Asymmetric Reactions of Retail Gasoline Prices on the Changes in Crude Oil Prices in Chosen US Cities

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Abstract

Many empirical studies state that retail gasoline and diesel prices react more quickly when the crude oil price rises rather than decreases. In the paper, we confirm these asymmetric reactions of retail fuel prices in selected cities in the United States of America. We use the adjustment cost function in the linear-exponential form to derive nonlinear retail gasoline and diesel reaction functions. The correspondent model is estimated with the system's generalised method of moments. The model allows us to compute average one-gallon gasoline and diesel price biases from the increase in oil by one dollar per barrel caused by the given asymmetric reactions. The average biases differ from city to city; their values are between 0.02 cents in Los Angeles and 0.44 cents in Cleveland.

Keywords: asymmetry; retail gasoline and diesel prices; linex adjustment cost function; generalised system method of moments
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Introduction

Several studies dealing with the transmission of crude oil prices to retail gasoline prices indicate that retail gasoline prices respond more quickly when crude oil price rises rather than when it decreases; e.g., Radchenko (2005) and Liu et al. (2010). Bacon (1991) called this asymmetric retail gasoline price adjustment the" rockets and feathers" effect. His study was followed by the paper of Borenstein et al. (1997), who provided strong evidence of asymmetry in the US market between 1986 and 1992 in different stages of the production and distribution of gasoline.

Some theoretical explanations of asymmetry have been proposed and tested. A short review is provided by Brown et al. (2000) and also Radchenko (2005). Borenstein et al. (1997) suggest three possible explanations for the asymmetric response of gasoline prices:

- the oligopolistic coordination theory,
- the production and inventory cost of adjustment, and
- the search theory.

The commonly used methods in given empirical studies are error correction models (ECM) and vector autoregressive models (VAR); e.g., Radchenko (2005), Honarvar (2009), Liu et al. (2010) and Szomolányi et al. (2020a).

The US Energy Information Administration website provides data on retail gasoline prices on the aggregate US level and the lower levels (US regions, states, and selected cities.) In the paper, we focus on asymmetric reactions of retail gasoline prices to the changes in crude oil prices in chosen US cities. According to our best knowledge, the asymmetric reactions of retail prices on lower geographical levels have not been studied yet.

We provide an alternative empirical approach based on the adjustment cost function in linear-exponential (linex) form (Szomolányi et al., 2020b). The nonlinear reaction function of fuel prices is derived from the linex adjustment costs function form. Estimating the coefficients of the reaction function, one can verify the asymmetric reactions of fuel prices on price changes in crude oil. The approach allows for estimating an average weekly gasoline price bias per liter of gasoline. By the traditional approach, Szomolányi et al. (2020b) could not confirm the asymmetric reactions of fuel prices in the Slovak market. However, by the linex approach, the asymmetries were confirmed. We prefer this approach because, in our opinion, the character of fuel price-making is rather discretionary, and it better corresponds to the process of minimizing price adjustment costs.

The paper aims to verify the asymmetric reactions of retail gasoline prices on the changes in crude oil prices in chosen US cities using the linex approach. As a result of the paper, we confirm the asymmetries and state that the average biases differ from city to city, and their values are between 0.02 cents in Los Angeles and 0.44 cents in Cleveland.

The paper is divided into sections as follows. The short literature review, motivation, and objective of the paper are in this section. From the problem of a firm minimizing its adjustment costs in the linex form, the reaction function of retail gasoline prices is derived in the next section. The following section describes the data obtained for the analysis. The methodology used to estimate the coefficients of the reaction function is in the next section. The results of estimates follow this section. The implications of the study are discussed in the next section. The final section concludes.

Methodology

Consider that gasoline seller reacts asymmetrically to changes in crude oil price. His adjustment costs will be lower after the crude oil price rises and higher after the crude oil price lowers. Therefore, after the fashion of Surico (2007) and (2008), we consider the adjustment costs function *F* is in the linex form:

$$F\left[p_t, E_{t-1}(c_t)\right] = \frac{-\gamma\left[p_t - kE_{t-1}(c_t)\right] + e^{\gamma\left[p_t - kE_{t-1}(c_t)\right]} - 1}{\gamma^2} \quad (1)$$

where p_t is the retail gasoline price, c_t is the crude oil price, *k* is the technology coefficient, and γ is an asymmetry coefficient. A negative value of the coefficient γ implies that a negative value of the difference $p_t - kE_{t-1}(c_t)$ causes higher costs to the price-maker than it would if γ were positive. The linex specification nests the quadratic form as a special case so that applying l'Hôpital's rule twice when γ tends to zero results in a reduction in the loss function (1) to the following symmetric parameterization:

$$\lim_{\gamma \to 0}\left\{F\left[p_t, E_{t-1}(c_t)\right]\right\} = \frac{1}{2}\left[p_t - kE_{t-1}(c_t)\right]^2 \quad (2)$$

