

# Regional Gasoline Price Dynamics

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A large literature has argued that gasoline prices respond more rapidly to increases in oil prices than to decreases in oil prices. Moreover, some of this literature has found heterogeneous asymmetry in gas price responses across cities. Here, we reconsider the causes of heterogeneous asymmetric pass-through. Consistent with the previous literature, we find heterogeneity in the magnitudes of asymmetric pass-through across cities. We also find a large number of cities that exhibit no asymmetries. We then examine whether heterogeneous asymmetry results from city-level differences in (i) the demand for gasoline, (ii) the supply of gasoline (proxied by the distance from Cushing, Oklahoma), or the cities' fiscal environments (proxied by the level of taxes). We examine whether these characteristics affect either the magnitudes of the asymmetries or the presence of asymmetries. While we find that city-level characteristics cannot (robustly) explain variation in the magnitudes of the asymmetries, they do seem to affect the probability that a city experiences asymmetric pass-through. (JEL C32, Q41)

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## 1 INTRODUCTION

Oil shocks have been important factors in most postwar recessions (Hamilton, 2011). One of the primary channels through which oil price shocks are felt by consumers is through their effect on gasoline prices. Similar to other prices and exchange rates, pass-through indicates the degree to which oil price fluctuations affect gasoline prices. The extant literature has identified a number of asymmetries in the pass-through of oil price shocks to gasoline prices, with particular focus on the hypothesis that gasoline prices respond more rapidly to increases in oil prices and less rapidly to decreases in oil prices.

The previous literature finds mixed evidence of asymmetry in the gasoline market, with variety in the type of asymmetry, the level of geographic granularity (e.g., national versus regional), and the time sample and frequency of data used. Much of the extant literature

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focuses on the asymmetric pass-through of input costs to retail gasoline prices at the U.S. national level.<sup>1</sup> Most studies find asymmetry at the national level (e.g., Karrenbrock, 1991, using monthly data on wholesale to retail pass-through; Borenstein, Cameron and Gilbert [BCG], 1997, using semi-monthly crude oil to retail pass-through; Balke, Brown, and Yucel, 1998, using various weekly intermediate good prices; and Chen, Finney, and Lai, 2005, using spot and future oil prices). A few papers, however, find no evidence of asymmetry (Bachmeier and Griffin, 2003, using daily crude oil to wholesale gasoline prices; and Douglas, 2010, using weekly input costs to retail gasoline prices).<sup>2</sup>

At the subnational level, evidence of asymmetric pass-through is also mixed. For example, Deltas (2008) finds evidence of asymmetric pass-through from wholesale gasoline prices to retail gasoline prices at the state level. States with higher average retail-wholesale margins have higher degrees of asymmetry, suggesting that sticky prices and asymmetric price responses in the gasoline market may be in part due to retail market power. Ye et al. (2005) also find asymmetries in the pass-through of wholesale gasoline prices to retail prices at the Petroleum Administration for Defense District level. Adilov and Samavati (2009) find heterogeneous asymmetries between weekly oil and gasoline prices: Gasoline prices in California, Texas, and Washington react faster to oil price increases than decreases, while gasoline prices in Massachusetts, Minnesota, and Ohio react faster to oil price decreases. Chesnes (2016) documents the largest degrees of asymmetry in Louisville, Minneapolis, Cleveland, and Detroit—Midwestern cities—and the smallest degrees in San Francisco and the West Virginia suburbs of Washington, DC.

Research examining the factors underlying asymmetric pass-through largely focuses on market power (Verlinda, 2008; Tappata, 2009; Radchenko, 2005; and Hong and Lee, 2020, for Korea) or consumer search costs (Davis, 2007; Lewis, 2011; and Yang and Ye, 2008). Remer (2015) determines that premium gasoline prices fall more slowly than regular fuel prices but rise at the same speed, supporting the theory that asymmetry occurs as a consequence of firms extracting informational rents from customers with positive search costs. Verlinda (2008) finds that factors associated with gasoline demand have little to no effect on the degree of asymmetry.

We evaluate asymmetric pass-through from oil prices to pre-tax gasoline prices at the metropolitan statistical area (MSA) level and consider the causes of heterogeneous pass-through across MSAs. Variation in the price of gasoline across locations has been well documented, but these differences have often been attributed to differences in state and local taxes. However, we find evidence of some remaining pre-tax heterogeneity. We test various hypotheses about the cause of regional variations in the pass-through of oil price shocks to gasoline prices. In particular, we consider geographic and demand issues. We estimate a hierarchical model in which the degree of pass-through is determined by city-level characteristics that reflect the demand for gasoline (e.g., the average commute time per worker) and the elasticity of the supply of gasoline (e.g., the distance from Cushing, Oklahoma).

The balance of the article is laid out as follows: Section 2 presents the data. Section 3 describes two versions of the empirical model: the baseline symmetric case and the model with asymmetries. We also describe the cross-sectional evaluation of the asymmetries. Section 3.4 describes how the model is estimated. Section 4 details our results, and Section 5 offers concluding remarks.

## 2 THE DATA

### 2.1 Oil and Gasoline Prices

We use weekly oil and gasoline price data from March 2005 to August 2013 in our analysis. For oil prices, we use the West Texas Intermediate (WTI) domestic spot market price (Cushing, Oklahoma) in dollars per barrel from the Energy Information Administration (EIA). We use the average of daily values for a given week for each weekly value, with a week defined as the seven day period from Sunday to Saturday. Because oil prices are only reported on non-holiday weekdays, the weekly value is the average of Monday through Friday oil prices, excluding holidays.

In order to evaluate city-level differences in the pass-through of oil prices to gasoline prices, we obtained weekly regional gasoline price time-series data from GasBuddy.com. Over the time frame of our sample period, GasBuddy reported average gas price data according to custom geographic definitions that resemble, but do not precisely correspond to, MSAs as constructed by the Bureau of Labor Statistics. We use these custom geographic definitions when matching regional gasoline taxes and regional characteristics (discussed in proximate paragraphs) with the gasoline price data; thus, all reported pass-through results are associated with the regions as defined by the gasoline price data rather than by MSAs. Because these two definitions are very similar, however, we will continue to refer to the areas as MSAs.

The gasoline price data reflect the observed weekly gasoline prices averaged from a number of stations within a given region.<sup>3</sup> The gasoline prices in the raw data are nominal, and they include state and local taxes. Taxes vary across regions and across time and are generally uncorrelated with demand. Thus, we wish to work with pre-tax gasoline prices. While a large portion of the cross-MSA variation in retail gasoline prices results from differences in taxes, there remains some regional heterogeneity left to analyze.

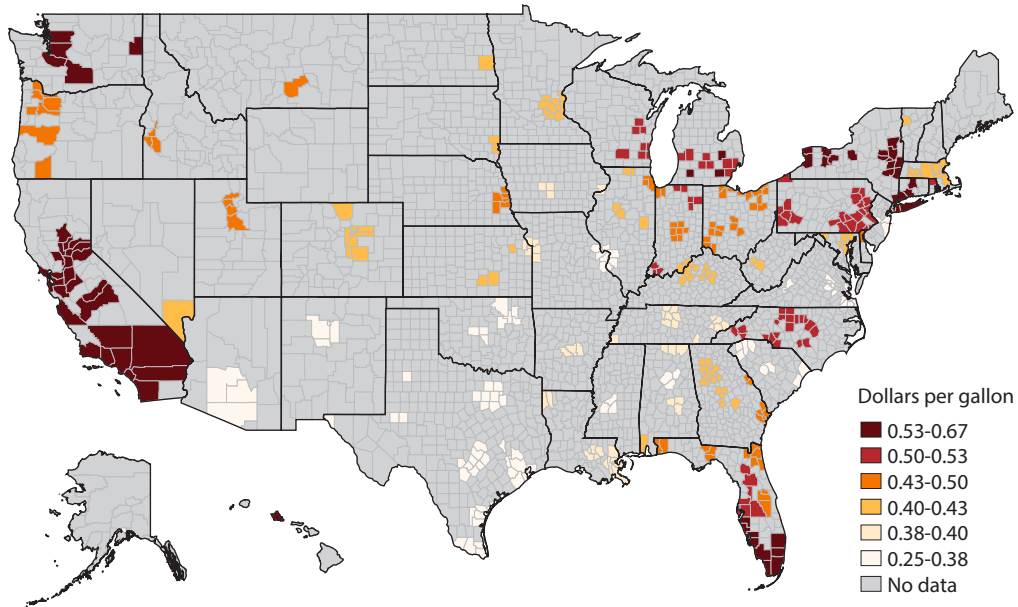
To compute pre-tax gasoline prices, we assume that all taxes and fees are fully passed on to the consumer and are embedded in the retail price of gasoline. We make this assumption to avoid the complication that the pass-through of taxes to retail gasoline prices may vary across locations.

