Price adjustments by a gasoline retail chain*

by

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Abstract

We use daily data to provide a detailed examination of price responses in the Swedish gasoline market to changes in the Rotterdam spot price, exchange rates and taxes. The distribution of price adjustments by a leading retail chain, for the period January 1980 to December 1996, is symmetric with no small adjustments. An error correction model shows that in the short run prices are gradually moving towards the long run equilibrium in response to cost shocks. There is some evidence that, in the short run, prices are stickier downwards than upwards. Prices respond more rapidly to exchange rate movements than to spot market price. Our analysis stresses that to fully understand price adjustments it is necessary to examine data sets where the sample frequency at least matches that of price adjustments.

Key words: Price adjustment; sticky prices; pass-through of costs; gasoline market.

JEL classification: C22; E31; F14; L71.

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I.Introduction

In this paper we study the pass-through of cost changes to retail prices in the Swedish gasoline market. This market gives an unusually clean case to test hypotheses on firms' reactions to changes in the underlying costs of inputs, as both price and costs are observable on a daily basis. Despite daily fluctuations in the spot market price and the exchange rate, the retail price is held constant in the short run. In the longer run, however, prices follow the cost movements quite closely. The first part of the paper provides a detailed description of individual price adjustments. We then proceed to an econometric analysis of the long-run pass-through of costs, in particular the presence of various asymmetries in the pricing pattern.

Figure 1 shows the relationship between price and costs in the Swedish gasoline market for September-November, 1995. The pattern can be regarded as typical for many products; price remains fixed for some period of time, and when adjusted, it is in the direction motivated by the underlying cost. The stickiness of prices is a well known phenomenon and has been the focus of considerable theoretical and empirical attention (see e.g. Blanchard and Fisher, 1989). Let us use Figure 1 to illustrate some of the problems that empirical studies have encountered.

Figure 1 about here

Our work is related to a number of recent empirical studies concerned with price adjustments in response to cost changes. Awh and Primeaux (1992) use annual price data from electric utilities and measure costs by total operating expenditure. Dahlby (1992) uses quarterly data on insurance premiums and Kraft (1995) annual price indexes for two digit German industries, and both control for cost with wage indexes. A common feature of these studies is that the data have low frequency, in Figure 1 corresponding to a situation where prices and cost are only observed with long intervals. Moreover, often the prices are average market prices whose development will be smoother than prices set by individual firms.

Another line of research uses quoted prices of specific products and is primarily interested in how often prices are adjusted in times of inflation. Cecchetti (1986) studies cover prices of magazines and Kashyap (1995) prices in retail catalogs.

Lach and Tsiddon (1997) provide evidence of the timing of price adjustment of food products and beverages in Israel. With reference to the data depicted in Figure 1 the price is measured accurately but the development of costs is unobserved in so far as it differs from inflation.

The relatively clean data on input and output prices have made gasoline prices the subject of several studies of price adjustments. Some recent examples include Bacon (1991), Borenstein et al (1997), Borenstein and Shepard (1996a, b), and Slade (1992); additional references are found in Duffy-Deno (1996). However, all studies that examine long time periods use price data aggregated to regional or national levels. Again referring to Figure 1, information is lost about when, and by how much, individual firms adjust their prices.

A recurring theme in the literature is whether price adjustments are symmetric with respect to some underlying variable(s). For example Borenstein et al (1997) are interested in whether gasoline prices are more flexible upwards than downwards. Feenstra (1989) tests if the long-run pass-through of tariffs and exchange rates onto prices of Japanese cars, trucks and motorcycles in the US market are equal. In this paper we test for various symmetries, e.g. upward and downward flexibility of prices, symmetry in response to exchange rates, spot market prices and taxes.

II. Market and data description

We study the retail price of leaded premium gasoline in Sweden for the period January 1, 1980 to December 31, 1996. Gasoline is sold almost exclusively by branded stations and prices in the retail market are determined by the list prices of retail chains (from now on referred to as "firms"). In this respect the Swedish gasoline market is distinctly different from many other countries, for instance the United States where vertical integration is much less prevalent (see Borenstein et al, 1997). The Swedish gasoline market is remarkably stable during the sample period. For example, the quantity of gasoline sold annually has increased only slightly over the period (from 4913' m^3 in 1980 to 5682' m^3 in 1996) and market concentration is virtually unchanged (the Herfindahl-index was 0.127 in 1980 and 0.152 in 1996). This is attractive since changes in these two factors could influence the pricing behavior (see Borenstein and Shepard, 1996b, for discussion and evidence).

