New Evidence on Asymmetric Gasoline Price Responses

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Abstract

In a recent paper, Borenstein, Cameron and Gilbert (1997) (BCG) claim that gasoline prices rise quickly following an increase in the price of crude oil, but fall slowly following a decrease in the price of crude oil. This paper estimates an error correction model with daily spot gasoline and crude oil price data over the period 1985-1998 and finds no evidence of asymmetry in wholesale gasoline prices. The sources of the difference in results are twofold. First, our paper uses the standard Engle-Granger two-step estimation procedure while BCG used a nonstandard estimation methodology. Second, even using BCG's nonstandard specification, the use of daily as opposed to weekly data shows little evidence of price asymmetry.

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1 Introduction

Recently, Peltzman (2000) has revitalized interest in asymmetric output price responses to input price shocks.[1] This topic is particularly relevant for gasoline markets since every positive crude price shock seems to evoke a congressional investigation. In fact, Borenstein, Cameron, and Gilbert (1997, hereafter BCG) find persuasive evidence for asymmetry – that gasoline prices respond quickly to crude oil price increases, but adjust much slower to crude oil price decreases. Bacon (1991) characterizes this type of response as the "rockets and feathers" hypothesis with gasoline prices shooting up like rockets for positive oil price shocks and floating downward like feathers in response to negative oil price shocks.[2] This type of asymmetry has lead to a variety of theoretical explanations including oligopolistic behavior, inventory explanations, and consumer search explanations (Borenstein (1991), Reagan and Weitzman (1982) and Borenstein and Shepherd (1996)). While asymmetric price responses do not necessarily emanate from market inefficiencies, evidence of symmetric, rapid price responses is clear evidence of an efficient market.

The purpose of this paper is to rigorously test the robustness of the rockets and feathers hypothesis by examining the sensitivity of the BCG results both to data frequency and model specification. In contrast to BCG and other studies[3] which rely on weekly price data, this paper uses *daily* data spanning 13 years of volatile oil prices (1985-1998). In principle, daily data provide a much richer data set for eliciting effects from lagged changes in crude oil prices. As demonstrated by Geweke (1978), estimation over broader data intervals can result in significant bias. In our case, daily data may provide more reliable estimates than weekly data, particularly if gasoline prices respond almost instantaneously to crude price changes. Geweke points out that aggregation over time can create a type of omitted variables bias problem because the intertemporal lag distribution is not properly specified. Another distinctive difference in our approach is that we adopt the standard Engle-Granger error correction model, which offers a parsimonious modelling approach ideally suited for distinguishing price asymmetries.

Section 2 briefly describes previous tests of the rockets and feathers hypothesis and their underlying assumptions. Section 3 presents the error correction model with and without price asymmetries

[1] For other earlier papers interested in asymmetries, see Wolfram (1971), Blanchard and Summers (1987) and Granger and Lee (1989) to name only a few.

[2] Interestingly, Bacon (1991) finds only slight evidence for asymmetry using UK data.

[3] Also see Bacon (1991), Balke, Brown, and Yucel (1998) and Norman and Shin (1991).

and reconciles our results with BCG. Section 4 recapitulates the key results.

2 Background

2.1 Determinants of Gasoline Prices

Due to the extreme short run inelasticity of supply and demand for crude oil, crude oil prices have exhibited extreme volatility in day-to-day trading, making it ideally suited for study of the transmission of price shocks. With crude oil being the principal input in the production of gasoline, one would expect crude oil prices to be a primary determinant of gasoline prices. Like previous research we abstract from other determinants of gasoline prices and simply focus on variants of the following simple specification:

$$PG_t = \gamma (L) PG_{t-1} + \beta (L) PC_t + \varepsilon_t \tag{1}$$

where the price of gasoline (PG) is an autoregressive process which depends on a distributed lag ($\beta (L)$) of current and past crude oil prices (PC). Nevertheless, this specification should not be interpreted as a structural price equation. It is clear that other factors also influence the price of gasoline such as refinery capacity utilization, inventory levels, and future price expectations.[4]

The omission of these other determinants seems justifiable if the purpose of equation (1) is simply to examine the transmission of crude price shocks to gasoline prices. Besides, capacity utilization and inventory data are available only on a monthly frequency. Yet another potential concern with equation (1) is simultaneous equation bias since crude oil and gasoline prices are determined jointly. Fortunately, simultaneity is not likely to be a serious problem here because crude oil prices are determined in world markets.

