

Price Asymmetries in International Gasoline Markets

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Abstract: This paper re-examines the issue of asymmetries in the transmission of shocks to crude oil prices onto the retail price of gasoline. Relative to the previous literature, the distinguishing features of the present paper are: i) use of updated and comparable data to carry out an international comparison of gasoline markets; ii) two-stage modeling of the transmission of oil price shocks to gasoline prices (first refinery stage and second distribution stage), in order to assess possible asymmetries at either one or both stages; iii) use of asymmetric error correction models to distinguish between asymmetries that arise from short-run deviations in input prices and from the speed at which the gasoline price reverts to its long-run level; iv) explicit, possibly asymmetric, role of the exchange rate, as crude oil is paid for in dollars whereas gasoline sells for different sums of national currencies; v) bootstrapping of F tests of asymmetries, in order to overcome the low-power problem of conventional testing procedures. In contrast to several previous findings, the results generally point to widespread differences in both adjustment speeds and short-run responses when input prices rise or fall.

1. Introduction

This paper deals with the transmission of positive and negative changes in the price of oil to the price of gasoline. There is a sizeable literature looking for empirical evidence in support of asymmetries in this transmission mechanism: allegedly, gasoline prices go up faster than they go down whenever there is turbulence in international crude oil markets. Indeed, in every recurring period of tension in the price of oil there has been renewed interest and even heated debate about the level of gasoline prices, the magnitude of its cost components, including retailers' margin, and the taxes that contribute to keep those prices high and sluggish. The debate invariably centers on the fact that gas prices do not decrease so rapidly as oil prices do.

Asymmetries in the transmission of changes in the price of oil are in general possible if gasoline markets are non-competitive. Indeed, unlike the case of perfect competition, varying degrees of price rigidity are a feature of oligopolistic and monopolistically competitive markets. Economic theory offers a few explanations of such price rigidity, and these often contemplate the possibility of an asymmetric transmission of cost changes onto product prices.

However, perhaps because structural models of asymmetric price effects are not easily translated into empirical models, the literature on gasoline prices has typically employed reduced-form dynamic equations relating the price of gasoline to the price of oil.

Findings vary across countries and periods, but on the whole they do not provide firm evidence that prices rise faster than they fall. To date, therefore, the empirical evidence does not seem to justify the blame that the press, public opinion, some political groups and environmentalist movements put on the oil industry particularly in periods of highly volatile prices.

This paper provides fresh new evidence to bear on the issue of price asymmetries in gasoline markets: are they real or are they only imaginary as people tend to pay attention to gasoline prices only when they are rising rapidly?

In this paper we study potential price asymmetries in the markets of leaded gasoline of five European countries, namely Germany, France, U.K., Italy, and Spain. The data are monthly and in general range from the 1985 to 2000. Relative to the previous literature, the paper is novel in several respects.

First of all, the paper presents an international comparison employing the same empirical model and estimation technique and using a very recent, comparable data set. The fact that no unanimous conclusions could be drawn by previous individual country studies may, among other things, depend upon the fact that no similar data across countries for a uniform time period were used.

A second consideration concerns the econometric methodology and the dynamic model used to assess price asymmetries. In this paper an error correction

mechanism (ECM henceforth) is estimated throughout after applying modern unit root and cointegration techniques. Relative to partial adjustment, “old-fashioned” ECM and general dynamic models, we are here able to distinguish between two types of asymmetries: the first refers to the fact that adjustment of current price levels to desired targets may differ depending on the sign of the adjustment, the second one instead has to do with asymmetries in transitory price movements.

A third aspect that distinguishes the present contribution is a more satisfactory consideration of the organizational structure of the industry under scrutiny. The majority of previous studies investigated the relationship between crude oil and retail gasoline prices as a single stage process. However, the industry has a more complex structure, often varying country by country. We may make a small step forward and roughly suppose the existence of two stages in the production and distribution process: the first one concerns the transformation of crude oil into the refined product, while the second one has to do with the distribution of gasoline to retailers. The relevant prices involved in the first stage, therefore, are crude oil price and ex-refinery price. In addition, since crude oil is paid for in dollars whereas gasoline sells for different sums of national currencies, the exchange rate plays a relevant, possibly asymmetric, role at this stage. The subsequent stage instead deals with the relationship between ex-refinery and retail gasoline prices. We think that this strategy provides a more satisfactory representation of the complex chain linking crude oil to pump prices. Moreover, we believe that it is of interest to find out whether price asymmetries originate upstream or downstream in the transmission process: in view of the suspicions of collusive behavior that often accompany increases in retail gasoline prices, the two stage nature of our investigation is clearly useful.