From January 1990 and onwards the data set includes prices for virtually all the retail chains (seven firms representing 94.5 percent of sales in 1996). For the period 1980-89 price data are available for two of the firms (Shell and Norsk Hydro). We restrict our attention to the retail list price of one of the firms, Shell, which throughout the period is either the largest or the second largest firm (with a market share of 16.5-21.0 percent, Source: Swedish Petroleum Institute). The behavior of Shell's retail price is representative for the prices of other firms since, more often than not, firms' list prices are identical and they all adjust their prices the very same day or within a day.[1] This can be exemplified with two simple observations: During the seventeen years there were just eleven occasions when the prices of Shell and Norsk Hydro were different more than three days in a row. And in the seven years 1990-1996 the saving from buying 1500 liters/year from the firm with the lowest average price, compared to the firm with highest, was a meager SEK 140 (or less than USD 20!).[2] As we are interested in how the price is adjusted in response to cost changes, and not strategic issues such as price leadership, the fact that prices of firms sometimes differ one or two days is of no importance to our analysis.[3]

Even though the prices are more or less identical for a retail chain across the country (save for some minor differences due to transport costs) there is some local variation in retail prices. The local variation refers primarily to constant differences in price levels (for instance due to the localization of the stations) and not to differences in the pattern of price adjustments. The chain from input price to consumer price is simple in Sweden. The relevant input price is the Rotterdam spot price for gasoline. Some firms buy their gasoline at this price in the spot market, but even those who operate their own refineries claim to use it as the transfer price between the producing and the selling divisions.

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[1] According to discussions with Shell the procedure to adjust the price is as follows. Executives meet before noon and decide whether to adjust or not, and if so, the magnitude. The suggested retail price is then submitted by fax to all the gasoline stations (612 as of January 1996) which adjust price the following morning. It is not possible to keep a price adjustment secret to rival firms until the next morning. Also news agencies are notified and transmit the information to rivals. According to Shell the cost of conveying the message has decreased over time as a consequence of improvements in information technology.

[2] The saving would be larger, SEK 2,817~USD350, (or about 3.5 percent) if the discount gasoline retailer JET had been included. JET, however, is only active in some regions and with unmanned stations.

[3] The complexity involved in econometric modelling of a dynamic game along the lines of Slade (1998) is quite substantial and would cloud the present issue of price responses to cost changes.

Let *RP* denote the retail list price of one liter of premium leaded gasoline (excluding value added tax introduced in March 1990) measured in SEK*100. See Appendix for detailed variable descriptions. This price is observed every day and may be adjusted any day. The Rotterdam spot market price of gasoline in USD, *SP*, and the SEK/USD exchange rate, *E*, are not quoted on weekends and public holidays. We assume these variables to be unchanged these days. The marginal cost of gasoline in SEK is denoted *MC* and defined as *SP*E.* The only variable not measured in SEK (or USD) per liter is *WAGE*, an index of the nominal wage. The price changes are denoted *ΔRP*. The change in marginal cost since the last price adjustment is denoted *ΔMC*. With marginal cost composed of two factors, *SP* and *E*, it is relevant to decompose *ΔMC* into its parts. *ΔE*SP* denotes movements due to the exchange rate, holding *SP* fixed. *ΔSP*E* is defined analogously. A factor of great, but varying, importance is the quantity (per liter) tax, denoted *TAX*. In 1980, 1982, 1988 and 1996 it accounted for approximately 50, 40, 65, and 50 percent of *RP*, respectively. A legally imposed price freeze and three price wars are excluded. For the purpose of this work it is natural to exclude those periods when price changes do not reflect cost movements.[4]

III. Price adjustment: Part I

Much of the recent literature on pricing has been concerned with the distribution and frequency of price adjustments. To add to the evidence on the behavior of prices we begin by a detailed description of the distribution of price adjustments, before relating them to cost changes. There are 250 price adjustments in the sample, implying that on average price is adjusted every third week. The size distribution of price increases is strikingly similar to that of price decreases, as shown in Table 1a and Figure 2. A stark feature of the figure is the minimum absolute size of

[4] The price freeze period excludes August 29, 1986 -August 23, 1987. The price war periods exclude January 2, 1984 - February 21, 1984, April 2, 1988 - May 6, 1988 and September 30, 1993 - October 28, 1993 and were identified partly from information provided by firms. We drop from our sample the period beginning the day after the last price adjustment prior to the price war (freeze) and ending the day after the price increase that ends the price war (freeze). Since the regressions include at most two lagged variables this implies that at most two additional observations are dropped for each occasion. The coefficients in the reported regressions are, however, only marginally affected by excluding the price wars periods. Ellison (1994) and Slade (1992) have dealt with the causes and timing of price wars.

|ΔRP|=2. This strongly indicates that there is some fixed cost associated with price changes that keeps firms from making very small adjustments. All adjustments larger than |18| are associated with tax changes or large discrete changes in E due to devaluations of the Swedish currency.[5] The next important fact is the existence of absolute changes of quite different magnitude in the interval between |2| and |18|, with changes around |6| being the most frequent.

Tables 1a-b and Figure 2 about here

Considering that the data cover seventeen years, many with high general inflation, one would expect a distribution skewed to the right, not the symmetric distribution seen in the figure. This has two explanations. Firstly, the retail price of gasoline is largely determined by the highly volatile spot market price and the likewise volatile exchange rate, which incidentally resulted in the input cost in local currency being almost the same in 1980 as in 1996. Secondly, the size of the price adjustments and the time between them is not stable over time. Table 1b shows that there are more adjustments, which on average are smaller in size, in the 1990's than in the 1980's. Nevertheless, there is considerable variability in the size of adjustment within each subperiod.

