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# Milk Retail Sales Patterns in a Transition Economy. The Case of Hungary

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## Abstract

Modern theories of sales make conflicting predictions about the temporal pattern of sales, which we test using retail chain level data. In this paper, we focus on the retail sale patterns of two retail milk prices in a New Member State (NMS), Hungary using weekly data across eight retail chain between 2005 January and 2008 June. We employ a battery of empirical tests, to try a number of sale theory hypotheses. First, we present summary statistics, histograms, and correlations of prices and sales from which we conclude that no theory of sales fully describes sale patterns and price distributions. Second, we apply vector autoregressive analysis and Granger tests of temporal ordering ("causality tests") to determine whether the sale of one retail chain is followed in a predictable way by the sale of another retail chain or its own later sales. Our results suggest a dual retail market structure. Finally, we employ panel cointegration to test confirm that durable goods should have qualitatively different pricing pattern than less-durable goods. Similarly to Berck et al. (2007) we fail to see a clear difference between storable milk and boxed milk patterns.

**Keywords: Sales, retail prices, milk**

## I. Introduction

Price dispersion has long been in the focus of economics literature. According to Zhao (2006), price dispersion may have three dimensions: between stores, within a store (between similar products or competing brands), and in time. According to the literature, price dispersion may have two broader explanations. Some authors (Stigler 1961, Reingaum 1979, Salop and Stiglitz 1982, Burdett and Judd 1983, Carlson and McAfee 1983, Rob 1985 and Stahl 1989) use *search costs theory* to explain price dispersion. They argue that consumers faced with imperfect price information need to spend time and money to obtain comparable price information. Consumers' *search costs* enable retailers to apply different pricing. Consumers are also heterogeneous from this point of view. Some are willing to pay for their *search costs* to find the best price, others just buy the product from a randomly chosen shop or the one *though* to have convenient prices compared to competition. Other authors (Borenstein 1985, Holmes 1989, Borenstein and Rose 1994) emphasise that price dispersion may also be due to increasing competition between retailers. According to theory, price dispersion between retailers decreases with increasing competition if sectors' elasticity is supporting market segmentation (monopolistic price dispersion). If however price dispersion is due to heterogeneous cross elasticities (competition based price discrimination) than increasing competition leads to increased price dispersion. To put is other way, if retailers position themselves too close to each other, than consumers differentiate based on available price information, and thus they increase retailer competition. Retailers however may choose to differentiate themselves from competition along non-price related dimensions (e.g. additional services, larger spectrum of similar products, etc), thus increasing price dispersion and increasing competition. The analysis of price dispersion is somewhat imbedded into the Law of One Price (LOP) theory as well.

Price dispersion closely relates to various sale theories since price variability is greatly influenced by periodic sales. Part of the literature (Salop 1977, Salop and Stiglitz 1982, Conlisk et al. 1984, Pesendorfer 2002, Sobel 1984) emphasise the time dimension of price discrimination explained by the different consumer preferences and imperfect price information. Well informed consumers may purchase large quantities and store them at home when prices are low, thus encouraging price discrimination. Other authors (Shilony 1977, Varian 1980, Lal and Villas-Boas 1998) argue that retailers follow a mixed strategy when determining prices, discriminating between well informed consumers facing zero, and others with increased search costs. Thus retailers may apply different pricing for homogenous products using for example various brand names, however informed consumers choose the cheaper whilst less informed ones the more expensive brand names.

Despite the extensive number of empirical applications focusing on retail sale patterns, as far as we are aware no empirical application has yet been made focusing on a New Member State. In this paper, following Berck at al. 2007, we apply time series techniques, such as summary statistics, histograms, correlations of prices and sales, Vector Autoregressive Models (VAR), Vector Error Correction (VECM) and panel cointegration techniques are used to analyse the sales patterns of retail boxed and storable milk in eight Hungarian supermarket chains, using weekly price data between 2005 January and 2008 June.

More specifically, the following we empirically test the following hypotheses derived from the literature:

1. Considering that boxed and storable milk are relatively homogenous products, there is no price dispersion on the market, i.e. LOP holds.
2. Sales do not normally occur at the same time across retail chains.
3. Due to high market concentration, and thus strong competition, retailers closely monitor and follow each others' prices.
4. Perishable and storable products follow distinct sale patterns.

The rest of the paper is organised as follows. Section II presents the data and summary statistics, section III discusses the empirical analysis, and finally, section IV concludes.

