Non-linearities in mark-up on costs

Wlazlowski, Szymon and Binner, Jane and Giulietti, Monica and Joseph, Nathan

Aston Business School

21 November 2006

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Szymon Wlazlowski, Jane Binner, Monica Giulietti, Nathan Joseph

November 21, 2006

Abstract

This study employs an error-correction SETAR model to analyse the non-linearities in the behaviour of the mark-up on costs charged by the filling stations in the New York metropolitan area. While usual price transmission gained significant attention in the literature, the mark-up portion of the price has not been analysed to date. The results indicate that the adjustment to mark-ups to their long run values is non-linear, but the speeds with they adjust to their long-run values are equal across regimes for two out of three series analysed. For one of the series the adjustment is beneficial for the end consumers such that prices fall faster than they rise. The findings are somewhat surprising, indicating that there is no need for government intervention in the NY petroleum market.[1]
JEL Classification: C52, D4, L11, Q40.
Keywords: Rockets and feathers, asymmetry, petroleum, SETAR.

1 Introduction

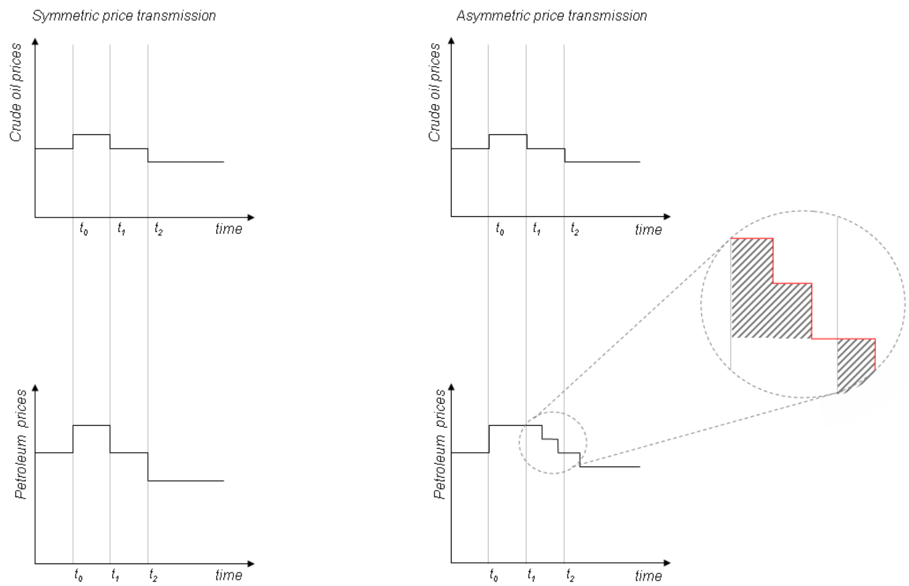
This paper analyses the non-linearities in the behaviour of the cost items in the local market for petroleum in the New York area. A SETAR model of the class proposed by (Tong (1978) and Tong & Lim (1980)) is used to analyse the reversion of the mark-up on costs charged by the filling stations to its long run equilibrium level. This approach allows us to check for the responses of the petrol prices to upstream price changes and verify the old claim that petrol prices "rise faster than they fall". Karrenbrock (1991) presents an impressive list of excerpt from newspapers quoting drivers and officials outraged at the behaviour of the petrol prices.

Non-linearities in the speed of adjustment to the upstream prices have attracted a significant attention, both from applied researchers and from governmental agencies. Since non-linearities in transmission might involve welfare transfer from agents downstream / end users to companies upstream, the public agencies vigorously pursued this issue - see reports by General Accounting Office (1993) for US, Competition Bureau (1997) for Canada, and Monopolies and Mergers Comission (1990) and Office of Fair Trading (1998) for the UK. .

[1]Special thanks to Michael J. Dueker, Assistant Vice President, Federal Reserve St. Louis for useful comments.

This phenomenon is more formally referred to as "asymmetric price transmission". The graphic term usually used in this context "rockets and feathers" was coined by Bacon (1991) to describe fast increases in downstream prices following upstream increases- rockets launched, and slow decreases following upstream price decreases - feathers falling. The difference between asymmetric and symmetric price transmissions is illustrated in the lower right panel in Figure 1.

Figure 1: Examples of symmetric (lower left panel) and asymmetric (lower right panel) price transmission



The existence of asymmetric price transmission implies that by postponing lowering the prices, agents artificially increase their margins causing the abovementioned welfare transfer. This usually forms the most typical motivation for formal research as it might result from tacit or even formal collusion or serious problems with the degree of competition Godby, et al. (2000).

Previous studies into the area had several common shortcomings. Firstly, researchers used prices aggregated in terms of geographical markets (e.g. on a national level), frequency (e.g. monthly averages), products (e.g. aggregated unleaded petrol) or market stage (e.g. from refiners directly to filling stations) or cost items (e.g. prices including taxes or net of country-wide taxation rate) Frey & Manera (2005). Secondly, the testing framework used implies that asymmetric price transmission was analysed with respect to *changes* in disequilibria measures, instead of *overall* profitability (see Section 4.3 for a more formal discussion). Thirdly, while those studies were utilizing the non-linear time series, no formal testing for the presence of non-linearities was reported (with the exception of Frey & Manera (2005) and Godby et al. (2000)). Finally, although it was proven that structural changes in the relationship between upstream and downstream prices can be mistaken for the signs of asymmetric price transmission Cramon-Taubadel & Mayer (2001), studies do not analyse stability of pricing relationships (with the exception of work by Reilly & Witt (1998)).

The novelty of this study comes from the fact that it tries to approach the problem of asymmetries in a different manner. Firstly (and most importantly), instead of focusing on the behaviour of downstream prices, it focuses on the behaviour of mark-ups on costs, i.e. residual portion of the downstream (retail) petroleum prices, not coming from upstream wholesale stage. This allowed us to check for the presence of asymmetric price transmission and also to get some insight into behaviour of adjustment of mark-up on costs towards its long-run equilibrium.