There is some seasonal variation in sales with a peak in the summer months, as seen in Table 2. If there are fixed costs of adjusting price, but the loss of having a misadjusted price is proportional to the sales volume, one would expect to find more adjustments during the high demand months. This is not borne out by the table. On the other hand, we find substantial variation in the frequency of price adjustments over the week; few changes made on Saturdays, Sundays, and Mondays. The simplest explanation is that financial markets and the Rotterdam spot market are closed on Saturdays and Sundays and thus no new information arrives on these days.

Table 2 and Figure 3 about here

Inspection of the three episodes in our sample revealed no apparent explanation (such as unusually high or low margins) to why they occurred.

[5] Until May, 1991 the USD was included in the currency basket against which SEK was tied. Even though the USD was included in the basket, the SEK/USD exchange rate exhibited large fluctuations. From May 1991 to November 1992 SEK was tied to the ECU. Since then it has floated.

Now turn to an examination of the relationship between price and cost. As a first step we use monthly data to estimate the long run relationship in levels between *RP* and the explanatory variables *MC*, *TAX* and *WAGE*, Figure 3 shows the development of the first three over the period.[6] The margin (*RP-MC-TAX*) is increasing over the period. This reflects general inflation, which is highly correlated with the explanatory variable *WAGE*. This regression fills a dual purpose. First, a high explanatory value of the regression indicates that these three variables are able to explain almost the entire variation in price. Second, the estimated error term will be used in error correction regressions, reported below. The estimated relationship is

$$\underset{}{RP} = \underset{(6.26)}{22.9} + \underset{(0.03)}{0.902} * MC + \underset{(0.03)}{0.658} * TAX + \underset{(0.12)}{2.01} * WAGE + u \quad (1)$$

D-W: 0.63 Adj.R^2: 0.988

In the long run there is a near one-to-one relationship between *RP* and *MC*. *TAX* and *WAGE* are highly correlated with each other as well as with inflation which may go some way towards explaining the low coefficient on the former.[7] The Durbin-Watson statistic shows evidence of positive autocorrelation - periods with relatively high prices tend to be followed by another period of relatively high prices, and vice versa.

A non-negative relation between recent cost changes and price adjustments is expected. Our data suggest that this is true on average, but that there are considerable deviations from this on many occasions. In Table 1a the means and medians of ΔMC have the expected signs for $\Delta RP>0$ and $\Delta RP<0$, respectively. However, the minimum and maximum values of ΔMC show that sometimes the price moves in one direction when the marginal cost has moved in the other direction. In fact, about one fifth of the price adjustments are in these two quadrants, but in most of these cases the preceding change in marginal cost has been small. Although this could be due to omitted

[6] A log-formulation is sometimes used in studies of pass-through of costs when only price indexes are available (e.g. Feenstra, 1989). However, with a quantity tax that constitutes a large and varying share of the retail price, the coefficients from a log-formulation are less readily interpreted. Moreover, the specification in levels is standard in the literature that examines price adjustment on gasoline markets (see for instance Borenstein et al, 1997). We also estimated all reported regressions in log form (available upon request), results are robust and none of the main conclusions are altered.

[7] Excluding *WAGE*, the estimated coefficient on *TAX* is above unity as it captures not only the quantity tax but also inflation over the period.

variables in the marginal cost measure this is probably not the case here, since we would then arguably get far lower explanatory power in regression (1).[8] It could also be explained by strategic elements. For example, we have not identified all price war periods, the firm wishes to undercut its competitors, or it reacts to its competitors' previous price changes. We have looked thoroughly for more price wars but found none. The latter two explanations can only be examined for the 1990's where we have price information from all firms. The observations in the 'wrong' quadrants could not be related to instances when Shell had a price different from its competitors. Further we could get the observed pattern if the firm tried to predict marginal cost movements and some price changes were made in anticipation of future developments.[9] Hedging opportunities and inventory situation could also influence the price setting process. We explicitly asked the firm about these issues and it clearly stated that such concerns were not present in the pricing decision.

An explanation to the large number of observations of the 'wrong' sign is a gradual adjustment pattern. If the firm, for some reason, wishes to avoid large price changes it may result in occasional violations of a monotone relation between cost change and price adjustment. Take the following simple example: marginal cost rise sharply by 15 but that the firm judges that this is too large a price increase to make at once. It instead raises price by 7 in a first step such that the price is still 8 'too low'. Marginal cost now falls by 1. The firm again raises its price by 7, even though cost has actually fallen since the last price adjustment.

