survey. It is important to use a time-invariant measure of bilateral truck flows, since changes in bilateral shipment volume between two states could be in part related to changes in the diesel tax rates set in the two states

[6] Regional prices are reported for five Petroleum Area Defense Districts that correspond to groups of states with common sources of refined petroleum products. For example, the upper-midwest (PADD 2) obtains refined products from a combination of local refineries and refineries in Texas, Oklahoma and Louisiana that deliver product through dedicated pipelines.

[7] The CFS does cover auxiliary establishments, such as warehouses for retail establishments.

(though as we argue this effect is likely to be small). Some bilateral flows are not reported in the CFS, either due to sampling error, for confidentiality reasons, or when the estimated shipment is close to zero. Bilateral truck flows in tons are missing for 441 of 2304 possible lower-48 bilateral flows. Most of these missing values are due to sampling error, and further examination indicates that this is most likely to occur for bilateral trade between smaller, more distant states. We therefore set missing values to zero, recognizing there may be a small number of cases where the true value of shipments is larger.[8]

5 Results

5.1 Fiscal externalities

We test for fiscal externalities by examining the relationship between the gallons of diesel on which taxes were collected and the tax rate in other states. In many contexts (e.g., cigarettes sales), we expect fiscal externalities to be positive – a neighboring state increasing the tax on cigarettes leads to an increase in smuggling or cross-border purchases, benefitting local cigarette sales and tax revenues. Since truckers are taxed based on where the diesel is used, rather than where it is purchased, we would not necessarily expect a strong relationship between local quantities and the tax revenues in neighboring states if all truckers were tax-compliant. As the theoretical model notes, in the absence of perfect compliance there are two broad strategies which a firm engaged in tax evasion might employ: (1) underreporting total gallons, and (2) misreporting usage in high-tax and low-tax jurisdictions. The first would lead state tax rates to impose negative externalities on neighbors – as a firm's average tax bill rises, it might be inclined to underreport total gallons. The second would lead to positive externalities – similar to cross-border sales, high tax rates in a neighboring jurisdiction would increase reported local miles and local tax revenues.

The approach we take, consistent with the prior literature in tax externalities, is to regress the log taxed quantity on a weighted average of other states' tax rates:

$$Log(q_{it}) = \alpha_i + \gamma log(\tau_{-it}) + \beta_1 Log(p_{it}) + \beta_2 Log(1 + \frac{\tau_{it}}{p_{it}}) + \theta X + \delta_t + \epsilon_{it} \tag{8}$$

[8] The Freight Analysis Framework produced by the Federal Highway Administration attempts to impute these missing values, as well as estimate flows in industries that are not covered. We are concerned that the FAF may use variables endogenous to the tax rate to help impute missing shipment values and missing industry shipments, and we therefore elect to use the CFS despite its imperfect coverage. The FAF estimates from 2007 indicate that the CFS covers 66 percent of truck shipments.

where the variable τ_{-it} is the weighted average of other states' tax rates: $\tau_{-it} = \sum_{j \neq i} w_{ij} \tau_{jt}$. A critical step is defining the weights w_{ij}, and we consider several strategies. Our preferred approach is to use the value of bilateral trucking flows from the Commodity Flow Survey. Doing so places a higher weight on taxes in states where interstate truckers will travel. An alternative strategy would set weights equally at $1/n_i$ for each of state i's n_i neighbors, and zero for all other states. We also consider weighting by the value of bilateral non-truck shipments, the average diesel consumption of neighboring states across all years in the sample, and finally setting a weight of one on the tax rate of the minimum state.

We also include additional explanatory variables related to: (1) local economic conditions (unemployment rate and state GSP), (2) tax administration (the identity of the party responsible for remitting state taxes) and (3) demand for untaxed diesel fuel (heating degree days and heating degree days interacted with the fraction of households using diesel fuel for heat). All specifications further include state and time fixed effects to capture time-invariant and state-invariant differences in diesel consumption.

Table 2 presents our main set of results. Of primary interest is the coefficient on the log of the weighted tax rate in other states. In our base specification, we weight other states' taxes by the value of bilateral shipments between state i and each of its trading partners. We see a negative and statistically significant coefficient on the log of other states' taxes, implying negative fiscal externalities – as other states increase tax rates, own state revenues fall. Interpreting the magnitudes, one-standard deviation increase in the other states' taxes (2.8 cpg) is associated with a 7 percentage point reduction in a state's taxed gallons. This result remains as additional covariates capturing diesel demand shifters are included in the model.

Since both tax rates and taxed gallons are likely to be serially correlated, in the specification shown in column 3, we include a control for the lag of the dependent variable. The coefficient on the lag of log taxed gallons is 0.55 and statistically significant. The inclusion of this control attenuates the primary coefficient of interest substantially, though the effect of t_{-i} is still large and statistically significant. A one standard deviation increase in in the other states' taxes (2.8 cpg) is associated with a 3.5 percentage point reduction in a state's taxed gallons.