Since gasoline prices are observed at several points after leaving the refinery and ending at the service station, it is important to distinguish at what point in the distribution chain asymmetries are observed. Gasoline prices are observed at the following four stages of the distribution channel: regional bulk spot markets, wholesale city terminals, dealer tank wagon, and the retail pump.[5] BCG find that wholesale city terminals react almost instantaneously to regional bulk spot prices

[4]See Adams and Griffin (1972).

[5]Dealer tank wagon prices have not been typically used because they generally do not include discounts from reported prices.

and conclude that there are two economically interesting lags – the lag in reaction of the regional spot market price to changes in crude oil prices and the subsequent lag in adjustment of the retail price. BCG find evidence of price asymmetries in both relationships.[6] Because of the availability of daily data, our focus here is limited to the former relationship – the linkage between crude oil prices and gasoline prices at the regional bulk spot markets.[7]

2.2 Results From Previous Research

Previous research is divided as to whether equation (1) can be analyzed in levels or first differences because of the potential non-stationarity of the time series. Bacon's (1991) study of U.K. retail gasoline prices simply proceeded with a levels specification assuming a partial adjustment mechanism and found a statistically significant, but slight rockets and feathers effect. BCG perform augmented Dickey-Fuller tests for a unit root and since they cannot reject the unit root hypothesis for 3 of the 4 price series analyzed, they proceed to first difference equation (1) and postulate an error correction model. Balke, Brown, and Yucel (1998), find that evidence for asymmetry depends critically on the choice of levels versus a first difference specification. They find asymmetry using first differences but symmetry when using data in levels. We focus on comparison of our findings with those of BCG, because of its comprehensive nature and its unequivocal evidence for asymmetry.

3 Model Specification and Estimation

3.1 The Standard Error Correction Model

In recent years, the error correction model has emerged as the preferred approach for modelling series which are cointegrated (Watson (1994)). The Granger Representation Theorem (Engle and Granger (1987)) shows that any cointegrated series will have an error correction representation. Failure to include cointegrating relations implies model misspecification. In the context here, the

[6]Even the semi-monthly Lundberg Survey data overstates the true frequency of the data as the surveys are based on a rotating set of cities in which the same set of cities only appear monthly. The frequency of the data has been a serious impediment to researchers trying to identify complex lagged price responses using weekly, semi-monthly, or monthly data.

[7]The results presented here are based on the Houston, Texas regional bulk price reported by Platt's.

idea is that gasoline prices and crude oil prices may be cointegrated even though both series may be non-stationary.[8] If the price series in (1) are cointegrated, and there is no time trend in PG, the familiar error correction model then follows:

Basic Error Correction Model:

$$\Delta PG_t = \sum_{i=0}^{k} \beta_{ci} \Delta PC_{t-i} + \sum_{i=1}^{n} \beta_{gi} \Delta PG_{t-i} + \theta \left(z_{t-1} \right) + \varepsilon_t \tag{2}$$

The β_{ci} coefficients measure the short run impact of crude prices while the β_{gi} coefficients measure the short run impact of lagged gasoline prices. θ is the long-run equilibrium adjustment parameter while the term in parenthesis ($z_{t-1} = PG_{t-1} - \gamma_0 - \gamma_1 PC_{t-1}$) represents the long run equilibrium relationship between gasoline and crude oil prices. The parameters, γ_0 and γ_1, can be estimated superconsistently by a previous OLS regression of gasoline prices on crude oil prices. Thus z_{t-1} measures the long run disequilibrium between crude and gasoline prices, which follows a stationary process because the two series are cointegrated. Because the OLS estimates of γ_0 and γ_1 are superconsistent, inference on the parameters of equation (2) can proceed as though γ_0 and γ_1 are known with certainty. Additionally, because all of the regressors in (2) are stationary, inference on functions of the parameters (including impulse responses) is standard.[9]

