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ROCKETS AND FEATHERS REVISITED: AN INTERNATIONAL COMPARISON ON EUROPEAN 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.

JEL: C220, D400, Q400.
Keywords: Gasoline prices; speed of adjustment; asymmetric adjustment; exchange rate.

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1. Introduction

Drivers throughout the world are very sensitive to the money they pay for the fuel consumed by their car or truck. Because individual mobility is so essential or, in economists jargon, because gasoline demand is so inelastic a reduction in the price of gasoline makes drivers very happy just as a price rise makes them very upset. Or: very, very upset in the latter case while only very happy in the former?

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.

The paper is structured as follows. We begin in the next section with a cursory review of theoretical explanations of price rigidity and asymmetric price effects. In section 3 we provide a brief overview of the literature on gasoline prices. Section 4 describes the data and the econometric methodology adopted in the paper. The results are presented and discussed in section 5. Concluding remarks close the paper.

2. Price Asymmetries in Gasoline Markets: What Economic Theory Says

A necessary condition for the presence of asymmetric price effects is price rigidity, which gives rise to sluggish adjustment of output prices to shocks in cost conditions. However, according to Peltzman (2000) economic theory suggests no pervasive tendency for prices to respond faster to one kind of cost change than to another (p.467). Yet, there are a number of more or less standard arguments that can be put forth concerning the issue of asymmetric adjustment.

To begin with, profit maximizing behavior forces firms in competitive markets to adjust their prices to new cost conditions immediately, and presumably symmetrically. This holds when frictions and imperfections are absent from markets.

Menu costs, however, preclude instantaneous price adjustment even if firms have no market power. Similarly, accountancy rules and inventory valuation may be responsible for the sluggish adjustment of final prices with respect to increase or decrease of major exogenous variables. Take, for example, inventory valuation.

As is well known, there are two generally accepted ways of valuing products held by a firm, one based on historical costs and the second based on replacement costs. When a historical criterion (FIFO) is adopted to value inventories, the firm does not adjust its output price immediately when costs change, but awaits until the stocks of inputs bought at the old price are depleted. When instead a replacement cost criterion (LIFO) is applied, the firm adjusts its price very rapidly in response to changes in input costs. The accounting convention chosen by a firm can therefore have an influence on the speed of adjustment: application of a FIFO criterion results in longer lags than in the case of a LIFO principle.

Market power is probably the greatest concern to those who observe that gasoline prices respond more quickly to oil price increases than when they fall. The standard argument goes as follows. Retailers allegedly try to maintain their normal profit margins when prices rise, but they try to capture the larger margins that result, at least temporarily, when upstream prices fall. In both cases the situation is not to last because, for instance, consumer search costs are present. When costly search is completed, profits go down and prices tend to competitive levels. A version of this story that emphasizes tacit collusion in oligopolistic markets notes that, when upstream prices rise, each firm is quick to increase its selling price in order to signal its competitors that it is adhering to the tacit agreement; when upstream prices fall, it is slow in adjusting its price because it does not want to run the risk of selling a signal that it is cutting its margins and breaking away from the agreement.

Finally, another argument is the fact that adjusting production is costly. When a cost shock occurs profit maximizing competitive firms absorb part of the shock by depleting inventories when input prices fall and storing output when they rise. This leads

prices not to immediately adjust to cost shocks even in competitive markets, although it is perfectly consistent with firms enjoying market power. According to Borenstein, Cameron, and Gilbert (1997), asymmetry is consistent with the above story if the net marginal convenience yield (the change in net distribution costs resulting from a change in inventory levels) is convex. In this case cost increases will be accomodated more quickly.
Coming back to Peltzman (2000) s examination of literally hundreds of markets (p.469), the author finds that neither inventory holdings nor menu costs seem a key ingredient in producing price asymmetries. The hypothesis of asymmetric costs of input adjustment appears to be more consistent with price asymmetry. More generally, price asymmetry is as characteristic of competitive as oligopoly market structures.