## II. Data

Weekly boxed (PMB) and storable (PMS) milk retail prices from 8 retail chains between January 2005 and August 2008, totalling 192 observations were used for the empirical analysis. The 8 retail chains are: Auchan (_A), CBA (_CB), Cora (_CA), COOP (_CP), Interspar (_IN), Match (_M), Plus (_P) and finally Tesco (_T). Data was supplied by the Agricultural Research Institute (AKII), some missing observations were interpolated. Figure 1. presents the evolution of boxed milk prices, and Figure 2. storable milk prices. Graphical analysis suggests that despite some differences prices move together along an increasing trend. On both graphs, a sharp price increase may be noticed towards the end of year 2007, suggesting the possibility of a structural break around that time.

We employ three groups of methods to answer the question whether there are any empirically testable relationships between the pricing of selected retail chains. We start with mean and variance equality tests and graphical probability distribution analysis of milk prices, followed by correlation analysis between level as well as first differences to obtain some insight on the correlation of price changes as well. Then we test to which degree retailers influence each others' milk prices, and whether boxed and storable milk prices within one retail chain influence each other using VAR causality analysis. Finally we employ cointegration and panel cointegration methods to test the degree of market integration of selected retailers, and to analyse how the two different milk prices (boxed and storable) are related to each other on long run.

## III. Empirical results

### 3.1. Mean and variance equality tests, probability distribution and correlation analysis

Tables 1. and 2. present the descriptive statistics of boxed and storable milk prices respectively. At a first glance there seem to be significant price differences across retail chains. For boxed milk prices, Interspar has the lowest (HUF 164.) whilst Coop has the highest (HUF 216) average prices.  For storable milk, the same retail chains as for boxed milk are on average the cheapest (Interspar, HUF 181) and the most expensive (Coop, HUF 240). Mean and variance equality tests across retail chains for boxed and storable milk prices (Tables 3 and 4) reject the null of equality concluding that there are significant mean and variance differences.

Figures 3. and 4., present the probability distribution of boxed an storable milk prices by retail chains.  For boxed milk prices, Auchan, Cora and Tesco seem to follow a normal distribution whilst other retail chains don't. Rows 9 and 10 of table 1 present Jarque-Bera normality statistics and their significance. At 5% level of significance only Auchan and Cora boxed milk prices follow a normal distribution. Coop has the most stable prices whilst Match has the largest changes. The distribution of Interspar prices is skewed to the left, supporting the lowest average prices results. Graphically, for storable milk prices the same retail chains seem to follow a normal distribution as for boxed milk prices. At 5% level of significance, the normality null hypothesis cannot be rejected for Auchan, Cora and Tesco storable milk prices (rows 9 and 10 of table 2.). The frequently and extensively changing prices indicate thet for storable milk product sales are more common than for boxed milk prices (eg. Price distributions for Interspar, Coop).  And finally, a more stable pricing may be noticed for Plus and Match chains, with a distribution skewed to the left on a more narrow interval than their competitors.

One indicator of the relationship between prices observed in various retail chains is the correlation coefficient. Table 5. and 6. present the correlation coefficients and their significance between boxed and storable milk prices respectively. As expected there are significantly positive correlations between boxed milk prices of individual retail chains. Their magnitude stretches from 0.48 (Interspar and Cora) to 0.98 (Plus and Coop). The correlation coefficient of retail chains typically located in city centres with rather small area (Coop, Match, CBA and Plus) is high (above 90%), whilst the coefficient is significantly smaller for larger area hypermarkets (Tesco, Auchan, Cora and Interspar). This result may be explained by the lower *search costs* experienced by consumers in the case of retail chains within city centres or neighbourhoods compared to hypermarkets on the outskirts of cities.

The correlation coefficients between boxed and storable milk price changes (first differences) and their significance are presented in tables 7. and 8. respectively. There are both negative and positive coefficients, however most of them are not significant. Significant correlation coefficients are generally low, with the exception of the 0.7 coefficient for boxed milk prices between Plus and Coop. As before, significant correlation coefficients may be found between retail chains located in the city centres. Compared to level data, the correlation coefficient of storable milk price changes is also significant between Cora and Tesco, suggesting that hypermarkets pay attention to price changes of the competition.