To capture the possibility that price adjustments partly reflect previous changes in costs, lagged variables are included in the subsequent econometric analysis. We estimate the relationship between all the price changes and the preceding changes in marginal cost and tax. *WAGE* is not included since it is only observed monthly and price adjustments do not have a fixed frequency. In addition we split the

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[8] As one anonymous referee suggested, transport costs are excluded and may influence the results. Oil tanker freight rates show wide fluctuations over the years. However, they will at least partly be incorporated in the measure of marginal cost we use (FOB Rotterdam). The change in road transport cost from terminal to station should be positively correlated with our measure of the change in marginal cost.

[9] Asset prices in liquid markets (such as the foreign exchange market and spot market for gasoline) follow random walks, and are thus intrinsically unpredictable. Dickey-Fuller tests for random walks in *E*, *SP*, and *MC* (203 monthly observations) confirm this presumption. The test statistics are (including a constant) -2.24, -2.87, and -2.22, respectively, compared to a critical value of -3.51.

observations into positive and negative price adjustments.[10] The results are reported in Table 3.

Table 3 about here

When pooling all observations (column 3:1) the intercept is not significantly different from zero and taxes are reflected almost completely in the price change. Further, about half of the drift in marginal cost since the last price adjustment is reflected in today's price change. The pricing decision also reflects earlier *ΔMC* with a coefficient of 0.28. Adding the two coefficients yields approximately the long-run coefficient in (1) - it takes two adjustments to respond to the cost movement. The picture is distinctly different in 3:2 and 3:3 where we condition on the sign of the price change. In absolute terms the size of the intercept is the same, but in contrast to 3:1 significantly different from zero. This mirrors the minimum absolute size of price changes. Hence, pooling all price changes results in a bias towards a steeper slope of the regression line compared to the slopes conditional on the direction of the adjustment. The coefficient on *ΔMC* is greater (0.28) for price rises than for price cuts (0.19); indicating an asymmetry in the price adjustments. The effect of lagged *ΔMC* remains significant but is considerably lower than in 3:1. It is noteworthy that price increases are well explained by the changes in the underlying costs, compared to the price cuts. Partly this is due to tax changes, but even excluding those observations, the explanatory power is greater for price increases.

Columns 3:4-3:6 show the results from the decomposition of marginal cost into movements in the spot price (Δ*SP*E*) and the exchange rate (*ΔE*SP*). For the constant and the tax change the coefficients are virtually the same as in 3:1-3:3. Each of the other coefficients has the expected sign. The interesting point, however, is that the price response to a given change in the marginal cost is dependent on whether it is

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[10] The days when price is adjusted is presumably not a random sample of days. Neither are days when the price is increased a random draw from the days when price was adjusted. Both factors can potentially cause sample selection bias. To test this we used a method similar to the well known Heckman two-stage procedure. The first stage selection mechanism is an ordered (rather than a standard binary) probit model and the second stage, the price change regression, is an ordinary least squares estimator with a correction for sample selection. However, the price is held constant in about 95 percent of the days and the predictive ability of the sample selection model is poor. Reducing the frequency to weekly data improves predictive power somewhat but insufficiently to allow identification of the effects of sample selection. For a full account of the results see Asplund, Eriksson and Friberg (1997).

caused by the exchange rate or the spot market price. Pooling all observations (3:4) reveals that exchange rates are more important than spot market price for the adjustment (the current coefficient is considerably larger whereas the lagged is about the same, and an F-test confirms that their sums are statistically different). A closer examination of columns 3:5 and 3:6 shows that the strength of the exchange rate pass-through comes primarily from the price increases, whereas changes in spot market prices are important for both rises and cuts.

IV. Price adjustment: Part II

Even though lagged independent variables were included in the previous section, the standard procedure for studying dynamic adjustment is to employ an error correction framework, which is pursued here. Instead of using the change in the cost variables since the last price adjustment, we now analyze cost and price changes on a monthly basis. The first step in an error correction approach is to estimate the relationship in levels between price and the explanatory variables, reported in equation (1). The estimated error term, $\hat{u}$, may be interpreted as the deviation from the long-run relation. Engle-Granger tests reject that $\hat{u}$ has a unit root (the test statistic is, including a constant, –6.60 compared to a Dickey-Fuller critical value of -3.51) such that (1) represents a cointegrating relationship. The second step is estimation of the error correction form

$$\Delta RP_t = \alpha_0 + \alpha_1 \hat{u}_{t-1} + \alpha_2 \Delta \mathbf{X}_t + \alpha_3 \Delta \mathbf{X}_{t-1} + \alpha_4 \Delta \mathbf{X}_{t-2} + v_t \, , \qquad (2)$$

where preliminary regressions revealed that two lags of the independent variables are sufficient to capture the dynamics. Note that Δ's now measures change on a monthly basis. α_1 is an estimate of the fraction of the misadjustment (relative to long-run equilibrium) in the previous month that is 'corrected' in the current month.