A final point made in the paper is methodological. A few applied studies employing the asymmetric ECM model have recently documented that the commonly used F-tests of equality among the coefficients accounting for the asymmetries are biased toward accepting the null of symmetry in small samples. This fact could explain why the data fail to turn up the asymmetric price adjustments that many commonly suspect. A way around this technical difficulty is to bootstrap the asymmetry tests. We carry out this task in the paper and present results from both standard and bootstrapped test outcomes.

The results of the estimated parameters generally point to widespread differences both in adjustment speeds and short-run elasticities when input prices rise or fall. This appears to confirm the common perception that price increases are larger than price reductions. This finding characterizes, albeit to a different extent, nearly all countries and both stages of the transmission chain. Conventional tests, however, fail to reject the

symmetry hypothesis. Yet, drawing from a few contributions which have addressed this specific aspect in related contexts, we have reasons to believe that those usual tests have low power when samples are of limited size. We therefore bootstrap the F statistics and report rejection frequencies of our tests. The results strongly confirm the emergence of widespread price asymmetries in the data we have examined.

2. Data and Econometric Methodology

We represent the complex chain of transformation of crude oil into the refined gasoline product as a two-stage process: first we consider the transformation of oil into the refined product, and then its distribution to gas stations. Of each stage we investigate the potential asymmetries in the transmission of input price changes onto output prices. For the sake of comparison with the bulk of the literature and in order to appreciate the advantages of a two-stage representation, we also consider the transmission of changes in crude oil prices directly on the price of gasoline.

We conduct an international comparison of the issue at hand among five European countries, namely Germany, France, U.K., Italy, and Spain. The sample period ranges from January 1985 to June 2000 (the German sample stops at February 1997) and leaded gasoline has been considered.

The variables used in this paper are the price of crude oil (C), the gasoline spot price (S), the before-tax gasoline retail price (R), and the exchange rate between U.S. dollar and individual national currencies (ER). We denote the natural logarithm of these variables by lowercase letters. In particular, crude oil price is the Crude Oil Import Costs in U.S. dollars/bbl (average unit value, c.i.f.) published by the International Energy Agency. As a proxy for the ex-refinery gasoline price we use the gasoline spot price f.o.b. Rotterdam for the European countries. The gasoline retail prices are also from the International Energy Agency. Since any company purchasing in the spot market must pay in dollars, the exchange rate between the national currency and U.S. dollar is used. These series are taken from the International Monetary Fund. As already emphasized by Bacon (1991), it is clear that the exchange rate may be a relevant source of asymmetry in non-U.S. countries. Hence the importance of allowing separately for positive and negative changes in exchange rates.

Summarizing, the basic relationships we take to the data are the following:

$$s_t = a_0 + a_1 c_t + a_2 e r_t + \mathbf{e}_t \quad (1)$$

$$r_t = a_0 + a_1 s_t + \mathbf{e}_t \quad (2)$$

$$r_t = a_0 + a_1 c_t + a_2 e r_t + \mathbf{e}_t \quad (3)$$

Equations (1)-(3) represent the long-run or equilibrium relationships relating output prices to input prices and exchange rates. Equation (1) refers to the first stage in which the price of crude oil, along with the exchange rate, determines the spot gasoline price; according to (2) this price affects the retail price of gasoline. It is apparent that the exchange rate enters only the first stage of the chain as both retail and spot prices are denominated and posted in the same national currency. Finally, (3) relates in a single stage the retail price of petrol to that of crude oil.

The asymmetry in the transmission of changes in input prices to output prices can be accommodated within a dynamic model. However, it is important to distinguish between two types of asymmetries. This distinction can be best entertained by a dynamic ECM specification estimated in two steps. That is, let $\hat{\epsilon}_t$ denote the residual of (1) through (3) and define $ECM_t^{(+)} = \hat{\epsilon}_t > 0$ and $ECM_t^{(-)} = \hat{\epsilon}_t < 0$. These two terms account for asymmetry in the adjustment to equilibrium, whereas short-run asymmetry is captured by similarly decomposing price (and exchange rate) changes into $\Delta x_t^{(+)} = x_t - x_{t-1} > 0$ and $\Delta x_t^{(-)} = x_t - x_{t-1} < 0$ for $x=c,s,er$. Thus asymmetry of the first type is related to the speed at which a gap between the current and the equilibrium level (as described by the long-run relationships (1)-(3)) of spot or retail prices is filled within the period. This speed can differ according to whether the current price is below or above its equilibrium level. The asymmetric ECMs can therefore be formulated as follows:

$$\begin{aligned} \Delta s_t = & \mathbf{a} + \mathbf{b}^{(+)}ECM_{t-1}^{(+)} + \mathbf{b}^{(-)}ECM_{t-1}^{(-)} + \\ & \mathbf{g}^{(+)}\Delta c_t^{(+)} + \mathbf{g}^{(-)}\Delta c_t^{(-)} + \\ & \mathbf{d}^{(+)}\Delta er_t^{(+)} + \mathbf{d}^{(-)}\Delta er_t^{(-)} + u_t \end{aligned} \quad (4)$$

$$\begin{aligned} \Delta r_t = & \mathbf{a} + \mathbf{b}^{(+)}ECM_{t-1}^{(+)} + \mathbf{b}^{(-)}ECM_{t-1}^{(-)} + \\ & \mathbf{g}^{(+)}\Delta s_t^{(+)} + \mathbf{g}^{(-)}\Delta s_t^{(-)} + u_t \end{aligned} \quad (5)$$

$$\begin{aligned} \Delta r_t = & \mathbf{a} + \mathbf{b}^{(+)}ECM_{t-1}^{(+)} + \mathbf{b}^{(-)}ECM_{t-1}^{(-)} \\ & + \mathbf{g}^{(+)}\Delta c_t^{(+)} + \mathbf{g}^{(-)}\Delta c_t^{(-)} + \\ & \mathbf{d}^{(+)}\Delta er_t^{(+)} + \mathbf{d}^{(-)}\Delta er_t^{(-)} + u_t \end{aligned} \quad (6)$$

where \mathbf{D} is the first difference operator. Augmented Dickey-Fuller (ADF) tests for unit roots have been used and all variables have been found to be integrated of order one, or I(1), most of them with intercept and trend. Though non-stationary, these series may form a linear combination which is stationary, or I(0). In this case there are long-run or equilibrium relationships

between relevant price series as represented in (1)-(3). The relevant series are said to be cointegrated and this implies that the residual of the equations $\hat{\epsilon}_t$ is I(0). Again ADF tests are used to test for cointegration.

All the above considerations apply to the case of symmetric effects, but the ECM has been extended to the case of asymmetric adjustment originally by Granger and Lee (1989). In this case first differences and cointegration residual can be decomposed into positive and negative changes as shown above.

3. Empirical Results

Table 1 reports the magnitude and statistical significance of the adjustment speed coefficients $\mathbf{b}^{(+)}$ and $\mathbf{b}^{(-)}$, which allow us to evaluate long-run or persistent asymmetry, and magnitude and significance of the coefficients of price changes $\mathbf{g}^{(+)}$ and $\mathbf{g}^{(-)}$, which instead account for short-run or transitory asymmetry. The results suggest several remarks. Firstly, the table shows that, with just five exceptions, all coefficients are statistically significant, in the vast majority of cases at the 1% confidence level. According to Granger and Lee (1989), the significance of individual coefficients is a necessary condition for testing for asymmetric effects. Secondly, the comparison between "positive" and "negative" coefficients shows that the former in general exceed, in absolute value, the latter. This holds for each stage of the production and distribution chain and both for long-run and short-run. However, to establish significant divergences between the two groups of parameters requires rigorous statistical testing, an aspect we tackle below. Thirdly, if we consider the two-stage approach we have adopted to describe the transmission chain of price shocks to final gasoline prices relative to the single-stage practice, we see that numerical estimates are very different. In particular, first-stage adjustment speeds are generally smaller in absolute value than second-stage speeds, whereas the contrary appears to be true for short-run price elasticities. These differences do not surface in the single-stage approach. If we restrict our attention to point estimates, the picture that emerges appears to confirm the general perception of a more rapid adjustment in the case of price rises relative to price falls. This can be seen, as far as the short-run is concerned, by direct comparison of the estimated parameters in that they represent contemporaneous price adjustments: in the majority of cases the coefficient \mathbf{g} associated with price increases is larger than that corresponding to price reductions. There are exceptions though, but the differences among coefficients do not appear to be large. It is clear that in these cases a test of equality between coefficients is called for. As for the long-run, note that the positive and negative \mathbf{b} coefficients are respectively associated with adjustment to the long-run equilibrium level of price from above and from below. Also these

parameters differ in general. It is however perhaps useful and more informative to use an alternative statistics based on those adjustment speed coefficients.