3. Price Asymmetries in Gasoline Markets: What the Applied Literature Says

Numerous attempts have been made to analyze the relationship between the price of the input (crude oil in the present case) and the price of the corresponding output (here petroleum products). The product which has been most studied is gasoline because its share of petroleum consumption is large and because the wide geographical dispersion of sales (relative to the total volume sold) gives rise to a diversity of market situations within a single country.[1]
About a dozen studies have specifically dealt with the issue of the asymmetric transmission of price changes in gasoline markets. These studies generally differ in one or more of the following aspects: the country under scrutiny; the time

[1] Unlike previous studies, which have documented price asymmetries in selected markets (including gasoline, bank deposits, agricultural products), Peltzman (2000) uses large samples of diverse products: 77 consumer and 165 producer goods.

frequency and period of the data used; the focus on wholesale and retail gas prices or on oil and gasoline prices; the dynamic model employed in the empirical investigation.

The problem of a different response to price increases and decreases is first considered in Bacon (1991) s work on the U.K. gasoline market, which is however limited to the second stage of the transmission chain (the ex-Rotterdam spot price is used as a proxy of the product price).[2] Biweekly data are used for the period 1982-1989. The author finds that increases in the product price are fully transmitted within two months, in the case of price reductions an extra week is necessary. Moreover, changes in the exchange rate necessitate two extra weeks relative to product prices before being incorporated in retail gas prices.

Manning (1991) looks directly at the impact of changes in oil prices on U.K. retail prices. The data are monthly for 1973-1988 and an ECM specification allowing for asymmetry only in the dynamic part of the equation is used. Weak and non-persistent asymmetry in price changes, which is absorbed within four months, is found. No formal tests of asymmetric price effects are however performed.

Shifting attention to the U.S., Karrenbrock (1991) employs 1983-1990 monthly data to study the empirical relationship between wholesale and (after tax) retail gasoline prices. The author uses a distributed lags model to find that the length of time in which a wholesale price increase is fully reflected in the

[2] Although not directly testing for asymmetric price changes, Bacon (1986) is probably the first study to structure the analysis of pricing in gasoline markets into two stages: first the relationship between crude oil price and factory gate product prices, and then the relationship between product prices and net of tax retail prices. The data refer to the United Kingdom and are monthly covering the 1977-1985 period. The fitted equation is specified as an autoregressive-distributed lag. The author finds that crude oil price changes are passed on to refinery prices quickly, within the current month; this is not so for changes in product to retail prices, whose adjustment is much slower, although the speed of reaction does not appear to differ between product price and exchange rate changes.

retail gasoline price is the same as that of a wholesale price decrease for premium and unleaded regular gasoline. Instead, wholesale price increases for leaded regular gasoline are passed along to consumer more quickly than price decreases. Nevertheless, the author concludes, contrary to the popular belief that consumers do not benefit from wholesale gasoline price decreases, these are eventually passed along to consumers as fully as are wholesale gasoline price increases.

Lanza (1991) chooses the Federal Republic of Germany as the country to study. The period is 1980-1990, thus including the oil price collapse of 1986. The analysis is structured in two stages, employs monthly data and is based on an asymmetric partial adjustment model: the dependent price variable (wholesale or retail gasoline price) responds to its lagged value differently depending upon positive or negative changes in the price explanatory variable (crude oil or wholesale price respectively). The author s findings are: (i) at the refinery level there is only weak evidence of asymmetric reaction (the average lag is about three months); (ii) at the consumers level the speed of adjustment is lower in the case of price reductions than for price rises.

Kirchgässner and Kübler (1992) also look at West Germany for the period 1972-1989 using monthly data. The authors consider the response of both consumer and producer leaded gasoline prices to the spot price on the Rotterdam market; they distinguish two periods, before and after January 1980. The methodology adopted is very rigorous: the time series are tested for, respectively, unit roots, Granger causality, cointegration, and structural breaks. When cointegration cannot be rejected, both symmetric and asymmetric ECMs are fitted. Unfortunately, the asymmetry is permitted only for price changes, thus allowing only for a different response in the short-run but not in adjustment speeds. Briefly stated, the results show that, while long-run reactions are not significantly different for the 1970s and the 1980s, there is considerable asymmetry in the former period but not in the latter in the short-run adjustment processes. In particular, reductions in the Rotterdam prices are transferred faster to German markets than increases.