As discussed, our hypothesis is that tax compliance by truckers through two channels – a positive fiscal externality via misreporting where miles were driven, and a negative fiscal externality from underreporting the number of gallons consumed. We attempt to separately identify these two channels by also including in our base specification the equally weighted average tax rate of neighboring states. Shifting miles should be more important between neighboring states, since a trucker can simply alter the recorded odometer reading when crossing state lines, or more plausibly report an alternative route that passes through a lower tax jurisdiction (even if that route was not actually the one taken). Conditional on the t_{-i} weighted by truck shipments, the tax rates of neighboring states is more likely to show the effect of the positive fiscal externality.

We show the estimates of this specification in column (4) of Table 2. As with the base specification, the truck-shipment weighted tax rate exerts a negative influence on own-state revenue. The magnitude of the coefficient is considerably bigger, as the estimated effect is twice as large when conditioning on neighboring states' tax rates. In contrast, a higher tax rate in neighboring states leads to *more* own-state revenues. This provides evidence in favor of both channels of fiscal externalities. It also suggests that when only the shipping weighted tax measure is used, the estimated coefficient combines both of these conflicting channels, thereby understating the degree of fiscal linkages across states.

Both of the types of tax evasion the we have discussed should exert a similar influence on the coefficient on the own-state tax rate. As own-state taxes rise, trucking companies would both report using fewer gallons, and report more of their miles being driven in other states. In each regression specification, we include own-state prices and taxes. Due to evasion, the effects of these two variables may be distinct, though in the absence of evasion they enter linearly into the tax-inclusive price $p_{it} + t_{it}$. In our regression specification, we split the tax inclusive price into its two components, the log of the pre-tax price (p_{it}) and the log of the tax rate $(1 + \tau_{it}/p_{it})$, and separately estimate coefficients for both terms. In Marion and Muehlegger (2008), we demonstrate that in markets with evasion, it is important to allow taxed gallons to respond differently to changes in the pre-tax price and changes in the tax rate. If firms increase evasion in response to a change in the tax rate, we should expect quantities to change more in response to taxes than prices.

As in previous work, we find that the coefficient on the log of the local tax rate is of greater magnitude than the coefficient on the log of the pre-tax price. The more negative point estimate on a state's own tax rate suggests that taxed quantities decline more with an increase in taxes than changes in the pre-tax price. The relative magnitudes of the coefficients on taxes and prices are consistent with both types of evasion – as local taxes rise, firms are more likely to both underreport fuel usage as well as misreport local mileage.

Aggregate demand and output in other states is also likely to affect own-state diesel tax revenues, since the economic health of trading partners translates into more trade and therefore more truck shipments. This could bias our estimates of γ if taxes are set endogenously. In column (5) we include the weighted average of other state's Gross State Product (GSP) and unemployment rate, again using 2007 bilateral truck shipments in tons as the weights. We see that indeed the GSP of a state's trading partners is positively correlated with own-state diesel tax revenues. It is also worth noting that this only slightly attenuates the coefficient estimate γ from -0.51 to -0.40.

To further establish that the behavior of the trucking sector is likely to be the source of the fiscal externality, we consider several other weighting schemes. These weights will suggest geographic or economic linkages between states, but will not be directly related to the degree of truck traffic. In Table 3, we show estimates of our base specifications under the alternative weighting strategies. In the specifications shown in columns (1)-(5), we include each measure in turn, and in columns (6)-(9) we show the effects of including both our preferred weighted tax rate measure and each of the alternatives together. Despite the different measures of the weighted tax rate being highly correlated, we find that only the measure weighting by bilateral truck shipments has a statistically significant effect on own-state revenues. This is not due to being less precisely estimated – in each case, the coefficient on the alternative measure is substantially smaller, and in fact has a smaller standard error. The coefficient on the truck shipment-weighted tax rate is -0.24. The alternative measures weighting taxes by (1) a weight of one for the minimum neighboring state, (2) equally-weighting the neighboring states, (3) weighting by the quantity of diesel consumed in each state, and (3) by the value of non-truck shipments have estimated coefficients of -0.017, -0.013, -0.010, and -0.060 respectively.

The results in columns (6)-(9) further support the notion that the two candidate sources of compliance-related fiscal externalities, cross-border manipulation and gallons underreporting, work in opposite directions. In these specifications we include both the truck-shipment-weighted t_{-i} and each alternative weighted t_{-i} in turn. In each case, the effect of the former is negative and statistically significant, while the effect of the latter is positive.

