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Perfect Competition, Spatial Competition, and Tax Incidence in the Retail Gasoline Market

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Abstract

In this paper we use monthly gasoline price data for all fifty U.S. states over the period 1984 to 1999 to examine the incidence of state gasoline excise taxes. Standard economic theory predicts full shifting of the excise tax to consumers when the supply of gasoline is perfectly elastic, and our empirical results are largely consistent with this prediction. In general, we find full shifting of gasoline taxes to the final consumer, with changes in gasoline taxes fully reflected in the tax-inclusive gasoline price almost instantly, a result consistent with a retail gasoline market in which firms are perfectly competitive and produce at constant cost. In addition, although we find that gasoline retail prices demonstrate asymmetric responses to changes in gasoline wholesale prices, we find only limited evidence of such behavior for retail prices with respect to gasoline excise taxes. Importantly, we also present a novel application of a spatial price discrimination model to examine tax incidence in markets that are not perfectly competitive. In this alternative framework, the incidence of excise taxes depends upon the competitiveness of retail gasoline markets, which depends in turn on spatial aspects of the market. Consistent with this alternative theoretical framework, our empirical estimates demonstrate that gasoline markets in urban states exhibit full shifting, but those in rural states demonstrate somewhat less than full shifting.

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I. INTRODUCTION

In applied tax incidence studies it is typically assumed that prices respond one-for-one to changes in sales and excise taxes (Zupnick, 1975; Shepard, 1976; Pechman 1985; Weise, Rose, and Schluter, 1995; Chernick and Reschovsky, 1997; Alleyne, Alm, Bahl, and Wallace, 2004; Wisconsin Tax Incidence Study, 2004). Is this assumption reasonable? Despite the fundamental role of tax incidence in the study of public finance, there is surprisingly little empirical analysis that sheds light on who bears the burden of taxes. In this paper, we examine the incidence of state gasoline excise taxes, using monthly price data for all 50 states in the United States over the period 1984 to 1999. Our estimation results generally indicate full shifting of gasoline taxes to the final consumer, with changes in gasoline taxes fully reflected in the tax-inclusive gasoline price almost instantly. We also find that the incidence of excise taxes depends upon the competitiveness of retail gasoline markets (e.g., urban versus rural markets). Gasoline markets in urban states typically exhibit full shifting, but those in rural states demonstrate somewhat less than full shifting.

Although the issue of sales and excise tax incidence has received considerable attention over the years, most research has focused on tax incidence theory, and the standard conclusion of much of this theoretical analysis is that consumers bear the full burden of any sales and excise taxes.[1] Based primarily on this theoretical foundation, most applied incidence studies assume that sales and excise taxes are fully reflected in consumer prices, and the distribution of tax burdens across income classes necessarily reflects this assumption. However, actual empirical testing of this assumption of full forward shifting has been surprisingly sparse.[2] In important recent research, Poterba (1996) and Besley and Rosen (1999) have conducted empirical analyses of the incidence of excise taxes.

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[1] For example, see Brown (1939), Due (1942), Rolph (1952, Musgrave (1959), and Bishop (1968). For more general analyses of the theory of tax incidence, see Harberger (1962), Mieszkowski (1967), McLure (1975), Kotlikoff and Summers (1987), and Fullerton and Metcalf (2002).

[2] For some examples of early empirical research on the incidence of sales and excise taxes, see Due (1954), Brownlee and Perry (1967), Woodard and Spiegelman (1967), and Sidhu (1971). For comprehensive discussions of this early work, see Poterba (1996) and Besley and Rosen (1999).

Poterba (1996) uses city-specific clothing and personal care price data covering the 1947-1977 and the 1925-1939 periods to examine the degree to which state and local retail sales taxes are shifted to consumers, with two data sets based on Bureau of Labor Statistics (BLS) city-specific consumer price indices. Using these BLS data on tax-inclusive prices, Poterba (1996) constructs quarterly price indices for each of 28 Standard Metropolitan Statistical Areas (SMSAs). Many of these 28 SMSAs experienced significant changes in sales tax rates, and Poterba (1996) uses these tax "shocks" to determine the incidence of sales taxes. His estimation results are somewhat variable, but in general he finds for the post-war period that taxes are fully shifted to consumers; in some cases he finds limited evidence of over-shifting, although it is never possible to reject the null hypothesis that prices rise "point-for-point" with the changes in the tax, and he also finds that full shifting typically (though not always) occurs in the first quarter of the tax change. Poterba (1996) also examines tax incidence for individual SMSAs during the Depression era, and his results indicate significant differences across metropolitan areas in the degree of tax shifting. For example, prices on women's clothing in Chicago show significant over-shifting, but Atlanta shows negative shifting, a result that does not seem plausible.

Besley and Rosen (1999) also examine the incidence of sales taxes using price data for 12 narrowly defined commodities in 155 different U.S. cities, using quarterly price data for the period 1982-1990 issued by the American Chamber of Commerce Researchers Association (ACCRA).[3] They find full shifting for a number of the commodities, but they also find over-shifting for more than half the products, a result they attribute to imperfect competition in the retail sector.

While this recent empirical research has significantly expanded our understanding of the actual nature of sales and excise tax incidence, we believe that our work here on gasoline excise taxes

[3] The ACCRA price information was originally gathered from establishments and neighborhoods used by a "mid-management executive household." Comparisons by Schoeni (1996) indicate that the ACCRA price index is similar to the BLS price index, generating a correlation of 0.715.

makes several contributions to the empirical literature. First, we examine regular unleaded gasoline, and so we are able focus exclusively on a narrowly defined commodity that has not changed significantly over time in its characteristics.[4] Second, it is important in empirical incidence work to obtain reliable cost data for use as a key control variable, and one limitation of some previous work is that reliable cost data may have been difficult to obtain. With the retail gasoline market, the single most important cost variable is the wholesale price of gasoline, and we are able to obtain information on its cost (as well as other cost information). Third, pricing data used in previous studies came almost exclusively from urban markets, which are likely to be more competitive than rural areas. Our gasoline pricing data are statewide weighted averages, and are generated from both urban and rural markets. These data are therefore likely to provide a more representative picture of tax incidence across an entire state. Fourth and relatedly, these data allow us to examine separately urban and rural gasoline tax incidence, in order to test whether more competitive (e.g., urbanized) states yield findings similar to less competitive (e.g., rural) states. Fifth, we use monthly data on gasoline prices, rather than the quarterly price information of Poterba (1996) and Besley and Rosen (1999). The use of monthly data may allow for a more accurate assessment of the length of time required for a complete price response. Finally, we have a number of tax reductions during the period of analysis, so that we can use these episodes of tax reductions to identify whether prices respond asymmetrically to tax changes.