Shin (1994) relates the average wholesale price of oil products to the price of oil in his investigation of the U.S. market. He uses monthly data for the period 1986-1992; his dynamic model quite simply regresses average wholesale price changes on positive and negative oil price changes and shows no evidence of short-run asymmetric effects.

The focus of Duffy-Deno (1996) is again on the U.S., and in particular on the downstream relationship between wholesale and net-of-tax-retail gasoline prices. The data this time are weekly for 1989-1993 and the econometric model, a general unrestricted distributed lag specification, shows strong short-run and long-run asymmetries, with a fuller, longer (4 weeks) adjustment in the case of price rises and an incomplete, shorter (2 weeks) adjustment for price falls.

Borenstein, Cameron, and Gilbert (1997) study the U.S. gasoline market using weekly data for 1986-1992. The empirical investigation confirms the common belief that retail gasoline prices react more quickly to increases in crude oil prices than do decreases (4 weeks versus 8 weeks). An ECM is estimated but, like the previous paper, only asymmetry for price changes is permitted.

Balke, Brown, and Yücel (1998) extend the work of Borenstein et al. (1997) by using two different model specifications with weekly data from 1987 through 1997. In particular the authors use a distributed lags model in the levels of prices with asymmetric effects and an ECM representation which allows for both long-run and short-run asymmetries.[3] On the basis of

[3] Both in Borenstein et al. (1997) and in Balke et al. (1998) the restriction represented by the long-run level relationship is not imposed (no cointegration analysis is performed) in the ECM. This implies that the long-run asymmetry introduced in the second paper applies to the different parameters of the price level variables and not to the error correction coefficient.

an encompassing test this last specification is preferred. Both models involve three prices, with the wholesale price depending upon oil and spot prices and the retail price upon wholesale and spot prices. The authors do not obtain unambiguous evidence concerning asymmetry, being weak in the specification in levels and moderate and persistent in the ECM.

Reilly and Witt (1998) go back to the U.K. market to revisit the evidence of Bacon (1991) and Manning (1991) with monthly data for 1982-1995 and emphasizing the role of the dollar-pound exchange rate and the potential asymmetries associated with it, in addition to those of crude oil prices. A restricted ECM is estimated which allows only for short-run asymmetry. The hypothesis of a symmetric response by petrol retailers to crude price rises and falls is rejected by the data, and so is for changes in the exchange rate.

Finally, three recent papers look at the experience of other countries. Godby, Lintner, Stengos, and Wandschneider (2000) study the Canadian market for both premium and regular gasoline. The analysis is based on weekly data for thirteen cities between 1990 and 1996. By noting that the asymmetric ECM specifications used in previous studies are misspecified if price asymmetries are triggered by a minimum absolute increase in crude cost, a Threshold AutoRegressive model within an ECM is implemented in the paper. On this basis the authors fail to find evidence of asymmetric pricing behavior.

Asplund, Eriksson, and Friberg (2000) investigate the Swedish retail market by fitting a restricted ECM with asymmetries only on the short-run dynamic components. The data are monthly and cover the period 1980 through 1996. There is some evidence that in the short-run prices are stickier downwards than upwards. Also, prices respond more rapidly to exchange rate movements than to the spot market prices.

Berardi, Franzosi, and Vignocchi (2000) study the Italian lower end of the market considering the retail price of both leaded and unleaded gasoline as a function of Platt s Med ex-refinery price. The data are weekly 1991-2000 and are used in the estimation of an ECM specification which allows for asymmetries both in the long-run and short-run components. The authors conduct formal tests of equality between coefficients associated with these asymmetries and find that the hypothesis of a differential response in the long-run is rejected, while the evidence is less clear-cut for the short-run (symmetry is rejected at 5% for unleaded but not for leaded gasoline; at 1% symmetry is always rejected).

Summarizing, most previous articles have studied markets of individual countries, most often the U.S. and U.K. The period usually investigated covers the 80s and 90s, although Manning (1991) looks back at the period after 1973 and Berardi et al. (2000) arrive at year 2000. The frequency of the data is typically either weekly or monthly, although sometimes biweekly data are also employed. In general the contributions surveyed consider the lower end of the market, the one in which the product is distributed and sold to the pump. The relevant prices involved are therefore some wholesale price and the retail price. The other prevailing type of analysis is the one that in a single stage relates the price of crude oil to the pump price. Lanza (1991) appears to be the only study to analyze asymmetries in both stages of the transmission chain of cost shocks to the final gasoline prices. Finally, only a few recent papers make use of the latest developments in time series econometrics: by rigorously testing for unit roots and finding evidence of long-run cointegrating relationships between the relevant prices, it is possible to model, estimate and test for asymmetric price effects both in the short-run and long-run.