Secondly, data used offer a distinct improvement as (i) it is constrained to only one geographically distinct market (greater New York metropolitan area), (ii) instead of using product aggregates, it focuses on three distinct kinds of petrol (regular, midgrade and premium unleaded petrol), (iii) prices are quoted on a particular point in time, thus representing true market outcome, rather than average over days or weeks, (iv) data focuses on *one* transmission stage only (from New York harbour warehouses to New York filling stations), which is more likely to result in a stable pricing relationship. As demonstrated by Geweke (1978) aggregation over time can create a type of omitted variables bias resulting from insufficient lag structure and result in finding asymmetries in symmetric processes Bachmeier & Griffin (2003).

The structure of the paper is as follows: Section 2 presents the motivation for the research. Section 3 summarizes framework for testing for the presence of asymmetric price transmission, Section 4 presents overview of data, Section 5 presents the results of empirical application of non-linear analysis. Summary and description of further research follows.

2 Motivation

2.1 Focus

Most of the research into pricing on the petroleum markets was focused on the "rockets and feathers" phenomena i.e. on answers of downstream prices to upstream price changes (see section 2.2). The behaviour of other costs was completely excluded from the analysis and the behaviour of margins was analysed only indirectly, through an analysis of market disequilibria, which were expected to squeeze the margins Abdulai (2002). This approach has its virtues (most importantly it allows us to directly address the issue of interest, i.e. whether downstream consumers can enjoy upstream price decreases as quickly as they have to suffer upstream price increases), but it focuses only on one element of the market.

This paper focuses on the behaviour of residual costs (not coming from upstream). Focusing on this portion of the price allows for:

- testing for the presence of asymmetric price transmission. When mark-up portion of the price increases faster than it decreases it means that downstream prices rise faster than they fall, and
- gaining some insight into how agents behave - by analysing their margins, expenditure on marketing, etc.

2.2 Overview of Research Focused on Rockets and Feathers

This section deals with studies on the North American markets, for comprehensive review of other markets see Frey & Manera (2005).

In perhaps the first study for the US market, Karrenbrock (1991) employed monthly data for 1983-1990 to study the empirical relationship between wholesale and retail petrol prices regressing downstream price changes on positive and negative upstream prices (but not in the ECM fashion, i.e. without an error correction term). Both prices used were reduced by the sum of the federal petrol tax and average of the 50 states petrol tax. He found that the length of time in which a wholesale price increase is fully reflected in the retail petrol price is the same as that of a wholesale decrease for premium and unleaded regular petrol. The null hypothesis of symmetric transmission was not rejected. It was concluded that, contrary to commonly held belief that drivers do not benefit from wholesale petrol price decreases; these are passed along as fully and quickly as are wholesale price increases.

Shin (1992) applied model by Karrenbrock (1991) to the analysis of the US crude-wholesale price transmission, using monthly data over the period 1986-1992. He estimated a model with only contemporaneous price effects (i.e. regressed upstream changes on downstream increases and decreases. Results show that crude oil price variations have a symmetric impact on the wholesale market.

Another study concerned with asymmetric transmission in the USA was by Borenstein, et al. (1997). For their analysis of price transmission between 1986 and 1992, they used weekly data on prices of West Texas Intermediate crude oil, prices of generic petrol in New York and the Gulf Coast, average price of branded petrol sold at terminals in 33 cities east of the Rocky Mountains, average prices of unleaded regular self-service petrol net of all taxes in those cities. After testing for the homogeneity of the contemporaneous change in the upstream price in all of the transmissions they estimated, they proceeded with two-stage LS estimation. Using ECM framework (but with short-run adjustment variables split between upstream increases and decreases, they confirmed that retail petrol prices respond more quickly to increases than to decreases in crude oil prices. The adjustment takes approximately 8 weeks in case of decrease in crude oil prices but only 4 weeks in case of increase in prices of crude oil. However, the results of tests for equal speeds of adjustments to increases and decreases were not presented.

Balke, et al. (1998) extended the work of Borenstein et al. (1997) using different model specification. They used data from January 1987 through August 1996 on weekly prices of West Texas Intermediate crude, spot prices for unleaded petrol in the New York harbour, wholesale price of petrol and retail prices of self-service unleaded motor spirit with and without taxes. After finding out that their series are stationary, they proceeded with analysis of Granger-causality and sources of variance. They established that upstream prices Granger-cause downstream prices at all stages of the distribution chain. The results of bivariate vector autoregressive models for each pair suggested that with one exception (relationship between spot price of crude oil and wholesale spot price of petrol) price shocks originate upstream and are transmitted downstream. The null of symmetry in transmission was rejected in nine of ten price pairs (except for spot retail transmission).

Godby et al. (2000) used weekly data on self-service regular and premium patrol net of taxes and Edmonton par and Montreal Brent crude oil cost for the period January 1990 to December 1996 for 13 Canadian cities. They applied bootstrap procedure by Hansen (1996) to test the null hypothesis of a linear formulation against an asymmetric alternative. The test was based on bootstrap critical values of a Wald type heteroskedasticity-consistent tests. Only weak signs of asymmetry were found Godby et al. (2000, p. 364) . This was attributed to the frequency of the data used and to the fact that previous studies used aggregate data on prices from distinct regions.

Bachmeier & Griffin (2003) revisited data by Borenstein et al. (1997) using high frequency (daily and weekly) data, and larger sample (from February 1985 to November 1998). Their results indicate that daily retail prices adjust almost instantaneously and symmetrically to crude oil price changes.