In general, we find consistent evidence of full shifting of gasoline taxes to the final consumer, with changes in gasoline taxes fully reflected in the tax-inclusive gasoline price almost instantly, a result consistent with a retail gasoline market in which firms are perfectly competitive and produce at constant cost. In addition, although we find that gasoline retail prices demonstrate

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[4] For example, Poterba (1996) examines price reactions of "women's and girl's clothing," men's and boys' clothing" and "personal care items." Besley and Rosen (1996) examine more specific commodities such as bananas, Crisco, eggs, and shampoo.

asymmetric responses to changes in gasoline wholesale prices, we do not find such behavior with respect to gasoline excise taxes, perhaps due to the institutions by which taxes are collected and under which wholesale and retail gasoline firms operate. We also formulate an alternative theoretical perspective in which the incidence of excise taxes depends somewhat upon the competitiveness of retail gasoline markets, which depends in turn on spatial aspects of the market. Consistent with this alternative theoretical perspective, our empirical estimates show that gasoline markets in urban states exhibit full shifting, but those in rural states demonstrate somewhat less than full shifting.

In the following sections, we first present a brief overview of state taxation of gasoline. We then discuss a standard theoretical analysis of excise tax incidence, as well as a novel application of a spatial price discrimination model of tax incidence. We then present our empirical approach, followed by our empirical estimates of retail price reactions to changes in taxes. The final section discusses implications and concludes.

II. THE PRACTICE OF STATE GASOLINE TAX POLICY [5]

Gasoline taxes have changed considerably over time. Figure 1 presents the distribution of taxes in nominal cents per gallon by state in 1984 and 1999, a period that spans our empirical analysis. In 1984 the average state tax in nominal terms was 11.9 cents per gallon; by 1999 the average state tax had increased to 20.1 cents per gallon. In real terms the tax increase has obviously not been as large as indicated in Figure 1, but presenting the data in nominal terms demonstrates that there are many policy-driven tax changes over the period of analysis from which we can generate estimates of tax incidence. It is noteworthy that, of the 202 policy driven tax changes

[5] See the Federation of Tax Administrators for a useful discussion of state gasoline taxation, at http://www.taxadmin.org/fta/mf/rate/ssi . Also, the U.S. Department of Energy has an overview of the gasoline market in "A Primer on Gasoline Prices" (DOE/EIA-X040-2-01) at http://www.eia.doe.gov/pub/oil_gas/petroleum/analysis_publications/primer_on_gasoline_prices/html/petbro.html .

during the period of analysis, 24 were tax reductions, which provides an opportunity to examine whether prices respond asymmetrically to tax increases versus tax decreases. The tax changes were distributed fairly uniformly over this period. We observe 45 tax changes during the 1984-1987 period, 82 changes between 1988 and 1991, 50 changes from 1992-1995, and 45 changes during the 1996-1999 period.[6]

The exact procedure by which the state gasoline excise taxes are administered varies across the states. In forty-two states (plus the District of Columbia), the tax is administered by a department of revenue or of taxation; in most remaining states there is a separate transportation or motor vehicles department that is responsible for the administration. Similarly, the agent that collects the gasoline tax (or the "point of taxation") also varies across the states. In many states it is the gasoline distributor that collects the excise tax; in a smaller number of states the tax is collected by the retail gasoline station; and several other states collect the tax either on a "first sale" basis, in which the importer of the gasoline pays the tax upon receipt, or on a "first import" basis with the tax collected by the agent responsible when the gasoline first comes into the state.

III. ANALYTICAL FRAMEWORK

As noted by Poterba (1996) and Besley and Rosen (1999) and as we highlight below in our analytical framework, in theory the degree of competitiveness is important in determining tax incidence. In the simple case of a perfectly competitive market, the after-tax price of a commodity will increase by precisely the amount of the tax if supply is perfectly elastic (although by less than the

6 Eight states apply the general sales tax to the purchase of gasoline (California, Georgia, Illinois, Indiana, Louisiana, Michigan, Mississippi, and New York). However, since sales tax rates in these states changed little over the period of analysis, we do not focus on this tax in our analysis.

amount of the tax if the supply curve slopes upward). However, if markets are not perfectly competitive, then the pattern of excise tax incidence becomes more complicated.[7]

Although the retail gasoline market is often considered to be very competitive, several studies indicate that market power may exist in certain submarkets. Increased market concentration has been found to lead to higher energy market prices in general (Borenstein, Cameron, and Shepard, 1997; Joskow and Kahn, 2000) and within the gasoline market in particular (Borenstein and Shepard, 1996). There is also some recent evidence from California showing that the preservation of a competitive market structure enhances price competition in the gasoline market and thereby lowers gasoline prices (Hastings, 2004; Verlinda, 2004). This work suggests that not all gasoline markets are perfectly competitive. Furthermore, Skidmore, Peltier, and Alm (2004) find that state government antitrust policies play a role in determining the degree of market concentration and competition across states and over time.[8]

As a result, we believe that it is possible, indeed likely, that states differ systematically in the degree of competitiveness in the gasoline market. If so, it is important to explore whether tax incidence also differs in predictable ways across the states that vary in competitiveness.

Our analytical framework therefore incorporates both kinds of perspectives – a perfectly competitive retail gasoline market and a retail market in which firms have some market power, based on spatial aspects of the market. The following subsections present both models.

1. A Simple Model of a Perfectly Competitive Market

7 For example, see the theoretical analyses of Katz and Rosen (1985) and Stern (1987), and the empirical work of Sidhu (1971), Poterba (1996), and Besley and Rosen (1999); see also Sumner (1981), Bulow and Pfleiderer (1983), and Sullivan (1985).

8 Skidmore, Peltier, and Alm (2004) show that the adoption of a motor fuel sales-below-cost law (or a minimum mark-up law) by a state enhances the competitiveness of the retail gasoline market.

Consider first the simplest case, the introduction of a gasoline excise tax in a single, perfectly competitive retail gasoline market. It is well-known the split of the tax between consumers and producers depends upon the relative elasticities of demand and supply; consumers bear relatively more of the tax burden the greater is elasticity of supply, and relatively less of the burden the greater is the elasticity of demand (in absolute value). In this simple world, there are two circumstances in which consumers will bear the full burden of an excise tax on gasoline: if demand is perfectly inelastic or if supply is perfectly elastic.