A variety of taxes and fees were imposed on gasoline prices over the course of the sample period. We sort these taxes into six categories: federal excise taxes, state excise taxes, state fees, state sales taxes, local taxes, and wholesale taxes. For more details on sources, assumptions, and calculations pertaining to these gasoline taxes, see the appendix. Some gasoline taxes are imposed as percentages and some are imposed in dollars per gallon. We calculate the net-of-taxes retail price,  $G_t$ , as

$$G_t = \frac{P_t - D_t}{1 + T_t} - (W_t R_t),$$

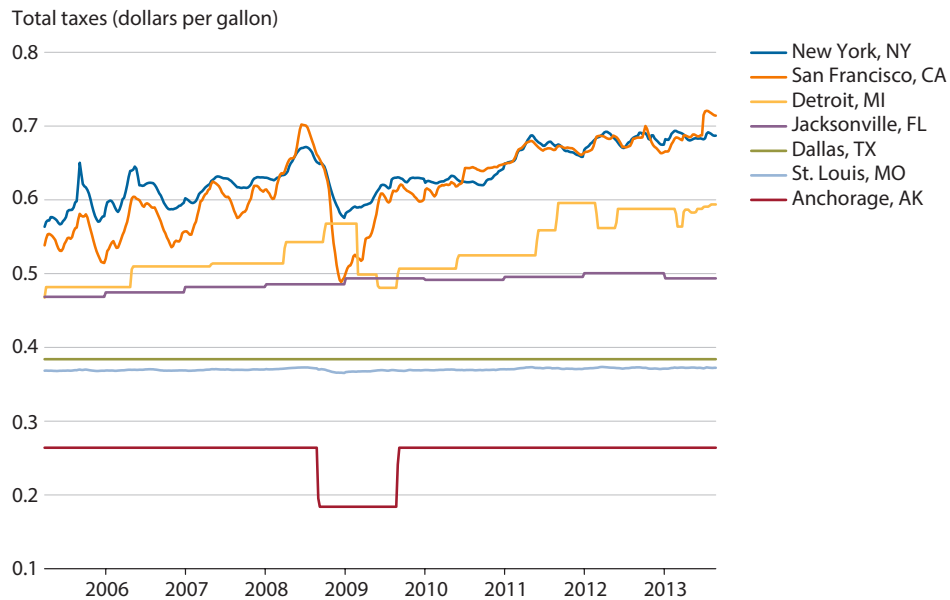
where  $P_t$  denotes the observed gasoline price;  $D_t$  denotes any federal excise taxes, state excise taxes, state fees, state sales taxes, or local taxes imposed in dollars per gallon; and  $T_t$  denotes any of those taxes imposed as a percentage of gross sales. We subtract out wholesale taxes via the  $(W_t R_t)$  term, where  $W_t$  indicates the wholesale tax on gasoline and  $R_t$  indicates the

**Figure 1**  
**Average Level of Gasoline Taxes Across MSAs, 2005-13**



SOURCE: See the gasoline tax sources in the appendix.

**Figure 2**  
**Total Gasoline Taxes Per Gallon for Select MSAs, 2005-13**



SOURCE: See the gasoline tax sources in the appendix.

estimated wholesale price on gasoline, which is assumed to be 80 percent of the post-tax retail price.

Both the net-of-taxes gasoline prices and the oil prices are adjusted to be in March 2005 dollars using the consumer price index for all urban consumer, not seasonally adjusted, with the base period 1982-84.<sup>4</sup>

Figure 1 displays the average level of all taxes (indicated in dollars per gallon) across MSAs over the sample period. Taxes are generally higher in the Northeast, Great Lakes region, and West Coast as well as in Florida and Hawaii, and they are generally lower in the South and Midwest. Figure 2 demonstrates how aggregate gasoline taxes fluctuated over the sample period for select MSAs. For some MSAs, taxes vary substantially over time; for others, taxes stay fairly constant. Time variation in taxes can be caused either by changes in the tax laws or by the use of proportional sales taxes. Table A3.1 in the appendix details the average level of each tax component and the fraction of the average retail price that taxes comprise for each MSA over the sample period.

## 2.2 *Pretests*

The literature is mixed as to whether energy prices are stationary or unit roots. In their study of the relationships between prices at different levels of the (aggregate) supply chain, Balke, Brown, and Yucel (1998) conclude that the energy price data are stationary. Their sample consists of data from 1987 to 1996, when, outside of a spike associated with the first Gulf War, oil prices were relatively stable around \$100 per barrel of oil (bbl). In our sample, oil prices fluctuate between \$33 to \$143 bbl. Thus, we conduct a few pretests to determine the appropriate model.

Gasoline prices comove across MSAs; there is also comovement between MSA gasoline prices and the national average of gasoline prices. Rather than testing for the number of cointegrating vectors independently in each MSA, we test for cointegration at the national level and assume that a similar relationship exists at the subnational level.

We use the augmented Dickey-Fuller (ADF) test to evaluate whether the national-level retail gasoline and WTI spot oil price data series follow a unit root. For both series, we cannot reject the null hypothesis of a unit root.<sup>5</sup> We then test for cointegration using a Johansen test.<sup>6</sup> Using the Johansen test maximum eigenvalue statistics (EV) and corresponding  $p$ -values ( $p$ ), we reject the null hypothesis of zero cointegrating vectors (EV = 9.68,  $p$  = 0.09) at the 10 percent level but do not reject the null hypothesis of one cointegrating vector or less (EV = 0.0054,  $p$  = 0.95).

## 2.3 *Cross-Sectional Data*

As discussed above, several papers have attempted to explain heterogeneity in the speed of adjustment across geographies. We separate the vector of MSA-level factors that may affect asymmetric adjustment into three categories: (i) demand factors, (ii) supply factors, and (iii) the fiscal environment.

Demand-side factors include each MSA's population density (in thousands of persons per square mile), commute time per worker (in fractions of an hour), the fraction of commuters that use cars to commute to work, the fraction of households that own multiple cars, and the hospitality industry share of total gross domestic product (GDP). An increase in any of these demand-side factors could increase the demand for gasoline under the assumption that commuting and tourist vehicles are primary sources of gasoline demand. The population density was calculated by aggregating the population and land area (in square miles) of all of the Census-designated places within the area in which the gasoline prices were collected. These data are from the Missouri Census Data Center's MABLE/Geocorr12k Geographic Correspondence Engine. The commuting-vehicle-related data are aggregated up according to MSA from the Census-designated place level, averaged over the 2006-10, 2007-11, and 2008-12 American Community Survey (ACS) five-year samples. These data were provided by the National Historical Geographic Information System. The hospitality industry shares of GDP were calculated using annual county-level GDP data from the Bureau of Economic Analysis (BEA), averaged over 2005-13 and aggregated up to the MSA level. We use the GDP data corresponding to the North American Industry Classification System (NAICS) for the Arts, Entertainment, and Recreation industry and the Accommodation and Food Services industry to capture the hospitality industry, assuming these industries' share of GDP captures relative tourism levels, therefore tourism-related demand for gasoline, across MSAs.<sup>7</sup>

Supply-side factors include the distance in miles from each MSA's nominal downtown to downtown Cushing, Oklahoma. Because Cushing is the settlement location for WTI crude, we assume that the distance between the retail market and Cushing is proportional to the transportation costs that are passed on to consumers. Even as transportation costs for each MSA vary over time, the relative costs across MSAs should remain proportional to the transportation distance.

The fiscal environment factors include the average level of gasoline taxes in the MSA and an indicator that takes on a value of 1 if the taxes include a proportional tax and a value of 0 otherwise. Cities or states with proportional sales taxes would see an increase in the gross tax when prices rise, which could affect the speed at which retailers adjust prices.

### **3 THE EMPIRICAL APPROACH**

Being unable to reject the null of nonstationarity in both the gasoline and the oil price series and because gasoline prices and oil prices are thought to comove, we model pass-through in a vector error correction model (VECM). The VECM allows a long-run relationship between oil prices and gasoline prices through the cointegrating vector.

We first describe the cointegration problem and outline the two-variable version of the VECM, which is particularly useful in understanding the relationship between gasoline and oil prices. We then consider asymmetric adjustment back to the cointegrating vector(s). Finally, we describe how we estimate these models.

### 3.1 The Baseline VECM

Let  $G_t$  represent a national average gasoline price (in dollars per gallon) and  $O_t$  represent oil prices. If the two prices are nonstationary but a linear combination of them is stationary, they are said to be cointegrated (Engle and Granger, 1987; see Dickey, Jansen, and Thornton, 1991, for a summary). Suppose that there exists a (time invariant) relationship between gasoline prices and oil prices:

$$(1) \quad G_t = \beta_0 + \beta_1 O_t + u_t,$$

where  $\beta_1$  represents the long-run pass-through of changes in oil prices to gasoline prices. If  $u_t \sim N(0, \omega^2)$  is stationary, gasoline and oil prices are said to be cointegrated.

What does it mean for these variables to have a long-run relationship? Equation (1) can be thought of as a common trend for the two prices. Short-run fluctuations in either price can still cause temporary deviations around the long-run relationship, but the two prices are attracted to the common trend line. These short-run fluctuations in gasoline prices can be written as

$$(2) \quad \Delta G_t = \phi_{gasoline}(L)\Delta G_{t-1} + \phi_{oil}(L)\Delta O_{t-1} + \alpha u_{t-1} + e_t,$$

where  $e_t \sim N(0, \sigma^2)$ . The first term represents persistence in gasoline price fluctuations. The second term represents the short-run influence of (past) changes in oil prices on the change in gasoline prices.

The third term is called the error correction term because it “corrects” gasoline prices back to the long-run relationship. When  $u_{t-1} > 0$ , the past-period gasoline price is above the long-run relationship. If  $\alpha$  is negative, the term makes gasoline prices fall—equivalently, the change in gasoline prices is negative or  $\Delta G_t < 0$ . The parameter  $\alpha$  determines how much the deviation from the long-run relationship affects gasoline prices—the larger  $\alpha$  is in magnitude, the larger the change in gasoline prices.

While much of the literature focuses on the national level, we consider this relationship at the MSA level. Let  $G_{nt}$  represent the period- $t$  level of gasoline prices in MSA  $n$ . Then, the long-run relationship can be MSA specific:

$$(3) \quad G_{nt} = \beta_{0n} + \beta_{1n} O_t + u_{nt},$$

where we assume that pass-through can be idiosyncratic to the MSA. We can also rewrite (2):

$$(4) \quad \Delta G_{nt} = \phi_{n,gasoline}(L)\Delta G_{n,t-1} + \phi_{n,oil}(L)\Delta O_{n,t-1} + \alpha_n u_{n,t-1} + e_{nt},$$

where  $\alpha_n$  is the MSA-specific speed of adjustment.

### 3.2 Asymmetric Correction

The previous literature on the relationship between oil and gasoline prices has conjectured that the pass-through is asymmetric. For example, gasoline prices may adjust faster when oil

prices are rising than when they are falling. Alternatively, gasoline prices may adjust faster when they are *below* the long-run relationship than when they are above it. The first form of asymmetry can be incorporated into the model by partitioning the data into dates in which oil prices were increasing or decreasing in the previous period. The second form of asymmetry can be incorporated into the model by partitioning the data into dates when the gasoline price was above or below the long-run relationship in the previous period. Then, the speed of adjustment back to the long-run relationship would depend on the gasoline price relative to the long-run relationship or the sign of the change in oil prices.