The research by Eckert (2002) was inspired by the cyclical behaviour of downstream prices in Ontario, Canada, which *might* be mistaken for asymmetries. The testing was conducted in a tradition of Borenstein et al. (1997), with the use of quarterly dummies and three level shifts accounting for the first Gulf war. In such model, the null symmetry in transmission was rejected. After ascertaining that asymmetric transmission is present, the more sophisticated model of price cycles was estimated with the use of two stage procedure (probit estimation of switching parameters and OLS estimation of logarithms of downstream price change module on downstream and upstream price levels). The results were interpreted as a proof that changes in both regimes were dependent on upstream prices and were decreasing functions of margins. After analysing those results, Eckert (2002, p.74) concludes that asymmetries between different portions of the price cycle described by Maskin & Tirole (1988) can be mistaken for asymmetries in price responses ”rockets and feathers”.

In a more recent paper, Radchenko (2005b) analyzed the link between oil price volatility and the asymmetric response of petroleum prices to oil price variations. Weekly data from March 1991 to February 2003 was used to compute the impulse response functions to crude price increases and decreases. Results show that the response of retail prices to changes in crude oil prices is asymmetric. In a different study, Radchenko (2005a) applied a similar model to geographically aggregated (region-wide) weekly data from March 1991 to February 2003. Impulse response functions were again used and the spot-retail price transmission mechanisms were found to exhibit asymmetries.

3 Traditional models in analysis of mark-up behaviour

3.1 Relationship between prices

In order to analyse asymmetries in petroleum pricing it is necessary to explain responses of downstream prices to changes upstream. One model to capture changes in the downstream prices is:

$$y_t = y_{t-1} + \gamma_0(y^*_{t-1} - y_{t-1}) + \nu_t \tag{1}$$

where y^*_t is the equilibrium upstream price, y_t is the actual upstream price and γ_0 is adjustment speed (a shock to $y_{t-1} = y^*_t$ would linger forever if $\gamma_0 = 0$ or would be eliminated at once if $\gamma_0 = 1$). The equilibrium prices (y^*_t) is established based on the long-run relationship between upstream and downstream prices, i.e.:

$$y^*_t = \beta_0 + \beta_1 x_t + \epsilon_t \tag{2}$$

where x_t is the downstream price, β_1 is the proportion of downstream costs passed through upstream and ϵ_t represents shocks to the system.

Approach by Engle & Granger (1987) combines the above and might be estimated to analyse the adjustment of downstream prices:

$$\Delta\hat{\epsilon}^{(j)}_t = \gamma_0\hat{\epsilon}^{(j)}_{t-1} + \sum_{i=1}^{m}\gamma_i\Delta\hat{\epsilon}^{(j)}_{t-i} + \nu^{(j)}_t \tag{3}$$

where $\hat{\epsilon}_t$ are OLS residuals from level price equation, γ_0 is the speed of adjustment and $\sum_{i=1}^{m}\gamma_i\Delta\hat{\epsilon}^{(j)}_{t-i}$ is the lagged left-hand side variable.

In this two-stage cointegration analysis, the existence of the long-run relationship between prices in question is done by testing $H_0 : \gamma_0 < 0$, i.e. traditional cointegration analysis. On the basis of that, it is assumed that upstream and downstream prices are related, and that residuals proxy the disequilibria to the system. This forms the basis for testing for asymmetric price transmission Abdulai (2002).

3.2 Non-linear Modelling

Given such model formulation, it is assumed that the residuals $\hat{\epsilon}_t$ proxy changes to margins earned (positive residuals correspond to bigger margins, while negative residuals indicate squeezed margins, see Frey & Manera (2005) for an overview of non-linear models applied to studies of asymmetric price transmission). Based on the analysis of those residuals, researchers look for the signs of the presence of asymmetric price transmission.

Analysis of asymmetric price transmission focuses on non-linear (piece-wise linear) models of the threshold class (Tong (1978) and Tong & Lim (1980)). The idea is that (because of the menu costs, transaction costs, search costs, etc.) pricing decisions follow two regimes[2] depending on market characteristics.

In such setting the piece-wise linear model can capture the differences between regimes and establish the presence of asymmetric price transmission. Such piecewise linear extension of (3) into two different regimes is:

$$\Delta\hat{\epsilon}_t = \begin{cases} \gamma_0^{(L)}\hat{\epsilon}_{t-1} + \sum_{i=1}^{m}\gamma_i^{(L)}\Delta\hat{\epsilon}_{t-i} + \nu_t^{(L)} \text{ when } \hat{\epsilon}_{t-d^{(j)}}^{(j)} < r^{(j)} \\ \gamma_0^{(H)}\hat{\epsilon}_{t-1} + \sum_{i=1}^{m}\gamma_i^{(H)}\Delta\hat{\epsilon}_{t-i} + \nu_t^{(H)} \text{ when } \hat{\epsilon}_{t-d^{(j)}}^{(j)} \geq r^{(j)} \end{cases} \quad (4)$$

where ϵ_{t-d} is the self-exciting threshold variable with delay set to d. The estimation of threshold parameters and slope variables should be done via a grid search (as advised by Hansen (1997) and Tsay (1998)), i.e. over all possible values of thresholds and over all possible lags d and r so as to minimize sum of squared residuals from a fitted model, i.e.:

$$(r, d) = \underset{r,d}{\operatorname{argmin}}\, RSS(r, d) \quad (5)$$

To avoid trivial results, as advised by Hansen (1997) the extreme values of threshold variables should be excluded from the estimation.

The last remaining task is to test for the presence of piecewise linear adjustment, i.e. for the presence of asymmetric price transmission. This boils down to testing of $H_0 : (\forall_i \gamma_i^{(L)} = \gamma_i^{(H)})$), i.e. of no significant difference between parameters in each of the regimes. As recommended by Hansen (1997), this could be done with Wald test in the following form:

$$F_{12} = n * \frac{RSS_1 - RSS_2}{RSS_2} \quad (6)$$

where:

- RSS_1 is the RSS from (3);
- RSS_2 is the RSS from (4);
- n is the sample size.