A simple algebraic example illustrates this scenario. Suppose that a perfectly competitive market has a demand curve defined by [$P=a-bQ$] and a supply curve defined by [$P=c+dQ$], where a, b, c, and d are positive parameters. The imposition of a specific excise tax t changes the supply curve to [$P=c+t+dQ$], where the price P is interpreted as the gross-of-tax price paid by consumers. Solving these equations gives:

$$P=(ad+bc+bt)/(b+d)]. \qquad (1)$$

The tax therefore raises the price gross-of-tax paid by consumers and lowers the price net-of-tax received by producers; that is, $\partial P/\partial t = b/(b+d)$, and the incidence is in general split between consumers and producers depending upon the slopes (and the elasticities) of the demand and supply curves. The incidence will fall completely on consumers (e.g., $\partial P/\partial t=1$) in the special cases that b equals infinity or d equals 0; the former case implies that demand is perfectly inelastic, and the latter case implies that supply is perfectly elastic.[9]

Consequently, although in the short run the incidence is likely to be split between consumers and producers, it also seems likely that, as the elasticity of supply increases with an increase in the time horizon, the relative burden on consumers will increase in the long run in perfectly competitive

[9] Altering this simple model to allow for monopoly provision of gasoline does not change the basic result that the incidence is split between consumers and the producer, although the amount of shifting is different than under perfect competition. With monopoly, the equilibrium price with the tax becomes [$P=(ab+ad+bc+bt)/(2b+d)$], so that [$\partial P/\partial t=b/(2b+d)$].

markets. Indeed, if in the long run the elasticity of supply becomes perfectly elastic, then the burden of the gasoline excise tax will fall completely upon consumers. Other, more complicated scenarios also generally imply that consumers are likely to bear the bulk of the tax burden.

2. A Simple Model of Spatial Price Competition[10]

Now consider instead the standard spatial price discrimination setting, in which firms and consumers are dispersed over a geographic, or spatial, environment. Because of this spatial distribution, each consumer faces varying travel costs to any firm, and each firm faces somewhat separable geographic markets. In this environment, firms have some degree of market power, and price discrimination by firms is possible.

More precisely, assume that each of $i=1,\ldots,n$ firms produces a product with constant marginal cost m_i and that the cost to firm i of shipping one unit of the good from its site to a buyer at distance T_i is T_i dollars. Because consumers are at varying distances from a seller, a discriminating seller will be able to price discriminate, and will do so by equalizing marginal revenue on sales to every separable market (and by setting marginal revenue equal to marginal cost). As demonstrated by Greenhut and Greenhut (1975), the market equilibrium for spatial competitors who price discriminate is given by:

$$P(1-1/\varepsilon n) = (\overline{m} + \overline{T}), \tag{2}$$

where P is again the product price paid by the consumer, ε is the elasticity of demand (defined as $\varepsilon \equiv -\partial Q/\partial P)(P/Q)$, Q is the total output in the market, n is the number of firms, $\overline{m}$ is the average marginal cost of the firms (equal to $\overline{m} \equiv \sum_i m_i/n$), and $\overline{T}$ is the average distance (equal to $\overline{T} \equiv \sum_i T_i/n$). The left-hand side of the market equilibrium condition in equation (2) is the usual expression for marginal revenue, and the right-hand side is the sum of the average marginal cost and the

[10] This analysis closely follows that of Greenhut and Greenhut (1975).

average transportation cost. The equilibrium condition simply requires that marginal revenue equals the average of full marginal production plus delivery costs across all firms.

In the special case that the (non-spatial) demand curve is given by the exponential form $P=b[1-(Q/a)^{\gamma}]$, where a and b are the quantity and price intercepts of the demand curve and γ is a parameter that determines the concavity or convexity of the demand curve, the elasticity of demand ε equals $[(P/(\gamma(b-P))]$ and marginal revenue becomes $[(1/n)(P(n+\gamma)-\gamma b]$. Equating marginal revenue with full marginal production plus delivery costs (or $\overline{m}+\overline{T}$), the delivered price P_d is shown by Greenhut and Greenhut (1975) to equal:

$$P_d = (\gamma b + n\overline{m} + n\overline{T})/(n + \gamma). \quad (3)$$

Now suppose that a gasoline excise tax t is imposed on all firms. The excise tax changes the market equilibrium equation (2) to:

$$P(1-1/\varepsilon n) = (\overline{m} + \overline{T} + t). \quad (4)$$

It is straightforward to demonstrate that when the (non-spatial) demand curve is given by the exponential form the delivered gross-of-tax price now becomes:

$$P_d = (\gamma b + n\overline{m} + n\overline{T} + nt)/(n + \gamma). \quad (5)$$

As emphasized by Greenhut and Greenhut (1975), equation (5) demonstrates that the delivered price to any given location is unaffected by the delivered price to any of the other locations. Put differently, equation (5) shows that a spatial competitor has some degree of market power because the existence of transportation costs limits the ability of consumers to move from one spatial competitor to another. This result can be shown to hold in a number of other, more specific, locational arrangements (Greenhut and Greenhut, 1975). In addition, equation (5) shows that an increase in the number of firms, and so an increase in the degree of competition, will reduce the delivered price as long as $[b > \overline{m} + \overline{T} + t]$, which is simply the condition that the willingness to pay at a quantity of zero (or b) exceeds the marginal production costs plus the delivery costs plus the excise tax facing the average firm.

In the presence of spatial competition, the incidence of a gasoline excise tax therefore differs from the simple competitive result. In particular, the degree of shifting depends in part upon the number of firms in the relevant spatial market, so that there may well be a difference in gasoline tax incidence between, say, urban and rural gasoline markets. More specifically, taking the partial derivative of equation (5) with respect to t yields $\partial P_d/\partial t = n/(n + \gamma)$, showing that as n increases (i.e., the market becomes more competitive) a higher portion of the tax will be passed on to consumers.[11] The next section presents our empirical approach for estimating the incidence of the gasoline tax.

IV. EMPIRICAL FRAMEWORK

1. Methods

We collect monthly price and tax data for all states for the period 1984 to 1999, which allow us to use variation across the states in the timing of tax changes to investigate how taxes affect average prices in states where the changes occurred. We estimate a within-group model that exploits the panel nature of our data and controls for fixed state and time effects.[12] We also include a full array of control variables, including the state gasoline excise tax, demand-side variables, and supply-side factors, and we estimate a range of alternative specifications to test for the robustness of our results.

