The patterns of retail price variation. The case of milk products

Imre Fertő* and Lajos Zoltán Bakucs**

*senior research advisor,
Institute of Economics Hungarian Academy of Sciences, Budapest Budaorsi út 45. H-1112,
professor,
Corvinus University of Budapest, Budapest, Fővám tér 8. H-1098
email: ferto@econ.core.hu
**research fellow
Institute of Economics Hungarian Academy of Sciences, Budapest Budaorsi út 45. H-1112
email: bakucs@econ.core.hu

We examine retail price variation across a range of milk products in Hungary. Our results show that majority of products have regular prices and the most deviations from that regular price are upward. We find significant differences across products in terms of price distributions. Sales are infrequent for majority of products and its role is limited in annual price variation. Results do not confirm that durable goods should have qualitatively different pricing pattern than less-durable goods. Although existing models of retail sales yield predictions consistent with some aspects of the retail pricing distributions, all of these models fail to explain other important aspects of retail pricing identified here.
Keywords, retail prices, sales, milk products

Selected Paper prepared for presentation at the 27th Conference of the International Association of Agricultural Economics, Beijing, China, August 16-22, 2009

The patterns of retail price variation. The case of milk products

Introduction

Periodic price reductions, or sales, constitute a widely observed phenomenon in retailing. Sales occur on a regular basis, which suggests that they are not entirely due to random variations such as shocks to inventory holdings or demand. In recent years the frequency of periodic price reductions has increased, indicating that the sales phenomenon has become more important for retailers and consumers. Consumers, have some familiarity with the complex pricing strategies employed by supermarkets. Despite the high administrative costs of changing retail prices (Levy et al., 1997), retailers clearly find it profit maximizing to temporarily reduce the prices of different items each week. Recent studies suggest that a significant proportion of the movement in retail prices is due to these temporary reductions (e.g. Hosken and Reiffen 2004; Li et al. 2005). Despite of emerging importance of this phenomena, there is little empirical literature on retail sales and pattern of retail prices especially on food products (e.g. Berck et al. 2007, Chevalier et al 2003; McDonald et al. 2000 and Pesendorfer 2002). In addition, similar research on transition countries does not exist. The aim of this paper is to provide evidence on the extent of this aspect of retailer behaviour. More specifically, we examine a particular market in which price reductions occur, namely, the market for milk products in supermarkets in Hungary.

The theoretical backgrounds

In the literature, different explanations for retail sales and price dispersion have been offered. Varian (1980) formulates a model in which there are consumers who are informed about prices and uninformed consumers. Retailers randomly choose prices every period, and

informed consumers purchase from the retailer offering the lowest price. An implication of this model is that prices are not predictable and, thus, not correlated over time. Conlisk, Gerstner, and Sobel (1984) and Sobel (1991) study intertemporal pricing decisions of a durable goods monopolist with a constant inflow of consumers. They consider strategic behaviour by consumers who may purchase later if they expect the price to fall. The policy of the monopolist is to start at a high price, selling only to high-valuation consumers, then gradually lower the price over time until low-valuation consumers are willing to purchase. After a sale has occurred the cycle starts over. These gradual declines in prices differ from the observed price paths in my data, in which prices remain at high levels for extended periods of time followed by a sudden price cut. Sobel (1984) considers competition between retailers for lows. He assumes that only low valuation consumers behave strategically. High-valuation consumers do not discount the future. The resulting equilibrium price path consists of sudden price cuts similar to be observed price path in the data. Pesendorfer (2002) extends the Sobel model and explicitly applies it to food retailing. The Pesendorfer model is essentially one in which both types of consumers consume one unit of the good in every period, but the low-value consumers consume from their own inventory whenever the price is above their reservation values. Although Pesendorfer's model explains price discounts for goods that can be inventoried by consumers, or goods that are infrequently purchased (which amounts to a kind of inventorying if consumers wait until price is low to buy and consume), it does not explain discounts for perishable goods that are frequently purchased and not inventoried by consumers, such as dairy products and produce.

In short, the theoretical models have very different implications in terms of the patterns of prices we might actually observe in a market. We focus on two specific issues. First, the existing sales literature presents conflicting predictions about the distribution of prices over

time. We use our data set to examine three price distribution-related hypotheses. Second, different predictions by these theories that assume that the good is storable and those that consider only perishable goods, one might expect that the temporal price patterns to vary with the durability of the product.