### 3.2. Causality analysis

We conduct the milk price causality tests in two steps. First we analyse whether there is any causality running between milk prices of retail chains, than we test whether there is any short-run relationship between retail prices of boxed and storable milk within a given retail chain. Tables 9. and 10. present causality test results for boxed and storable milk prices respectively. For boxed milk, the dual structure observed in the correlation analysis can be found in causality test results as well. There are causality links between the ‘big chains’, Auchan, Cora and Tesco (bi-directional between Auchan and Cora, uni-directional from Cora to Tesco and Tesco to Auchan) and ‘small chains’, Coop, Plus, CBA, Match and to some extent Interspar (mostly bi-directional). The pricing of Interspar seems to be largely exogenous, being influenced only by its past values. On the other hand, Interspar boxed milk prices influence the most, four, retail chains.

For storable milk prices (table 10.) the different causality relationship of 'large' and 'small' chains is less obvious. As with boxed milk prices, storable milk prices of smaller area city centre retail chains also follow bi-directional causality links. It should be noted however, that causality results are highly influenced by lag length selection. There are bi-directional links between Cora and Auchan, Tesco and Auchan and uni-directional from Auchan to Tesco. Tesco storable milk prices are also influenced by Interspar prices, whilst Match prices are exogenous, determined only by its past values. The storable milk prices of Cora influence the most retail chain prices (Auchan, CBA, Interspar and Plus).

Table 11. presents tests the causality links between the two milk products (boxed and storable) in a given retail chain. For most retail chains there is a bi-directional causality (Auchan, CBA, Cora, Match at 5% significance, and Plus at 10% significance). For Interspar and Tesco the boxed milk price cause the storable milk price, whilst for Coop there is no causality running from any milk price to another.

### 3.3. Cointegration analysis

The next step of the empirical analysis is the long-run modelling of the relationship between the milk price series recorded in various retail chains. Standard Augmented Dickey-Fuller (ADF) unit root tests are first applied to test the stationarity properties of price data. Results (not presented here but available upon request) provide a mixed picture. With constant only specification, all price series are integrated of order one. With constant and trend deterministic specification, boxed and storable milk prices recorded in Auchan, Cora and Tesco are trend stationary. Results might however be biased due to a possible structural break (see figures 1. and 2.) occurring towards the end of year 2007. Tables 12. and 13. present the Perron type unit root test results in the presence of structural breaks for boxed and storable milk prices respectively. Results show highly significant break point t statistics. Contrary to ADF results, all boxed milk prices seem to have a unit root, i.e. they are non-stationary. In 4 series the structural break point is observation 160, (December 2007), in 3 series is observation 144 (October 2007) and in 1 is observation 177 (May 2008). Similarly, all storable milk prices are non-stationary, with significant break points, with the exception of CBA storable milk price, where the break point is not significant, but the unit root null cannot be rejected. In 3 cases the breakpoint occurs at observation 144, (October 2007), in 2 cases at observation 160 (December 2007) and once at observation 103 (December 2006) and 185 (July 2008). Most likely, the breakpoints for boxed as well as for storable milk occurring in December 2007, reflect the sudden price increase due to lack of raw milk supply. The economic significance of breakpoint in 2008 is questionable, since only a few observations are left for the second period. A unit root in all price series mean that prices do not have a constant mean and variance, they mostly depend on the marketing strategy of retail chains.

Since price series are non-stationary, cointegration is the appropriate methodology to test their long-run integration. Johansen cointegration tests results for boxed milk prices are presented in table 14., for storable milk prices in table 15. For boxed milk there are 4 cointegration vectors at 5% (5 at 10%) level of significance. Storable milk prices are also cointegrated, with 2 cointegration vectors. A higher number of cointegrating vectors indicates a higher degree of integration, i.e. boxed milk prices are more cointegrated than storable milk prices. This result might be due to 2 reasons. First, boxed milk is a perishable product, with a lower shelf life, meaning that stocks are more frequently sold and renewed, and second, 'sales' are more characteristic for storable milk, where the pricing strategy quite often focuses to attract, 'invite' consumers into super – hypermarkets

In the last part of the empirical analysis, we test the relationship between boxed and storable milk prices using panel cointegration. The panel database contains 2 variables (boxed and storable milk prices) and 1544 observations. A battery of panel unit root test, not presented here due to space limitations, but available upon request, confirms that both series contain panel unit roots. Table 16. presents the results of various panel cointegration tests. Regardless of the method employed boxed and storable milk prices are panel cointegrated, meaning that there is a long-run relationship between boxed and storable milk prices in a pooled sample.