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11 Alternative theoretical frameworks can also generate the result that tax incidence depends upon market structure. For example, see Anderson, de Palma, and Kreider (2001).

12 State fixed effects capture any permanent differences across states (e.g., laws banning self-service, divorcement, transportation costs) not otherwise captured by other explanatory variables. Similarly, the time effects capture any variation in prices over time that affects the whole country (e.g., changes in national environmental standards, federal excise taxes, crude oil prices).

The econometric model is as follows. Denote P_{it} as the real monthly weighted average tax inclusive end-user price of unleaded gasoline for state *i* in period *t*. We assume that the relationship between the explanatory variables and the price of unleaded gasoline is given by:

$$P_{it} = t_{it}\alpha + X_{it}\beta + \mu_i + \eta_t + \varepsilon_{it} \ , \quad (6)$$

(plus a constant term), where t_{it} represents the tax in real cents per gallon in state *i* at time *t*, X_{it} is a vector of demand-side and supply-side characteristics that determine prices, μ_i and η_t are fixed state and monthly time effects, α and β are coefficient vectors, and ε_{it} is a random error term. In several specifications, we also utilize the log-linear version of this equation.

The fixed-effects model is appropriate for our analysis for two reasons. First, much of the variation in prices is between states rather than within states. Although it would be difficult to specify all the institutional, economic, and demographic characteristics that determine the differences across states in prices, we can capture permanent differences between states with state fixed-effects. Similarly, there are many factors that may affect prices over time, and we capture those differences with monthly time effects. Second, the fixed-effects model is a within-group estimator that uses a weighted average of the within-state and the across-state variation to form the parameter estimates. Therefore, our estimate of the effects of tax changes measures how prices change within the states as taxes change. Having said this, we have also estimated similar specifications with a random-effects model, and our results are unaffected.[13]

Given that our panel consists of 50 states for which we have monthly series over 16 years, it is likely that the errors are serially correlated. A Durbin-Watson test indicates that autocorrelation is a concern, and all standard errors are adjusted for autocorrelation using an AR1 procedure. From the 5 percent critical values presented in Bhargava et al. (1982), our modified Durbin-Watson

[13] Hsiao (1986) presents an excellent discussion of panel data estimation procedures.

statistics are less than the lower bound, suggesting that we fail to reject the null hypothesis of a random walk process.

2. Data

Our dependent variable is the inflation-adjusted monthly tax-inclusive retail price of unleaded gasoline in state *i* for time period *t*, measured in cents per gallon (or in its natural log). We obtain information on the retail and wholesale prices for the years 1984 to 1999 from a report published by the U.S. Energy Information Administration (Petroleum Marketing Monthly). The Petroleum Marketing Monthly reports retail and wholesale prices that are inflation-adjusted weighted averages net of all federal, state, and local sales and excise taxes, and are drawn from a sample of over 3,500 companies. [14] As discussed below, we collect detailed information on state gasoline taxes. To obtain a measure of the tax-inclusive price (P), we add the retail price obtained from the Petroleum Marketing Monthly and our tax measure together.

We use weighted averages of both the retail and wholesale prices of gasoline across the entire state, rather than price data from a few selected cities and/or localities, to analyze consumer activity and behavior within a given state as a whole. Along the same lines, we believe that the use of a weighted monthly average gasoline price data over a substantial period of time captures more accurately both the immediate and the long-run impact of gasoline taxes on gasoline retail prices within each state. However, as noted by Skidmore, Peltier, and Alm (2004), one drawback to the use of state-average measures of price is that potential differential effects in sub-markets within a given state cannot be captured. Overcoming this limitation is cumbersome given that it is difficult to obtain consistent disaggregated data for an extended period of time (e.g., data collected and analyzed at the store level for all states).

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[14] For a more detailed discussion of the price data, see http://www.eia.doe.gov/oil_gas/petroleum/data_publications/petroleum_marketing_monthly/pmm.html.

We include several explanatory variables to measure the variations in the gasoline retail price across states and over time. Our primary regressor is the inflation-adjusted state gasoline tax, measured in real cents per gallon.[15] Our specifications include variants of this gasoline tax variable: the level of the gasoline tax in cents per gallon, the natural logarithm of the gasoline tax, and lagged values of the gasoline tax (in order to account for the fact that changes in the gasoline tax may take time to be fully reflected in gasoline prices).

To assess the impact of gasoline taxes on gasoline prices, it is necessary to control for other factors that potentially affect gasoline prices. Following Lin (1985), Vita (1999), and Skidmore, Peltier, and Alm (2004), we include several demand-side and supply-side factors that influence gasoline prices. These include: the average annual real retail wage, real per capita income, the total number of vehicles per capita, the total number of licensed drivers per capita, the real resale gasoline price (real wholesale price of unleaded gasoline in cents), the number of heating days in the census region (average heating degree days), and population density. As noted above, we include state and time dummy variables to control for the unobservable, permanent differences across states as well as the factors that affect all prices over time. Finally, following Skidmore, Peltier, and Alm (2004), we include a reformulated gasoline dummy variable. Beginning 1 January 1994, the Clean Air Act Amendments of 1990 required that cleaner burning and more expensive reformulated gasoline be sold in the nine worst "ozone nonattainment" areas; the reformulated gasoline dummy is included to

[15] In principle, we might also include the federal gasoline excise tax. However, since the federal tax is the same for all states at any given time, the time effects control for this. Since we cannot include both the time effects and the federal tax simultaneously, we choose to include only the time effects. Our tax measure also includes local taxes that are consistently applied statewide, but not location-specific taxes. Including local excise and sales taxes imposed on gasoline is difficult to incorporate into a statewide analysis. However, the estimated coefficient on the state tax variable is only biased by this omission if changes in state taxes are systematically correlated with changes in local taxes.

control for this factor.[16] Table 1 gives the definitions and sources of the variables, and Table 2 provides summary statistics on the variables.

On the demand side, Vita (1999) has shown that gasoline demand is influenced by population and population density. An increased population may lead to increased demand for gasoline and thus an increase in price. The effect of population density is ambiguous. More densely populated areas have other alternative transportation modes, leading to a reduction in demand.[17] However, more densely populated areas experience greater traffic congestion and thus more fuel consumption per mile traveled, as well as higher rental values, and these factors suggest that prices may be higher in more densely populated areas. We also include the number of vehicles per capita, the number of drivers per capita, and income per capita to control for changes in gasoline demand.