The patterns of retail price movements

Our time span is between 2005 January and 2008 August. The data are provided by the Agricultural Economics Institute in Budapest, and they consist of weekly prices for seven products (storable and boxed milk, kefir, fruit yoghurt, sour cream, cheese and butter) for 8 most important retail chains yielding 192 observations per product groups and chains.

We present our results in three different stages. First, we investigate the price distributions. Second, we analyse the extent of temporary price movements. Finally, we focus on the importance of sales as a source of retail price variation.

Price distributions

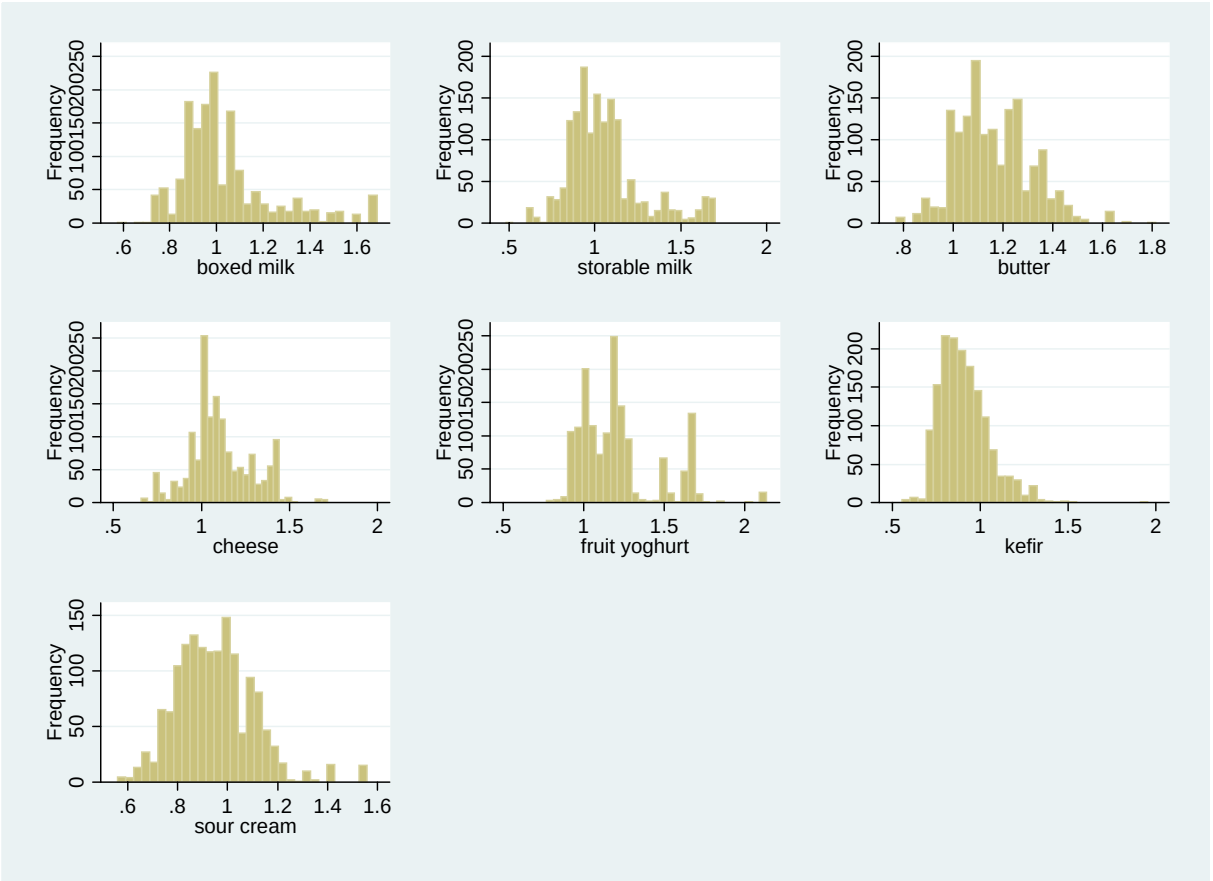
The first feature of retail prices we document is the extent to which a product can be characterized as having a "regular" price. Following the empirical literature we define the regular price for a specific good as its modal price during analysed period (e.g. Pesendorfer 2002, Hosken and Reiffen 2004, Berck et al 2007). This approach implicitly assumes that a product has a single "regular" price each period.