5.2 Estimate by state characeristics

In Table 4, we allow for the effect of the tax rate in neighboring jurisdictions to vary with state characteristics. All else equal, we expect small states to face stronger externalities from neighboring states if a greater fraction of the miles driven by locally-registered trucks occur in neighboring states. In addition to the direct effect, in column 1 we interact the tax rate in neighboring states with the share of a state's shipments that begin and end locally. The positive point estimate suggests that as the share of in-state shipments rises, the fiscal externality imposed by neighboring jurisdictions declines. We find similar results when we interact the weighted tax rate with a state's area or estimate it separately by quartiles of state size. Thus, we find the effect exactly where we would expect to find the effect - neighboring states impose greater fiscal externalities on small states.

As further evidence that the fiscal externalities are a result of evasion, we exploit state-level variation in the point at which taxes are collected. U.S. states choose to collect taxes at one of three different parties in the supply chain: (1) the wholesale terminal operators who store fuel in bulk tanks near most major metropolitan areas, (2) the distributors who trucks the product from the storage terminals to the retail stations, and (3) the retail station operators themselves.[9] Importantly, the opportunities for evasion by trucking firms differ when fuel taxes are levied upstream rather than downstream. Our main set of results suggest that underreporting of gallons plays a greater role in evasion than misreporting the location of use. If taxes are levied sufficiently downstream, trucking firms may be able to purchase bulk fuel pre-tax, making it easier to underreport gallons and tax liability.

We extend our base specifications above to estimate separate models for each of the three diesel fuel collection regimes. Table 5 presents the results - we find that the fiscal externalities are greater in states that choose to collect from the distributors, precisely the situation in which trucking firms might be able to purchase bulk fuel pre-tax. In contrast, we find little evidence of fiscal externalities when the taxes are collected from wholesale terminal operators. In this case, it is more difficult for trucking firms to purchase bulk fuel at a point in the supply chain before taxes are levied. This bolsters the explanation that these fiscal externalities are driven by the method of taxing interstate truckers rather than other unobserved linkages between states, and that gallons underreporting is the likely explanation.

5.3 Robustness Checks

We next conduct a series of robustness checks to bolster our conclusion that tax compliance is driving fiscal externalities in interstate trucking. We examine gasoline tax collections, where fiscal externalities should be limited. We also estimate regressions similar to our base specifications, where rather than other state's taxes we examine the effects of a weighted average of other state's prices. Finally we estimate our base specification in first-differences rather than a panel regression.

Unlike diesel fuel, retail stations account for almost all of U.S. gasoline sales. Stations sell

[9] See Kopczuk et al (2013) for more detail about variation in the point of tax collection.

the vast majority of gasoline to non-commercial vehicles, and sell all gasoline at a tax-inclusive price. Also, the cross-border shopping for gasoline is less prevalent, as the typical gasoline consumer is less frequently crossing state boundaries. Thus, estimating fiscal externalities for gasoline provides a falsification test for our interpretation of the diesel results. If we find similar fiscal effects for gasoline, where the scope for evasion is significantly less, it would suggest that the fiscal externalities in both markets are due to some characteristics of local fuel taxation rather than diesel tax evasion.

We replicate our preferred specification using gasoline volumes and gasoline taxes in Table 6. As above, we separately estimate coefficients for a state's own tax-exclusive price and own tax rate. In addition, all specifications further include state effects, year effects, covariates for local economic activity and lagged gasoline volumes. In each of the four columns, we include one of measures of the tax rate in neighboring states. Only the coefficient on the minimum tax rate in neighboring states is significant and all point estimates are of much smaller magnitude than the coefficient estimates for the diesel volumes. This suggests that horizontal fiscal externalities are substantially less for gasoline than diesel fuel, consistent with the conclusions in Devereux et al (2007).

We next estimate our base specification allowing for own-state taxed diesel quantity to depend on the tax inclusive price of other states rather than merely the tax rate. While we attribute the fiscal externality to tax non-compliance, an alternative explanation is that truckers alter their route in response to tax differences across jurisdictions. A second alternative explanation is that higher taxes make shipping via truck (or at all) unattractive. Similarly, cross-country shippers may select a route passing through many states that minimizes fuel tax costs if average tax rates differ along two routes.

We provide empirical evidence against these alternative hypotheses by examining the effect of prices in other states on own state tax revenues. Interstate differences in prices should induce identical incentives to alter the truck route or mode of shipping since the pre-tax price and tax is additive and empirically is fully passed through to the price. Thus, comparing the effect of prices with that of taxes provide a falsification test.