To model the first alternative, define an indicator  $I_{[\Delta O_{t-1} > 0]} = \{0,1\}$  that takes the value 1 if  $\Delta O_{t-1} > 0$  and 0 otherwise. Then, the asymmetric adjustment model is

$$(5) \quad \Delta G_{nt} = \phi_{n,gasoline}(L)\Delta G_{n,t-1} + \phi_{n,oil}(L)O_{n,t-1} + \left(1 - I_{[\Delta O_{t-1} > 0]}\right)\alpha_n^- u_{n,t-1} + I_{[\Delta O_{t-1} > 0]}\alpha_n^+ u_{n,t-1} + e_{nt},$$

where  $\alpha_n^-$  and  $\alpha_n^+$  reflect the speeds of adjustment when oil prices are falling or rising, respectively, and the rest of the terms are defined as before.

Similarly, to model the second alternative, define an indicator  $I_{[u_{n,t-1} > 0]} = \{0,1\}$  that takes the value 1 if  $u_{n,t-1}^* > 0$  and 0 otherwise. Then, the asymmetric adjustment model is

$$(6) \quad \Delta G_{nt} = \phi_{n,gasoline}(L)\Delta G_{n,t-1} + \phi_{n,oil}(L)O_{n,t-1} + \left(1 - I_{[u_{n,t-1} > 0]}\right)\alpha_n^- u_{n,t-1} + I_{[u_{n,t-1} > 0]}\alpha_n^+ u_{n,t-1} + e_{nt},$$

where  $\alpha_n^-$  and  $\alpha_n^+$  now reflect the speeds of adjustment when gasoline prices are below or above their long-term equilibrium relationship with oil, respectively, and the rest of the terms are defined as before.

We assume that the long-run relationship is invariant to whether oil prices are rising or falling (or, in the second case, whether the local gasoline price is above or below the long-run relationship); only the speed of adjustment is asymmetric. Note also that the persistence of gasoline price changes (first term) and the short-run response to oil prices (second term) are symmetric—that is, they do not vary with the indicator variable. We do this to focus on the asymmetry in the transition path back to the long-run equilibrium rather than the short-run dynamics: The two models are differentiated by what drives differences in the adjustment dynamics.

### 3.3 Explaining Cross-Sectional Differences

Much of the variation in the MSA-level retail gasoline prices is the result of differences in taxes. However, even after correcting for taxes, some variation still exists. In particular, we are interested in the variation in the speed of adjustment back to the long-run relationship. We can determine the factors,  $X$ , that affect the speed of adjustment,  $\alpha$ , with the following cross-sectional regression:

$$(7) \quad \alpha_n = \delta X_n + v_n,$$

where  $\alpha_n$  can be from the symmetric case or either of the  $\alpha$ 's or  $\Delta\alpha$  from the asymmetric case and  $v_n \sim N(0,\Omega)$ .



Previous studies have found heterogeneity in both the presence and magnitudes of asymmetries across cities. The regression above asks whether the magnitudes of the asymmetries can be explained by MSA-level covariates. We can also examine what factors might determine whether a city experiences asymmetric price adjustment. To do this, we estimate a probit:

$$(8) \quad \Pr[S_n = 1 | X] = \Phi(\gamma X_n),$$

where  $\Delta\alpha_n = \alpha_n^+ - \alpha_n^-$ ,  $S_n = 1$  if 0 is not contained in the 68 percent posterior coverage of  $\Delta\alpha_n$ ,  $\Phi(\cdot)$  is the standard normal cumulative density function, and  $\gamma$  is a vector of coefficients.

### 3.4 Estimation

We estimate the model using Bayesian methods. For larger systems, Koop et al. (2004) offer a survey of methods for estimating cointegrating models with Bayesian methods. Because we work in the Engle-Granger form, we can estimate the model in four steps for each MSA. First, we draw the parameters of the cointegrating vector. Next, we compute the residuals from equation (3). Conditional on these residuals, we estimate the error correction equation with the Gibbs sampler using two blocks: (i) the coefficients,  $\alpha_n$ ,  $\phi_n$ , and (ii) the variance,  $\sigma^2$ . Finally, we collect the draws of the parameters from each MSA and draw  $\delta$  and  $\sigma^2$ . Because we construct  $S_n$  based on the posterior distributions of  $\alpha^+$  and  $\alpha^-$ , we estimate the probit after completing the full sampler above.

The prior at each stage is normal-inverse-Wishart. Conditional on the prior and the residuals computed from equation (3), the posterior is conjugate normal-inverse-Wishart.

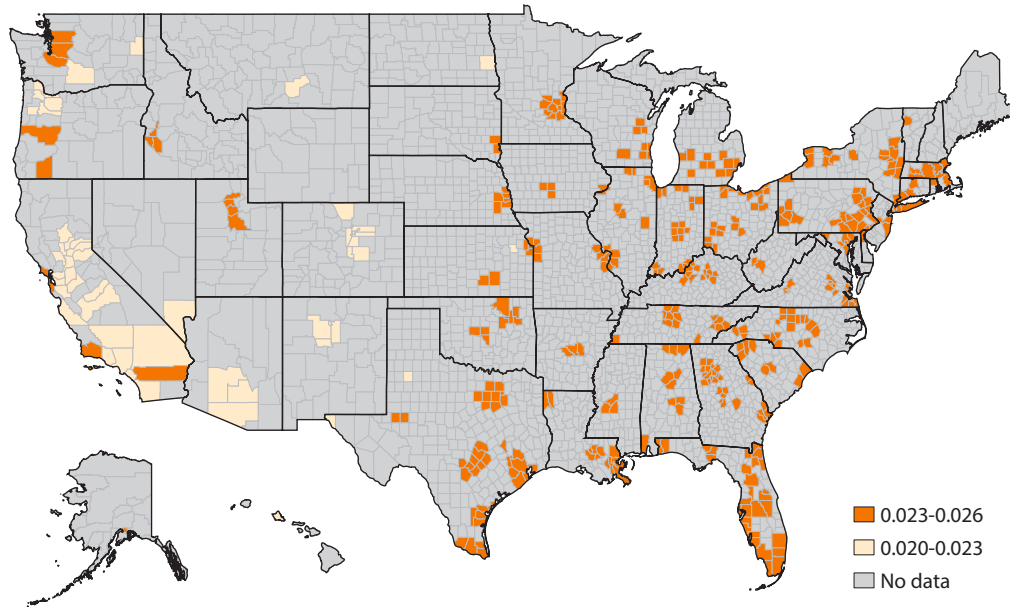
To achieve convergence, we burn the initial 4,000 draws from each location for the first three steps. Because of the large cross section of MSAs, we found it computationally more convenient to execute the first three steps together and then execute the fourth step separately. To execute the fourth step, we used the saved distributions for all MSAs from the first three steps and took one draw without replacement from the posterior distributions of each MSA. We then burned the first 100 draws of  $\delta$  and  $\sigma^2$ , saving the next draw. We repeated this for each 1,000 draws from the third stage posterior. Thus, we account for the variation in all three stages of the estimation. After computing  $S_n$  for each  $n$ , we estimated the probit using 4,000 burn draws and 1,000 saved draws.

## 4 RESULTS

### 4.1 Pass-through

The first-stage regression produces a set of MSA-specific cointegrating relationships. Implicit in these are the estimates of how oil price changes pass through to the price of gasoline. Figure 3 plots the geographic distribution of the medians of the posteriors for the pass-through parameter,  $\beta$ , for all MSAs. We note two main findings. First, the variation in the pass-through by MSA is small, ranging from 0.020 (Albuquerque, New Mexico) to 0.026 (Chicago, Illinois). When oil prices rise by \$1 bbl in a given week, gasoline prices rise that week, on average by 2 to 2.6 cents per gallon. Second, even with limited variation, the MSAs with

**Figure 3**  
**Pass-through ( $\beta$ ) Across MSAs**



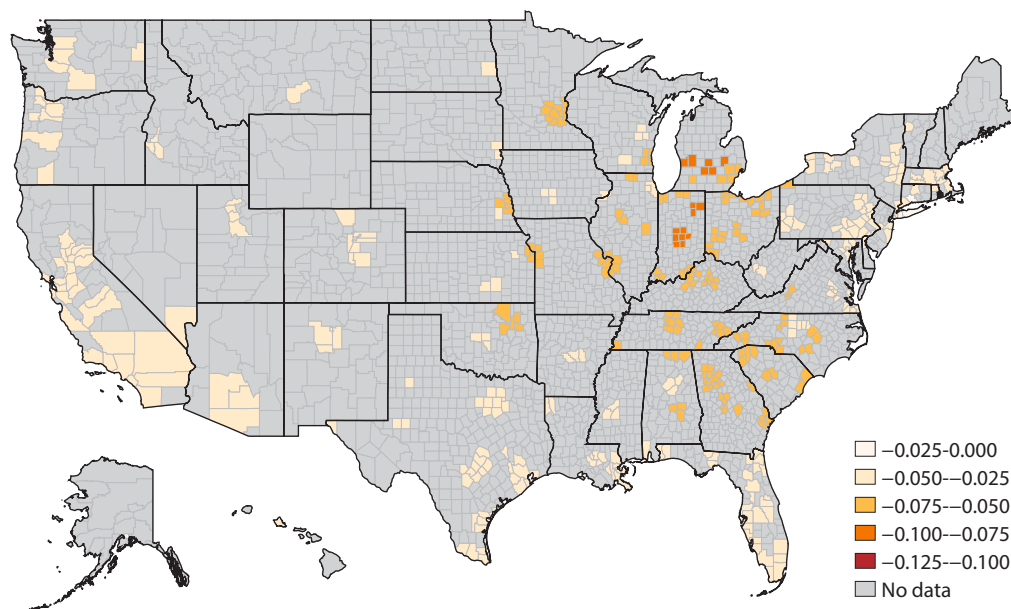
SOURCE: EIA, GasBuddy, and the gasoline tax sources noted in the appendix.

lower pass-through are all located in the western region of the country and the MSAs with higher pass-through are predominantly located in the eastern regions of the country.