To compare price variation within and across categories, it is useful to divide a specific product's price by a measure of the central tendency of that product's price. The fact that the empirical distributions have significant mass points suggests that the appropriate measure of central tendency is a product's annual mode. Therefore, we define scaled prices (P_{jt}) as:

$$P_{jt} = \frac{r_{jt}}{r_{j,\mathrm{mode}}}, \qquad (1)$$

where r j t is the raw price (as reported by the AKI) of product j in month t, and r j,mode is the modal raw price of product j in the year that contains month t.

Figure 1 Frequency distribution of milk products



Source: Own calculations based AKI dataset

Figure 1 presents the empirical density function of scaled prices across all seven product groups. Hosken and Reiffen (2004) results show that the large mass point is at one, and when price is not at its annual mode, it is much more likely to be below the mode than above it. However, our estimations do not confirm these patterns. The mass points of prices of milk products in Hungary are not at one and annual mode is below one only for two products (sour cream and kefir) from the seven items. Third feature of price patterns there is considerable heterogeneity in the share of the cumulative distribution at the mode across products. Interestingly, these differences can not be explained by characteristics of products, namely whether they are storable or not.

Table 1: Difference in Proportion of Pricing Distribution 10per cent or 20per cent Above Mode to 10per cent or 20per cent Below Mode

	Proportion of Observations 10per cent or More			Proportion of Observations 20per cent or More		
	Below mode	Above mode	Z test	Below mode	Above mode	Z test
Storable milk	20.5	31.3	0.000	6.4	18.2	0.000
Boxed milk	23.4	23.6	0.911	6.4	16.2	0.000
Fruit yoghurt	1.1	62.1	0.000	0.1	45.5	0.000
Kefir	51.5	9.2	0.000	23.1	4.6	0.000
Sour cream	43.0	16.1	0.000	17.6	4.1	0.000
Cheese	8.2	43.2	0.000	4.4	28.1	0.000
Butter	8.5	38.8	0.000	1.2	15.5	0.000

Source: Own calculations based AKI dataset

One of the main hypothesis of the sales literature that the sales play important role in price distribution, thus we can expect that prices more likely deviate down than up. We formally test the asymmetry of the price distribution by examining the proportion of prices above and below the mode. Specifically, if sales are an important component of price variation, we would expect to see more deviations below the mode than above it. We apply this test by examining two typical levels of "sales," a 10 per cent or more reduction from the regular (modal) price, and a 20 per cent or more reduction. We calculate the difference between the proportion of prices 10 per cent (20 per cent) above the mode and the proportion of prices 10 per cent (20 per cent) below the mode. The results are presented in Table 1. Estimations confirm the graphical analysis. Prices are much more likely to be below than above the mode only for kefir and sour cream. The asymmetry is significant with both threshold values (10 and 20 per cent). We can observe upward asymmetry for other products except boxed milk with 10 per cent cutting value, where price distribution is symmetric.

The extent of temporary price movements

Following Hosken and Reiffen (2004) we examine the pricing distribution is to determine whether most price reductions are indeed temporary "sales." To do this, we analyze the time series of first differences in price. Specifically, we examine the price changes between month t and t + 1, conditional on price falling between months t − 1 and t. If a price reduction is temporary rather than permanent, then price would rise between month t and t + 1. In contrast, if the price change between months t and t + 1 is zero (or negative), it would suggest that the retail price movement reflects a permanent change in the retailer's cost (and/or the manufacturer's cost).

Table 2: **Direction of Price Change Following a Price Decrease**

	Percentage of Observations with	
	Price Increases Following a Price Decrease	No Change in Price Following a Price Decrease
Storable milk	43.7	36.2
Boxed milk	48.3	31.3
Fruit joghurt	68.3	6.5
Kefir	71.0	3.1
Sour cream	71.3	3.5
Cheese	68.0	8.7
Butter	70.8	5.9

Source: Own calculations based AKI dataset

Table 2 indicates, across majority of products, 68-71 per cent of all price reductions are followed by a price increase, while only 3-9 per cent remains at the new, lower level. This suggests that the majority of retail price reductions are temporary "sales." Two exceptions are the stored and boxed milk, where 43-48 per cent of all price reductions are followed by a price increase, while 31-36 per cent remains at the new, lower level

There are different definitions for the sale in empirical literature. Hosken and Reiffen (2004) offer a useful operational definition of sales. They define a sale as occurring if price falls by at least some fixed percentage (e.g., 10 per cent) between periods $t - 1$ and t and then rises by at least that percentage between period t and $t + 1$. Berck et al. (2007) point out that store has a product "on sale" if its weekly price is at least a given (25, 35 or 50) percent below the modeprice (across all weeks in the analysed period) for that product in that store. Pesendorfer (2002) defines the sale only after a careful analysis of price distributions employing specific

prices as a sale. In this paper we apply the approach proposed by Hosken and Reiffen (2004) using 10 and 20 per cent thresholds.