On the supply side, we include the wholesale gasoline price variable in the retail price regressions to control for changes in the most important input cost for retailers. We also include the real annual retail wage variable to control for changes in wage costs for gasoline retailers. Following Borenstein, Cameron, and Shepard (1997) and Vita (1999), we include average heating degree days as an exogenous determinant of gasoline production costs.[18] Finally, we include the reformulated gasoline dummy to control for the Clean Air Act Amendments of 1990 regulations on ozone nonattainment regions.

As discussed in more detail later, we also categorize states into three groups based on "low", "medium", and "high" urbanicity to determine tax incidence in environments that differ

[16] These areas are Baltimore, Chicago, Hartford, Houston, Los Angeles, Milwaukee, New York, Philadelphia, and San Diego. Also, Sacramento was added later.

[17] Note that increased population density may lead via the supply side to reduced wholesale transport costs.

[18] Transportation and production costs of gasoline are affected by the demand for jointly produced products such as home heating oil, which has a demand that is weather determined. Gasoline is a by-product of the production of home heating oil so that gasoline and home heating oil are complements in production but substitutes in transportation. The expected sign on this variable is indeterminate.

in spatial competition. It is important to note that the changing patterns in gasoline taxation within these groupings do not exhibit any systematic geographical patterns – all three categories include states from all regions (New England, Middle Atlantic, South, Midwest, Southwest, and West).

IV. ESTIMATION RESULTS

1. Linear Specifications

Consider first Table 3, which presents the estimation results from a linear model without lags, and from a linear model that includes a single lag for both the tax variable and the wholesale price variable.[19] Specification 1 of Table 3 reveals that a 10 cent increase in the inflation-adjusted gasoline tax (rtax) leads to a 10.08 cent increase in the inflation-adjusted retail price of unleaded gasoline, a magnitude that is not significantly different from one (e.g., full shifting). This result therefore suggests that there is a one-for-one increase in the tax-inclusive gasoline price from an increase in the gasoline tax, a result consistent with a retail gasoline market in which firms are perfectly competitive and produce at constant cost

Specification 2 in Table 3 reveals that there is no statistical evidence of lagged responses of tax inclusive gasoline prices (rtaxl) to changes in the gasoline tax, so that prices shift fully during the first month of the tax change. If we sum the coefficients on the tax variable and on the lagged tax variable, the full effect is 10.07 cents, a result that is again consistent with full forward shifting of a 10 cent increase in the gasoline tax.

The control variables generally have the expected signs, although several coefficients are statistically insignificant and one is contrary to expectations. For instance, a one cent increase in the

[19] Changes in the gasoline taxes may not be instantaneously reflected in the tax-inclusive gasoline price. We include the lag of the gasoline tax to account for this effect; additional lags beyond one month provide no additional information to the regression.

wholesale price of gasoline (resale) raises the tax-inclusive price by nine-tenths of a cent, when a lagged response to the wholesale price (resalel) is included. As expected, increases in real income per capita (rincome) and real retail wages (rwage) are correlated with higher prices, and an increase in the average number of heating degree days (heatdays) is negatively correlated with prices. More drivers per capita (pcdriv) lead to higher prices, but, somewhat surprisingly, an increase in the number of vehicles per capita (pcveh) is associated with lower prices. The population density and the reformulated gasoline dummy variable (reformD) are not significant determinants of retail price.

2. Log-Linear Specifications

Specifications 3 and 4 in Table 4 use double log functions, and thus the coefficient estimates are interpreted as elasticities. These specifications indicate that a 10 cent increase in the gasoline tax raises the tax-inclusive gasoline price by 9.80 cents.[20] These results further confirm that gasoline tax changes lead to complete (or nearly complete) forward tax shifting. As in specifications 1 and 2 in Table 3, the other key explanatory variable, or the wholesale price of gasoline, again exerts a positive and statistically significant impact on the tax-inclusive gasoline price. Further, specifications 3 and 4 show that gasoline prices in the nine worst ozone nonattainment areas are on average about one percent higher compared to the other states in our sample, as shown by the positive though statistically insignificant coefficient on the reformD variable in both specifications 3 and 4.

3. Asymmetric Responses

Specifications 5 and 6 in Table 5 test for the asymmetric response of gasoline prices to gasoline tax changes. Here we test the hypothesis that the tax-inclusive gasoline retail price is more

[20] Interpreting the tax coefficient as an elasticity (ε) and using average values of the tax-inclusive gasoline price (P) and the real gasoline tax per unit of 96.69 and 18.98 cents, respectively, then the impact of the excise tax on price is given by $\Delta P = [\varepsilon\ (\Delta t/t)\ P]$. This equation yields $\Delta P = 0.978$ for specification 3 in Table 4. A similar estimate is found for specification 4.

responsive to gasoline excise tax increases than to gasoline tax reductions. Given that previous work shows that retail prices respond asymmetrically to wholesale prices, we also examine whether the tax-inclusive gasoline retail price responds asymmetrically to changes in gasoline wholesale prices.

To test these hypotheses, we construct the variables ctaxpd and cresalepd, which are dummy variables equal to one if tax changes (ctaxpd) or wholesale price changes (cresalepd) are positive and equal to zero otherwise. The existence of an asymmetric response will be reflected by positive and statistically significant coefficients on the ctaxpd and cresalepd variables. As shown in specifications 5 and 6 in Table 5, there is no statistical evidence of an asymmetric response of tax-inclusive gasoline prices to changes in gasoline taxes. However, these specifications also reveal that tax-inclusive gasoline prices are more responsive to increases than to decreases in gasoline wholesale prices. This finding is consistent with Borenstein, Cameron, and Shepard (1997), who find that retail gasoline prices respond more quickly to increases than to decreases in crude oil prices.

These results may be due to the institutions by which gasoline taxes are collected and under which wholesale and retail gasoline firms operate. For example, retail gasoline stations are likely to watch wholesale prices on a daily basis and attempt to set prices in accordance with the replacement costs of gasoline, which suggests a quick response to any change in wholesale gasoline prices. However, if there is a competitor with a large inventory of gasoline and if that competitor chooses to keep prices low, then others in the market might not increase retail prices to reflect fully and immediately any change in wholesale prices. Consequently, inventories may provide an opportunity for competitors to hold down retail prices in an effort to generate volume and market share, and thereby weaken somewhat the connection between wholesale price changes and subsequent retail prices changes. As for tax payments, gasoline excise taxes are collected in different ways across the states (e.g., from gasoline distributors, from retailers, on a "first sale" basis, or a "first import" basis). Regardless, however, the agent at the "point of taxation" is responsible for collection and remittance of the excise tax, and this agent is responsible for all of the gasoline tax from the time of any increase. There would therefore seem to be no incentive for a lagged response to tax changes by the agent at the point of taxation.[21] Also, tax changes are likely to be known in advance of the effective date, thereby allowing collection agents to plan accordingly; in contrast, wholesale prices may change daily without advance warning.