4. 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.[4]

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.[5] 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

[4] We have chosen this sample for at least two reasons. In terms of product and geographical coverage, we want to have an idea of possible price asymmetries, taking into account that leaded gasoline has been very important over the sample period in the European countries. In terms of time period, we start from right before the 1986 oil price collapse until the most recent months. Finally, the reason why the German sample stops at a different date is due to the unavailability of the relevant information from the official source of our data.

[5] More information on gasoline spot prices can be found in General Note on Definition Methods and Source published in the quarterly statistics *Energy Price and Taxes* of the International Energy Agency, Paris.

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:

$$s_t = a_0 + a_1 c_t + a_2 er_t + e_t \tag{1}$$

$$r_t = a_0 + a_1 s_t + e_t \tag{2}$$

$$r_t = a_0 + a_1 c_t + a_2 er_t + e_t \tag{3}$$

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.[6] 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 accomodated 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 $\hat{e}_t$ denote the residual of (1) through (3) and define

[6] Note that in principle the coefficient in front of the exchange rate should be the same as that of crude oil price. We do not impose such restriction. In addition, the influence of sources of costs other than the relevant prices (and exchange rate) are considered to be negligible and relegated into the disturbance term. Finally, in order not to clutter notation we have maintained the same symbols for coefficients and disturbance term of different equations.

$ECM_t^{(+)} = \hat{e}_t > 0$ and $ECM_t^{(-)} = \hat{e}_t < 0$.[7] 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:

$$\Delta s_t = a + b^{(+)} ECM_{t-1}^{(+)} + b^{(-)} ECM_{t-1}^{(-)} + g^{(+)} \Delta c_t^{(+)} + g^{(-)} \Delta c_t^{(-)} + d^{(+)} \Delta er_t^{(+)} + d^{(-)} \Delta er_t^{(-)} + u_t \tag{4}$$

$$\Delta r_t = a + b^{(+)} ECM_{t-1}^{(+)} + b^{(-)} ECM_{t-1}^{(-)} + g^{(+)} \Delta s_t^{(+)} + g^{(-)} \Delta s_t^{(-)} + u_t \tag{5}$$

$$\Delta r_t = a + b^{(+)} ECM_{t-1}^{(+)} + b^{(-)} ECM_{t-1}^{(-)} + g^{(+)} \Delta c_t^{(+)} + g^{(-)} \Delta c_t^{(-)} + d^{(+)} \Delta er_t^{(+)} + d^{(-)} \Delta er_t^{(-)} + u_t \tag{6}$$

where D is the first difference operator. Recent advances in time series econometrics suggest that the first step toward estimation of (4)-(6) is to check whether or not the different price series and exchange rates are stationary. 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),

[7] The two *ECM* series take on only positive (resp. negative) values and zero otherwise.

most of them with intercept and trend.[8] 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 $\hat{e}_t$ is I(0). Again ADF tests are used to test for cointegration. OLS estimation of (1)-(3) yields (super) consistent estimates of long-run responses of output prices to changes in input prices and exchange rates. Finally, when two or more variables are cointegrated, we know from the Engle-Granger representation theorem that they admit an ECM formulation of the type (4)-(6).

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. We merely note here that in order to allow for asymmetric adjustment to long-run equilibrium it is necessary to estimate the asymmetric ECM in two steps.[9]

5. Empirical Results

[8] Results from tests and estimation of (1) through (6) are not reported here to economize on space. We just concentrate on results and tests concerning price asymmetries. The complete set of results is contained in an appendix available from the authors.

[9] One could observe that estimation of equations (4)-(6) is affected by a a generated regressor problem, as the *ECM* terms are obtained from the prior estimation of (1)-(3). While this is certainly reason for concern in the usual context, McAleer, McKenzie and Pesaran (1994), among others, note that generated regressors cease to be a problem when variables are non-stationary and cointegrated.