Table 3: Percentage of Observations with a 10per cent or 20per cent Sale, by Category

	with a 10per cent Sale	with a 20per cent Sale
Storable milk	7.8	1.6
Boxed milk	7.3	0.0
Fruit joghurt	13.0	6.8
Kefir	13.5	4.2
Sour cream	6.8	1.6
Cheese	13.0	3.1
Butter	13.0	4.2

Source: Own calculations based AKI dataset

Table 3 shows the frequency of the sales with 10 and 20 per cent cut off values for each product. The first striking feature of the results that there are considerable differences across products, the share of sales fluctuates between 7 and 14 per cent of observations with 10 per cent threshold. These ratios dramatically decline if we increase the cut off value for 20 per cent. We can divide the milk products into two groups. First group contains the yoghurt, kefir, cheese and butter, where the shares of sales are relatively high. Second group consists of boxed and storable milk and sour cream, where the proportion of the sales is below half of previous group. We can argue partly that these differences can be explained by characteristics of the products (storable or not storable). However, this relationship is not unambiguous.

The importance of sales as a source of retail price variation

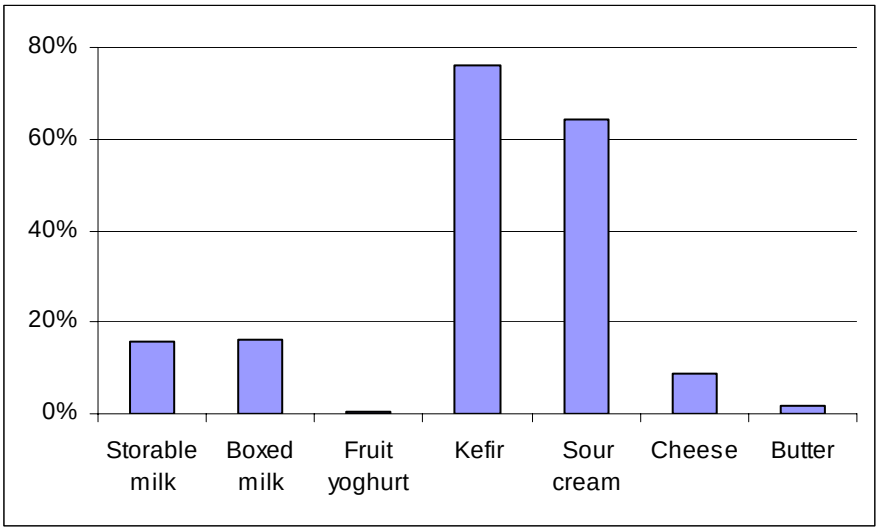
The previous section documented some aspects of retail price movement. The evidence presented there conforms only partly with our a priori expectations, namely that most milk products have a "regular" price and that most deviations from that regular price are downward. This section investigates further the pattern of price distributions and changes. We examine the extent to which this pattern is the result of changes in retail margins, rather than changes in retail costs. Following Hosken and Reiffen (2004) we apply two statistical approaches to determine the relative contribution of retail margin changes to retail price variation.

First way to examine the importance of retail margin change is to decompose price variability into two components: one associated with sales and the other associated with other effects (such as changes in wholesale price). Because the annual mode seems to be the most appropriate measure of a product's regular price, our measure of variation examines dispersion around the mode. Based on this measure of variation, we calculate a statistic analogous to an R^2. Equation (2) is the formula for our statistic, which is essentially the proportion of total price variation about the mode associated with sales. In (2) the i subscript refers to the product category, j is the unique price series (specific to a retailer/product), and t is the time subscript.

$$\frac{\sum_{j,t}\left[\left(p_{ijt}-1\right)^2 \mid p_{ijt}{}^{l}\right]}{\sum_{j,t}\left(p_{ijt}-1\right)^2}, \qquad (2)$$

Figure 2 displays the percentage of variability explained by sales in each of product, using a 10 per cent sale definition. Similarly to our previous results, we observe significant differences across products. The impacts of the sales are negligible for fruit yoghurt and cheese, while these effects extend the 60 per cent in the case of kefir and sour cream. That such a large percentage of variability is associated with sales is particularly noteworthy given the fact that a small percentage of all observations (between 6 per cent and 13 per cent for 7 of the categories) is made up of sales.