Specifications 5 and 6 also indicate that a 10 cent increase in the gasoline tax raises the tax-inclusive gasoline price by 10.06 cents, a result that is consistent with full forward shifting.

4. Spatial Competition and Prices

The estimation results in Tables 6 and 7 examine whether price reactions are similar in markets with differing levels of competitiveness. Here we split the states into three equally sized categories based on a constructed measure of urbanicity (e.g., low, medium, and high urbanicity), and we estimate separate regressions on each sub-sample to examine whether tax shifting differs systematically among these states. Given that urban areas exhibit a more competitive retail gasoline market, our theoretical discussion indicates that urbanized states should experience close to full forward shifting, while rural states should experience less than full shifting.

More specifically, we create a measure of "urbanicity" to proxy the level of market competition in the retail gasoline market. Our data are sorted in ascending order according to the proportion of the population residing in urban areas. We then group the states into three categories defined as "low", "medium", and "high" urban states. The cut-offs for the proportion in urban areas are chosen to classify approximately 1/3 of the states in each category, and are specified as 32.2 percent to 63.2 percent for the low urbanicity category, 64.9 percent to 74.1 percent for

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[21] We thank Robert Bartlett of the Wisconsin Petroleum Marketers and Convenience Store Association for insight into the dynamic pricing behavior of gasoline retailers.

medium urbanicity, and 76.4 percent to 92.6 percent for high urbanicity.[22] States in these groupings do not exhibit any systematic geographical patterns; that is, all three categories include states from all regions (e.g., New England, Middle Atlantic, South, Midwest, Southwest and West). As shown in specification 7 in Table 6, the low urbanicity states exhibit marginally less than full shifting. For every 10 cent increase in taxes, retail prices increase by 9.4 cents in the low urbanicity states, a result that is statistically different than full shifting at the 99 percent confidence level. In contrast, the medium and high urbanicity regressions (specifications 8 and 9) reveal full shifting.

In Table 7, we present three additional specifications that examine both the timing and the asymmetry of the price response in the low, medium, and high urbanicity states. In the medium urban states, we observe a full price response in two months; however, in the low and high urban states the price response is immediate. In fact, the analysis suggests that in medium urban states the price response in the first month is less than full shifting, but in the second month prices rise to reflect full shifting. In contrast, both low and high urbanicity states appear to exhibit greater than full shifting in the first month, and then in the second month prices tend to fall. Also, for the medium urban states we find evidence of an asymmetric response to a tax change, but we find no such response for the low and high urban states.

VI. CONCLUSIONS

So who bears the burden of gasoline excise taxes? We find strong and consistent evidence of full shifting of gasoline taxes to the final consumer. We also find that changes in gasoline taxes

[22] The "low" urbanicity category has 17 states, including Alabama, Arkansas, Georgia, Idaho, Iowa, Kentucky, Maine, Mississippi, Montana, North Carolina, North Dakota, New Hampshire, South Carolina, South Dakota, Tennessee, Vermont, and West Virginia. The "medium" urbanicity category also includes 17 states: Alaska, Delaware, Kansas, Indiana, Louisiana, Michigan, Minnesota, Missouri, Nebraska, New Mexico, Ohio, Oklahoma, Oregon, Pennsylvania, Virginia, Wisconsin, and Wyoming. The "high" category includes 16 states, or Arizona, California, Colorado, Connecticut, Florida, Hawaii, Illinois, Maryland, Massachusetts, Nevada, New Jersey, New York, Rhode Island, Texas, Utah, and Washington.

are reflected almost instantly in the tax-inclusive gasoline price, whereas gasoline retail prices exhibit a more gradual response to changes in gasoline wholesale prices. Additionally, although gasoline retail prices depict asymmetric responses to changes in gasoline wholesale prices, we find little evidence that such behavior of retail prices is reflected with respect to changes in gasoline excise taxes. Finally, our estimation results indicate that tax shifting depends in part on the degree of competition in a state, with less than full shifting in more rural (and so less competitive) states.