We form the truck-shipment weighted quantity tax rate of other states, t_{-i}, and the similarly weighted average of other states' prices, p_{-i}. This leads to a tax inclusive retail price, which enters in into our specification as $log(p_{-i} + t_{-i})$. As with own state prices, we factor out the price from this expression, which allows us to estimate a different coefficient on $log(p_{-i})$ and $log(1 + t_{-i}/p_{-i})$. This allows us to separately estimate the effect of other states' from other states' taxes. The price in other states could lead to cross-border purchase timing by truckers, however tax evasion will of course be irrelevant.

In column (1) of table 7, we present the results. We find that the coefficient on the log percentage tax rate is negative and statistically significant, and that the log of other state's prices exerts a positive, though statistically insignificant, influence on own-state gallons. This is consistent with our hypothesis. It suggests that cross-border shopping may exist, however the taxation of other states exerts a distinct negative effect on own-state revenues.

The fact that truckers do not strongly respond to price differences along a route is not entirely surprising. Fuel costs are a relatively small component of overall shipping costs. In addition, the convenience of point-to-point trucking relative to other modes of transportation and high degree of competition within the inter-state trucking market likely leaves relatively few shipments on the margin. Furthermore, few city pairs have more than one path along the interstate highway system that are both similar in length and travel through substantially different states. Even when more than one feasible path exists, the tax differential across routes is not large. For example, a truck traveling from New York to Los Angeles has a choice between a northernly-route (2,790 miles along I-80), a middle-route (2,806 miles along I-70) or a southernly-route (2,775 miles along I-40). [10] The simple average state tax rate along the northernly route is 25 cents per gallon while the simple average state tax rate along the southernly route is 22.2 cents per gallon. Along a 2,790 mile route, the different translates into approximately $14 for a truck of average fuel economy.

We next examine an alternative specification of the truck-shipment weights. The CFS reports both the value and the weight of bilateral truck shipments between states. In our base weighting scheme, we have elected to use the value of truck shipments rather than their weight. In column (2) of table 7, we examine whether this choice is relevant for our results. Although the magnitude of the coefficient declines slightly, weighting by ton rather than value does not affect our conclusion.

Lastly, we estimate our base specification in first-differences. This is potentially relevant given the serial correlation in the dependent variable. The results presented in column (3) of Table 7 indicate that the sign and magnitude of our primary coefficient of interest is similar as in our panel regression.

[10] All the three routes travel through Pennsylvania, Ohio, Indiana, and Illinois. he southernly route travels through Missouri, Oklahoma, Texas, New Mexico, and Arizona, while the northernly route travels through Iowa, Nebraska, Colorado, Utah, and Nevada.

5.4 Tax Setting

A key question is how the presence of fiscal externalities affects the tax rates chosen in equilibrium. In this section, we provide estimates of the reaction of a state's tax rate to that of its neighbors. As mentioned in the theory section, when tax externalities are positive, the tax reaction curve is upward sloping. That is, when increases in other states' tax rates lead to increases in own-state revenue, there is an incentive to lower taxes in response to lower taxes by competing states. As has been widely recognized, this would lead to a race-to-the-bottom in tax rates. This intuition changes in the current setting. The tax reaction curves are downward sloping when tax externalities are negative. Rather than taxes that are too low, this potentially leads taxes to be higher than in a cooperative outcome.

In this section, we describe estimates of the tax reaction function. Estimating this function is complicated by the fact that the observed tax rates are an equilibrium. To identify the slope of the reaction function, one needs some sort of exogenous variation in the tax rates chosen by other states. We take an instrumental variables approach, using the rate of gasoline taxation as an instrument. The gas tax rate is attractive as an instrument for two reasons. First, gasoline taxes and diesel taxes are strongly correlated. In Figure 2, we plot the change in the average diesel tax rates of other states, weighted by bilateral truck shipments, against the similarly weighted average of other states' gasoline taxes. There is a strong, close to linear, relationship between these two variables. Second, the evasion response that is the source of the tax externality in this paper is unlikely to be affected by the gasoline tax. Gasoline is irrelevant for the predominant users of diesel.

We follow Devereux et al (2007) by including the lagged dependent variable to account for serial correlation in the dependent variable. As they point out, this introduces correlation with the fixed effect, and as they do we instrument for the lagged dependent variable with its second lag. The equation we estimate is therefore

$$t_{i,t} = \beta_0 + \beta_1 t_{-i,t} + \beta_2 t_{i,t-1} + BX_{it} + \gamma_i + \rho_t + \epsilon_{it} \tag{9}$$

where as before $t_{-i,t}$ is the weighted average of other states' tax rates.