#### 4.2 The Speed of Adjustment

Before proceeding to the asymmetric model, we briefly discuss the results from the symmetric model, which will provide a baseline for analyzing the asymmetric response of gasoline prices to changes in oil prices. Figure 4 shows the geographic distribution of the medians of the posteriors for the speeds of adjustment,  $\alpha$ , for all of the MSAs using the symmetric model. Note that, while the prior for  $\alpha$  is mean zero, all of the MSAs have posterior median  $\alpha < 0$ . When the residual in the cointegrating equation is positive (negative), gasoline prices are above (below) the long-run equilibrium. Thus, the value  $\alpha < 0$  implies that the error correction term pushes gasoline prices back toward the long-run equilibrium, regardless of whether gasoline prices are above or below it. Note also that the MSAs with faster speeds of adjustment—larger in absolute value—are mostly located in the Great Lakes and Southeast regions.

We next consider the asymmetric model using, separately, the two different indicators discussed above: (i) increasing or decreasing oil prices (left panels of Figure 5) and (ii) gas prices above or below the long-run equilibrium (right panels of Figure 5). Panel A (Panel C) of Figure 5 shows the geographic distribution of the speed of adjustment parameter when the oil price is decreasing (increasing). As is the case for the symmetric model, both  $\alpha^+ < 0$  and  $\alpha^- < 0$  imply that, regardless of whether oil prices are increasing or decreasing, the error

**Figure 4****Speed of Adjustment ( $\alpha$ ) Across MSAs in the Symmetric Model**

SOURCE: EIA, GasBuddy, and the gasoline tax sources noted in the appendix.

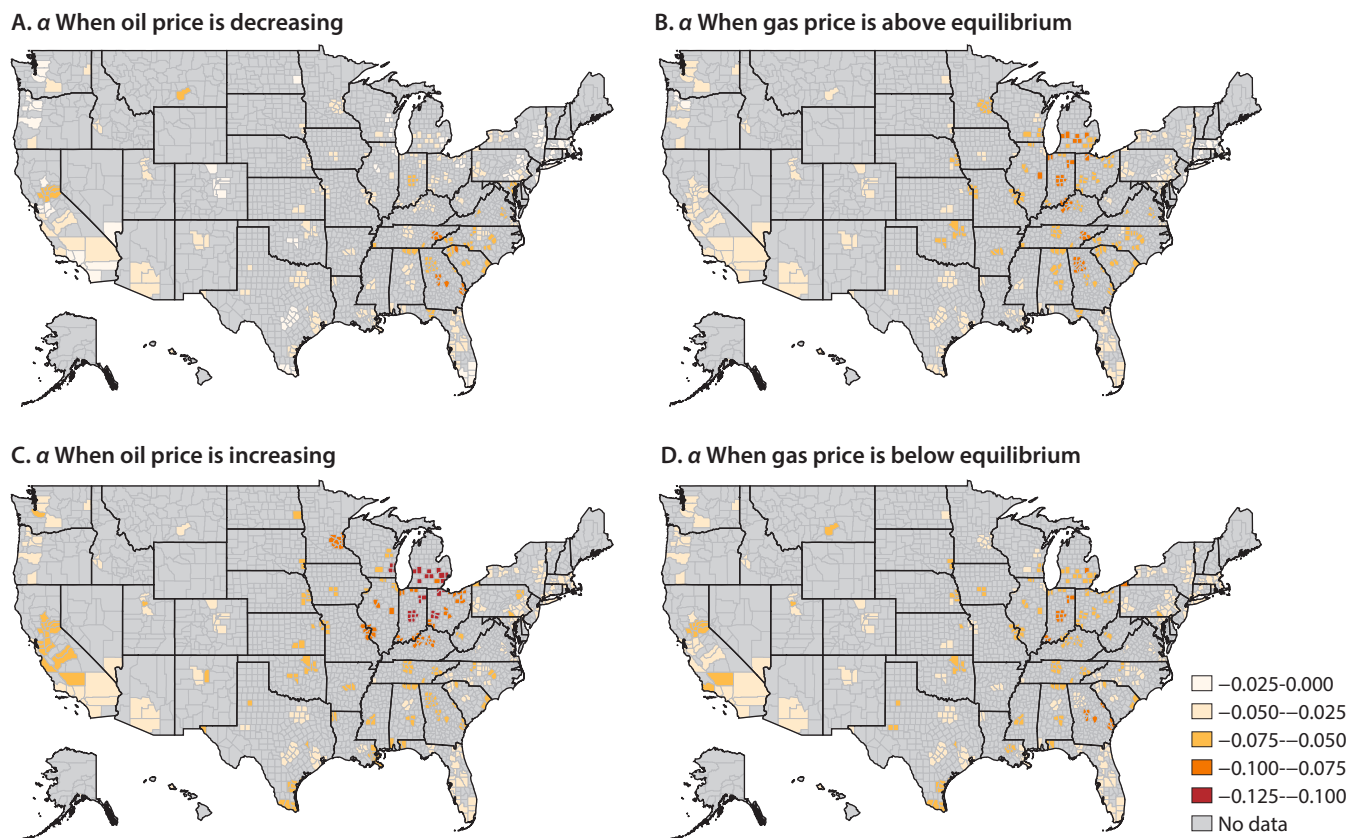
correction term pushes gasoline prices back toward the long-run equilibrium. Moreover, for most MSAs,  $\alpha^+ < \alpha^- < 0$ , suggesting that gasoline prices correct faster when oil prices are increasing than when they are decreasing. For example, in Detroit, Michigan—an MSA with a relatively large degree of asymmetry—the speed of adjustment back to the long-run equilibrium between gasoline and oil prices when oil prices are increasing is four times larger than the speed of adjustment when oil prices are decreasing ( $\alpha^+ = -0.1$ ,  $\alpha^- = -0.025$ ). To illustrate, this would mean that if in Detroit in a given week gas prices were 50 cents below the long-run equilibrium between gas and oil prices, and oil prices increased that week, then the speed of adjustment would contribute +5 cents to the change in gasoline prices the proximate week. If in a given week gas prices were 50 cents above the long-run equilibrium and oil prices decreased that week, then the speed of adjustment would contribute -1.25 cents to the change in gasoline prices the proximate week.

Panel B (Panel D) of Figure 5 shows the geographic distribution of the speed of adjustment parameter when gasoline prices are above (below) their long-run relationship with oil prices. A similar interpretation of the signs and magnitudes of  $\alpha$  can be made for this indicator, though the relationship appears weaker, with less differentiation between  $\alpha^+$  and  $\alpha^-$ .

Although the results are starkest when the speed of adjustment depends on the direction of oil price changes, there are a few general takeaways from Figure 5. When oil prices fall, the speed of adjustment is slow ( $|\alpha|$  is small) for essentially all of the MSAs in the sample. When oil prices rise, the speed of adjustment is typically greater; in some cases in the Great Lakes,

**Figure 5**

**Speed of Adjustment ( $\alpha$ ) Across MSAs for the Asymmetric Model**



SOURCE: EIA, GasBuddy, and the gasoline tax sources noted in the appendix.

the speed of adjustment is substantially greater. Thus, the symmetric model tends to overestimate the magnitude of the speed of adjustment when oil prices are falling and underestimate the magnitude of the speed of adjustment when oil prices are rising. There is, however, some evidence for the symmetric model: The 68 percent centered posterior coverage for the difference between  $\alpha^+$  and  $\alpha^-$  includes 0 for some MSAs when asymmetries are driven by the sign of oil price changes and for a vast majority of MSAs when the asymmetries are driven by gasoline prices relative to the long-run equilibrium.

### 4.3 Explaining the Heterogeneity

Finally, we consider the MSA-level factors that might affect the speed of adjustment. While mapping the speed of adjustment parameters can suggest geographic relationships, we now perform a formal evaluation of whether regional supply or demand effects have roles in creating asymmetries, focusing on asymmetries under the specification where the speed of adjustment parameter varies by whether the oil price is increasing or decreasing.

**Table 1****Multivariate Regression Results**

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Population density	-0.005*										
Car commute percentage		-0.025*									
Commute time per worker			-0.063*			-0.083*	0.006	-0.063*	0.012	-0.088*	0.012
Hospitality industry share of GDP				-0.409*							
Distance from Cushing, OK					-0.018*	0.008			0.018	0.009	0.017
Level of taxes							-0.052		-0.093		-0.087
Proportional taxes								0.004		0.001	0.004

NOTE: \*0 is not included in the coefficient's 68 percent centered posterior coverage.

SOURCE: ACS, GasBuddy, EIA, the Missouri Population Data Center's MABLE/Geocorr12k Geographic Correspondence Engine, BEA, U.S. Geological Survey, and the gasoline tax sources noted in the appendix.

Table 1 presents the results from the estimation of equation (7) for  $\Delta\alpha$  as the dependent variable and a number of combinations of explanatory variables. In each case, we use a single demand-side variable with combinations of the supply-side variable and the fiscal environment. All of the estimated coefficients that do not contain 0 in the 68 percent coverage interval are negative, suggesting that larger asymmetries appear to be associated with higher gasoline demand across all demand-side variables. Moreover, increasing the distance from Cushing, Oklahoma, also appears to increase the speed of adjustment. When considering multiple demand-side variables simultaneously (results not reported here), we find that commute time per worker remains statistically relevant, while other demand-side variables do not. We conclude that, of the variables we consider, commute time per worker is the best measure of gasoline demand, at least in so far as it relates to measured asymmetries. However, when combined with supply and fiscal variables, the statistical importance of commute time varies across specifications.

The preceding analysis appears inconclusive as to the source of heterogeneity in the magnitudes of the asymmetries across cities. Because we do not observe statistically relevant asymmetries in every MSA, we now ask whether these same MSA-level covariates can explain the presence of asymmetries. As we mentioned above, for each MSA, we create an indicator that takes a value of 1 if that MSA exhibits asymmetry and 0 if it does not. We assume that the MSA exhibits asymmetry if the difference between  $\alpha^+$  and  $\alpha^-$  does not include 0 in its 68 percent (centered) posterior coverage. We then estimate the probit from equation (8).