The appeal of the error correction model is that it postulates a type of underlying equilibrium in which if there is no change in crude oil prices and if gasoline and crude prices are in long run equilibrium, gasoline prices will be unchanged. Implicit in the error correction model is a type of equilibrium condition in which the long run impact of a permanent change in crude oil prices is given by γ_1. This equilibrium relationship is extremely important for economic theory reasons. Even though asymmetric adjustment responses are plausible, the long run cointegrating relationship between gasoline and crude prices must be identical for price increases or decreases.

Generalization of the basic error correction model to account for asymmetric short run price responses is simple.

[8] Augmented Dickey-Fuller (Said and Dickey (1984)) test results were sensitive to the choice of lag length and deterministics, as is common in the applied literature. p-values were between 12% and 2%. AR(1) estimates indicate both series had coefficients of autocorrelation in excess of 0.99 for the period 1985-1998.

[9] See, for instance, Hamilton (1994).

Asymmetric Error Correction Model:

$$\Delta PG_t = \sum_{i=0}^{k} \beta_{ci}^{+} \Delta PC_{t-i} + \sum_{i=1}^{n} \beta_{gi}^{+} \Delta PG_{t-i} + \theta^{+} \left(PG_{t-1} - \gamma_0 - \gamma_1 PC_{t-1} \right)$$
$$+ \sum_{i=0}^{k} \beta_{ci}^{-} \Delta PC_{t-i} + \sum_{i=1}^{n} \beta_{gi}^{-} \Delta PG_{t-i} + \theta^{-} \left(PG_{t-1} - \gamma_0 - \gamma_1 PC_{t-1} \right) + \varepsilon_t \quad (3)$$

Here the β_{ci}^{+} apply when $\Delta PC_{t-i} > 0$, while the β_{gi}^{+} apply when $\Delta PG_{t-i} > 0$, and similarly for β_{ci}^{-} and β_{gi}^{-}. θ^{+} corresponds to situations where $\Delta PC_t > 0$, while θ^{-} corresponds to situations where $\Delta PC_t \leq 0$. Equation (3) retains the basic spirit of the error correction model but allows greater flexibility of the response of gasoline prices to crude oil prices.

Table 1 reports the results of estimating (2) and (3) by OLS on daily data from February 1985 to November 1998. Lag lengths, k and n, were chosen to be one using the Schwarz (1978) information criterion, which is a consistent lag selection criterion (Lutkepohl (1991)).[10] The reported standard errors are Newey and West (1987) HAC consistent standard errors, computed using lag truncation equal to $4\left(T/100\right)^{2/9}$. The cointegrating vector parameters γ_0 and γ_1 were estimated by OLS as in Engle and Granger (1987). Similar results were obtained when using the full information maximum likelihood procedure of Johansen (1988, 1991). The data are daily observations from February 1985 to November 1998.

The parameter estimates in Table 1 for the symmetric and asymmetric ECMs suggest a large instantaneous response from a crude price shock and minor differences in the asymmetry parameters. Indeed, a Wald test reveals that the symmetric specification cannot be rejected.[11] The estimated impulse response functions for spot gasoline price following positive and negative one dollar changes in the price of crude oil revealed differences of less than 5 cents per gallon. Furthermore, both confidence intervals overlap both point estimates of the responses at each lag period,[12] leading us to ask why our results differed so dramatically with BCG. To what degree are the results due to our longer sample period, a standard ECM specification, or the use of daily instead of weekly data?

[10] The constant term was not significant at the five percent level in either equation, and so was omitted.

[11] $\chi^2 = 2.462 < \chi^2(4) = 9.49$, p-value=0.65.