Figure 1: Distribution of State Gasoline Taxes, 1984 and 1999

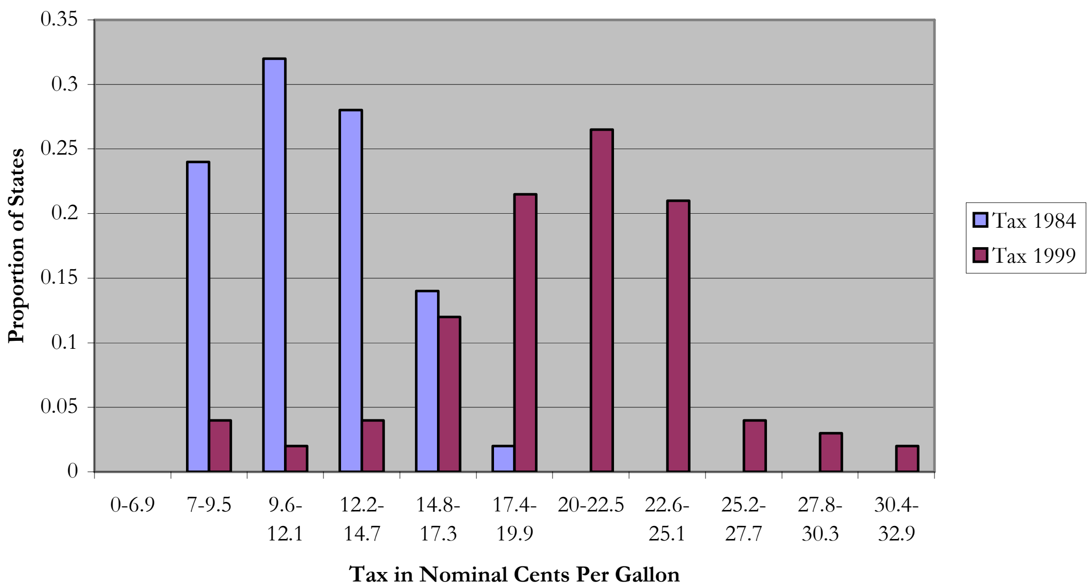

Table 1. Variable Definitions and Sources

Variable	Details	Source
Average Annual Inflation Adjusted Wage Per Service Station Employee	SIC 5541: Gasoline Service Station, Average Annual Inflation-adjusted Wage Per Service Station Employee in the State	Http://stats.bls.gov/sahome.html
Drivers Per Capita	Total Number of Driver Licenses Divided by State Population	Federal Highway Administration, *Highway Statistics*, 1980-1999
Heating Degree Days	Heating Degree Days by Census Division (where "Heating Degree-Days" are deviations from the mean daily temperature below 65F)	Http://www.eia.doe.gov/emeu/aer/overview.html
Per Capita Income	Inflation-adjusted Per Capita Income	Http://www.bea.doc.gov/bea/regional/data.htm
Population	Total State Population	Http://www.census.gov/population/www/estimates/statepop.html
Population Density	Total State Population Divided by State Land Area in Square Miles	Http://www.census.gov/population/www/estimates/statepop.html
Proportion of Drivers Between the Ages of 20 and 44	Number of Drivers Between Ages of 20 and 44 Divided by Total Number of Drivers in the State	Federal Highway Administration, *Highway Statistics*, 1980-1999
Proportion of Population Over the Age of 65	Proportion of Population Over 65 Within the State	Http://www.census.gov/population/www/estimates/statepop.html
Retail Price of Unleaded Gasoline	Average Monthly Inflation-adjusted Price of Unleaded Gasoline Sales to End-users Net of All Taxes (where "Sales to End-users" are sales made directly to the ultimate consumer, including bulk customers such as agriculture, industry, and utilities, as well as residential and commercial customers)	Energy Information Administration, *Petroleum Marketing Monthly*, 1984-1999
State Gasoline Tax	State Gasoline Tax in Inflation-adjusted Cents Per Gallon	Federal Highway Administration, *Highway Statistics*, 1980-1999
Vehicles Per Population	Total Number of Vehicles Divided by State Population	Federal Highway Administration, *Highway Statistics*, 1980-1999
Wholesale Price of Unleaded Gasoline	Average Monthly Inflation-adjusted Price of Unleaded Gasoline Sales for Resale Net of All Taxes (where "Sales for Resale" are those made to purchasers who are other than ultimate consumers)	Energy Information Administration, *Petroleum Marketing Monthly*, 1984-1999

Table 2. Summary Statistics for All States, 1984 to 1999

Variable	Mean	Standard Deviation
Weight	1.00	0.01
reformD (Reformulated Gasoline Dummy)	0.05	0.22
crudeprice (Crude Oil Price)	18.23	93.05
euser (Real Retail Price of Unleaded Gasoline in Cents)	77.71	13.02
resale (Real Wholesale Price of Unleaded Gasoline in Cents)	66.11	12.78
rtax (Real State Gasoline Tax in Cents)	18.98	4.69
pop (Population in Thousands)	5075.66	5492.11
rncome (Real Per Capita Income in Dollars)	21901.70	3869.38
density (Population Density)	167.41	231.13
pccveh (Vehicles Per Capita)	0.79	0.12
pcdriv (Drivers Per Capita)	0.68	0.05
rwage (Average Annual Real Retail Wage in Dollars)	13946.88	1734.68
heatdays (Average Heating Degree Days in the Census Region)	4687.17	1663.50
lnresale (Natural log of resale)	4.17	0.19
lneuser (Natural log of euser)	4.34	0.17
lnrwage (Natural log of rwage)	9.41	0.19
lnpop (Natural log of pop)	8.05	1.01
lnrincome (Natural log of rincome)	9.98	0.17
lndensity (Natural log of density)	4.30	1.42
lnpcveh (Natural log of pcveh)	-0.24	0.14
lnpcdriv (Natural log of pcdriv)	-0.38	0.08
lnheatdays (Natural log of heatdays)	8.38	0.39
lncrudeprice (Natural log of crudeprice)	2.81	0.26
raxl (Lag of rtax)	18.98	4.69
resalel (Lag of resale)	66.04	12.82
lnrtaxl (Natural log of rtaxl)	2.91	0.27
lnresalel (Natural log of resalel)	4.17	0.19
ctax (rtax-rtaxl)	0.01	0.44
cresale (resale-resalel)	-0.05	4.43
clntax (lnrtax-lnrtaxl)	0.00	0.02
clnresale (lnresale-lnresalel)	0.00	0.07
P (Tax-inclusive Real Retail Price of Unleaded Gasoline in cents)	96.69	13.26
lnP (Natural log of P)	4.56	0.14
positivedummy1 (Dummy=1 if ctax>0)	0.03	0.17
positivedummy2 (Dummy=1 if cresale>0)	0.51	0.50
positivedummy3 (Dummy=1 if clntax>0)	0.03	0.17
positivedummy4 (Dummy=1 if clnresale>0)	0.51	0.50
ctaxpd (ctax * positivedummy1)	0.04	0.41
cresalepd (cresale * positivedummy1)	1.57	2.69
clntaxpd (clntax * positivedummy1)	0.00	0.02
clnresalepd (clnresale * positivedummy1)	0.02	0.04

Table 3. Perfect Competition: Linear Specifications
(t-value in parentheses)

Independent Variables	**Dependent Variable: Tax-inclusive Price P**	
	(1)	(2)
rtax	1.008	1.012
	(32.38)**	(30.34)**
rtaxl		-0.005
		(0.16)
resale	0.878	0.547
	(68.27)**	(68.58)**
resalel		0.311
		(39.09)**
density	-0.004	0.000
	(0.45)	(0.02)
pcveh	-1.092	-0.826
	(0.82)	(0.71)
pcdriv	0.712	1.487
	(0.36)	(0.86)
rincome	0.000	0.000
	(0.53)	(1.37)
heatdays	-0.000	-0.000
	(1.67)	(0.45)
rwage	0.000	0.000
	(2.17)*	(1.79)
reformD	0.101	-0.025
	(0.23)	(0.06)
Constant	8.776	3.888
	(14.01)**	(6.65)**
Observations	9550	9500
Number of states	50	50
R-squared	0.85	0.88
Durbin Watson[a]	0.5538	0.4508
Rho	0.8074	0.7886

*significant at 5%; ** significant at 1%
[a] Modified Durbin Watson statistic (Bhargava et al. 1982)
All regressions include state and time fixed effects.