Figure 2 Percentage of variation about modal price association with sales



Source: Own calculations based AKI dataset

The second tool of examining the contribution of wholesale price changes to retail price variability is to use a simple regression analysis to determine the extent to which national shocks in each time period explain retail price variation. Specifically, for each product j in category i, we regress p_i j_t on separate dummy variables for each of the 192 weeks in our data as described in equation (3) below.

$$p_{ijt} = \sum_{i=1}^{192} \beta_{it} * (week_t) + \varepsilon_{ijt} \quad (3).$$

Each month's β_i t is the average level of scaled retail price in category i across all cities in month t. The underlying logic of (2) is that most changes in wholesale prices are likely to be national and affect most, if not all, products in a category similarly (e.g., cost shocks to an important input used in producing all goods in a category). Thus, changes in the β_i t from month to month reflect retail price changes due to nationwide wholesale price changes (e.g., shifts in supply).

Table 4: Summary Statistics of Weekly Dummy Variables (*Bit*), by Category

	mean	St. Dev.	Minimum	Maximum
Storable milk	0.187	0.159	-0.027	0.543
Boxed milk	0.153	0.176	-0.110	0.541
Fruit yoghurt	0.101	0.110	-0.069	0.375
Kefir	0.101	0.093	-0.055	0.283
Sour cream	0.136	0.106	-0.065	0.394
Cheese	-0.008	0.094	-0.200	0.214
Butter	0.104	0.100	-0.077	0.317

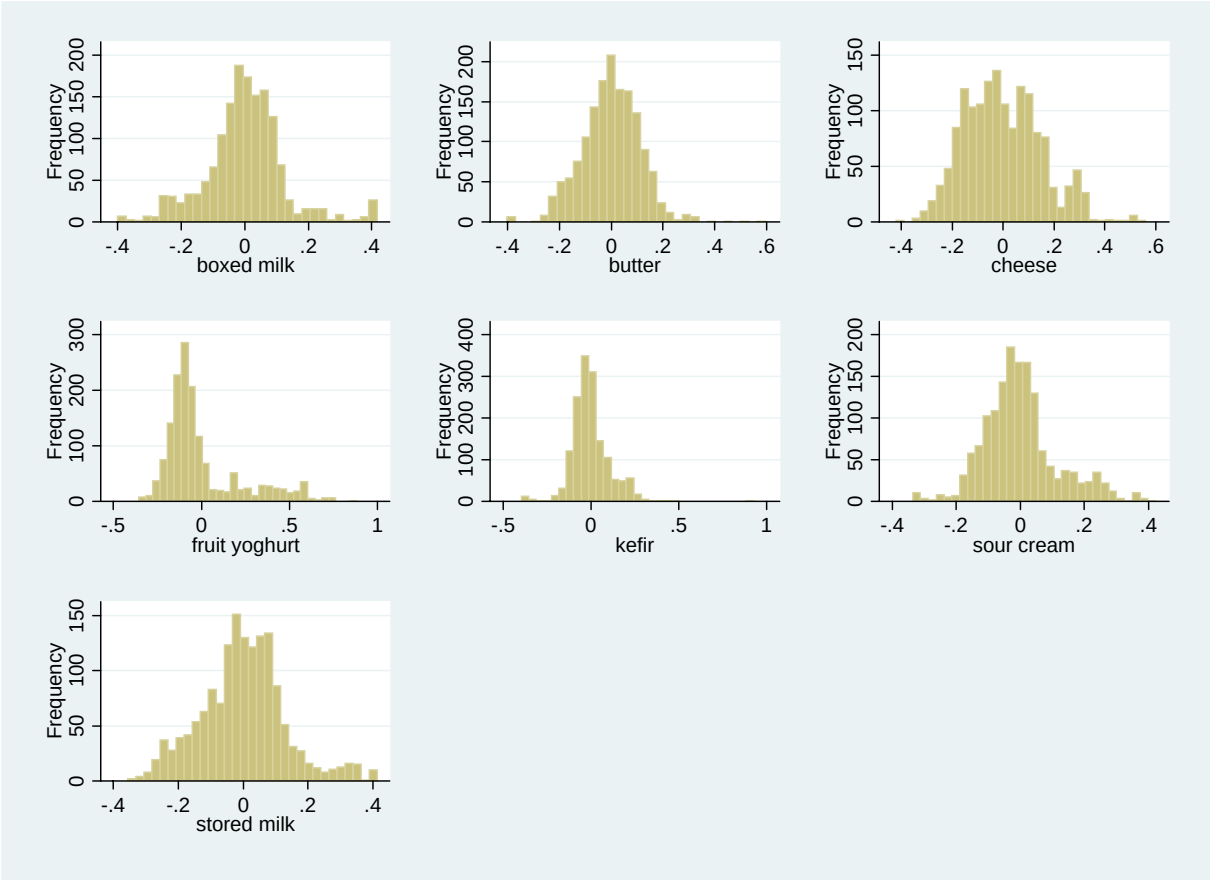
Source: Own calculations based AKI dataset