As noted by Hansen (1996), since the threshold parameter is not identified under the null, the asymptotic distribution of F_{12} is not standard, but can be bootstrapped by the following procedure. Denote $u_t^* \sim^{iid} N(0; 1)$, (i) draw u_t^*, (ii) regress u_t^* on right hand side variables from (3) and obtain residual variance

[2] The author knows no study dealing with 3 or more regimes

RSS^*_1, (iii) regress u^*_t on right hand side variables from (4) obtain residual variance RSS^*_2, (iv) calculate (6), repeat (i)-(iv) a large number of times and use sample quantiles as critical values.

In the setting described above, the process of eliminating the disequilibria determine the adjustment of downstream prices to upstream price changes. In non-linear framework, those disequilibria are eliminated in regimes (H) and (L) with different speeds which gives rise to non-linearities - phenomena of prices rising faster than they fall occur when positive disequilibria (corresponding to times of decreasing upstream prices) are eliminated at a slower pace than negative disequilibria (corresponding to time of increasing upstream prices).

Modelling of mark-up on costs, added at a given transmission level, is essentially the same traditional models described above, the only difference is that it is assumed that upstream costs are fully passed downstream ($\beta_1 = 1$ which given the vertical span between tiers is a viable assumption) so that the residual between upstream and downstream prices (mark-up) comprises retailers' margins and other costs (mainly marketing). As such, (2) becomes:

$$y_t = \pi_t + x_t + \nu_t \tag{7}$$

where π_t represents the mark-up, and the problem of adjustment of downstream prices to upstream price changes (i.e. elimination of disequilibria) is simplified to the problem of adjustment of π_t to its long run level:

$$\pi_t = \pi_{t-1} + \gamma_0(\pi^*_{t-1} - \pi_{t-1}) + \nu_t \tag{8}$$

where (since it is assumed that mark-up on costs is constant and does not depend on upstream prices) $\pi^*_t = \alpha + \epsilon_t$. Now analysis of disequilibria in mark-up $\hat{\epsilon}_t$ can be done just as in (3) and (4).

4 Petroleum Product Prices

4.1 Overview of the Data

Weekly retail data from June 2000 until December 2005 was obtained from Energy Information Agency (the sample includes all the data points available). Those series represent prices charged for three grades of petroleum products in approximately 900 retail outlets. The prices are published by 5:00 P.M. Monday, except on government holidays, when the data are released on Tuesday (but still represent Monday's price). The reported price includes all taxes and is the pump price paid by a consumer as of 8:00 A.M. Monday. This price represents the self-serve price except in areas having only full-serve.

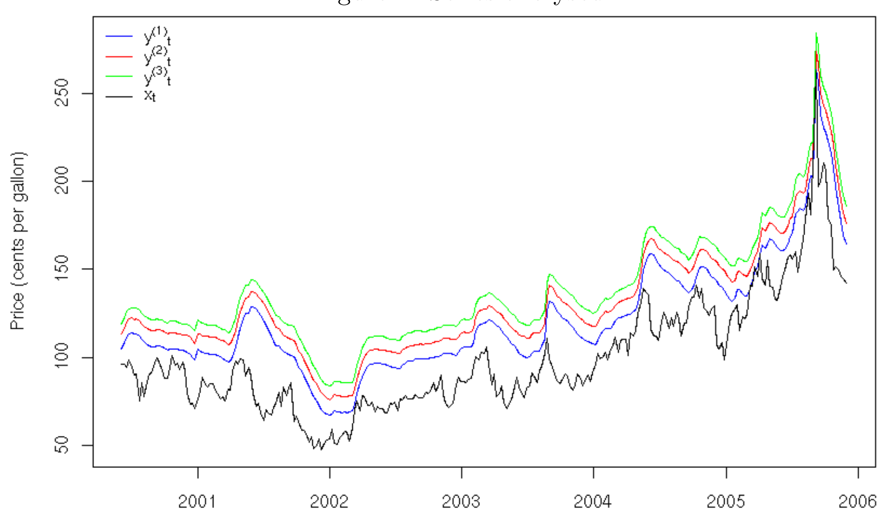
Daily spot prices for New York area from June 2000 until December 2005 were obtained from Energy Information Agency. Series include wholesale prices quoted on a day when retail prices was collected. When data on wholesale prices for a given day was not available, the previous day's prices were used.

The series analysed include:

- downstream prices:
  - y_t^1 - NYC / harbour regular all formulations / reformulated retail petrol prices net of all taxes. Regular petroleum is petroleum having an octane rating greater than 85 and less than or equal to 90;
  - y_t^2 - NYC / harbour midgrade all formulations / reformulated retail petrol prices net of all taxes. Midgrade petroleum is petroleum having an octane rating greater than 88 and less than or equal to 90;
  - y_t^3 - NYC / harbour premium all formulations / reformulated retail petrol prices net of all taxes. Premium petroleum is petroleum having an octane rating greater than 90.
- x_t - upstream prices - New York harbour reformulated regular petrol.

Figure 2 presents the retail and wholesale prices over the sample period. As

Figure 2: Series analysed.



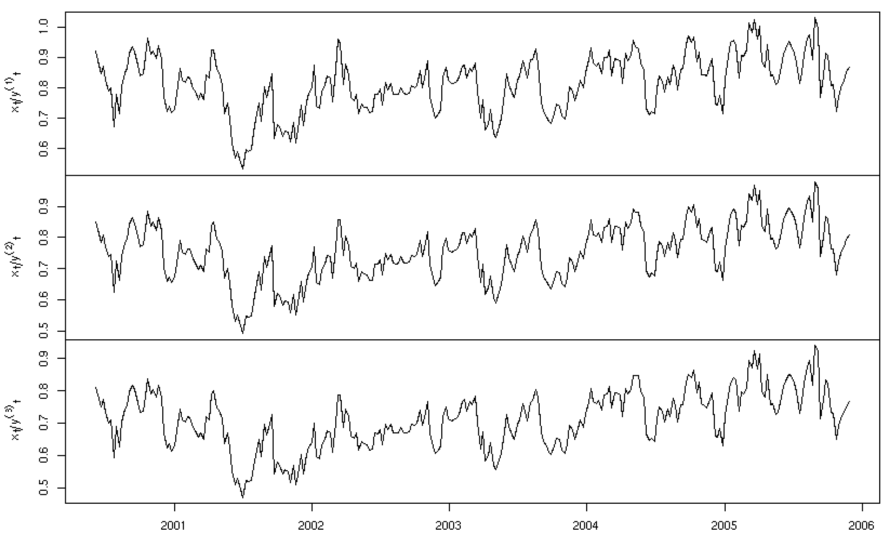
discussed in (4), the differences between upstream prices result mainly from costs of additives and enhancements, some of which (but not all) might be assumed as constant over time (some however, especially costs of ethanol change in line with upstream prices). This is supported by the analysis of product spreads, which do not change by more than 3-5 cents over the sample size.