[12] The results showing the impulse response functions and the 95% confidence intervals are available upon request.

3.2 Specification Differences

In contrast to the method outlined above, BCG estimated the parameters of the error correction model, including γ_0 and γ_1, in one step. They estimated the following equation by 2SLS, including time fixed effects as well:

$$\Delta PG_t = -\theta_1\phi_0 + \textstyle\sum_{i=0}^{n}\left(\beta_i^{+}\Delta PC_{t-i}^{+} + \beta_i^{-}\Delta PC_{t-i}^{-}\right) + \sum_{i=1}^{n}\left(\gamma_i^{+}\Delta PG_{t-i}^{+} + \gamma_i^{-}\Delta PG_{t-i}^{-}\right)$$
$$+ \theta_1 PG_{t-1} - \theta_1\phi_1 PC_{t-1} + \theta_1\varphi_2 TIME_t + \varepsilon_t. \quad (4)$$

Using the parameters of this equation, it is possible to infer the parameters of the cointegration vector and thus impulse responses for PG following positive and negative changes in PC.

There are two reasons we might prefer the impulse responses which are derived from the two-step procedure of Engle and Granger (1987). First, little is known about the finite sample properties of cointegration vectors estimated by BCG's non-standard method, especially given that 2SLS was used to estimate equation (4).[13] Given that BCG found an implied estimate of γ_1 of less than 0.8, which is highly implausible, there are grounds to be suspicious of the estimation procedure. Using either OLS or the full information maximum likelihood approach of Johansen (1988, 1991), we find an estimated coefficient on PC_{t-1} which is slightly greater than one, implying dollar per dollar pass throughs in crude oil costs. Second, equation (4) involves the regression of a stationary variable on a nonstationary variable, and the coefficients will have a nonstandard limiting distribution (see e.g. Watson (1994)).[14] In view of these concerns, it is important to determine the extent to which BCG's results rest on their non-standard estimation approach or their use of weekly data. Henceforth, we limit the sample period to that of BCG (March 1986 to November 1992).

Figure 1 shows the point estimates of impulse responses estimated using OLS with BCG's specification and compares them to the standard ECM specification described in equation (3).[15] The corresponding parameter estimates are reported in Table I under the headings "BCG Model/Data"

[13] The rate of convergence for γ_1 using BCG's procedure will be $\sqrt{T}$ rather than T, because γ_1 is calculated as the ratio of two variables with a $\sqrt{T}$ rate of convergence. More importantly, the finite sample performance of BCG's method has not been studied extensively in the literature, and it may potentially be badly biased, which is not uncommon among other estimators that have been proposed (see Banerjee, et al (1993)).

[14] See Mankiw and Shapiro (1985) for evidence that the incorrect assumption of asymptotic normality can have very significant effects on hypothesis tests.

[15] The impulse response function confidence intervals are available upon request.

and "ECM Model/BCG Data". OLS estimation using BCG's non-standard estimation approach and their weekly data show a typical rockets and feathers response to crude oil price shocks, similar to their 2SLS results. Asymmetry is reflected as in BCG. But when using the standard two-step estimation procedure, we cannot reject symmetry. While there is still a difference in the point estimates of the impulse responses through week 2, the difference is only 30 cents, as opposed to the approximately 75 cents found by BCG. Furthermore, the point estimates are well within the 95% confidence interval, meaning that their finding of asymmetry may be accounted for by sampling variation. After week 2, the impulse responses are almost exactly the same. Finally, it is interesting to note that the shape of the impulse responses for the ECM in Figure 1 is more in line with what should be expected. BCG found a pronounced "overshooting" of gasoline prices following a crude price increase – gasoline prices increased $1.50 in the first two weeks, then proceeded to decline about 75 cents over the next eight weeks. Clearly, their evidence for asymmetry rests on their non-standard estimation approach, which has dubious properties.