The fuel price-maker chooses p_t to minimize the cost function (1). The first-order condition concerning p_t is in the form:

$$\frac{-1 + e^{\gamma\left[p_t - kE_{t-1}(c_t)\right]}}{\gamma} = 0 \quad (3)$$

Condition (3) is a general description of the reaction function of the fuel price-maker. Performing the second-order Taylor expansion of the exponential terms in (3), we gain:

$$p_t - kE_{t-1}(c_t) + \frac{\gamma}{2}\left[p_t - kE_{t-1}(c_t)\right]^2 + v_t = 0 \quad (4)$$

The remainder of the approximation is v_t, containing terms of the third or higher orders of the expansion.

We solve equation (4) for p_t and, before the generalised method of moment estimation (GMM) of the short-run relation, we replace expected values with actual values and take the relation's first differences. In practice, we estimate the following nonlinear specification:

$$\Delta p_t = k\Delta c_t - \frac{1}{2}\gamma\Delta\left[\left(p_t - kc_t\right)^2\right] + u_t \quad (5)$$

From (3), we can also express the average weekly gasoline price bias caused by the rockets and feathers effect, $\gamma < 0$. Assuming that oil shocks Δc_t is a normally distributed process with zero mean and variance σ^2, taking the first differences, expected values, and logarithms of (3) and after rearranging terms, we gain the price bias in the form:

$$E(\Delta p_t) = -\frac{k^2\gamma}{2}\sigma^2 \quad (6)$$

Our paper will estimate the (5) equation corresponding to each city retail gasoline price time series. The orthogonality condition implied by the rational expectation hypothesis makes the general method of moments (GMM) a natural candidate to estimate equation (5). The Breusch et al. (1980) χ^2 distributed LM statistics were computed to confirm that all the equations are statistically significantly correlated. Therefore, we estimate them as the system with the GMM method. The one-period lags of the first differences between retail gasoline prices and crude oil prices are used as instruments. A Newey et al. estimator is used to provide the estimates of standard errors. The Newey et al. (1987) estimator's most important feature is its consistency in heteroskedasticity and the autocorrelation of unknown forms.

Data

Our analysis studies the relationship between crude oil prices and retail gasoline prices. Data obtained from the US Energy Information Administration website are:

- Cushing, OK WTI Spot Price FOB (Dollars per Barrel, 8452 observations),
- Weekly Boston, MA Regular All Formulations Retail Gasoline Prices (Dollars per Gallon, 843 observations),
- Weekly Chicago Regular All Formulations Retail Gasoline Prices (Dollars per Gallon, 998 observations),
- Weekly Cleveland, OH Regular All Formulations Retail Gasoline Prices (Dollars per Gallon, 843 observations),
- Weekly Denver Regular All Formulations Retail Gasoline Prices (Dollars per Gallon, 998 observations),
- Weekly Houston Regular All Formulations Retail Gasoline Prices (Dollars per Gallon, 998 observations),
- Weekly Los Angeles Regular All Formulations Retail Gasoline Prices (Dollars per Gallon, 998 observations),
- Weekly Miami, FL Regular All Formulations Retail Gasoline Prices (Dollars per Gallon, 842 observations),
- Weekly New York City Regular All Formulations Retail Gasoline Prices (Dollars per Gallon, 998 observations),
- Weekly San Francisco Regular All Formulations Retail Gasoline Prices (Dollars per Gallon, 998 observations), and
- Weekly Seattle, WA Regular All Formulations Retail Gasoline Prices (Dollars per Gallon, 843 observations).

Crude oil spot prices are collected at the daily sampling frequency, while retail gasoline prices are available only at the weekly frequency. The spot and retail prices of petroleum products are denominated in dollars per gallon, while the spot price of oil is expressed in dollars per barrel. According to the US Energy Information Administration website, the retail fuel prices are collected every Monday; therefore, the daily spot prices are aggregated weekly to match their Monday spot values.