Table 4 about here

Overall in Table 4, contemporaneous explanatory variables are significant at the 1 percent level whereas lagged variables have varying significance levels. First we focus on the estimation reported in column (4:1). A change in marginal costs of one unit leads to a price adjustment of 0.54 in that same month (which is similar to the point estimate in 3:1). Not all adjustment takes place in the same month; the price change on average reflects 0.18 of the previous month's change in marginal cost. Further, the estimated coefficient for $\hat{u}$ indicates that about 0.27 of the misadjustment from the previous month is corrected. Estimates confirm the finding in the preceding section that tax-changes are immediately passed through to prices (point estimate 0.74). It can not be rejected that the accumulated pass-through of ΔMC and ΔTAX are equal. For more details on joint tests and alternative specifications see Asplund, Eriksson and Friberg (1997).

Next, in column (4:2), we study if the responsiveness of price is symmetric in decreases and increases of the marginal cost. A rise in *MC* of one unit yields a contemporaneous price increase of about 0.7. There is no statistically significant effect of previous month's increases in *MC* on the price change. A fall in *MC* of one unit, on the other hand, results in a contemporaneous price effect of only 0.35. However, there is a statistically significant effect of the previous months decrease in *MC* on the price change of about 0.31. Taken together this means that the price responded more rapidly to cost increases than to decreases, but that the accumulated pass-through is symmetric (around 0.7). At the 5 percent level it can not be rejected that the accumulated effects are the same.

Despite the marked differences in market structure we find a similar pattern in our Swedish data as previously found on British and U.S. data. Borenstein et al. (1997) find that during 1986-1992 U.S. retail gasoline prices responded more rapidly to cost increases than to cost decreases. Bacon (1991) found that British retail gasoline prices responded more rapidly to upward movements in costs during 1982-1989. Kirchgässner and Kübler (1992), on the other hand, find that for the German gasoline market retail price adjustment has been rapid, symmetric and full to Rotterdam spot price fluctuations during 1980-1989 (but asymmetric 1972-1979).

Column (4:3) presents the results with *MC* separated into *E* and *SP*. Note first that point estimates of $\hat{u}$, ΔTAX and $\Delta WAGE$ are essentially unchanged. The contemporaneous pass-through is greater for exchange rates than for spot-prices. It is possible to reject that the accumulated pass-through of $\Delta SP*E$ and $\Delta E*SP$ are the same. At the 10 percent level of significance it can be rejected that the long-run pass-through of *ΔTAX* is the same as for *ΔSP*E* and *ΔE*SP*. For taxes and exchange rates more of the adjustment takes place in the same month compared to spot market price.

Finally, column (4:4) separates cost changes into increases and decreases in *E* and *SP*, respectively. *SP* increases are passed through in the same month as they occur (point estimate of about 0.62), whereas long-run price adjustment to *SP* decreases is about the same, but distributed over two months (pass-through of 0.3 in the same month and of 0.28 from the previous month). Similarly, the adjustment to *E* takes place fully the same month as it occurs. Also in the case of *E*, the price response to increases is larger (0.94) than the response to decreases (0.74).

V. Discussion

Seventeen years of daily input and output prices for a major gasoline retail chain gives an unusual opportunity to confront price setting theories with data. The three main theories for how prices are set when there are costs of adjustment are state-dependent pricing with fixed adjustment costs (Ss-models), time-dependent pricing, and partial adjustment. Below we summarize the contribution that each one of these theories makes to the understanding of the observed pattern of price adjustment.

At a first glance the Swedish gasoline industry seems to offer a text-book example of state-dependent pricing in its simplest form. Even though input prices move virtually every day we observe infrequent price adjustment and no small price changes. The price adjustment to tax changes is also consistent with fixed adjustment costs, adjustment appears to take place immediately and almost fully. Evidently there is a fixed cost component of price adjustments for the retail chain, at a minimum the cost of disseminating the information to all gasoline stations. The most obvious inconsistency with fixed costs is that there are a number of occasions when the price is increased (decreased) despite the fact that cost has decreased (increased). Other features left unexplained are extended periods when price is well above the long run equilibrium level, and that prices are not fully adjusted to this level when they are reset.

We study the timing of the price changes and find only very limited evidence of time-dependent pricing, that is of price adjustment taking place at a specific point in time (‘prices are reset on the first day each month’). Time dependent price setting rules are likely to be most relevant when it is costly to learn about the state and when one wants to economize on information collection (Blanchard and Fischer, 1989, p 413). The most important factors in the gasoline market are readily observable and change rapidly, and the firm continuously monitors the market for significant changes in underlying conditions.

If the costs of adjusting price are convex in the size of the price adjustment it will result in gradual movement towards long run equilibrium following a shock. This is well in line with the observed response to input cost changes. However, the full and rapid pass-through of tax changes is inconsistent with adjustment costs that are convex in the price change *per se*. Rotemberg (1982) motivated convex adjustment costs with consumer dislike for large price changes. Instead, interpret this as an aversion to large price changes due to reasons that consumers do not fully understand, whereas 'well motivated' price changes are not be perceived as equally bad. Tax increases are given extensive media coverage and could not be blamed on the firm. This behavioral assumption is consistent with both the gradual pass-through of marginal cost changes and the instantaneous pass-through of taxes.