Tables 1 and 2 present the results from estimation of asymmetric price effects, whereas Tables 3 and 4 present the evidence of testing for price asymmetries.

5.1 Evidence on Asymmetric Adjustment Speeds and Short-run Price Asymmetries

Table 1 reports the magnitude and statistical significance of the adjustment speed coefficients $b^{(+)}$ and $b^{(-)}$, which allow us to evaluate long-run or persistent asymmetry, and magnitude and significance of the coefficients of price changes $g^{(+)}$ and $g^{(-)}$, 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 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 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.

5.2 Evidence on Asymmetric Adjustment

Table 2 presents evidence on this type of asymmetry by computing the number of weeks necessary to close the gap between current and desired (long-run or equilibrium) levels of price. In particular, we compute the following statistics:

$$t = \frac{\ln\left(\dfrac{p_t - p_t^*}{p_0 - p_t^*}\right)}{b} \tag{7}$$

where the numerator is the log of the percentage gap closed and b is the speed of adjustment coefficient estimated, for either upward and downward adjustments, in the ECM equations (4)-(6). Formula (7) can be used to compute the number of weeks necessary to close *x%* of the gap between actual and long-run price levels.[10] Because monthly data are used in estimation, (7) becomes:

$$t = \frac{30}{7}\frac{\ln(1-x)}{b} \tag{8}$$

Letting *x=50%, 95%* Table 2 tells us how many weeks it takes for the price of gasoline to revert to its equilibrium level once a shock has caused him to diverge upward or downward. The results show that it often takes less time to go back up to the equilibrium level when the price is forced downward: as an example 9 weeks are necessary to re-establish the long-run level in the case of a negative shock to the German leaded retail gasoline against 12.6 in the case of a positive shock. This is not however always the case, as again the example of Germany for the first-stage documents (22.2 versus 15 weeks). At any rate, when we translate differences in adjustment speeds into time periods there do not appear to exist sizeable differences between upward and downward deviations from equilibrium. Finally, adjustment is faster in the second-stage of the chain than in the first-stage.

5.3 Evidence on Exchange Rate Asymmetries

The next table considers the issue of the asymmetric transmission of shocks in exchange rates to retail gasoline prices. Table 3 deserves a few comments. First, dollar exchange rate effects are statistically significant in all cases. Interestingly, this significance often disappears in the single-stage case. This evidence lends support to the idea of breaking up into two stage the production and distribution chain of gasoline on the one hand, and of allowing for exchange rate asymmetries on the other. Finally, we see that gasoline prices are more responsive

[10] This statistics has been suggested and used in other contexts by Christiano and Eichenbaum (1987) and Eichenbaum (1989). A full derivation of (7) is contained in an appendix available from the authors.

to increases in the exchange rate than decreases, and this fact again emerges clearly in the first-stage results.

5.4. Evidence on Tests of Price Asymmetries

We have remarked above that in order to establish significant divergences between positive and negative estimated coefficients formal statistical testing is required.

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 $H_0^L : \boldsymbol{b}^{(+)} = \boldsymbol{b}^{(-)}$ implies asymmetric adjustment to a long-run equilibrium, whereas short-run asymmetries arise when the null hypothesis $H_0^S : g^{(+)} = g^{(-)}$ is rejected. Table 4 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 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. Cook, Holly, and Turner (1998) note that, for the asymmetric adjustment ECM to be valid, $b^{(+)}$ and $b^{(-)}$ must be both significantly different from each other and individually significant (similar considerations apply to the other coefficients of asymmetry). Using the Granger and Lee (1989) data, Cook (1999) estimates an asymmetric ECM and finds that the corresponding null hypotheses are rejected by conventional F and t tests at 5% significance level in only 8% of all the estimated models. Cook, Holly, and Turner (1999) show that the variance of the difference between the estimated $b^{(+)}$ and $b^{(-)}$ tends to zero as the sample size increases. However, for a given sample size, this variance is increasing in $\left|\hat{b}^{(+)} - \hat{b}^{(-)}\right|$ and in the ratio of the variance of the independent variable to that of the dependent variable in the ECM. Monte Carlo simulation experiments confirm that some improvements in the power of the F statistics are made when the difference between the adjustment speed parameters doubles, while rejection frequencies rise substantially only for large samples (500 observations or more). Overall, rejection frequencies remain low, in the order of 17%, for economically plausible sample sizes and magnitudes of $\left|\hat{b}^{(+)} - \hat{b}^{(-)}\right|$.[11]