Table 2 shows the results of the probit regressions on combinations of a few demand-side variables, our main supply-side variable, and the level of taxes.<sup>8</sup> We find that increasing any of the demand-side variables decreases the likelihood of asymmetric adjustment. Coupled

**Table 2****Probit Regression Results**

	(1)	(2)	(3)	(4)	(5)
Car commute percentage	-2.567*				
Commute time per worker		-3.772*			-3.204
Multicar households			-5.684*		
Hospitality industry share of GDP				-13.634*	-11.077*
Distance from Cushing, OK	-2.141*	-1.536*	-1.713*	-1.470*	-1.7*
Level of taxes	6.493*	3.424*	4.365*	1.684*	4.042*

NOTE: \*0 is not included in the coefficient's 68 percent centered posterior coverage.

SOURCE: ACS, GasBuddy, EIA, the Missouri Population Data Center's MABLE/Geocorr12k Geographic Correspondence Engine, BEA, U.S. Geological Survey, and the gasoline tax sources noted in the appendix.

with the previous results, MSAs with higher demand are less likely to have asymmetries—but when they do, higher demand appears (weakly) correlated with larger asymmetry magnitudes. A similar result occurs when increasing the distance from the settlement site. Finally, increasing taxes appears to increase the likelihood of asymmetries. A possible explanation for this result is that gasoline retailers in regions with higher levels of taxes may not be able to mark up prices as high and therefore have lower profit margins; thus when oil prices rise, retailers may need to increase prices faster to maintain their slim profit margins, and when oil prices fall, retailers drop their prices slowly to maximize their profit margin, resulting in asymmetric pass-through.

## 5 CONCLUSIONS

We revisited models of asymmetric adjustment in how gasoline prices respond to changes in oil prices. In particular, we explore whether asymmetric adjustment is heterogeneous across cities and why. We find mixed evidence of asymmetries across MSAs when the asymmetries are driven by the direction of oil price changes. Consistent with the previous literature, when oil prices rise, gasoline prices adjust faster than when oil prices fall.

When considering the factors that either cause asymmetries or determine their magnitudes, we find mixed evidence that demand-side factors—for example, commute time per worker—increase the magnitude of any asymmetry but actually reduce the likelihood that asymmetries exist. On the other hand, in cities where the nominal level of taxes is high, asymmetries are more likely; this result is robust to the inclusion of supply- or demand-side variables. ■

## APPENDIX

Data for this article fall into four categories:

- (i) Geocoding data
- (ii) Oil and gasoline prices
- (iii) Gasoline taxes
- (iv) MSA-level covariates

The sections below provide additional information on sources, assumptions, and calculations associated with each category of data.

### A1 GEOCODING DATA

In our analysis, the geographic unit of observation is a GasBuddy ID region (GBID). We obtained our average gas price data from GasBuddy.com. Over the time frame of our sample period, GasBuddy reported average gas price data according to custom geographic definitions.<sup>9</sup> We use these definitions to geocode cities/Census designated places/counties to GBIDs in order to (i) weight gasoline taxes for each GBID and (ii) calculate regional covariates.

Each GBID spans many counties and cities, and some even span multiple states. To prepare the average gasoline price data for analysis, we subtract out the federal, state, and local taxes included in the retail price of gasoline (see Section A3 for more information on the tax data). We weight these taxes by the proportion of the GBID population that is affected by the tax. We use 2010 U.S. Census population data from the Missouri Census Data Center to calculate these weights.

### A2 OIL AND GASOLINE PRICES

#### *Oil Prices*

For oil prices, we use the WTI domestic spot market price (Cushing, Oklahoma) in dollars per barrel from the EIA.

We use the average of daily values for a given week for each weekly value, with a week defined as the seven day period from Sunday to Saturday. As oil prices are only reported on non-holiday weekdays, the weekly value is the average of Monday through Friday oil prices, excluding holidays.

#### *Gasoline Prices*

The average retail gas price data for each region were purchased from GasBuddy.com. These data reflect the average retail price per gallon for regular unleaded gasoline.

The data reported from GasBuddy are weekly data, with week 1 defined as January 1 to the proximate Saturday. To match these gas data with oil price data, we redefine a week as the seven day period from Sunday to Saturday that contains January 1. This means that the week 1 gas price for a given region in a given year is the weighted average of the last week from the previous year and week 1 data from the given year in the GasBuddy dataset. We seasonally

adjust the realized weekly gas and oil price series by regressing each one on 52 “week of year” dummies and then subtracting the relevant estimated “week of year” coefficients from the original series.

### A3 GASOLINE TAXES

To obtain the average gas price less taxes for each region, we collected motor fuel tax data for all U.S. states for the time period 2005-13 (Table A3.1). We categorize motor fuel taxes imposed on retail gasoline into six categories:

- (i) Federal excise tax: The federal excise tax on gasoline was 18.4 cents per gallon for all states across the entire sample period (Tax Policy Center, 2020).
- (ii) State excise tax
- (iii) State fees
- (iv) State sales tax: State sales tax on gasoline is applied differently from state to state. Many states exempt gasoline from general sales tax, but a few do not.
- (v) Wholesale tax: Some states impose a wholesale tax on gasoline. To estimate this tax, we assume that the wholesale price of gasoline is 80 percent of the retail price based on information from the EIA found here: <https://www.eia.gov/petroleum/gasdiesel/>.
- (vi) Local taxes: Local taxes consist of county, city, and business district taxes.

We assume that all taxes and fees on gasoline are fully passed on to the consumer and thus are reflected in the retail price of gasoline. Some taxes are reported as percentages and others are reported in dollars per gallon. As indicated in the previous section, we weight the application of taxes by the proportion of the GBID population that is affected by the tax. We calculated the net-of-taxes retail price,  $G_t$ , as

$$G_t = \frac{P_t - D_t}{1 + T_t} - (W_t R_t),$$

where  $P_t$  denotes the observed gasoline price;  $D_t$  denotes any federal excise taxes, state excise taxes, state fees, state sales taxes, or local taxes imposed in dollars per gallon; and  $T_t$  denotes any of those taxes imposed as percentages of gross sales. We subtract out wholesale taxes via the  $(W_t R_t)$  term, where  $W_t$  indicates the wholesale tax on gasoline and  $R_t$  indicates the estimated wholesale price of gasoline.

For the sources and notes for the tax data by state, see the Excel file available at <https://research.stlouisfed.org/publications/review/2021/07/01/regional-gasoline-price-dynamics>. For states, counties, or cities without a full history of tax data, we assumed that the various fees and taxes did not change during the sample period.

No GBIDs overlap any region of Wyoming, Maine, New Hampshire, or Washington, DC. Those states and Washington, DC, therefore, are omitted from the state data.



**Table A3.1**  
**MSA Average Tax Summary**

MSA	Dollars per gallon taxes						Proportional taxes				Avg. nominal retail price		Tax fraction of retail price
	Federal excise	State excise	State fees	State sales	County	City	State sales	County	City	Wholesale (\$/gallon)	Avg. level of taxes (\$/gallon)	Avg. level of taxes (\$/gallon)	
Anchorage, AK	0.18	0.07	0.00	0.00	0.00	0.00	0.00%	0.00%	0.00%	0.00%	\$3.23	\$0.25	0.08
Birmingham, AL	0.18	0.16	0.01	0.00	0.01	0.00	0.00%	0.00%	0.00%	0.00%	\$2.82	\$0.36	0.13
Huntsville, AL	0.18	0.16	0.01	0.00	0.03	0.01	0.00%	0.00%	0.00%	0.00%	\$2.89	\$0.40	0.14
Mobile, AL	0.18	0.16	0.01	0.00	0.02	0.04	0.00%	0.00%	0.00%	0.00%	\$2.82	\$0.41	0.15
Montgomery, AL	0.18	0.16	0.01	0.00	0.01	0.04	0.00%	0.00%	0.00%	0.00%	\$2.81	\$0.40	0.14
Little Rock, AR	0.18	0.22	0.00	0.00	0.00	0.00	0.00%	0.00%	0.00%	0.00%	\$2.80	\$0.40	0.14
Phoenix, AZ	0.18	0.18	0.01	0.00	0.00	0.00	0.00%	0.00%	0.00%	0.00%	\$2.90	\$0.37	0.13
Tucson, AZ	0.18	0.18	0.01	0.00	0.00	0.00	0.00%	0.00%	0.00%	0.00%	\$2.81	\$0.37	0.13
Bakersfield, CA	0.18	0.25	0.02	0.00	0.00	0.00	5.6%	0.0%	0.1%	0.0%	\$3.23	\$0.59	0.18
Chico, CA	0.18	0.25	0.02	0.00	0.00	0.00	5.6%	0.0%	0.0%	0.0%	\$3.19	\$0.58	0.18
Fresno, CA	0.18	0.25	0.02	0.00	0.00	0.00	5.6%	0.7%	0.0%	0.0%	\$3.21	\$0.60	0.19
Los Angeles, CA	0.18	0.25	0.02	0.00	0.00	0.00	5.6%	1.2%	0.0%	0.0%	\$3.26	\$0.62	0.19
Modesto, CA	0.18	0.25	0.02	0.00	0.00	0.00	5.6%	0.1%	0.0%	0.0%	\$3.18	\$0.59	0.18
Oakland, CA	0.18	0.25	0.02	0.00	0.00	0.00	5.6%	1.3%	0.0%	0.0%	\$3.26	\$0.62	0.19
Orange County, CA	0.18	0.25	0.02	0.00	0.00	0.00	5.6%	0.5%	0.0%	0.0%	\$3.25	\$0.60	0.18
Riverside, CA	0.18	0.25	0.02	0.00	0.00	0.00	5.6%	0.5%	0.0%	0.0%	\$3.22	\$0.60	0.19
Sacramento, CA	0.18	0.25	0.02	0.00	0.00	0.00	5.6%	0.3%	0.1%	0.0%	\$3.40	\$0.61	0.18
Salinas, CA	0.18	0.25	0.02	0.00	0.00	0.00	5.6%	0.0%	0.4%	0.0%	\$3.24	\$0.60	0.18
San Bernardino, CA	0.18	0.25	0.02	0.00	0.00	0.00	5.6%	0.5%	0.0%	0.0%	\$3.23	\$0.60	0.19
San Diego, CA	0.18	0.25	0.02	0.00	0.00	0.00	5.6%	0.5%	0.1%	0.0%	\$3.25	\$0.60	0.18
San Francisco, CA	0.18	0.25	0.02	0.00	0.00	0.00	5.6%	1.1%	0.0%	0.0%	\$3.34	\$0.62	0.19
San Jose, CA	0.18	0.25	0.02	0.00	0.00	0.00	5.6%	1.0%	0.0%	0.0%	\$3.27	\$0.61	0.19
Santa Barbara, CA	0.18	0.25	0.02	0.00	0.00	0.00	5.6%	0.5%	0.0%	0.0%	\$3.35	\$0.60	0.18
Stockton, CA	0.18	0.25	0.02	0.00	0.00	0.00	5.6%	0.5%	0.2%	0.0%	\$3.19	\$0.60	0.19
Ventura, CA	0.18	0.25	0.02	0.00	0.00	0.00	5.6%	0.0%	0.1%	0.0%	\$3.27	\$0.59	0.18
Colorado Springs, CO	0.18	0.22	0.00	0.00	0.00	0.00	0.0%	0.0%	0.0%	0.0%	\$2.85	\$0.40	0.14
Denver, CO	0.18	0.22	0.00	0.00	0.00	0.00	0.0%	0.0%	0.0%	0.0%	\$2.84	\$0.40	0.14
Fort Collins, CO	0.18	0.22	0.00	0.00	0.00	0.00	0.0%	0.0%	0.0%	0.0%	\$2.85	\$0.40	0.14
Bridgeport, CT	0.18	0.25	0.00	0.00	0.00	0.00	0.0%	0.0%	0.0%	7.5%	\$3.17	\$0.63	0.20