None of the above theories is consistent with all the features of price adjustments. This in itself is what one could have expected since there are specificities of each single price adjustment that are unobservable to the researcher. A good example of such unobservables is the beliefs of the firm regarding the price responses of the competitors. In the paper we have not studied any strategic considerations by the firm, but they are clearly important for price setting in the short run. We have discussed the issue with the firm. It pointed to that although all price adjustments can be observed almost instantaneously, rivals have the option of sticking to their old prices or changing by a different amount. This was given as motivation for avoiding 'very large' price changes, even though they may be called for due to large changes in the observable underlying variables. These behavioral assumptions would also be consistent with gradual adjustment. Again, for a tax change there is a natural focal point since they are known in advance. As the firm said, 'everybody knows that tax changes are passed through fully and at once'.

This points to that the characteristics of a variable, such as its stochastic properties, matter for the short-run price response. Tax increases are known in advance, and there is essentially a zero probability that they will fall shortly after. On the other hand, marginal cost is stochastic and there is always the probability that it will revert, such that there is an option value of waiting with the price adjustment. This may also go some way towards explaining the marked difference in the price response to exchange rates and spot market prices. The volatility in marginal cost is to a greater extent due to fluctuations in the spot market price than the exchange rate. Even though both variables enter the marginal cost symmetrically, firms may wait and see whether spot market price revert, but react faster to the less volatile exchange rate.

Finally, referring back to Figure 1, inferences on price setting behavior will be highly dependent on the data analyzed. For example, if one only had access to the price series (or only the distribution of price adjustments) it would be easy to conclude that an Ss-model is an accurate description of price setting. On the other hand, if data were sampled only at (longer) discrete intervals the conclusion could instead be in favor of a partial adjustment model. This clearly illustrates the necessity of examining data sets where the frequency at least matches the frequency of price adjustments.

References

Awh, RY. and Primeaux, W.J (1992), A more General Theory of Kinked Demand Curve: Theory and Empirical Test, *Quarterly Review of Economics and Finance 32*, 99-117.

Asplund, M., Eriksson, R. and Friberg, R. (1997), Price Adjustment by a Gasoline Retail Chain, Working Paper Series in Economics and Finance, Stockholm School of Economics, WP No. 194.

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

Blanchard, O.J. and Fisher, S. (1989), *Lectures on Macroeconomics*, The MIT Press, Cambridge, MA.

Borenstein, S.A. and Shephard, A. (1996a), Dynamic Pricing in Retail Gasoline Markets, *RAND Journal of Economics 27*, 429-451.

Borenstein, S.A. and Shephard, A. (1996b), Sticky Prices, Inventories and Market Power in Wholesale Gasoline Markets, NBER Working Paper 5468.

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

Cecchetti, S.G. (1986), The Frequency of Price Adjustment: A Study of the Newsstand Prices of Magazines, *Journal of Econometrics 31*, 255-274.

Dahlby, B. (1992), Price Adjustment in an Automobile Insurance Market: A Test of the Sheshinski-Weiss Model, *Canadian Journal of Economics*, 564-583.

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

Ellison, G. (1994), Theories of Cartel Stability and the Joint Executive Committee, *RAND Journal of Economics 25*, 37-57.

Feenstra, R.C. (1989), Symmetric Pass-Through of Tariffs and Exchange Rates under Imperfect Competition: An Empirical Test, *Journal of International Economics 27*, 25-45.

Kashyap, A.K. (1995), Sticky Prices: New Evidence from Retail Catalogs*, Quarterly Journal of Economics 110*, 245-274.

Kirchgässner, G. and Kübler, K. (1992), Symmetric or Asymmetric Price Adjustment in the Oil Market, *Energy Economics*, 171-185.

Kraft, K. (1995), Determinants of Price Adjustment, *Applied Economics 27*,501-507.

Lach, S. Tsiddon, D. (1996), Staggering and Synchronization in Price Setting: Evidence from Multiproduct Firms, *American Economic Review 86*, 1175-1196.

Rotemberg, J.J. (1982), Monopolistic Price Adjustment and Aggregate Output, *Review of Economic Studies 49*, 517-531.

Slade, M.E. (1992), Vancouver's Gasoline-Price Wars: An Empirical Exercise in Uncovering Supergame Strategies, *Review of Economic Studies 59*, 257-76.

Slade, M.E. (1998), Optimal Pricing with Costly Adjustment: Evidence from Retail-Grocery Prices, *Review of Economic Studies 65*, 87-107.

Table 1a: Descriptive statistics for all price adjustments.