In Table 8, we present estimates of equation (9). The first three columns of this table show OLS estimates of own-state diesel tax rates on the weighted average of other states' diesel tax rates. Consistent with the predictions of the model of tax setting, we see that other states' tax rates are negatively correlated with the own-state tax rate. A ten-cent increase in other states' tax rates is associated with a 2 cent reduction in own-state taxes. In column (3), we present estimates of a specification that also includes the average tax rate of neighboring states. In the taxed gallons specifications, we saw that the tax rates of neighboring states confers a positive tax externality, conditional on the average tax rate of the state's shipping partners. Consistent with this result, the estimates shown in column (3) indicate that the own-state tax rate responds positively to the tax rates set in neighboring states, though this coefficient is statistically insignificant.

In columns (4)-(6) we show the corresponding IV estimates. The results are similar in sign and magnitude. The primary difference is in column (6). When both the shipment-weighted and average neighbor tax rates are included, the IV estimates are somewhat larger and both statistically significant. The coefficient on the shipment-weighted tax is -0.40, and the coefficient on the average neighbor tax is 0.17. Recall that this is consistent with the fiscal externality results, which indicated that neighboring taxes increased own-state revenues while trading partner's tax decreased own-state revenues. Theory suggests that the former tax rate should therefore be strategic complements, while the latter should be strategic substitutes.

6 Conclusion

In this paper, we demonstrate a novel source of fiscal externalities that may arise in situations where parties in the tax base can engage in tax evasion. We highlight two forms of tax evasion particularly relevant to diesel fuel markets: (1) truckers may understate the total number of gallons purchased, and (2) truckers may overstate use in high-tax jurisdictions and understate use in low-tax jurisdictions. Interestingly, the fiscal externalities generated by each of these forms of evasion push in opposite directions. While mis-stating the location of use generates positive externalities, underreporting of taxes tends to cause taxes to impose negative externalities on neighboring jurisdictions. In essence, as the average tax paid by a firm increases, the firm underreports to a greater degree which adversely affects both a jurisdiction that changes a tax as well as neighboring jurisdictions. We then demonstrate evidence consistent with evasion-driven fiscal externalities in the context of diesel fuel markets and find evidence of negative externalities, consistent with underreporting of gallons being the primary form of evasion in which truckers engage.

In addition to the context we examine, our work has implications for the tax competition in other contexts. Of particular relevance is the taxation of internet commerce that faces similar incentives for evasion and tax competition as discussed in Goolsbee (2000, 2001) and Einav et al (2014). Similar issues arise related to the apportionment of corporate income, which requires self-reported information from firms on payroll, property and sales by jurisdiction. More broadly, our work suggests the importance of considering not only the fiscal externalities created by changes in the tax rate, but also externalities associated with enforcement.

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Figure 1: Year of IFTA Adoption