**Table A3.1, cont'd**  
**MSA Average Tax Summary**

MSA	Dollars per gallon taxes					Proportional taxes			Avg. nominal retail price (\$/gallon)	Avg. level of taxes (\$/gallon)	Tax fraction of retail price		
	Federal excise	State excise	State fees	State sales	County	City	State sales	County				City	Wholesale
Hartford, CT	0.18	0.25	0.00	0.00	0.00	0.00	0.0%	0.0%	0.0%	7.5%	\$3.11	\$0.62	0.20
New Haven, CT	0.18	0.25	0.00	0.00	0.00	0.00	0.0%	0.0%	0.0%	7.5%	\$3.11	\$0.62	0.20
Waterbury, CT	0.18	0.25	0.00	0.00	0.00	0.00	0.0%	0.0%	0.0%	7.5%	\$3.12	\$0.63	0.20
Wilmington, DE	0.18	0.23	0.00	0.00	0.00	0.00	1.7%	0.0%	0.0%	1.6%	\$2.92	\$0.49	0.17
Cape Coral, FL	0.18	0.16	0.08	0.00	0.12	0.00	0.0%	0.0%	0.0%	0.0%	\$2.97	\$0.55	0.18
Gainesville, FL	0.18	0.16	0.08	0.00	0.10	0.00	0.0%	0.0%	0.0%	0.0%	\$3.02	\$0.53	0.18
Jacksonville, FL	0.18	0.16	0.08	0.00	0.06	0.00	0.0%	0.0%	0.0%	0.0%	\$2.93	\$0.49	0.17
Miami, FL	0.18	0.16	0.08	0.00	0.11	0.00	0.0%	0.0%	0.0%	0.0%	\$3.03	\$0.54	0.18
Naples, FL	0.18	0.16	0.08	0.00	0.12	0.00	0.0%	0.0%	0.0%	0.0%	\$3.03	\$0.55	0.18
Ocala, FL	0.18	0.16	0.08	0.00	0.08	0.00	0.0%	0.0%	0.0%	0.0%	\$2.93	\$0.51	0.17
Orlando, FL	0.18	0.16	0.08	0.00	0.07	0.00	0.0%	0.0%	0.0%	0.0%	\$2.91	\$0.49	0.17
Pensacola, FL	0.18	0.16	0.08	0.00	0.07	0.00	0.0%	0.0%	0.0%	0.0%	\$2.94	\$0.50	0.17
Sarasota, FL	0.18	0.16	0.08	0.00	0.12	0.00	0.0%	0.0%	0.0%	0.0%	\$2.95	\$0.54	0.18
Tallahassee, FL	0.18	0.16	0.08	0.00	0.07	0.00	0.0%	0.0%	0.0%	0.0%	\$2.93	\$0.50	0.17
Tampa, FL	0.18	0.16	0.08	0.00	0.08	0.00	0.0%	0.0%	0.0%	0.0%	\$2.90	\$0.50	0.17
Atlanta, GA	0.18	0.07	0.00	0.10	0.00	0.00	0.0%	2.7%	0.2%	0.0%	\$2.87	\$0.43	0.15
Augusta, GA	0.18	0.07	0.00	0.10	0.00	0.00	0.0%	3.1%	0.0%	0.0%	\$2.84	\$0.43	0.15
Macon, GA	0.18	0.07	0.00	0.10	0.00	0.00	0.0%	2.8%	0.0%	0.0%	\$2.88	\$0.43	0.15
Savannah, GA	0.18	0.07	0.00	0.10	0.00	0.00	0.0%	2.8%	0.0%	0.0%	\$3.05	\$0.44	0.15
Honolulu, HI	0.18	0.17	0.01	0.00	0.17	0.00	4.0%	0.4%	0.0%	0.5%	\$3.42	\$0.66	0.19
Des Moines, IA	0.18	0.21	0.01	0.00	0.00	0.00	0.0%	0.0%	0.0%	0.0%	\$2.84	\$0.40	0.14
Quad Cities, IA	0.18	0.20	0.01	0.00	0.00	0.00	0.0%	0.0%	0.4%	0.0%	\$2.90	\$0.40	0.14
Boise, ID	0.18	0.25	0.00	0.00	0.00	0.00	0.0%	0.0%	0.0%	0.0%	\$2.98	\$0.43	0.15
Champaign, IL	0.18	0.19	0.01	0.00	0.00	0.00	0.0%	0.7%	1.1%	0.0%	\$2.96	\$0.43	0.15
Chicago, IL	0.18	0.19	0.01	0.00	0.00	0.00	0.0%	1.8%	1.0%	0.0%	\$3.20	\$0.47	0.15
Peoria, IL	0.18	0.19	0.01	0.00	0.00	0.00	0.0%	0.6%	1.1%	0.0%	\$2.98	\$0.43	0.14
Rockford, IL	0.18	0.19	0.01	0.00	0.00	0.00	0.0%	1.0%	0.5%	0.0%	\$3.01	\$0.42	0.14
Evansville, IN	0.18	0.18	0.01	0.12	0.00	0.00	0.0%	0.0%	0.0%	0.0%	\$2.97	\$0.50	0.17
Fort Wayne, IN	0.18	0.18	0.01	0.12	0.00	0.00	0.0%	0.0%	0.0%	0.0%	\$3.02	\$0.50	0.17

**Table A3.1, cont'd**  
**MSA Average Tax Summary**

MSA	Dollars per gallon taxes					Proportional taxes			Avg. nominal		Tax fraction of retail price		
	Federal excise	State excise	State fees	State sales	County	City	State sales	County	City	Wholesale (\$/gallon)		Avg. level of taxes (\$/gallon)	
Gary, IN	0.18	0.18	0.01	0.12	0.00	0.00	0.0%	0.0%	0.0%	0.0%	\$3.00	\$0.50	0.17
Indianapolis, IN	0.18	0.18	0.01	0.12	0.00	0.00	0.0%	0.0%	0.0%	0.0%	\$2.94	\$0.50	0.17
South Bend, IN	0.18	0.18	0.01	0.12	0.00	0.00	0.0%	0.0%	0.0%	0.0%	\$3.03	\$0.50	0.17
Topeka, KS	0.18	0.24	0.01	0.00	0.00	0.00	0.0%	0.0%	0.0%	0.0%	\$2.88	\$0.43	0.15
Wichita, KS	0.18	0.24	0.01	0.00	0.00	0.00	0.0%	0.0%	0.0%	0.0%	\$2.81	\$0.43	0.15
Lexington, KY	0.18	0.22	0.01	0.00	0.00	0.00	0.0%	0.0%	0.0%	0.0%	\$2.89	\$0.42	0.15
Louisville, KY	0.18	0.21	0.01	0.02	0.00	0.00	0.0%	0.0%	0.0%	0.0%	\$2.93	\$0.43	0.15
Baton Rouge, LA	0.18	0.20	0.00	0.00	0.00	0.00	0.0%	0.0%	0.0%	0.0%	\$2.88	\$0.39	0.13
New Orleans, LA	0.18	0.20	0.00	0.00	0.00	0.00	0.0%	0.0%	0.0%	0.0%	\$2.81	\$0.39	0.14
Shreveport, LA	0.18	0.20	0.00	0.00	0.00	0.00	0.0%	0.0%	0.0%	0.0%	\$2.80	\$0.39	0.14
Boston, MA	0.18	0.21	0.03	0.00	0.00	0.00	0.0%	0.0%	0.0%	0.0%	\$2.96	\$0.42	0.14
Springfield, MA	0.18	0.21	0.03	0.00	0.00	0.00	0.0%	0.0%	0.0%	0.0%	\$2.94	\$0.42	0.14
Worcester, MA	0.18	0.21	0.03	0.00	0.00	0.00	0.0%	0.0%	0.0%	0.0%	\$2.96	\$0.42	0.14
Baltimore, MD	0.18	0.24	0.00	0.00	0.00	0.00	0.0%	0.0%	0.0%	0.0%	\$2.91	\$0.42	0.14
Hagerstown, MD	0.18	0.24	0.00	0.00	0.00	0.00	0.0%	0.0%	0.0%	0.0%	\$2.94	\$0.42	0.14
Ann Arbor, MI	0.18	0.19	0.01	0.15	0.00	0.00	0.0%	0.0%	0.0%	0.0%	\$3.08	\$0.54	0.17
Detroit, MI	0.18	0.19	0.01	0.15	0.00	0.00	0.0%	0.0%	0.0%	0.0%	\$2.98	\$0.53	0.18
Flint, MI	0.18	0.19	0.01	0.15	0.00	0.00	0.0%	0.0%	0.0%	0.0%	\$3.04	\$0.54	0.18
Grand Rapids, MI	0.18	0.19	0.01	0.15	0.00	0.00	0.0%	0.0%	0.0%	0.0%	\$3.01	\$0.53	0.18
Kalamazoo, MI	0.18	0.19	0.01	0.15	0.00	0.00	0.0%	0.0%	0.0%	0.0%	\$3.05	\$0.54	0.18
Lansing, MI	0.18	0.19	0.01	0.15	0.00	0.00	0.0%	0.0%	0.0%	0.0%	\$3.00	\$0.53	0.18
Minneapolis, MN	0.18	0.24	0.00	0.00	0.00	0.00	0.0%	0.0%	0.0%	0.0%	\$2.90	\$0.43	0.15
Kansas City, MO	0.18	0.20	0.01	0.00	0.00	0.00	0.0%	0.0%	0.0%	0.0%	\$2.79	\$0.39	0.14
St. Louis, MO	0.18	0.17	0.01	0.00	0.00	0.00	0.0%	0.0%	0.1%	0.0%	\$2.83	\$0.37	0.13
Jackson, MS	0.18	0.18	0.00	0.00	0.00	0.00	0.0%	0.0%	0.0%	0.0%	\$2.78	\$0.37	0.13
Billings, MT	0.18	0.27	0.01	0.00	0.00	0.00	0.0%	0.0%	0.0%	0.0%	\$2.95	\$0.46	0.16
Asheville, NC	0.18	0.32	0.00	0.00	0.00	0.00	0.0%	0.0%	0.0%	0.0%	\$2.93	\$0.50	0.17
Charlotte, NC	0.18	0.32	0.00	0.00	0.00	0.00	0.0%	0.0%	0.0%	0.0%	\$2.93	\$0.50	0.17
Durham, NC	0.18	0.32	0.00	0.00	0.00	0.00	0.0%	0.0%	0.0%	0.0%	\$2.95	\$0.50	0.17