	Mean	*St.Dev*	*Skew*	*Kurt*	*Min*	*Max*	*Median*	*Cases*
ΔRP≠0								
ΔRP	1.55	11.05	3.0	23.7	-16.20	95.20	3.20	250
ΔMC	0.04	9.26	0.3	6.0	-37.26	35.54	-0.27	250
*ΔSP*E(-1)*	-0.31	8.84	0.4	6.2	-35.09	35.42	0.00	250
*ΔE*SP(-1)*	0.37	3.94	1.4	15.2	-14.27	26.24	0.12	250
DAYSFIXED	21.59	23.90	2.6	12.4	0	177	13	250
ΔRP>0								
ΔRP	9.09	10.22	5.4	41.8	2.00	95.20	6.00	130
ΔMC	4.62	8.69	0.9	5.3	-17.00	35.54	3.98	130
*ΔSP*E(-1)*	3.11	8.37	0.9	5.5	-17.64	35.42	1.79	130
*ΔE*SP(-1)*	1.54	4.46	1.4	14.0	-14.27	29.24	0.70	130
DAYSFIXED	24.81	26.64	2.6	12.3	1	177	14	130
ΔRP<0								
ΔRP	-6.62	3.59	-1.4	3.9	-16.20	-2.00	-5.60	120
ΔMC	-4.92	7.05	-1.2	8.5	-37.26	21.14	-3.55	120
*ΔSP*E(-1)*	-4.02	7.38	-0.8	7.1	-35.09	24.02	-2.78	120
*ΔE*SP(-1)*	-0.89	2.65	-0.5	4.4	-9.77	5.33	-0.68	120
DAYSFIXED	18.10	20.06	2.2	7.8	0	104	11	120

Table 1b: Descriptive statistics for the sub-periods 1980-84, 1985-89, and 1990-96.

	|ΔRP| *Mean* *(St.Dev)*	*|ΔMC|* *Mean* *(St.Dev)*	*|ΔSP*E|* *Mean* *(St.Dev)*	*|ΔE*SP|* *Mean* *(St.Dev)*	*DAYSFIXED* *Mean* *(St.Dev)*	*ΔRP>0* *Nobs.*	*ΔRP<0* *Nobs.*
1980 – 1984	8.89 (8.54)	7.61 (7.33)	7.10 (6.61)	4.08 (4.79)	38.18 (27.49)	28	16
1985 – 1989	9.45 (5.13)	9.06 (7.57)	8.63 (7.99)	3.30 (3.30)	31.84 (36.30)	20	24
1990 – 1996	7.22 (8.23)	5.53 (5.81)	4.93 (5.81)	1.88 (2.05)	14.30 (13.13)	82	80
1980 – 1996	7.90 (7.86)	6.52 (6.56)	5.96 (6.52)	2.52 (3.06)	21.59 (23.90)	130	120

Table 2: Number of price adjustments, by month and day of the week.

	Jan	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sep*	*Oct*	*Nov*	*Dec*
Quantity $1000m^3$	370	386	438	446	465	497	526	501	450	448	422	433
ΔRP>0	12	13	10	17	5	13	9	12	11	10	7	11
ΔRP<0	9	6	9	6	7	11	10	10	13	14	11	14
	Mon	*Tue*	*Wed*	*Thu*	*Fri*	*Sat*	*Sun*					
ΔRP>0	9	31	33	29	18	5	5					
ΔRP<0	13	34	25	20	20	8	0					

Table 3: Price adjustments in relation to changes in marginal cost, spot market price, exchange rate, and tax. Individual price adjustments (no fixed frequency).

VARIABLE	*3:1* *ΔRP*	*3:2* *ΔRP|ΔRP>0*	*3:3* *ΔRP|ΔRP<0*	*3:4* *ΔRP*	*3:5* *ΔRP|ΔRP>0*	*3:6* *ΔRP|ΔRP<0*
CONSTANT	0.0405	5.51**	-5.40**	0.295	5.37**	-5.47**
	(0.366)	(0.415)	(0.380)	(0.363)	(0.420)	(0.395)
ΔTAX	0.887**	0.801**		0.885**	0.802**	
	(0.0426)	(0.0298)		(0.0419)	(0.0297)	
ΔMC	0.548**	0.283**	0.192**			
	(0.0392)	(0.0403)	(0.0430)			
*ΔSP*E*				0.513**	0.277**	0.193**
				(0.0406)	(0.0417)	(0.0428)
*ΔE*SP*				0.790**	0.377**	0.134
				(0.0909)	(0.0793)	(0.121)
ΔMC_{-1}	0.279**	0.169**	0.123**			
	(0.0403)	(0.0398)	(0.0346)			
$(\Delta SP*E)_{-1}$				0.279**	0.165**	0.120**
				(0.0418)	(0.0424)	(0.0363)
$(\Delta E*SP)_{-1}$				0.260**	0.177*	0.131
				(0.0923)	(0.0845)	(0.0847)
Adj.R^2	0.733	0.853	0.178	0.742	0.855	0.171
D-W	2.21	1.64	1.21	2.18	1.59	1.21
NOBS	249	129	120	249	129	120

Heteroskedacity consistent standard errors. Variables starred with ** are significant at the 1 percent level and with * at the 5 percent level.

Table 4. Price changes in relation to changes in marginal cost, spot market price, exchange rate, and tax. Error correction model. Monthly frequency.