New York data was chosen for the purposes of the analysis as:

- New York metropolitan area constitutes economic hub on the East Coast;
- bulk of trade in wholesale petrol takes place in that area (with NY harbour prices being benchmark for the entire East Coast.

The usage of spot regular petroleum prices as proxy for upstream prices is justified as (i) New York harbour is a central supply hub for Greater New York Metropolitan area, (ii) regular petroleum forms the basis most retailers use to create and price premium and midgrade varieties (this is done with use of additives and enhancements which RFA (2006) increase octane index and help to differentiate petroleum products and create company-specific fuels, such as Formula, Silver Eagle, etc.). As seen on Figure 3, costs of wholesale petrol constitutes majority of downstream prices (the rest is cost of transportation, additives, marketing, costs of the day-to-day operations of the filling stations and profits)

Figure 3: Share of upstream prices in final product price.



4.2 Analysis of the Data

Before moving to application of non-linear models, series were analysed for the presence of unit roots, direction of causality and presence of the cointegration vector. The price series analysed were not subject to logarithmic transformation. Borenstein et al. (1997) pointed out that using logarithms implies that wholesale-retail margin increases with the upstream price. As an alternative he proposed using the raw data, which implies constant nominal margin in the level equation. Borenstein et al. (1997, p. 312) claims that for short sample with moderate inflation such adjustment is justifiable.

The direction of causality was tested with the use of the Granger test (i.e. it was tested whether the past values of z_t are useful for predicting w_t once w_t's history has been modelled. The null hypothesis is that the last week's value of z_t do not help in predicting the value of w_t. Table 1 presents the results indicating that upstream prices indeed drive downstream prices not the other way around (null that history of downstream prices cannot be used to explain upstream prices is not-rejected, while the reverse is rejected with all force). Series were

Table 1: Granger Causality tests for series analysed.

	F-statistic	p-value
$y_t^{(1)} \to x_t$	0.02	0.89
$y_t^{(2)} \to x_t$	0.00	0.99
$y_t^{(3)} \to x_t$	0.01	0.93
$x_t \to y_t^{(1)}$	110.06	0.00
$x_t \to y_t^{(2)}$	111.51	0.00
$x_t \to y_t^{(3)}$	110.63	0.00

tested for unit roots using the standard ADF test in the following form:

$$\begin{aligned} \Delta z_t &= \gamma^0 z_{t-1} + \ldots + \upsilon_t \\ \Delta\Delta z_t &= \gamma^1 \Delta z_{t-1} + \ldots + \upsilon_t \end{aligned} \tag{9}$$

where:

- γ^0 is the DF variable of interest in the level estimation;
- γ^1 is the DF variable of interest in the first difference estimation;
- ... stand for lagged left hand side variables (order determined to maximize AIC).

Table 2 presents the results of estimation of (9).[3]

Table 2: ADF tests for series analysed.

Variable	Estimate	Std.Error	t-stat	p-value
x_{t-1}	−0.02	0.02	−1.64	0.10
Δx_{t-1}	−1.16	0.06	−19.35	0.01
$y_{t-1}^{(1)}$	−0.00	0.01	−0.51	0.10
$\Delta y_{t-1}^{(1)}$	−0.80	0.06	−13.30	0.01
$y_{t-1}^{(2)}$	−0.01	0.01	−0.74	0.10
$\Delta y_{t-1}^{(2)}$	−0.80	0.06	−13.27	0.01
$y_{t-1}^{(3)}$	−0.01	0.01	−0.64	0.10
$\Delta y_{t-1}^{(3)}$	−0.63	0.09	−7.09	0.01

[3]Critical values from Banarjee (1993, Table 4.2, p. 103).

The existence of a long-run equilibrium relationship between prices was tested using the Phillips-Ouliaris test Phillips & Ouliaris (1990), with truncation parameter set to 2. According to Phillips & Ouliaris (1990, p. 165) this test should have better power than ADF and PP tests, at least in larger samples. As shown in Table 3, the null of no cointegration was rejected with all force for all price pairs.[4] It is in line with previous research - see Bachmeier & Griffin (2003) who also found full pass-through using disaggregated data.

Table 3: Phillips-Ouliaris tests for the null of no cointegration in the series analysed.

Cointegration Pair	Statistics	P-Value
$y_t^{(1)}$, x_t	-60.3520	0.01
$y_t^{(2)}$, x_t	-59.7279	0.01
$y_t^{(3)}$, x_t	-59.7693	0.01

After ascertaining that series cointegrate, (2) was estimated for all series. Table 4 presents the results.

Table 4: OLS estimation of the series analysed.

	Estimate	Std. Error	t value	Pr(>|t|)
$\beta_0^{(1)}$	27.8661	2.0896	13.34	0.0000
$\beta_1^{(1)}$	0.9372	0.0199	47.03	0.0000
$\beta_0^{(2)}$	35.8471	2.1328	16.81	0.0000
$\beta_1^{(2)}$	0.9520	0.0203	46.80	0.0000
$\beta_0^{(3)}$	41.7649	2.1690	19.26	0.0000
$\beta_1^{(3)}$	0.9687	0.0207	46.83	0.0000

Results confirm that upstream costs are passed downstream , thus confirming views presented in industry publications and previous studies. The notion of upstream and downstream prices being related is supported some of the earlier studies of US markets (Karrenbrock (1991), Duffy-Deno (1996), Balke et al. (1998), Energy Information Agency (1999), Borenstein et al. (1997)). However, this is not in line with some of the earliest studies, which were not based on cointegration analysis, e.g. Shin (1992). The stability for the relationship was also analysed and confirmed using CUSUM/CUSUMSQ tests. This is important, as Cramon-Taubadel & Mayer (2001), showed via Monte Carlo experiments, that SETAR class of models tends to mis-identify structural breaks occurring in the data as the signs of asymmetric price transmission.