## IV. Conclusions

In this paper we empirically analysed the pricing of two, milk products, boxed and storable milk in eight Hungarian retail chains.

The law of one price hypothesis across Hungarian milk retail prices is rejected, prices do have significantly different mean and variances. Correlation analysis however reveals a much stronger correlation between boxed milk prices than between storable milk prices. A number of theoretical explanations are provided to support the empirical result.

The timing of sales follows a specific pattern across retail chains. Both storable and boxed milk prices proved to be cointegrated, therefore we may reject Shiloney (1977) and Varian (1980) hypotheses that sales do not normally occur at the same time across retail chains. The degree of cointegration (number of cointegrating vectors) varies between the boxed and storable milk prices, the former being more integrated.

Granger causality tests suggest a dual retail market structure. Although results are highly dependant on the VAR lag length chosen, two distinctive groups of shops emerge. On one hand, the large hypermarkets, usually situated far from city centres, mostly aimed for family (weekend) shopping using own transport, and on the other hand smaller retail chains, that have most of their stores located in city centres, with most of their clients doing the daily shopping there. Causality link suggest that competitors within each group closely monitor each others' prices.

Cointegration analysis revealed a stronger relation between boxed than between storable prices. On the other hand, panel cointegration analysis testing the existence of a long-run relationship between boxed and storable prices, identified such a relationship, suggesting both milk prices follow a common trend. We conclude that the similar distribution in time null hypothesis cannot be rejected. Similarly to Berck et al. (2007), we fail to see a clear difference between storable milk and boxed milk patterns.