Table 4. Perfect Competition: Log Specifications
(t-value in parentheses)

Independent Variables	Dependent Variable: Natural Log of Tax-inclusive Price lnP	
	(3)	(4)
lnrtax	0.192	0.194
	(33.12)**	(30.49)**
lnrtaxl		-0.004
		(0.64)
lnresale	0.583	0.367
	(67.43)**	(68.48)**
lnresalel		0.198
		(36.95)**
lndensity	0.056	0.020
	(3.98)**	(2.18)*
lnpcveh	0.011	0.001
	(0.94)	(0.13)
lnpcdriv	0.032	0.023
	(2.45)*	(2.02)*
lnrincome	-0.071	-0.033
	(2.51)*	(1.33)
lnheatdays	-0.024	-0.011
	(2.67)**	(1.36)
lnrwage	0.040	0.034
	(2.74)**	(2.56)*
reformD	0.005	0.004
	(1.14)	(0.93)
Constant	0.548	0.363
	(9.43)**	(6.72)**
Observations	9550	9500
Number of state	50	50
R-squared	0.88	0.94
Durbin Watson[a]	0.5376	0.4483
Rho	0.8011	0.7873

* significant at 5%; ** significant at 1%
[a] Modified Durbin Watson statistic (Bhargava et al. 1982)
All regressions include state and time fixed effects.

Table 5. Perfect Competition: Linear and Log Asymmetric Response Specifications (t-value in parentheses)

Dependent Variable: Tax-inclusive Price P		Dependent Variable: Natural Log of Tax-inclusive Price lnP	
	(5)		(6)
rtax	0.844	lnrtax	0.196
	(6.17)**		(5.87)**
rtaxl	0.162	lnrtaxl	-0.006
	(1.19)		(0.17)
ctaxpd	0.180	clntaxpd	-0.004
	(1.16)		(0.12)
resale	0.460	lnresale	0.311
	(43.35)**		(43.88)**
resalel	0.400	lnresalel	0.259
	(37.11)**		(35.15)**
cresalepd	0.189	clnresalepd	0.126
	(12.17)**		(12.04)**
density	-0.000	lndensity	0.020
	(0.04)		(2.16)*
pcveh	-0.893	lnpcveh	0.001
	(0.77)		(0.11)
pcdriv	1.446	lnpcdriv	0.023
	(0.84)		(2.02)*
rincome	0.000	lnrincome	-0.031
	(1.48)		(1.23)
heatdays	0.000	lnheatdays	-0.006
	(0.16)		(0.70)
rwage	0.000	lnrwage	0.033
	(1.72)		(2.51)*
reformD	-0.040	reformD	0.004
	(0.10)		(0.93)
Constant	3.592	Constant	0.342
	(6.19)**		(6.39)**
Observations	9500	Observations	9500
Number of states	50	Number of states	50
R-squared	0.88	R-squared	0.94
Durbin Watson[a]	0.4589	Durbin Watson[a]	0.4538
Rho	0.7829	Rho	0.7883

* significant at 5%; ** significant at 1%
[a] Modified Durbin Watson statistic (Bhargava et al. 1982)
All regressions include state and time fixed effects.

Table 6. Spatial Competition: Linear Specifications
(t-value in parentheses)

	Dependent Variable: Tax-inclusive Price P		
	(7) Low Urban	**(8) Medium Urban**	**(9) High Urban**
rtax	0.945	1.031	1.026
	(18.80)**	(16.92)**	(19.72)**
resale	0.879	0.875	0.836
	(32.22)**	(35.80)**	(43.56)**
density	-0.091	-0.016	-0.010
	(3.58)**	(0.64)	(0.86)
pcveh	-1.879	5.483	-7.159
	(1.07)	(1.87)	(2.32)*
pcdriv	-3.983	3.920	-4.876
	(1.62)	(0.85)	(1.15)
rincome	-0.000	-0.001	0.000
	(0.11)	(2.53)*	(1.76)
heatdays	0.001	-0.001	-0.000
	(3.25)**	(3.04)**	(0.60)
rwage	0.000	0.000	0.000
	(2.25)*	(1.45)	(0.90)
reformD		-0.666	-1.315
		(0.60)	(2.33)*
Constant	43.741	54.849	33.539
	(39.56)**	(40.85)**	(23.51)**
Observations	3247	3247	3056
Number of states	16	17	17
R-squared	0.90	0.85	0.84
Durbin Watson[a]	0.5618	0.5926	0.5663
Rho	0.7952	0.7910	0.7850

* significant at 5%; ** significant at 1%
[a] Modified Durbin Watson statistic (Bhargava et al. 1982)
All regressions include state and time fixed effects.

Table 7. Spatial Competition: Linear Asymmetric Response Specifications
(t-value in parentheses)

	Dependent Variable: Tax-inclusive Price P		
	(10) Low Urban	(11) Medium Urban	(12) High Urban
rtax	1.147	0.513	1.114
	(4.83)**	(2.10)*	(4.82)**
rtaxl	-0.248	0.498	-0.055
	(1.04)	(2.03)*	(0.24)
ctaxpd	-0.166	0.543	-0.089
	(0.62)	(1.92)	(0.34)
resale	0.382	0.451	0.510
	(21.41)**	(22.29)**	(26.58)**
resalel	0.355	0.419	0.403
	(19.54)**	(20.46)**	(20.70)**
cresalepd	0.171	0.219	0.153
	(6.46)**	(7.26)**	(5.64)**
density	-0.089	-0.015	0.003
	(4.12)**	(0.82)	(0.36)
pcveh	-1.887	3.923	-8.197
	(1.20)	(1.47)	(3.01)**
pcdriv	-2.739	0.191	-2.325
	(1.23)	(0.05)	(0.62)
rincome	0.000	-0.000	0.001
	(0.36)	(1.89)	(3.28)**
heatdays	0.001	-0.001	0.000
	(4.36)**	(2.39)*	(0.47)
rwage	0.000	0.000	-0.000
	(2.39)*	(1.63)	(0.24)
reformD		-0.680	-0.830
		(0.69)	(1.67)
Constant	33.113	27.760	10.474
	(31.08)**	(21.48)**	(8.80)**
Observations	3230	3230	3040
Number of state	16	17	17
R-squared	0.92	0.88	0.88
Durbin Watson[a]	0.4889	0.4989	0.4815
Rho	0.7725	0.7772	0.7816

* significant at 5%; ** significant at 1%
[a] Modified Durbin Watson statistic (Bhargava et al. 1982)
All regressions include state and time fixed effects.

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