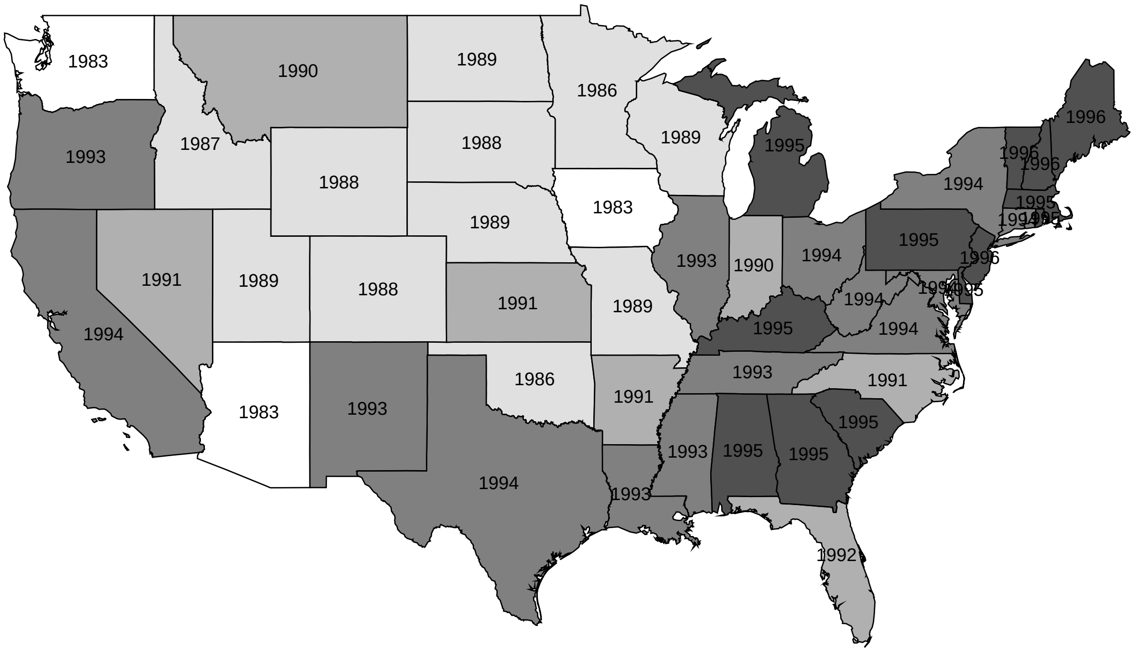

Figure 2: Other states' diesel tax rates versus gas tax rates

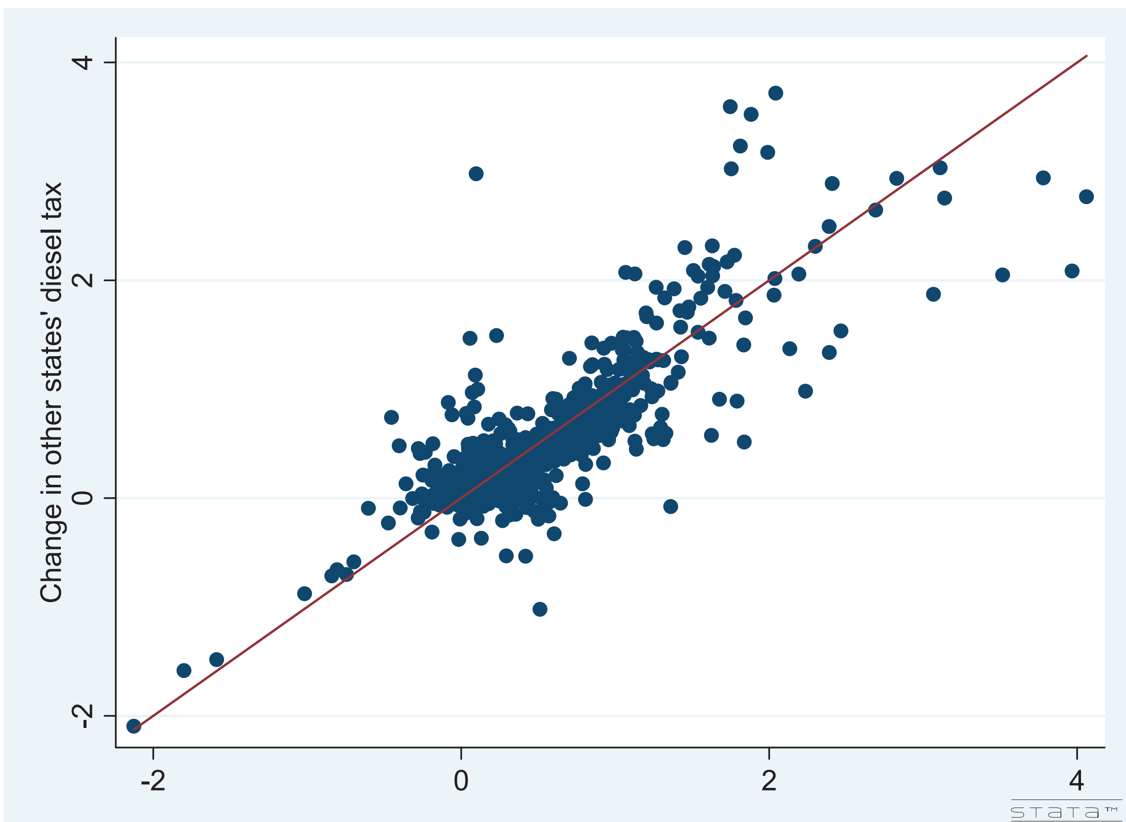

Table 1: Summary Statistics

	mean	sd	min	max
Prime supplier sales (000s gal)	2098.81	2182.51	0.00	16145.20
Taxed diesel sales	1580.48	1402.44	99.08	10950.84
Tax-exclusive diesel price (cpg)	92.30	41.73	55.73	230.91
State diesel tax (cpg)	19.03	4.99	7.00	38.10
Federal diesel tax (cpg)	21.63	3.86	15.00	24.40
State gas tax (cpg)	18.70	4.89	7.00	37.50
Federal gas tax (cpg)	15.63	3.86	9.00	18.40
Minimum neighbor tax	14.05	4.30	7.00	24.25
Mean neighbor tax	18.79	3.42	10.34	26.92
Mean neigh. tax, value weighted	18.62	2.81	11.23	26.68
Unemployment rate	5.24	1.54	2.24	12.43
Annual degree days	5181.61	2045.78	476.00	10547.00
Fraction In-state shipping	0.73	0.10	0.42	0.92
Supplier-remitted	0.18	0.38	0.00	1.00
Distributor-remitted	0.69	0.46	0.00	1.00
Observations	987			