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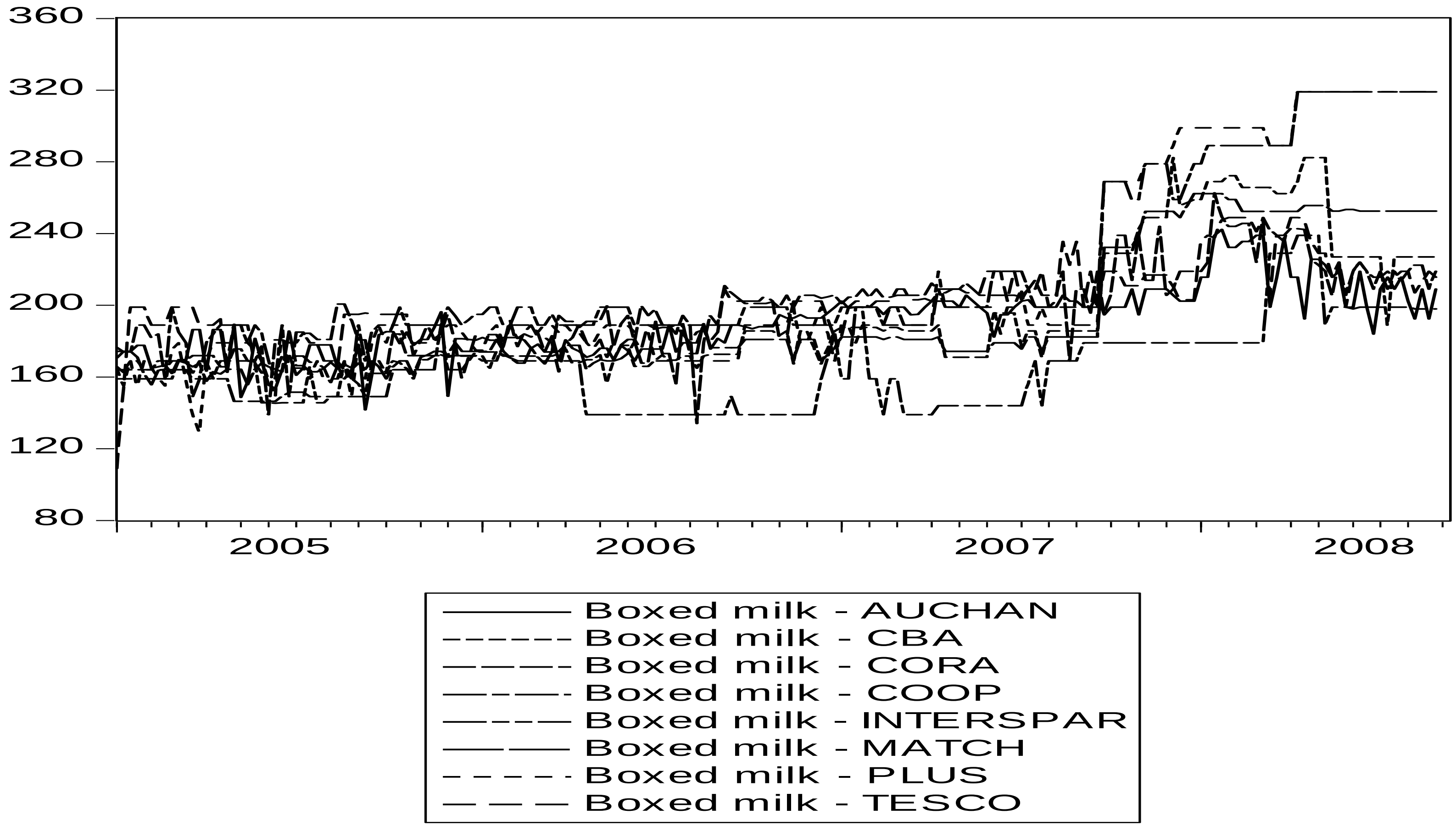
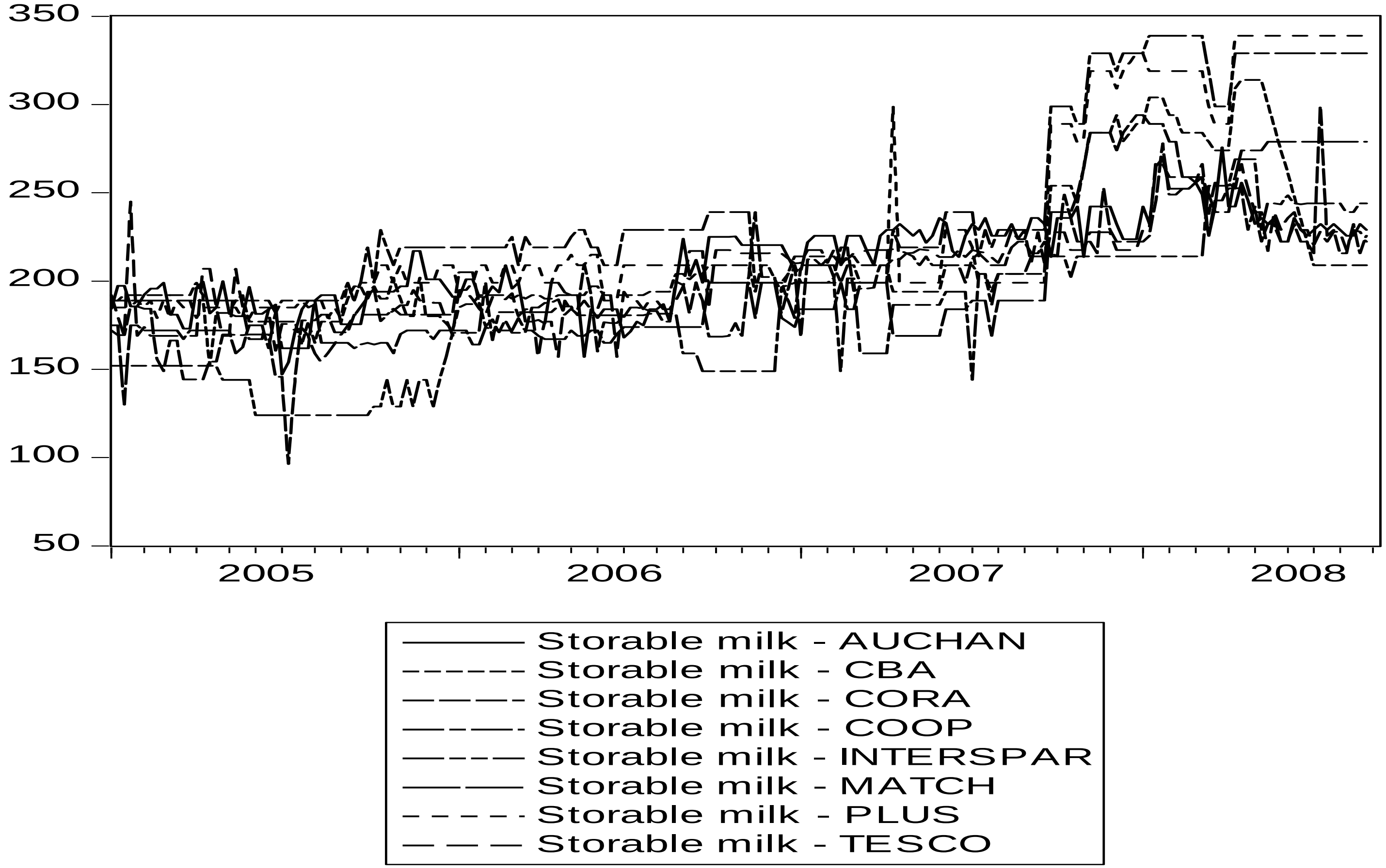
**Figure 1. Boxed milk prices by retail chains (HUF/liter)**