Table 4 presents the mean, standard deviation, minimum, and maximum of the β_{it} estimated separately by product category. As one would anticipate, the β_{it} tend to be most variable (e.g., have the largest standard deviation) for relatively unprocessed milk products, such as boxed and storable milk. We may interpret this result as suggesting that national wholesale price shocks are a large component of price variation for these products. Contrary to the results by

Hosken and Reiffen (2004), our estimations shows that the β_{it} tend to be strongly deviate from one (the annual modal price). Deviations from one reflect the extent to which the mean and mode differ. In our case the mode is systematically larger than the mean for a products, then β_{it} will be below one.

Because the β_{it} have the interpretation of removing the national wholesale price component from retail price variation, the residuals from (3) can be interpreted as the portion of the retail price of good j in category i in week k (scaled by good j 's annual mode) that is unrelated to (scaled) national wholesale prices in that week.

Figure 3: Frequency distribution of residuals from equation (3) by products



Source: Own calculations based AKI dataset

Figure 3 shows the residuals, for each product. Contrary to the individual (scaled) prices displayed in Figure 1 that missed to show a large point mass at the mode, a large percentage of all residuals are located very near zero for the majority of products.

We perform a similar test for the presence of sales in the residuals that we used in examining the asymmetry of the scaled price distribution. While, by construction, the average residual is zero in (3), if sales (in the sense of significant short-term reductions in retail margins) are an important phenomenon, the distribution of residuals will be asymmetric. Specifically, an observation with a sale will have a large negative residual, while all of the observations that are at their "regular" price will have small positive residuals. The residuals in Figure 3 just partly follow this prediction. We formally test for this asymmetry by comparing the percentages of residuals that are in the left- and right-hand tails of the distribution. Table 5 compares the percentage of the distribution of residuals that is more than 10 per cent (20 per cent) above zero to the percentage that is more than 10 per cent (20 per cent) below zero for each category.

We find for boxed and storable milk, fruit yoghurt and cheese that the percentage of the distribution made up of negative residuals greater than 10 per cent (in absolute value) is statistically significantly larger than the percentage that are positive residuals greater than 10 per cent. We have counter results for kefir, while the residuals are symmetric for butter and sour cream. The increase of threshold of sales alters considerably our results. The residuals become symmetric for boxed and storable milk, while asymmetry will be positive for fruit yoghurt and kefir. Only residuals of butter display negative asymmetry. Our results are the opposite as Hosken and Reiffen who find negative asymmetry for all 20 categories.

Table 5: Difference Between Proportion of Residual Distribution 10per cent or 20per cent > 0 and 10per cent or 20per cent < 0,

	Proportion of Proportion of Residuals 10per cent or More			Proportion of Proportion of Residuals 10per cent or More		
	Below Zero	Above Zero	Z test	Below Zero	Above	Z test
Storable milk	21.0	16.5	0.0041	7.0	5.9	0.2282
Boxed milk	15.6	13.3	0.0875	6.2	5.3	0.2913
Fruit yoghurt	41.5	21.5	0.0000	7.9	16.8	0.0000
Kefir	11.1	14.6	0.0067	1.8	5.9	0.0000
Sour cream	16.5	16.0	0.6870	2.2	7.7	0.0000
Cheese	28.4	24.9	0.0590	7.0	9.4	0.0167
Butter	17.4	17.2	0.8964	4.4	2.6	0.0090

Source: Own calculations based AKI dataset

Conclusions

This paper provides evidence on the pattern of retail pricing dynamics for a range of milk products in Hungary. While the pattern of price movements differs somewhat across products some broad patterns in pricing are apparent. First, most products have a regular price, and prices are at that level a relatively high percentage of the time. Second key aspect of retail price dynamics is that for majority of milk products, when price is not its mode, it is overwhelmingly more likely to be above the modal price than below it.