The general formulation of the asymmetric ECM, originally introduced by Granger and Lee (1989), has been often used as the appropriate statistical framework for conventional F tests of the null hypothesis of symmetric adjustment, both in terms of adjustment speeds towards a cointegrating equilibrium and of short-run responses. In terms of equations (4)-(6) a rejection of the null hypothesis $H_0^L : \mathbf{b}^{(+)} = \mathbf{b}^{(-)}$ implies asymmetric adjustment to a long-run equilibrium, whereas short-run asymmetries arise when the null hypothesis $H_0^S : \mathbf{g}^{(+)} = \mathbf{g}^{(-)}$ is rejected. Table 2 reports the calculated conventional F tests of H_0^L and H_0^S . It immediately appears that the symmetry hypothesis is rejected only in 5 cases out of 30 and, of these 5 cases, only 1 is a rejection at 1% significance level (3 cases at 5% and 1 at 10%). In addition, short-run symmetry is rejected in 2 cases out of 5, while symmetric adjustment to the long-run is rejected in 3 cases, including the one at 10% significance level. The countries which do not experience any asymmetry are Italy, U.K. and Germany. France and Spain show both types of asymmetries (at single and second stage, respectively). The overall picture which emerges from testing the symmetry hypothesis therefore runs contrary to both the common perception and to the visual inspection of the magnitude of the estimated coefficients made in the previous tables. A few recent papers (Cook, Holly and Turner, 1998, 1999; Cook, 1999) have questioned the reliability of conventional tests of symmetry in the above and similar contexts. In particular, these contributions note that there is a tendency to over-reject the null hypothesis of symmetry which can be traced to the low power of standard F statistics. In order to overcome the documented unreliability of standard tests of symmetry we have bootstrapped the F statistics for both H_0^L and H_0^S and have calculated the corresponding rejection frequencies at the 5% significance level on the basis of 1,000 replications. The results are presented in Table 3. Rejection frequencies greater than 15% are found in 17 cases out of 30, whereas 3 are the cases with high (i.e. greater than 58%) rejection frequencies. If we reinterpret the results of Table 2 in the light of these findings, the picture changes dramatically. In particular, each country is now more likely to be characterized by both long-run and short-run asymmetries. Moreover, in Italy, Spain and U.K. asymmetries arise in the second stage, whereas in France and Germany they appear mainly at first and single stage. Generally speaking, we find that in (almost) all countries asymmetries arise in the second stage. The straightforward interpretation of this result lies in the more competitive environment of the refining sector with respect to the distribution

sector where several different operators could act to increase upward rigidity.

4. Conclusions

In a recent paper, Peltzman (2000) states that “economic theory suggests no pervasive tendency for prices to respond faster to one kind of cost change than to another” (p.467). However, after an examination of “literally hundreds of markets” (p.469), he concludes that “the person in the street is right and we [economists] are wrong” (p.493).

This paper has re-examined the issue of presumed asymmetries in the transmission of shocks to crude oil prices onto the retail price of gasoline. Especially in periods of volatile international markets, this is an issue to which both public opinion (nearly all are driving cars and trucks) and policy makers are quite sensitive. It has therefore attracted the interest of energy economists, who have carried out several empirical investigations on gasoline markets with a special eye to the hypothesis that prices rise faster than they fall.

The results of the estimated parameters generally point to widespread differences both in adjustment speeds and short-run elasticities when input prices rise or fall. This appears to confirm the common perception amply echoed by newspapers in periods of increasing international oil prices of more rapid price increases relative to price reductions. This finding characterizes, albeit to a different extent, nearly all countries and both stages of the transmission chain. When however we turn to conventional testing, we find that the usual F tests overwhelmingly fail to reject the symmetry hypothesis. Yet, drawing from a few contributions which have addressed this specific aspect in related contexts, we have reasons to believe that those usual tests have low power when samples are of limited size. We therefore bootstrap the F statistics and report rejection frequencies of our tests. The results strongly confirm the emergence of widespread price asymmetries in the data we have examined. In summary, and in contrast to several previous findings, we do find that rockets and feathers appear to dominate the price adjustment mechanism of gasoline markets in many European countries.