Source: AKII

**Figure 2. Storable milk prices by retail chains (HUF/liter)**




Source: AKII

**Table 1. Boxed milk price descriptive statistics by retail chains**

| | PMB_A | PMB_CB | PMB_CO | PMB_CP | PMB_IN | PMB_M | PMB_P | PMB_T |
|---|---|---|---|---|---|---|---|---|
| Mean | 190.6880 | 191.6161 | 198.4571 | 216.6354 | 164.5729 | 193.3271 | 211.3750 | 199.4148 |
| Median | 189.1650 | 172.8350 | 201.0000 | 199.0000 | 164.0000 | 177.6700 | 189.0000 | 199.0000 |
| Maximum | 242.3300 | 282.3300 | 262.6700 | 319.0000 | 239.0000 | 262.3300 | 319.0000 | 249.0000 |
| Minimum | 141.6700 | 145.3300 | 134.0000 | 149.0000 | 139.0000 | 155.6700 | 129.0000 | 109.0000 |
| Std. Dev. | 18.88828 | 36.35492 | 22.70405 | 49.32733 | 23.54464 | 35.09302 | 54.79486 | 22.01422 |
| Skewness | 0.368066 | 1.142604 | 0.203213 | 1.074666 | 1.078506 | 1.036965 | 1.045508 | 0.043725 |
| Kurtosis | 3.257449 | 3.104341 | 2.933603 | 2.715474 | 4.094817 | 2.305489 | 2.479423 | 3.915280 |
| Jarque-Bera | 4.865367 | 41.86453 | 1.356721 | 37.60464 | 46.81061 | 38.26828 | 37.14681 | 6.763074 |
| Prob. | 0.087801 | 0.000000 | 0.507448 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.033995 |
| No. of obs. | 192 | 192 | 192 | 192 | 192 | 192 | 192 | 192 |