[4]The p-values are interpolated from Phillips & Ouliaris (1990, Table Ia and Ib, p. 189).

4.3 Mark-up on petroleum products

This application uses different approach. Instead of analysing *changes* to market disequilibria, it analyses long-run mark-up on costs on a given transmission level, calculated as a a difference between upstream and downstream prices and deviations from its long-run level;. This approach has its virtues given that:

- upstream prices are the major variable cost that filling stations face;
- it allows us to get further insight into market;
- the data is constrained to one geographically distinct market (New York City), and only one transition stage.

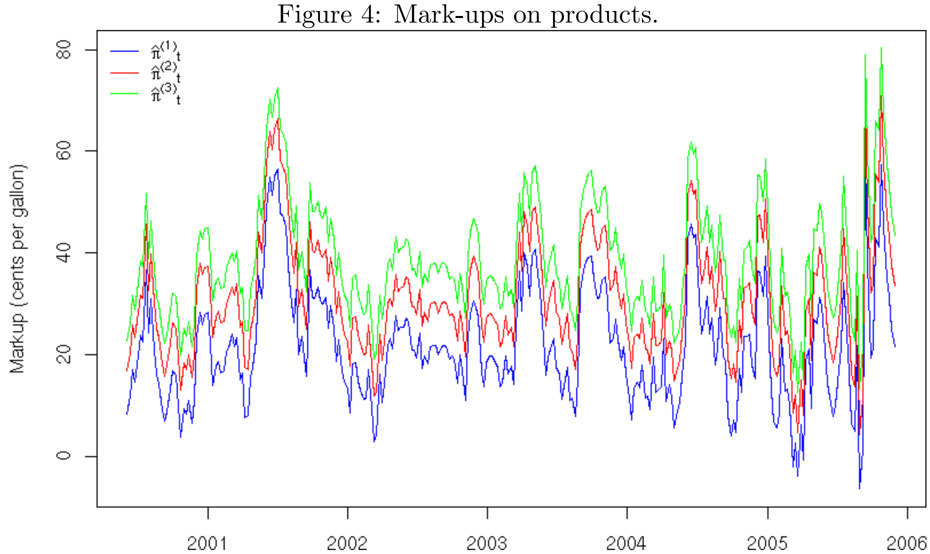
The virtue of this approach is that instead of analysing disequilibria, more detailed proxies for mark-up on upstream costs on a transmission stage could be used. While this difference might seem not that significant, it allows us to pose the research question differently - instead of asking what disequilibria trigger non-linearities, one can ask what levels of profitability trigger different market responses.

The proxies for the mark-up on costs on each product were calculated as:

$$\hat{\pi}_t^{(j)} = y_t^{(j)} - x_t \qquad (10)$$

Figure 4 presents the mark-up earned on particular products analysed in this article.

Figure 4: Mark-ups on products.



To analyse the long-run equilibrium mark-up (assumed to be constant and equal to α), the following equation was estimated:

$$\hat{\pi}_t^{(j)} = \alpha^{(j)} + \epsilon_t^{(j)} \tag{11}$$

for each of the series (i.e., for $j = 1, 2, 3$). Table 5 present the results.

Table 5: Estimation of Long-run level of mark-up proxies $\hat{\pi}_t^{(j)}$.

	Estimate	Std. Error	t value	Pr(>|t|)
$\alpha^{(1)}$	21.6146	0.6698	32.27	0.0000
$\alpha^{(2)}$	31.0668	0.6786	45.78	0.0000
$\alpha^{(3)}$	38.6502	0.6861	56.33	0.0000

Furthermore, stability of the relationship given by (11) was investigated with the use of CUSUM model. Figure 5 presents the results. Graphs show that LR equilibrium level of mark-up proxied by $\alpha^{(j)}$ is fairly stable over the sample size at 5%. Also empirical fluctuation test applied in the OLS-CUSUM and recursive flavours supported the null of stable parameters.

5 Non-linearities in mark-up behaviour

Residuals from (11) were used to establish the reversion process for the mark-up proxies. The search was conducted with maximum m equal to 12, equal number of observations in each model and was based on AIC criteria.[5] Table 6 presents the results of estimation of (3).

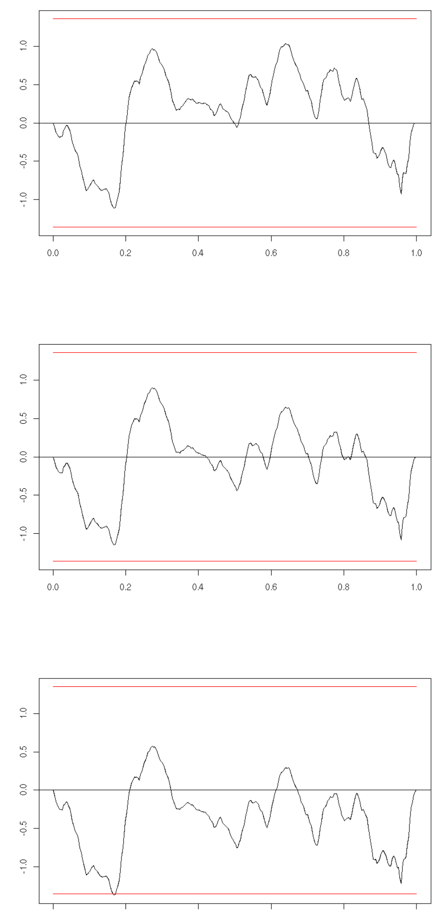
Table 6: Estimation of linear model of adjustment for $\hat{\pi}_t^{(j)}$.