We directly test for the presence of sales by examining whether most price reductions are temporary. Specifically, we examine price changes following a price reduction. Consistent with the premise that sales are prevalent, we find that a large majority of price reductions are immediately followed by price increases. Sales are infrequent for majority of products and its role is limited in annual price variation.

We examine the implications of the Varian model of sales, which is based on the idea that each period's price is drawn from a continuous price distribution. The graphical and statistical analysis appears to rule out a Varian-style sales model as an explanation of the temporary price reductions. The price distributions of some products show rather bi or multimodal patters. It may suggest that sales can be associated with the price changes. This fact can be consistent with hypothesis that stores have alternating sales among major brands Lal (1990).

The observed asymmetry in price distributions supports rather Pesendorfer's (2002) theory. Prices in these models are predicted to be at a high level (equal to high-valued consumers'

willingness to pay) most of the time, with periodic substantial discounts. However, this explanation of sales as a means of price discrimination seems to explain price variation only for non-perishable. Our results partly support that price asymmetry is more profound for durable goods.

Finally, contrary to models by Sobel (1984) and Conlisk et al (1984) we fail to confirm that durable goods (storable milk) should have qualitatively different pricing pattern than less-durable goods (boxed milk). In sum, in line with previous research we may conclude that although existing models of retail sales yield predictions consistent with some aspects of the retail pricing distributions, all of these models fail to explain other important aspects of retail pricing of milk products in Hungary.

References

Berck, P., Brown, J., Perloff, J.M., Villas-Boas, S.B. (2007). Sales: Tests of Theories on Causality and Timing. CUDARE Working Papers, No. 1031. University of California, Berkeley.

Carman, H.F., and Sexton, R. (2005). Supermarket Fluid Milk Pricing Practices in the Western United States. *Agribusiness*, 21: 509-53

Chevalier, J.A., Kashyap, A.K., and Rossi, P.E. (2003), Why Don't Prices Rise During Periods of Peak Demand? Evidence from Scanner Data. American Economic Review, 93: 15–37

Conlisk, J., Gerstner, E. és Sobel, J. (1984). Cyclic Pricing by a Durable Goods Monopolist, *Quarterly Journal of Economics*, 99: 489-505.

Hosken, D., Reiffen, D. (2004). Patterns of Retail Price Variation. *Rand Journal of Economics*, 35 (1): 128-146

Lal, R. (1990). Price Promotions: Limiting Competitive Encroachment, Marketing Science, 9: 247-262.

Li, L., Carman, H.F., Sexton, R. (2005). Grocery Retailer Pricing Behavior for California Avocados with Implications for Industry Promotion Strategies. Selected Paper prepared for presentation at the American Agricultural Economics Association Annual Meeting, Providence, Rhode Island, July 24-27,

MacDonald, J. (2000) Demand, Information, and Competition: Why Do Food Prices Fall at Seasonal Demand Peaks? *Journal of Industrial Economics*, 48 (1): 27-45.

Pesendorfer, M. (2002). Retail Sales: A Study of Pricing Behavior in Supermarkets, *Journal of Business*, 75: 33-66.

Shilony, Y. (1977). "Mixed Pricing in Oligopoly," *Journal of Economic Theory*, 14: 373-388

Sobel, J. (1984). "The Timing of Sales," *Review of Economic Studies*, 51: 353-368.

Stokey, N. L. (1981). "Rational Expectations and Durable Goods Pricing," *Bell Journal of Economics and Management Science*, 12:112-28.

Varian, H. (1980). A Model of Sales, *American Economic Review*, 70: 651-659.

Villas-Boas, J. M. (1995). Models of Competitive Price Promotions: Some Empirical Evidence from the Coffee and Saltine Crackers Markets, *Journal of Economics and Management Strategy,* 4: 85-107.