Table 2: Tax rates of other states and taxed gallons

	(1)	(2)	(3)	(4)	(5)
Log t_{-i}, Truck ship. value weighted	-0.52***	-0.50***	-0.24***	-0.51***	-0.40***
	(0.15)	(0.086)	(0.068)	(0.11)	(0.13)
Log t_{-i}, Neighbors equally weighted				0.19***	0.16**
				(0.056)	(0.057)
Log price	0.16	-0.17	-0.17	-0.17	-0.21
	(0.33)	(0.19)	(0.14)	(0.14)	(0.13)
Log tax rate	-1.00***	-0.83***	-0.49***	-0.52***	-0.55***
	(0.22)	(0.20)	(0.16)	(0.16)	(0.15)
Other states' unemployment rate					-0.012
					(0.012)
Other states' log GSP					0.36**
					(0.17)
Lagged dependent variable			0.55***	0.53***	0.52***
			(0.049)	(0.047)	(0.047)
State, year effects	X	X	X	X	X
Other covariates		X	X	X	X
Observations	987	987	987	987	987
R-Squared	0.99	0.99	0.99	0.99	0.99

Standard errors clustered by year are in parentheses.
*,**,*** denote significance at the 10%, 5%, and 1% level, respectively.
The dependent variable is the log of taxed gallons of diesel.
The other covariates are year and state effects, log GSP, unemployment rate, log degree days, log degree days interacted with household heating oil use, and indicators for the remitting party.

Table 3: Tax rates of other states and taxed gallons

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Log t_{-i}, Truck ship. value weighted	-0.24***					-0.27***	-0.51***	-0.59***	-0.50***
	(0.068)					(0.061)	(0.11)	(0.16)	(0.13)
Log t-i, Minimum neighbor tax		-0.017				0.017			
		(0.029)				(0.030)			
Log t_{-i}, Neighbors equally weighted			-0.013				0.19***		
			(0.034)				(0.056)		
Log t_{-i}, Quantity of diesel weighted				-0.010				0.17**	
				(0.028)				(0.062)	
Log t_{-i}, Value of non-truck ship. weighted					-0.060				0.56**
					(0.14)				(0.24)
Log price	-0.17	-0.12	-0.12	-0.12	-0.12	-0.17	-0.17	-0.16	-0.14
	(0.14)	(0.15)	(0.15)	(0.15)	(0.15)	(0.15)	(0.14)	(0.14)	(0.15)
Log tax rate	-0.49***	-0.42**	-0.42**	-0.41**	-0.43**	-0.48***	-0.52***	-0.55***	-0.43**
	(0.16)	(0.16)	(0.15)	(0.15)	(0.17)	(0.16)	(0.16)	(0.16)	(0.17)
Observations	987	987	987	987	987	987	987	987	987
R-Squared	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99

Standard errors clustered by year are in parentheses.

*,**,*** denote significance at the 10%, 5%, and 1% level, respectively.

The dependent variable is the log of taxed gallons of diesel.

The other covariates are the lag of the dependent variable, year and state effects, log GSP, unemployment rate, log degree days, log degree days interacted with household heating oil use, and indicators for the remitting party.

Table 4: Revenue externality and state size

	(1)	(2)	(3)	(4)	(5)
Log t_{-i}, Truck ship. value weighted	-1.15***	-0.69***	-1.14***	0.014	-0.43*
	(0.17)	(0.13)	(0.16)	(0.072)	(0.22)
Log t_{-i} X Log state area	0.11***		0.11***		
	(0.017)		(0.020)		
Log t_{-i} X In-state share shipments		0.74***	0.043		0.54**
		(0.14)	(0.16)		(0.21)
Log t_{-i} X State size quartile 1				-0.27***	-0.17***
				(0.035)	(0.057)
Log t_{-i} X State size quartile 2				-0.18***	-0.13*
				(0.064)	(0.071)
Log t_{-i} X State size quartile 3				-0.19***	-0.17***
				(0.057)	(0.057)
Log price	-0.41***	-0.30**	-0.41***	-0.35**	-0.36**
	(0.12)	(0.13)	(0.12)	(0.13)	(0.13)
Log tax rate	-0.52***	-0.50***	-0.52***	-0.54***	-0.53***
	(0.14)	(0.15)	(0.14)	(0.15)	(0.14)
Observations	987	987	987	987	987
R-Squared	0.99	0.99	0.99	0.99	0.99

Standard errors clustered by year are in parentheses.
*,**,*** denote significance at the 10%, 5%, and 1% level, respectively.
The dependent variable is the log of taxed gallons of diesel.
The other covariates are the lag of the dependent variable, year and state effects, log GSP, unemployment rate, log degree days, log degree days interacted with household heating oil use, and indicators for the remitting party.