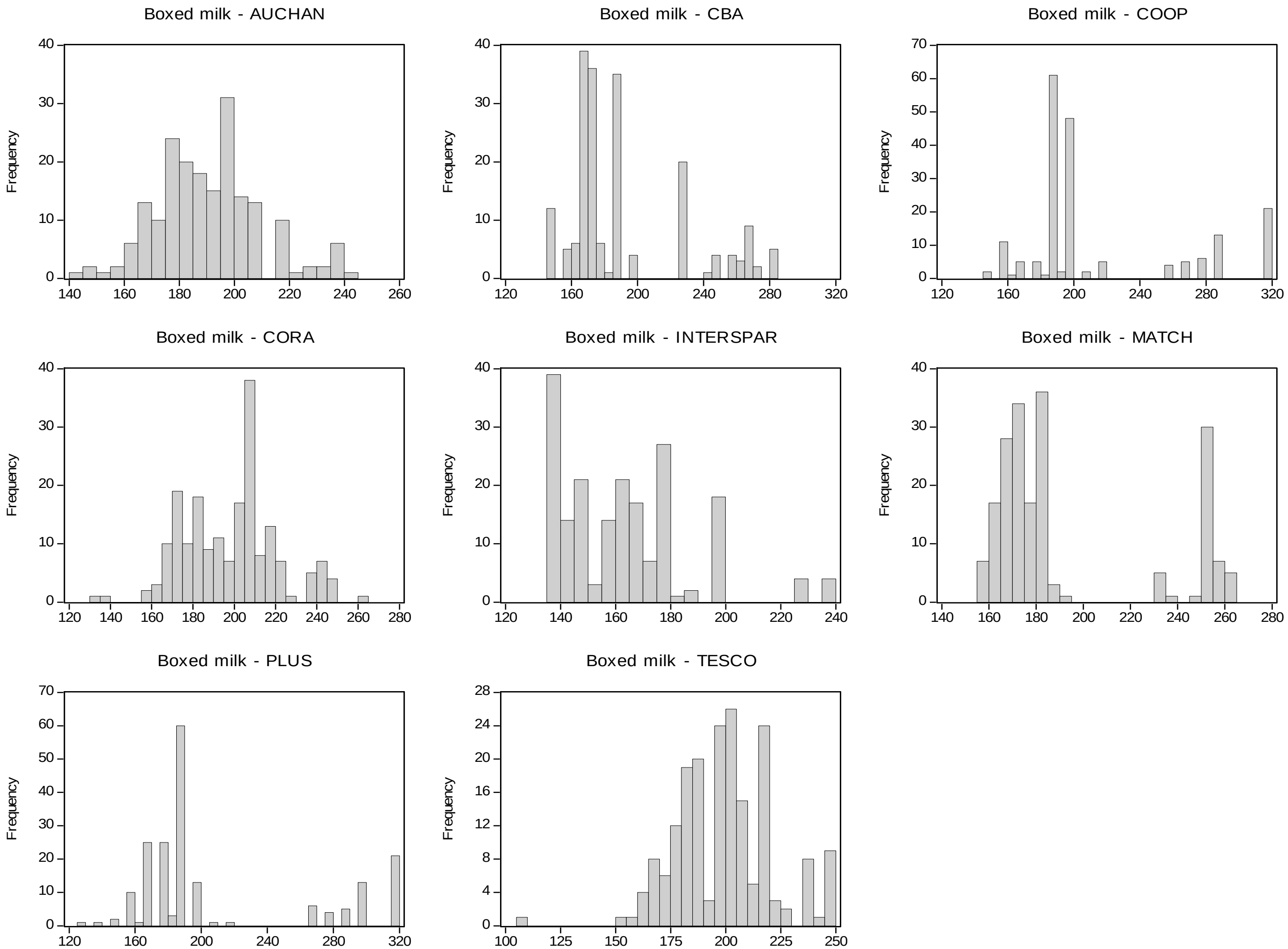
Source: Own calculations

**Table 2. Storable milk price descriptive statistics by retail chains**

| | PMS_A | PMS_CB | PMS_CO | PMS_CP | PMS_IN | PMS_M | PMS_P | PMS_T |
|---|---|---|---|---|---|---|---|---|
| Mean | 210.7180 | 213.1406 | 198.3384 | 240.2813 | 181.8339 | 200.1510 | 230.4792 | 205.0390 |
| Median | 215.3350 | 201.2500 | 196.0000 | 219.0000 | 181.9150 | 175.0000 | 199.0000 | 212.5825 |
| Maximum | 275.6700 | 314.0000 | 299.0000 | 339.0000 | 269.0000 | 294.0000 | 339.0000 | 267.6700 |
| Minimum | 147.0000 | 152.0000 | 96.33000 | 179.0000 | 124.0000 | 130.0000 | 179.0000 | 154.0000 |
| Std. Dev. | 24.52693 | 37.72598 | 29.42737 | 52.11982 | 38.10441 | 43.65105 | 55.58117 | 26.55609 |
| Skewness | -0.029954 | 1.361953 | 0.206646 | 0.902028 | 0.291115 | 1.059953 | 1.098802 | 0.193194 |
| Kurtosis | 2.326745 | 3.660378 | 3.432583 | 2.257719 | 2.275677 | 2.493872 | 2.457844 | 2.421739 |
| Jarque-Bera | 3.654888 | 62.84613 | 2.863502 | 30.44482 | 6.909089 | 38.00134 | 40.98720 | 3.869455 |
| Prob. | 0.160824 | 0.000000 | 0.238890 | 0.000000 | 0.031602 | 0.000000 | 0.000000 | 0.144464 |
| No. of obs. | 192 | 192 | 192 | 192 | 192 | 192 | 192 | 192 |