Variable	Estimate	Std. Error	t value	Pr(>|t|)
$\hat{\epsilon}_{t-1}^{(1)}$	−0.2455	0.0386	−6.36	0.0000
$\Delta\hat{\epsilon}_{t-3}^{(1)}$	0.1469	0.0567	2.59	0.0101
$\hat{\epsilon}_{t-1}^{(2)}$	−0.2404	0.0383	−6.28	0.0000
$\Delta\hat{\epsilon}_{t-3}^{(2)}$	0.1437	0.0569	2.53	0.0121
$\hat{\epsilon}_{t-1}^{(3)}$	−0.2410	0.0380	−6.34	0.0000
$\Delta\hat{\epsilon}_{t-3}^{(3)}$	0.1498	0.0570	2.63	0.0090
$\Delta\hat{\epsilon}_{t-9}^{(3)}$	0.0837	0.0573	1.46	0.1454

Based on AR order established in (3), equation (4) was estimated for all three series so as to assess the speed of adjustment of mark-ups to their long-run values. Table 7 summarizes results for models estimated ($r^{(j)}$ stands for

[5] The analysis was also performed for other values of m, the results were not changed.

Figure 5: CUSUM test of stability of parameters in 5.



threshold, $d^{(j)}$ for delay parameter, F_{12} for linearity test advocated in Hansen (1996), calculated using 2000 replications. To avoid trivial results, in the grid the top and bottom 15% threshold values were disregarded. Furthermore, thanks to that each of the regimes contained at least 15% observations, which allows us to get reliable parameter estimates.

Table 7: Overview of SETAR models - structure of models

Variable	$d^{(j)}$	$r^{(1)}$	F_{12}
$\Delta\hat{\epsilon}_t^{(1)}$	11	8.902501	16.59906*
$\Delta\hat{\epsilon}_t^{(2)}$	11	9.322401	19.34938*
$\Delta\hat{\epsilon}_t^{(3)}$	8	10.61444	52.24798*

Table 8 presents the results of estimation of (4) for each of the series.

Table 8: Estimation of non-linear model of adjustment for $\hat{\pi}_t^{(j)}$.

Variable	Estimate	Std. Error	t value	Pr(>|t|)
$\hat{\epsilon}_{t-1}^{(1,L)}$	−0.2587	0.0414	−6.25	0.0000
$\hat{\epsilon}_{t-1}^{(1,H)}$	−0.1814	0.1147	−1.58	0.1147
$\Delta\hat{\epsilon}_{t-3}^{(1,L)}$	0.1879	0.0701	2.68	0.0078
$\Delta\hat{\epsilon}_{t-3}^{(1,H)}$	0.0752	0.0975	0.77	0.4408
$\hat{\epsilon}_{t-1}^{(2,L)}$	−0.2441	0.0405	−6.02	0.0000
$\hat{\epsilon}_{t-1}^{(2,H)}$	−0.2488	0.1258	−1.98	0.0490
$\Delta\hat{\epsilon}_{t-3}^{(2,L)}$	0.1816	0.0701	2.59	0.0102
$\Delta\hat{\epsilon}_{t-3}^{(2,H)}$	0.0688	0.0982	0.70	0.4842
$\hat{\epsilon}_{t-1}^{(3,L)}$	−0.1832	0.0410	−4.47	0.0000
$\hat{\epsilon}_{t-1}^{(3,H)}$	−0.5111	0.0947	−5.40	0.0000
$\Delta\hat{\epsilon}_{t-3}^{(3,L)}$	0.0939	0.0604	1.55	0.1214
$\Delta\hat{\epsilon}_{t-3}^{(3,H)}$	0.4183	0.1608	2.60	0.0098
$\Delta\hat{\epsilon}_{t-9}^{(3,H)}$	0.0774	0.0697	1.11	0.2683
$\Delta\hat{\epsilon}_{t-9}^{(3,H)}$	0.1329	0.1042	1.27	0.2035

The results show that non-linearities in the pricing behaviour do exist. However, the nature of non-linearities is interesting in a number of ways. Firstly, note that the speed of adjustment towards the long-run equilibrium level of mark-up (as opposed to carry-on effect) is given by the coefficients $\gamma_0^{(j,L)}$ and $\gamma_0^{(j,L)}$ respectively. Results reported in Table 8 indicate that the speeds of adjustment are:

- similar for regular and midgrade petroleum (in fact the F-test failed to reject null hypothesis of $H_0 : \gamma_0^{(j,L)} = \gamma_0^{(j,H)}$ for $j = 1$ (regular petroleum) and $j = 2$ (midgrade) with p-values 0.5266 and 0.9717 respectively);

- much higher for regime H in the case of premium petrol (the F-test rejected the null of equal speeds of adjustment with p-value of 0.0017);

As a next step the time distribution of regimes was analysed. Figure 6 presents the series analysed (with solid circles correspond to H regime). The trend visible is that mark-up reverts to its long-run level faster when the disequilibrium was large and positive (so that the downstream prices were above their long-run levels).

It was observed that clustering of fast-adjustment observations (regime H) coincided with increases in taxes (marked as solid squares in Figure 6) but not with decreases in taxes (green triangles). Table 9 presents the percentage of observations falling into H regime within $\pm k$ weeks of the date when taxes were increased. The results indicate that faster adjustment periods tend to cluster around changes in taxes.