Table 5: Revenue externality by tax collection regime

	Retailer		Distributor		Prime Supplier	
	(1)	(2)	(3)	(4)	(5)	(6)
Log t_{-i}, Truck ship. value weighted	-0.084	0.014	-0.38***	-0.63***	-0.12	0.22
	(0.26)	(0.25)	(0.076)	(0.13)	(0.51)	(0.87)
Log t_{-i}, Neighbors equally weighted		-0.090		0.18**		-0.18
		(0.21)		(0.074)		(0.29)
Log price	-0.46	-0.42	-0.16	-0.13	-0.21	-0.17
	(0.33)	(0.38)	(0.16)	(0.16)	(0.36)	(0.40)
Log tax rate	-0.77	-0.72	-0.63***	-0.62***	-0.76	-0.64
	(0.81)	(0.84)	(0.17)	(0.17)	(0.44)	(0.53)
Observations	124	124	675	675	175	175
R-Squared	1.00	1.00	0.99	0.99	0.99	0.99

Standard errors clustered by year are in parentheses.
*,**,*** denote significance at the 10%, 5%, and 1% level, respectively.
The dependent variable is the log of taxed gallons of diesel.
The other covariates are the lag of the dependent variable, year and state effects, log GSP, unemployment rate, log degree days, log degree days interacted with household heating oil use, and indicators for the remitting party.

Table 6: Gasoline tax rates and taxed gallons

	(1)	(2)	(3)	(4)
Log price	-0.22***	-0.21***	-0.16**	-0.22***
	(0.059)	(0.060)	(0.056)	(0.058)
Log tax rate	-0.29**	-0.28**	-0.33***	-0.30**
	(0.12)	(0.12)	(0.099)	(0.12)
Bilateral truck shipments, value	-0.048			
	(0.068)			
Average neighbor		-0.030		
		(0.031)		
Minimum neighbor			-0.034**	
			(0.013)	
Bilateral non-truck shipments, value				-0.061
				(0.10)
Lagged dependent variable	0.76***	0.76***	0.80***	0.76***
	(0.035)	(0.037)	(0.057)	(0.036)
State, year effects	X	X	X	X
Observations	987	987	940	987
R-Squared	1.00	1.00	1.00	1.00

Standard errors clustered by year are in parentheses.
*,**,*** denote significance at the 10%, 5%, and 1% level, respectively.
The dependent variable is the log of taxed gallons of gasoline.
All specifications include log GSP and unemployment rate.

Table 7: Revenue externality alternative specifications

	(1) Other states' price	(2) Tons weighted shipments	(3) First differences
Log p_{-i}, truck value weighted	0.62		
	(0.51)		
Log $(1 + t_{-i}/p_{-i})$, truck value weighted	-0.99**		
	(0.37)		
Log t_{-i}, Truck ship. tons weighted		-0.11*	
		(0.053)	
Log t_{-i}, Truck ship. value weighted			-0.46*
			(0.24)
Log price	-0.51**	-0.15	-0.46**
	(0.22)	(0.15)	(0.19)
Log tax rate	-0.50***	-0.45***	-0.70**
	(0.15)	(0.16)	(0.26)
Observations	987	987	940
R-Squared	0.99	0.99	0.25

Standard errors clustered by year are in parentheses.
*,**,*** denote significance at the 10%, 5%, and 1% level, respectively.
The dependent variable is the log of taxed gallons of diesel.
The other covariates are the lag of the dependent variable, year effects, log GSP, unemployment rate, log degree days, log degree days interacted with household heating oil use, and indicators for the remitting party. The specifications shown in columns (1) and (2) also include state effects.
Column 3 displays a specification where all variables first-differences, with the exception of the remitting party. In this case, indicators are included for the specific collection regime transition, which takes on a value of one when, for instance, a state transitions from collecting from retail outlets to collecting from wholesale distributors.

Table 8: Tax Rate Reaction to Other States' Tax Rates

	OLS			IV		
	(1)	(2)	(3)	(4)	(5)	(6)
t_{-i}, Ship value weighted	-0.47*** (0.11)	-0.21*** (0.066)	-0.29*** (0.099)	-0.22* (0.12)	-0.18* (0.093)	-0.40*** (0.13)
t_{-i}, Average neighbor			0.057 (0.058)			0.17** (0.071)
Lagged dependent variable		0.78*** (0.044)	0.78*** (0.044)		0.71*** (0.055)	0.71*** (0.055)
Observations	987	987	987	987	987	987
R-Squared	0.78	0.93	0.93	0.78	0.93	0.93

Standard errors clustered by year are in parentheses.
*,**,*** denote significance at the 10%, 5%, and 1% level, respectively.
The dependent variable is the state quantity tax on diesel. The instrument for the weighted average of other states' diesel tax is the weighted average of other states' gasoline tax.
The other covariates are the lag of the dependent variable, year effects, log GSP, unemployment rate, log degree days, log degree days interacted with household heating oil use, and indicators for the remitting party.