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TABLE 1: Asymmetric Adjustment Speeds and Short-run Price Asymmetries

| | Italy | France | Spain | Germany | U.K. |
|---|----------|----------|----------|----------|----------|
| First Stage: spot = f(crude, exchange rate) | | | | | |
| Asym. adj. Speed $\mathbf{b}^{(+)}$ | -0.640* | -0.733** | -0.347* | -0.855** | -0.470** |
| Asym. adj. Speed $\mathbf{b}^{(-)}$ | -0.400 | -0.498* | -0.345* | -0.579** | -0.272 |
| Short-run asymmetry $\mathbf{g}^{(+)}$ | 0.877** | 0.801** | 0.839** | 0.867** | 0.766** |
| Short-run asymmetry $\mathbf{g}^{(-)}$ | 0.856** | 0.923** | 0.581** | 1.156** | 0.718** |
| Second Stage: retail = g(spot) | | | | | |
| Asym. adj. Speed $\mathbf{b}^{(+)}$ | -0.732** | -0.929** | -0.937** | -1.022** | -0.885** |
| Asym. adj. Speed $\mathbf{b}^{(-)}$ | -0.977** | -0.892** | -0.772** | -1.422** | -0.894** |
| Short-run asymmetry $\mathbf{g}^{(+)}$ | 0.180** | 0.362** | 0.216** | 0.478** | 0.306** |
| Short-run asymmetry $\mathbf{g}^{(-)}$ | 0.205** | 0.281** | 0.229** | 0.474** | 0.194** |
| Single Stage: retail = h(crude, exchange rate) | | | | | |
| Asym. adj. Speed $\mathbf{b}^{(+)}$ | -1.367** | -1.055** | -1.075** | -0.739** | -0.153 |
| Asym. adj. Speed $\mathbf{b}^{(-)}$ | -1.359** | -0.678** | -1.011** | -1.127** | -0.117* |
| Short-run asymmetry $\mathbf{g}^{(+)}$ | 0.196** | 0.562** | 0.236** | 0.788** | 0.435** |
| Short-run asymmetry $\mathbf{g}^{(-)}$ | 0.240** | 0.164 | 0.160** | 0.552** | 0.237** |

Notes to the table: a single (double) asterisk denotes significance at 5% (1%) level.

TABLE 2: Computed F Tests of Asymmetric Adjustment Speeds and Short-run Price Effects

| Null Hypothesis | Italy | France | Spain | Germany | U.K. |
|---|--------------|---------------|--------------|----------------|-------------|
| First Stage: spot = f(crude, exchange rate) | | | | | |
| Sym. adj. Speeds | 1.855 | 1.651 | 0.0001 | 2.058 | 1.076 |
| Short-run symmetry | 0.019 | 0.481 | 2.240 | 2.093 | 0.075 |
| Second Stage: retail = g(spot) | | | | | |
| Sym. adj. Speeds | 2.193 | 0.197 | 4.465** | 0.014 | 1.169 |
| Short-run symmetry | 1.707 | 0.017 | 5.900** | 2.404 | 1.083 |
| Single Stage: retail = h(crude, exchange rate) | | | | | |
| Sym. adj. Speeds | 0.004 | 3.999** | 0.128 | 2.926* | 0.091 |
| Short-run symmetry | 0.439 | 9.289*** | 0.618 | 1.613 | 2.348 |

Notes to the table: (i) entries are calculated F tests of the equality between estimated coefficients associated with error correction terms (sym. adj. speeds) and price changes (short-run symmetry); (ii) a single (double) [triple] asterisk denotes significance at 10% (5%) [1%] level.

TABLE 3: Simulated F Tests of Asymmetric Adjustment Speeds and Short-run Price Effects

| Null Hypothesis | Italy | France | Spain | Germany | U.K. |
|---|--------------|---------------|--------------|----------------|-------------|
| First Stage: spot = f(crude, exchange rate) | | | | | |
| Sym. adj. Speeds | 0.387 | 0.335 | 0.047 | 0.374 | 0.265 |
| Short-run symmetry | 0.045 | 0.117 | 0.369 | 0.334 | 0.053 |
| Second Stage: retail = g(spot) | | | | | |
| Sym. adj. Speeds | 0.244 | 0.069 | 0.425 | 0.063 | 0.177 |
| Short-run symmetry | 0.219 | 0.071 | 0.598 | 0.135 | 0.178 |
| Single Stage: retail = h(crude, exchange rate) | | | | | |
| Sym. adj. Speeds | 0.058 | 0.637 | 0.06 | 0.438 | 0.050 |
| Short-run symmetry | 0.082 | 0.882 | 0.129 | 0.292 | 0.346 |

Notes to the table: entries are simulated rejection frequencies, i.e. the percentage number of times (out of 1,000 replications) the null hypothesis of symmetric adjustment speeds (resp. short-run symmetry) is rejected by an F tests at 5% level.