Table 9: Changes in taxation and clustering of observations in regime H.

k	Variable	In regime H
± 4	$\Delta\hat{\epsilon}_t^{(1)}$	33%
± 4	$\Delta\hat{\epsilon}_t^{(2)}$	31%
± 4	$\Delta\hat{\epsilon}_t^{(3)}$	24%
± 6	$\Delta\hat{\epsilon}_t^{(1)}$	41%
± 6	$\Delta\hat{\epsilon}_t^{(2)}$	39%
± 6	$\Delta\hat{\epsilon}_t^{(3)}$	33%
± 8	$\Delta\hat{\epsilon}_t^{(1)}$	50%
± 8	$\Delta\hat{\epsilon}_t^{(2)}$	49%
± 8	$\Delta\hat{\epsilon}_t^{(3)}$	43%

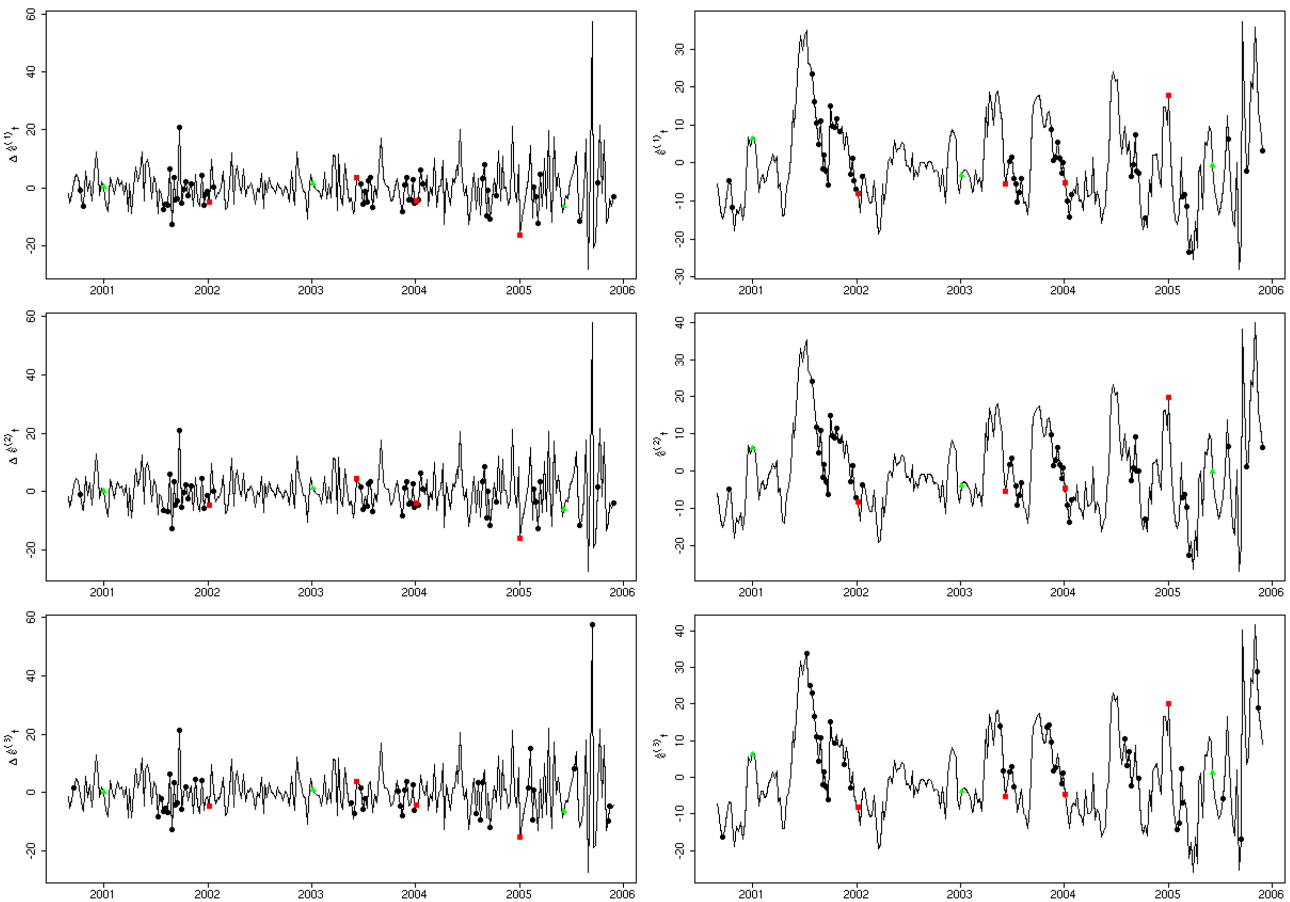
6 Summary

Relationships between upstream and downstream prices of petroleum products in New York area and the behaviour of the mark-up on costs were analysed with the use of cointegration framework and SETAR(2) model. The results indicate that:

- adjustment of mark-ups to their long run equilibrium level is non-linear in the sense that two distinct regimes can be found in the revision process;

- the differences between speeds of adjustments are greater for products with thin mark-up and the periods of faster adjustments are less frequent;

Figure 6: Regime behaviour - adjustment towards the long run equilibrium (left panel $\Delta\hat{\pi}_t^{(j)}$, right panel $\hat{\pi}_t^{(j)}$.



- ”ocular econometrics” suggests that change of adjustment regimes is more likely happen shortly before or after increases in taxation.

The results were obtained using disaggregated data on prices of three distinct kinds of petrol (regular, midgrade and premium unleaded petrol), constrained to only one geographically distinct market and one transmission stage (wholesale to retail). This might be the source of different results as other researchers used data aggregated (i) geographically - Borenstein et al. (1997) used averages of many metropolitan areas, Balke et al. (1998) used data aggregated across many municipal areas; (ii) in terms of products analysed Radchenko (2005b) and Balke et al. (1998) used crude oil data which are quoted at much higher transmission tier; (iii) over time Karrenbrock (1991) used monthly data. The results are similar to those obtained by Bachmeier & Griffin (2003) who also used disaggregated data but not analysed regime-type behaviour.

Results on application of rigorous testing for non-linearities using detailed and disaggregated data, proved that ”rockets and feathers” phenomena is not present. Further studies (possibly also using detailed data) should be made to establish the same for other areas and put the drivers at ease, after all, prices (of some products and in New York) fall faster than they rise.

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