**Table A3.1, cont'd**  
**MSA Average Tax Summary**

MSA	Dollars per gallon taxes				Proportional taxes				Avg. nominal retail price (\$/gallon)	Avg. level of taxes (\$/gallon)	Tax fraction of retail price	
	Federal excise	State excise	State fees	State sales	County	City	State sales	County				City
Fayetteville, NC	0.18	0.32	0.00	0.00	0.00	0.00	0.0%	0.0%	0.0%	\$2.91	\$0.50	0.17
Greensboro, NC	0.18	0.32	0.00	0.00	0.00	0.00	0.0%	0.0%	0.0%	\$2.89	\$0.50	0.17
Raleigh, NC	0.18	0.32	0.00	0.00	0.00	0.00	0.0%	0.0%	0.0%	\$2.92	\$0.50	0.17
Winston, NC	0.18	0.32	0.00	0.00	0.00	0.00	0.0%	0.0%	0.0%	\$2.95	\$0.51	0.17
Fargo, ND	0.18	0.23	0.00	0.00	0.00	0.00	0.0%	0.0%	0.0%	\$2.91	\$0.41	0.14
Lincoln, NE	0.18	0.26	0.01	0.00	0.00	0.00	0.0%	0.0%	0.0%	\$2.97	\$0.45	0.15
Omaha, NE	0.18	0.26	0.01	0.00	0.00	0.00	0.0%	0.0%	0.0%	\$2.92	\$0.45	0.16
Toms River, NJ	0.18	0.11	0.04	0.00	0.00	0.00	0.0%	0.0%	0.0%	\$2.87	\$0.33	0.11
Trenton, NJ	0.18	0.11	0.04	0.00	0.00	0.00	0.0%	0.0%	0.0%	\$2.86	\$0.33	0.12
Albuquerque, NM	0.18	0.17	0.02	0.00	0.00	0.00	0.0%	0.0%	0.0%	\$2.85	\$0.37	0.13
Santa FE, NM	0.18	0.17	0.02	0.00	0.00	0.00	0.0%	0.0%	0.0%	\$2.92	\$0.37	0.13
Las Vegas, NV	0.18	0.24	0.00	0.00	0.00	0.00	0.0%	0.0%	0.0%	\$3.01	\$0.43	0.14
Albany, NY	0.18	0.08	0.17	0.07	0.05	0.00	3.4%	0.1%	0.0%	\$3.10	\$0.65	0.21
Buffalo, NY	0.18	0.08	0.17	0.07	0.00	0.00	4.6%	0.0%	0.0%	\$3.14	\$0.63	0.20
Long Island, NY	0.18	0.08	0.17	0.07	0.01	0.00	4.1%	0.0%	0.0%	\$3.20	\$0.64	0.20
New York, NY	0.18	0.08	0.17	0.07	0.00	0.01	0.2%	4.1%	0.0%	\$3.21	\$0.64	0.20
Rochester, NY	0.18	0.08	0.17	0.07	0.00	0.00	4.0%	0.0%	0.0%	\$3.13	\$0.62	0.20
Syracuse, NY	0.18	0.08	0.17	0.07	0.08	0.00	3.1%	0.0%	0.0%	\$3.10	\$0.67	0.22
Akron, OH	0.18	0.28	0.00	0.00	0.00	0.00	0.0%	0.0%	0.0%	\$2.91	\$0.46	0.16
Cincinnati, OH	0.18	0.28	0.00	0.00	0.00	0.00	0.0%	0.0%	0.0%	\$2.92	\$0.46	0.16
Cleveland, OH	0.18	0.28	0.00	0.00	0.00	0.00	0.0%	0.0%	0.0%	\$2.92	\$0.46	0.16
Columbus, OH	0.18	0.28	0.00	0.00	0.00	0.00	0.0%	0.0%	0.0%	\$2.91	\$0.46	0.16
Dayton, OH	0.18	0.28	0.00	0.00	0.00	0.00	0.0%	0.0%	0.0%	\$2.90	\$0.46	0.16
Toledo, OH	0.18	0.28	0.00	0.00	0.00	0.00	0.0%	0.0%	0.0%	\$2.91	\$0.46	0.16
Oklahoma City, OK	0.18	0.16	0.01	0.00	0.00	0.00	0.0%	0.0%	0.0%	\$2.77	\$0.35	0.13
Tulsa, OK	0.18	0.16	0.01	0.00	0.00	0.00	0.0%	0.0%	0.0%	\$2.74	\$0.35	0.13
Eugene, OR	0.18	0.26	0.00	0.00	0.00	0.04	0.0%	0.0%	0.0%	\$3.09	\$0.48	0.16
Medford, OR	0.18	0.26	0.00	0.00	0.00	0.00	0.0%	0.0%	0.0%	\$3.13	\$0.44	0.14
Portland, OR	0.18	0.26	0.00	0.00	0.02	0.00	0.0%	0.0%	0.0%	\$3.05	\$0.46	0.15

**Table A3.1, cont'd**  
**MSA Average Tax Summary**

MSA	Dollars per gallon taxes					Proportional taxes				Avg. nominal			
	Federal excise	State excise	State fees	State sales	County	City	State sales	County	City	Wholesale (\$/gallon)	Avg. level of taxes (\$/gallon)	Tax fraction of retail price	
Salem, OR	0.18	0.26	0.00	0.00	0.00	0.00	0.0%	0.0%	0.0%	0.0%	\$3.05	\$0.44	0.15
Allentown, PA	0.18	0.31	0.01	0.00	0.00	0.00	0.0%	0.0%	0.0%	0.0%	\$2.95	\$0.51	0.17
Erie, PA	0.18	0.31	0.01	0.00	0.00	0.00	0.0%	0.0%	0.0%	0.0%	\$3.04	\$0.51	0.17
Harrisburg, PA	0.18	0.31	0.01	0.00	0.00	0.00	0.0%	0.0%	0.0%	0.0%	\$2.98	\$0.51	0.17
Lancaster, PA	0.18	0.31	0.01	0.00	0.00	0.00	0.0%	0.0%	0.0%	0.0%	\$2.92	\$0.51	0.17
Philadelphia, PA	0.18	0.31	0.01	0.00	0.00	0.00	0.0%	0.0%	0.0%	0.0%	\$3.01	\$0.51	0.17
Pittsburgh, PA	0.18	0.31	0.01	0.00	0.00	0.00	0.0%	0.0%	0.0%	0.0%	\$2.99	\$0.51	0.17
Reading, PA	0.18	0.31	0.01	0.00	0.00	0.00	0.0%	0.0%	0.0%	0.0%	\$2.92	\$0.51	0.17
Scranton, PA	0.18	0.31	0.01	0.00	0.00	0.00	0.0%	0.0%	0.0%	0.0%	\$2.96	\$0.51	0.17
York, PA	0.18	0.31	0.01	0.00	0.00	0.00	0.0%	0.0%	0.0%	0.0%	\$2.97	\$0.51	0.17
Providence, RI	0.18	0.31	0.01	0.00	0.00	0.00	0.0%	0.0%	0.0%	0.0%	\$2.99	\$0.50	0.17
Columbia, SC	0.18	0.16	0.01	0.00	0.00	0.00	0.0%	0.0%	0.0%	0.0%	\$2.77	\$0.35	0.13
Greenville, SC	0.18	0.16	0.01	0.00	0.00	0.00	0.0%	0.0%	0.0%	0.0%	\$2.72	\$0.35	0.13
Myrtle Beach, SC	0.18	0.16	0.01	0.00	0.00	0.00	0.0%	0.0%	0.0%	0.0%	\$2.79	\$0.35	0.13
Spartanburg, SC	0.18	0.16	0.01	0.00	0.00	0.00	0.0%	0.0%	0.0%	0.0%	\$2.71	\$0.35	0.13
Sioux Falls, SD	0.18	0.22	0.02	0.00	0.00	0.00	0.0%	0.0%	0.0%	0.0%	\$2.98	\$0.42	0.14
Chattanooga, TN	0.18	0.20	0.01	0.00	0.00	0.00	0.0%	0.0%	0.0%	0.0%	\$2.84	\$0.40	0.14
Knoxville, TN	0.18	0.20	0.01	0.00	0.00	0.00	0.0%	0.0%	0.0%	0.0%	\$2.78	\$0.40	0.14
Memphis, TN	0.18	0.20	0.01	0.00	0.00	0.00	0.0%	0.0%	0.0%	0.0%	\$2.80	\$0.40	0.14
Nashville, TN	0.18	0.20	0.01	0.00	0.00	0.00	0.0%	0.0%	0.0%	0.0%	\$2.84	\$0.40	0.14
Austin, TX	0.18	0.20	0.00	0.00	0.00	0.00	0.0%	0.0%	0.0%	0.0%	\$2.82	\$0.38	0.14
College Station, TX	0.18	0.20	0.00	0.00	0.00	0.00	0.0%	0.0%	0.0%	0.0%	\$2.88	\$0.38	0.13
Corpus Christi, TX	0.18	0.20	0.00	0.00	0.00	0.00	0.0%	0.0%	0.0%	0.0%	\$2.84	\$0.38	0.14
Dallas, TX	0.18	0.20	0.00	0.00	0.00	0.00	0.0%	0.0%	0.0%	0.0%	\$2.83	\$0.38	0.14
El Paso, TX	0.18	0.20	0.00	0.00	0.00	0.00	0.0%	0.0%	0.0%	0.0%	\$2.85	\$0.38	0.13
Fort Worth, TX	0.18	0.20	0.00	0.00	0.00	0.00	0.0%	0.0%	0.0%	0.0%	\$2.82	\$0.38	0.14
Houston, TX	0.18	0.20	0.00	0.00	0.00	0.00	0.0%	0.0%	0.0%	0.0%	\$2.81	\$0.38	0.14
Lubbock, TX	0.18	0.20	0.00	0.00	0.00	0.00	0.0%	0.0%	0.0%	0.0%	\$2.84	\$0.38	0.14
Midland-Odessa, TX	0.18	0.20	0.00	0.00	0.00	0.00	0.0%	0.0%	0.0%	0.0%	\$2.94	\$0.38	0.13