The findings just mentioned suggest that any straightforward interpretation of the results of Table 4 could be misleading. 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 5. Rejection frequencies greater than 15% are found in 17 cases

[11] See Cook et al. (1999), first row of Table 1, figure in column Rej , sample size T=100.

out of 30, whereas 3 are the cases with high (i.e. greater than 58%) rejection frequencies.[12] If we reinterpret the results of Table 4 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.

6. 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

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.

[12] See Cook et al. (1999), first row of Table 1, figure in column Rej , sample size T=500.

Relative to the previous literature the present paper contains several elements of novelty. Firstly, it uses updated and comparable data to carry out an international comparison of gasoline markets, unlike previous work which has invariably concentrated on individual national markets. Secondly, it breaks up the process of transmission of oil price shocks to gasoline prices into two stages, roughly corresponding to a first refinery stage and then to a second distribution stage. In so doing we are able to assess possible asymmetries at either one or both stages. This is obviously relevant from a market structure perspective. Thirdly, by a suitable choice of the dynamic regression model with which to analyze the problem, we are able to distinguish between asymmetries arising from short-lived deviations in input prices and asymmetries characterizing the speed at which the gasoline price, once shocked, reverts to its long-run or equilibrium level. The so-called asymmetric ECM allows precisely to carry out this task. Fourthly, we allow for an explicit possibly asymmetric role of the exchange rate, as crude oil price is paid for in dollars whereas gasoline sells for different sums of national currencies.

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.

References

Asplund, M., R. Eriksson, and R. Friberg (2000), "Price Adjustment by a Gasoline Retail Chain", *Scandinavian Journal of Economics*, 102, 101-121.

Bacon, R.W. (1986), UK Gasoline Prices: How Fast Are Changes in Crude Prices Transmitted to the Pump? , Oxford Institute for Energy Studies, Energy Economics Study N.2.

Bacon, R.W. (1991), Rockets and Feathers: The Asymmetric Speed of Adjustment of U.K. Retail Gasoline Prices To Cost Changes , *Energy Economics*, July, 211-218.

Balke, N.S., S.P.A. Brown, and M.K. Yücel (1998), Crude Oil and Gasoline Prices: An Asymmetric Relationship? , *Federal Reserve Bank of Dallas Economic Review*, First Quarter, 2-11.

Berardi, D., A. Franzosi, and C. Vignocchi (2000), Il prezzo dei carburanti in Italia: asimmetrie e mispecificazioni , *Contributi di Ricerca Irs* N.50.

Borenstein, S. and A. Shepard (1996), Sticky Prices, Inventories, and Market Power in Wholesale Gasoline Markets , National Bureau of Economic Research Working Paper N.5468.

Borenstein, S., A.C. Cameron, and R. Gilbert (1997), Do Gasoline Prices Respond Asymmetrically to Crude Oil Prices? , *Quarterly Journal of Economics*, February, 112, 305-339.

Christiano, L.J. and M. Eichenbaum (1987), Temporal Aggregation and Structural Inference in

Macroeconomics , *Carnegie-Rochester Conference Series on Public Policy*, 26, 63-130.

Cook, S. (1999), Nonsymmetric Error Correction Revisited , *Applied Economic Letters*, 6, 467-470.

Cook, S., S. Holly, and P. Turner (1998), DHSY Revisited: the Role of Asymmetries , *Applied Economics*, 31, 775-778.

Cook, S., S. Holly, and P. Turner (1999), The Power of Tests for Non-linearity: the Case of Granger-Lee Asymmetry , *Economics Letters*, 62, 155-159.

Duffy-Deno, K.T. (1996), Retail Price Asymmetries in Local Gasoline Markets , *Energy Economics*, 18, 81-92.