Results

The value of Breusch-Pagan LM test statistics with 45 degrees of freedom is 11651.61. This is why all equations (5) are estimated with the system GMM method.

The estimates of the coefficients of the (5) equation for each city retail gasoline price time series are in Table 1. The corresponding standard errors are computed with the Newey et al. (1987) estimator and are in parentheses. Three asterisks denote the statistical significance at the 1% level, two asterisks at the 5% level, and one asterisk at the 10% level. All the estimates are statistically significant at the 1% level, but the γ coefficient at the Denver equation is significant, and the k coefficient at the Los Angeles equation is significant at the 5% level. Average weekly one-gallon gasoline price biases from the rockets and feathers effect are computed according to the (6) relation and are in cents.

Table 1
Asymmetric Reactions of Retail Gasoline Prices on the Changes in Crude Oil Prices in Chosen US Cities

City	k	gamma	Bias
Boston	0.018039***	−0.685504***	**0.078918**
(std.err.)	(0.003822)	(0.130043)	
Chicago	0.026207***	−0.947743***	**0.230284**
(std.err.)	(0.005145)	(0.320860)	
Cleveland	0.028726***	−1.496240***	**0.436779**
(std.err.)	(0.002919)	(0.516326)	
Denver	0.019953***	−0.815281**	**0.114831**
(std.err.)	(0.007524)	(0.333588)	
Houston	0.023043***	−1.062391***	**0.199566**
(std.err.)	(0.004432)	(0.342203)	
Los Angeles	0.010804**	−0.423459***	**0.017485**
(std.err.)	(0.005313)	(0.067794)	
Miami	0.023451***	−0.822312***	**0.159988**
(std.err.)	(0.002830)	(0.137389)	
New York City	0.019534***	−0.654715***	**0.088383**
(std.err.)	(0.003227)	(0.097481)	
San Francisco	0.014321***	−0.509070***	**0.036937**
(std.err.)	(0.004256)	(0.080092)	
Seattle	0.015732***	−0.494553***	**0.043300**
(std.err.)	(0.003573)	(0.064116)	

Note: The weekly time series from 06/12/2000 – 07/15/2019 and the system GMM method are used to estimate the coefficients of the reaction functions (5). The one-period lags of the first differences between retail gasoline prices and crude oil prices are used as instruments. The Newey–West estimator is used to provide the estimates of standard errors. The average weekly one-gallon gasoline price biases from the rockets and feathers effect are computed according to the (6) relation and are in cents.
Source: Authors' calculations

Although we can confirm asymmetric reactions of retail gasoline prices on the changes in crude oil prices in each given city, the average weekly one-gallon gasoline price biases from the rockets and feathers effect differ from city to city. Their values are between 0.02 cents in Los Angeles and 0.44 cents in Cleveland.

Discussion

In our paper, we verified the hypothesis that the retail gasoline prices in chosen US cities react asymmetrically to changes in crude oil prices. We confirmed the hypothesis with the linex approach. We prefer the linex approach because, in our opinion, the character of fuel price making is rather discretionary, and it better corresponds to the process of minimizing price adjustment costs.

Our study may be useful for explaining price rigidities, currently vehemently used in the New Keynesian models of business cycles. It is worth focusing on in the paper of Douglas et al. (2010). According to the authors, asymmetric retail gasoline price reactions to crude oil price changes can be addressed by the theory of strategic interactions between a firm and its consumers, e.g., Okun (1981).

The theory of strategic interactions between a firm and its consumers is one of three theories explaining the price stickiness hypothesis, which is used in the New Keynesian monetary models. Douglas et al. argue that a good testing ground for various theories of price stickiness is the dataset describing the price adjustment of gasoline sellers.

Particularly, the theory predicting price adjustment asymmetry in the retail gasoline market is the theory of strategic interactions between a firm and its consumers.

Conclusion

The paper's objective was to verify if the retail gasoline prices in chosen US cities react asymmetrically to the changes in crude oil prices and to quantify the average weekly one-gallon gasoline price biases from the rockets and feathers effect. Using the linex approach and data from the US Energy Information Administration website, we confirmed the asymmetric effect in the chosen US cities. The average weekly one-gallon gasoline price biases from the rockets and feathers effect differ from city to city. Their values are between 0.02 cents in Los Angeles and 0.44 cents in Cleveland.

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