**Table A3.1, cont'd**  
**MSA Average Tax Summary**

MSA	Dollars per gallon taxes				Proportional taxes			Avg. nominal retail price (\$/gallon)	Avg. level of taxes (\$/gallon)	Tax fraction of retail price			
	Federal excise	State excise	State fees	State sales	County	City	State sales				County	City	Wholesale
Rio Grande Valley, TX	0.18	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	\$2.82	\$0.38	0.14
San Antonio, TX	0.18	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	\$2.80	\$0.38	0.14
Ogden, UT	0.18	0.25	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	\$2.88	\$0.43	0.15
Provo, UT	0.18	0.25	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	\$2.89	\$0.43	0.15
Salt Lake City, UT	0.18	0.25	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	\$2.88	\$0.43	0.15
Richmond, VA	0.18	0.17	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	\$2.83	\$0.36	0.13
Roanoke, VA	0.18	0.17	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	\$2.78	\$0.36	0.13
Virginia Beach, VA	0.18	0.17	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	\$2.82	\$0.37	0.13
Burlington, VT	0.18	0.20	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	\$3.02	\$0.42	0.14
Seattle, WA	0.18	0.36	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	\$3.15	\$0.54	0.17
Spokane, WA	0.18	0.36	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	\$3.06	\$0.54	0.18
Tacoma, WA	0.18	0.36	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	\$3.11	\$0.54	0.17
Yakima, WA	0.18	0.36	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	\$3.11	\$0.54	0.17
Appleton, WI	0.18	0.31	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	\$2.98	\$0.51	0.17
Madison, WI	0.18	0.31	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	\$2.97	\$0.51	0.17
Milwaukee, WI	0.18	0.31	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	\$3.00	\$0.51	0.17

NOTE: All reported pass-through results are associated with the regions as defined by the GasBuddy gasoline price data rather than by MSAs. Not all MSAs are represented by the GasBuddy data. The taxes listed under dollars per gallon taxes and proportional taxes are separate taxes. For example, the state sales tax listed under dollars per gallon taxes for an MSA is a separate tax from the state sales tax listed under proportional taxes for that MSA.

SOURCE: See the gasoline tax sources noted in this appendix.

## A4 MSA-LEVEL COVARIATES

In our analysis, we use MSA-level covariates to assess potential underlying causes of heterogeneous pass-through. We use MSA-level variables related to gasoline demand; the distance of the MSA from Cushing, Oklahoma; and the average level of taxes for the region over the sample period.

We calculate a majority of the gasoline demand variables using the ACS “Means of Transportation to Work by Selected Characteristics for Workplace Geography” dataset at the geographic level “Place” from the years 2010, 2011, and 2012 (2010 is the first dataset available). The 2010 dataset is an average of survey responses over the years 2006-10, the 2011 dataset is an average of survey responses over the years 2007-11, and the 2012 dataset is an average of survey responses over the years 2008-12. We use average values of each variable across the 2010, 2011, and 2012 datasets for our calculations. We then aggregate these average place-level values up to the MSA-level according to the GBIDs, weighting the aggregation by 2010 place-level population data from the Missouri Population Data Center’s MABLE/Geocorr12k Geographic Correspondence Engine. The ACS data were provided by the National Historical Geographic Information System.

Below are the definitions of the gasoline demand variables we calculate in terms of the ACS data. The results for the most relevant variables are reported in Section 4 of the article. Results for additional variables are available upon request.

$$\text{Car commute percentage} = \frac{\text{Number of workers who drove alone to work} + \text{Number of workers who carpoled}}{\text{Total number of workers}}$$

$$\text{Other commute percentage} = \frac{\begin{aligned} &\text{Number of workers who commuted by public transportation to work} \\ &+ \text{Number of workers who walked to work} \\ &+ \text{Number of workers who commuted by taxicab, motorcycle, bicycle, or other means} \end{aligned}}{\text{Total number of workers}}$$

$$\text{Commute time per worker} = \frac{\text{Aggregate travel time to work (hours)}}{\text{Total number of workers}}$$

$$\text{Commute time per vehicle} = \frac{\text{Aggregate travel time to work (hours)}}{\text{Aggregate number of vehicles (car, truck, or van) used in commuting}}$$

$$\text{Multicar households} = \frac{\text{Households where 3+ vehicles are available}}{\text{Total number of households}}$$

$$\text{Vehicles per worker} = \frac{\text{Aggregate number of vehicles (car, truck, or van) used in commuting}}{\text{Total number of workers}}$$

$$\text{Public transit option percentage} = \frac{\begin{aligned} &\text{Households with 1 vehicle available that use public transportation} \\ &+ \text{Households with 2 vehicles available that use public transportation} \\ &+ \text{Households with 3 vehicles available that use public transportation} \end{aligned}}{\text{Total number of households} - \text{Households that work from home}}$$

Related to gasoline demand, we also calculate the population density of the MSA by aggregating the (2010) population and land area (in square miles) of all of the Census-designated places within the (GasBuddy defined) MSAs. These data came from the Missouri Population Data Center's MABLE/Geocorr12k Geographic Correspondence Engine.

Related to gasoline demand, we also calculate each MSA's hospitality industry share of total GDP, assuming this reflects the relative gasoline demand for tourism-related vehicles across MSAs. We use county-level real GDP data for total GDP and for the NAICS Arts, Entertainment, and Recreation industry (71) and Accommodation and Food Services industry (72) GDP from the BEA, aggregating up to the MSA level and weighting by 2010 population. The GDP data are averaged over all available years, 2005-13.

The distance from Cushing, Oklahoma, for each MSA is calculated as the distance between the latitude and longitude coordinates of the downtown of each MSA's nominal city and downtown Cushing, Oklahoma. Latitude and longitude coordinates were obtained from [http://geonames.usgs.gov/domestic/download\\_data.htm](http://geonames.usgs.gov/domestic/download_data.htm), and the formula used to calculate the distance can be found here: <http://josephryanglover.com/the-poor-mans-proximity-tool-the-haversine-formula/#:~:text=The%20haversine%20formula%20is%20a,500%20meters%2C%20of%20a%20location>.

The average level of taxes over the sample period for each MSA is a simple average of the weekly values of total taxes applied to a gallon of gas in that region.

## NOTES

- <sup>1</sup> Asymmetries have also been studied in international markets, where evidence of asymmetries has been found for the United Kingdom (Bacon, 1991, and Reilly and Witt, 1998), Germany (Kirchgässner and Kübler, 1992), Sweden (Asplund, Eriksson, and Friberg, 2002), Australia (Valadkhani, 2013), and the Netherlands (Bettendorf, van der Geest, and Kuper, 2009) but not for Canada (Godby et al., 2000), or New Zealand (Liu, Margaritis, and Tourani-Rad, 2010). Grasso and Manera (2007) argue that finding asymmetric pass-through for the United Kingdom, France, Italy, Spain, and Germany is sensitive to model specification.
- <sup>2</sup> Douglas attributes asymmetry findings to outliers and argues that the majority of the weekly observations from 1990 to 2008 exhibit little evidence of asymmetry.
- <sup>3</sup> For details regarding gasoline data frequency, see the appendix.
- <sup>4</sup> We also conducted analysis adjusting prices by Census region consumer price indices (Northeast, South, Midwest, and West) and obtained similar results. Those results are available upon request.
- <sup>5</sup> We conduct ADF tests following an autoregressive model, an autoregressive model with drift, and an autoregressive model with drift and a time trend. For each series, we incorporate the number of lags that minimizes the Bayesian information criterion of the model, which for oil prices is eight lags and for gasoline prices is one lag. In the tests for oil prices, we cannot reject the null hypothesis of a unit root in the case of the autoregressive model. In the tests for gasoline prices, we cannot reject the null hypothesis of a unit root under any of the model specifications.
- <sup>6</sup> We use a Johansen test that models no intercepts or trends in the cointegrated series and assumes no deterministic trends in the levels of the data. We incorporate one lag in the model, following Schwarz Bayesian information criterion selection criteria.
- <sup>7</sup> For more details on the construction of these variables, see the appendix.
- <sup>8</sup> We also considered the binary tax variable, but it proved statistically irrelevant in all cases. Those results are available upon request.
- <sup>9</sup> These geographic definitions resemble MSAs, thus we use that terminology in the analysis. The custom geographic definitions are available from GasBuddy upon request.



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