VARIABLE	*4:1* *ΔRP*	*4:2*[a] *ΔRP*	*VARIABLE*	*4:3* *ΔRP*	*4:4*[a] *ΔRP*
CONSTANT	0.717	0.736	*CONSTANT*	0.408	0.102
	(0.599)	(1.01)		(0.589)	(1.346)
$\hat{u}$	-0.275**	-0.274**	$\hat{u}$	-0.292**	-0.288**
	(0.0523)	(0.0532)		(0.0520)	(0.0538)
ΔTAX	0.745**	0.750**	*ΔTAX*	0.726**	0.723**
	(0.0515)	(0.0512)		(0.0520)	(0.0523)
ΔTAX_{-1}	-0.0591	-0.0586	ΔTAX_{-1}	-0.0951	-0.0907
	(0.0525)	(0.0522)		(0.0525)	(0.0529)
ΔWAGE	1.01*	0.939*	*ΔWAGE*	1.01*	0.898*
	(0.452)	(0.450)		(0.440)	(0.447)
ΔMC	0.541**		*ΔSP*E*	0.476**	
	(0.0549)			(0.0564)	
			*ΔE*SP*	0.850**	
				(0.123)	
ΔMC|ΔMC>0		0.695**	*ΔSP*E|ΔSP>0*		0.624**
		(0.0970)			(0.101)
			*ΔE*SP|ΔE>0*		0.940**
					(0.172)
ΔMC|ΔMC<0		0.349**	*ΔSP*E|ΔSP<0*		0.298**
		(0.103)			(0.108)
			*ΔE*SP|ΔE<0*		0.745*
					(0.305)
ΔMC_{-1}	0.183**		$(\Delta SP*E)_{-1}$	0.194**	
	(0.0586)			(0.0608)	
			$(\Delta E*SP)_{-1}$	0.208	
				(0.124)	
$(\Delta MC \mid \Delta MC>0)_{-1}$		0.0289	$(\Delta SP*E \mid \Delta SP>0)_{-1}$		0.0660
		(0.103)			(0.110)
			$(\Delta E*SP \mid \Delta E>0)_{-1}$		0.235
					(0.178)
$(\Delta MC \mid \Delta MC<0)_{-1}$		0.311**	$(\Delta SP*E \mid \Delta SP<0)_{-1}$		0.282**
		(0.107)			(0.108)
			$(\Delta E*SP \mid \Delta E<0)_{-1}$		-0.0368
					(0.288)
ΔMC_{-2}	-0.0643		$(\Delta SP*E)_{-2}$	-0.112*	
	(0.0551)			(0.0566)	
			$(\Delta E*SP)_{-2}$	0.166	
				(0.126)	
Adj.R^2	0.693	0.698	Adj.R^2	0.711	0.711
D-W	1.96	1.97	D-W	1.91	1.93
NOBS	178	178	NOBS	178	178

Heteroskedacity consistent standard errors. Variables starred with ** are significant at the 1 percent level and with * at the 5 percent level.
a) Two lags of the signed variables included but coefficients not reported. None of them significant at the 10 percent level.

Appendix. Variable definitions and data sources.

VARIABLE	*DEFINITION AND DATA SOURCE*
RP	Retail list price for premium leaded gasoline for one of the firms, Shell. The retail price is at 0-zone, i.e. where the transport cost is the lowest. VAT (introduced in 1990) is excluded from the price according to the formula: *RP*=consumer price/(1+VAT) measured in SEK*100/litre. Source: Shell.
SP	The spot market price of premium leaded gasoline. From November 1985 to December 1996 it is the average of high (from refinery) and low (stored or blended material) daily quotations, FOB Rotterdam for Premium 0.15 g/l. Size is barges (1,000-5,000 mt) and delivery is North West Europe. Prices are assessed daily up until 1830 GMT. For the period January 1980 to October 1985 it is for Mediterranean/Italian delivery of regular gasoline plus USD 24, which was the average difference between the two prices for the period where we have access to both. The FOB price is transformed from USD/mt to USD/liter by the factor 8.35*159. *SP* is measured in USD*100/litre. Source: Platt's, London.
E	The exchange rate between Swedish kronor and US dollars. Source: Findata (January 1983 to December 1996), Stefan Nydahl, Uppsala University (January 1980 to December 1982).
MC	Spot market price of premium leaded gasoline measured in SEK*100/litre. MC is obtained by: *MC*=*SP***E*
TAX	Total tax per liter premium leaded gasoline. Source: The Swedish Petroleum Institute, Annual report 1995.
VAT	Value added tax. Calculated on producer price including *TAX*. A *VAT* of 23.46% was levied on gasoline on March 1, 1990, it was subsequently (July 1, 1991) increased to 25.00%. Source: The Swedish Petroleum Institute, Annual report 1995.
WAGE	Index of nominal hourly wages in the manufacturing sector (SNI 3). Source: International Financial Statistics, heading 14465.zf
ΔX_{lag}	Changes in the variable *X* is denoted ΔX. In Section 3 Δ refers to the change since the last price adjustment and in Section 4 it refers to the change since last month. The subscript on *X* denotes the number of lags.
DAYSFIXED	The number of days *RP* has been fixed since latest price adjustment.