3.3 Effects of Weekly vs. Daily Data

Now we turn to the issue of daily versus weekly data, adopting for purposes of comparison the BCG specification. Figure 2 presents impulse response functions using BCG's method estimated for both their weekly data and daily data which cover the same time span. The dotted and dashed lines in Figure 2 show point estimates of the impulse response functions obtained from using BCG's estimation procedure using ten lags of daily data.[16] The point estimates of the impulse responses are never more than 36 cents apart, which is substantially less than the 75 cent difference in point estimates found using weekly data. The differences in impulse response functions are never statistically significant.[17] The daily data fail to show the pronounced overshooting of gasoline price increases that is present in the weekly data. This is particularly striking since we are adopting the BCG specification so that the only difference is the use of daily rather than weekly data. It is, however, exactly what Geweke (1978) predicted could happen if one week is not a sufficiently small

[16] The estimated coefficients and standard errors, as well as the confidence intervals for the impulse response functions, are available upon request.

[17] On day 6, the day with the largest estimated difference, the confidence bands for the impulse response function following a positive crude price shock are approximately ±30 cents, while the confidence bands for a negative crude price shock are approximately ±50 cents.

interval.

3.4 Prediction Tests Using Out-of-Sample Forecasts

Yet an additional method for selecting among the symmetric and asymmetric models presented above is to ask which of them produces the best out-of-sample forecasts. If gasoline prices really do respond asymmetrically, and the asymmetry is as pronounced as that found by BCG, the asymmetric specification should produce much better forecasts. We first estimated symmetric and asymmetric versions of BCG's specification using BCG's weekly dataset. Then using those parameters and the observed time series for crude prices from 1992 to 1998, we computed forecasts of the change in gasoline price for the period November 1992 through November 1998, which is the six year period following the end of BCG's dataset. Surprisingly, the symmetric variant of the BCG model forecasts *better* for this time period, producing an MSE of $1.31 compared to an MSE of $1.45 for the asymmetric model. When using a standard ECM specification, we find the same result – a symmetric model forecasts better than an asymmetric model. Further, the standard ECM specification forecasts better than BCG's specification whether or not we allow for asymmetry. The MSE for a standard ECM specification was $1.29 for equation (3) assuming asymmetry, and $1.24 for equation (2) assuming symmetry.

4 Summary and Conclusions

We estimate a standard error correction model using daily data over a longer period (February 1985 to November 1998) and find no evidence of asymmetry in the response of regional wholesale gasoline prices to crude oil price shocks. Daily regional gasoline prices adjust almost instantaneously and symmetrically to crude oil price changes. This implies a very efficient market with few rigidities.

As we demonstrate, the BCG results turn out to be rather fragile. Either adoption of the standard estimation approach for error correction models or the use of daily instead of weekly data was sufficient to eliminate most of the evidence of asymmetry. While rigidities at the wholesale level appear minimal, their conclusions about rigidities at the retail gasoline price level may well turn out to be correct. We would urge caution, however, until daily data are available.

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Table 1

	Symmetric ECM/ Daily Data		Asymmetric ECM/ Daily Data		BCG Model/ BCG Weekly Data		ECM Model/ BCG Weekly Data	
Regressor	Coefficient	Std Error	Coefficient	Std Error	Coefficient	Std Error	Coefficient	Std Error
$constant$					3.324	0.897		
ΔPC_t	0.775	0.038						
ΔPC_t^+			0.748	0.049	0.856	0.100	0.803	0.164
ΔPC_t^-			0.799	0.055	0.883	0.092	0.984	0.136
ΔPC_{t-1}	-0.056	0.026						
ΔPC_{t-1}^+			0.002	0.048	0.604	0.124	0.505	0.153
ΔPC_{t-1}^-			-0.101	0.042	-0.147	0.112	-0.102	0.191
ΔPC_{t-2}^+					-0.080	0.126	-0.185	0.171
ΔPC_{t-2}^-					-0.273	0.105	-0.202	0.134
ΔPG_{t-1}	0.145	0.026						
ΔPG_{t-1}^+			0.139	0.046	-0.130	0.089	-0.140	0.130
ΔPG_{t-1}^-			0.154	0.036	-0.003	0.086	-0.011	0.142
ΔPG_{t-2}^+					0.059	0.091	0.050	0.087
ΔPG_{t-2}^-					0.237	0.083	0.224	0.088
PG_{t-1}					-0.156	0.030		
PC_{t-1}					0.086	0.032		
$Time$					0.007	0.002		
z_{t-1}	-0.021	0.004					-0.114	0.030
z_{t-1}^+			-0.017	0.007				
z_{t-1}^-			-0.025	0.008				