Eichenbaum, M. (1989), "Some Empirical Evidence on the Production Level and Production Cost Smoothing Models of Inventory Investment", *American Economic Review*, 79, 853-64.

Energy Information Administration (1999), Price Changes in the Gasoline Market , DOE/IEA-0626, February

Godby, R.M., A. Lintner, T. Stengos, and B. Wandschneider (2000), Testing for Asymmetric Pricing in the Canadian Retail Gasoline Market , *Energy Economics*, 22, 349-368.

Granger, C.W.J. and T.H. Lee (1989), Investigation of Production, Sales and Inventory Relationships Using Multicointegration and Non-symmetric Error Correction Models , *Journal of Applied Econometrics*, 4, S145-S159.

Karrenbrock, J.D. (1991), The Behavior of Retail Gasoline Prices: Symmetric or Not? , *Federal Reserve Bank of St. Louis Economic Review*, 73, 19-29.

Kirchgässner, G. and K. Kübler (1992), Symmetric or Asymmetric Price Adjustments in the Oil Market: An Empirical Analysis of the Relations between International and Domestic Prices in the Federal Republic of Germany, 1972-89 , *Energy Economics*, 14, 171-185.

Lanza, A. (1991), Speed of Adjustment and Market Structure: A Study of Gasoline Market in Germany , *Oxford Institute for Energy Studies*, Energy Economics Study N.14.

Manning, D.N. (1991), Petrol Prices, Oil Price Rises and Oil Price Falls: Evidence for the United Kingdom Since 1972 , *Applied Economics*, 23, 1535-1541.

McAleer, M., C.R. McKenzie and M.H. Pesaran (1994), Cointegration and Direct Tests of the Rational Expectations Hypothesis , *Econometric Reviews*, 13, 231-258.

Peltzman, S. (2000), "Prices Rise Faster Than They Fall", *Journal of Political Economy*, 108, 466-502.

Reilly, B. and R Witt (1998), Petrol Price Asymmetries *Energy Economics*, 20, 297-308.

Shin, D. (1994), Do Product Prices Respond Symmetrically to Changes in Crude Oil Prices? , *OPEC Review*, Summer.

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

	Italy	France	Spain	Germany	U.K.
	First Stage: spot = f(crude, exchange rate)				
50% of gap (upward deviation)	4.6	4.0	8.6	3.5	6.3
50% of gap (downward deviation)	7.4	6.0	8.6	5.1	10.9
95% of gap (upward deviation)	20.1	17.5	37.0	15.0	27.3
95% of gap (downward deviation)	32.1	25.8	37.2	22.2	47.2
	Second Stage: retail = g(spot)				
50% of gap (upward deviation)	4.0	3.2	3.2	2.9	3.3
50% of gap (downward deviation)	3.0	3.3	3.8	2.1	3.3
95% of gap (upward deviation)	17.5	13.8	13.7	12.6	14.5
95% of gap (downward deviation)	13.1	14.4	16.6	9.0	14.4
	Single Stage: retail = h(crude, exchange rate)				
50% of gap (upward deviation)	2.2	2.8	2.8	4.0	19.4
50% of gap (downward deviation)	2.2	4.4	2.9	2.6	25.4
95% of gap (upward deviation)	9.4	12.2	11.9	17.4	83.9
95% of gap (downward deviation)	9.4	18.9	12.7	11.4	109.7

Notes to the table: the figures represent the number of weeks needed to fill 50% and 95% of the gap between current and equilibrium price levels, distinguishing between price increases and decreases. The figures are computed using the error correction coefficients estimated in the asymmetric ECM.

TABLE 3: Exchange Rate Asymmetries

	Italy	France	Spain	Germany	U.K.
	First Stage: spot = f(crude, exchange rate)				
Short-run asymmetry $d^{(+)}$	1.055**	1.477**	1.297**	1.494**	1.503**
Short-run asymmetry $d^{(-)}$	0.828**	0.698*	0.825*	0.771**	0.481
	Single Stage: retail = h(crude, exchange rate)				
Short-run asymmetry $d^{(+)}$	-0.062	0.324	0.156	0.246	0.732**
Short-run asymmetry $d^{(-)}$	0.464**	0.693**	0.143	0.405	0.071

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

TABLE 4: 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 5: 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.