Cointegrating Relationship								
$constant$	2.970	0.177	2.970	0.177			3.877	0.265
PC_{t-1}	1.063	0.009	1.063	0.009			1.028	0.013

Figure 1
BCG Specification vs. Standard ECM Specification

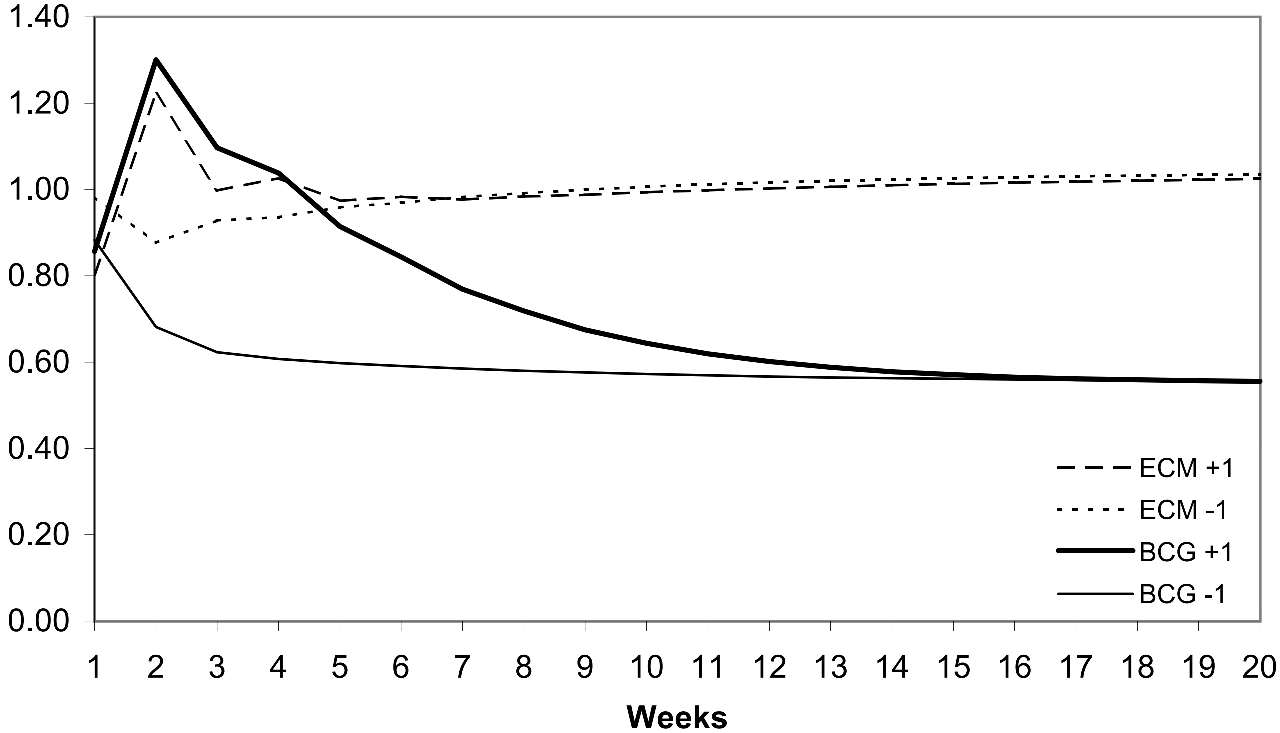

Figure 2
BCG Specification With Weekly vs. Daily Data