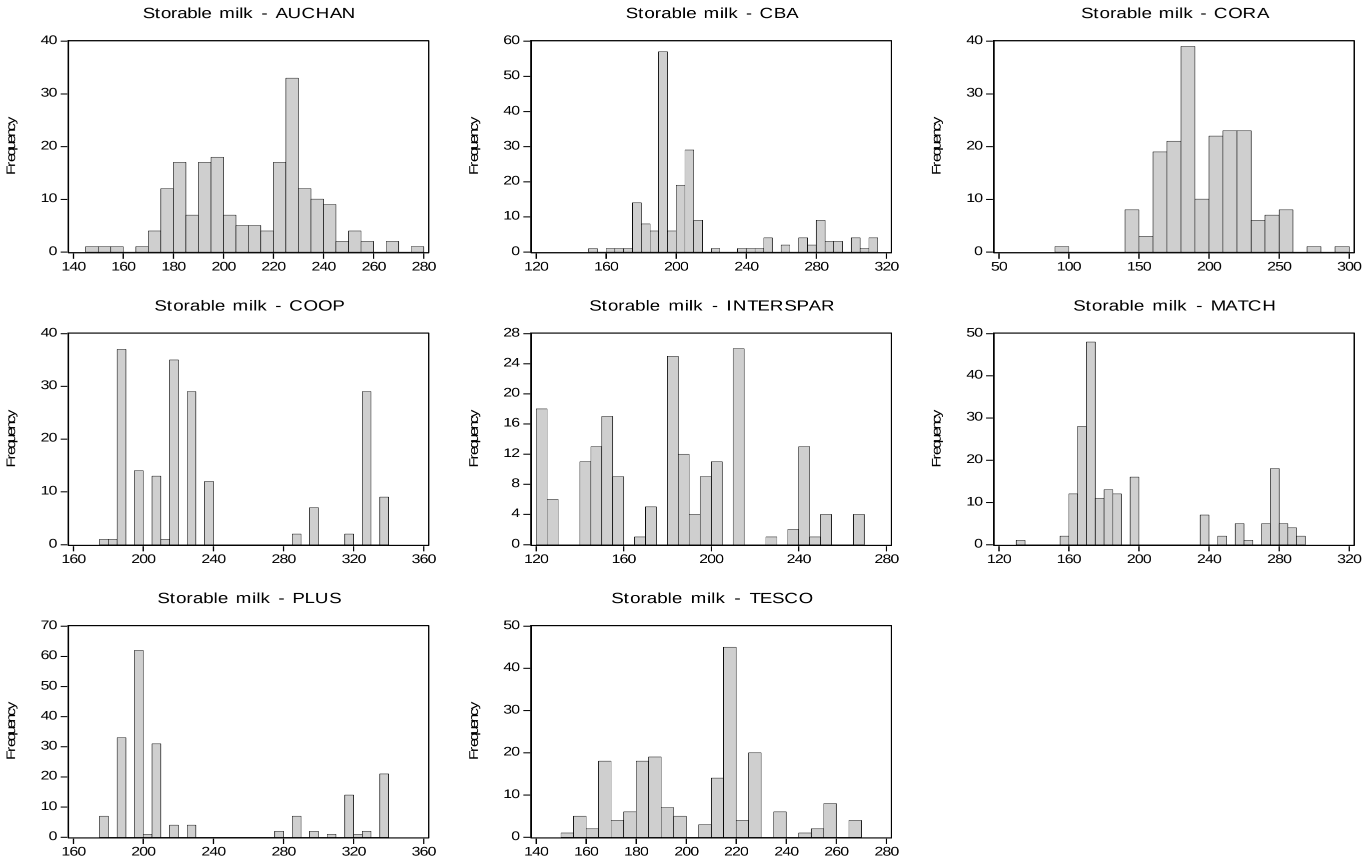
Source: Own calculations

**Figure 3. Probability distribution of boxed milk prices by retail chains**




Source: Own calculations

**Figure 4. Probability distribution of storable milk prices by retail chains**




Source: Own calculations

**Table 3. Mean and variance equality tests across retail chains for boxed milk prices**

| Method | df | Value | Probability |
|---|---|---|---|
| Anova F-test | (7, 1528) | 38.16018 | 0.0000 |
| Welch F-test* | (7, 649.763) | 52.51332 | 0.0000 |

*Test allows for unequal cell variances

| Method | df | Value | Probability |
|---|---|---|---|
| Bartlett | 7 | 426.3717 | 0.0000 |
| Levene | (7, 1528) | 65.65705 | 0.0000 |
| Brown-Forsythe | (7, 1528) | 15.25242 | 0.0000 |

Source: Own calculations

**Table 4. Mean and variance equality tests across retail chains for storable milk prices**

| Method | df | Value | Probability |
|---|---|---|---|
| Anova F-test | (7, 1528) | 41.23451 | 0.0000 |
| Welch F-test* | (7, 650.913) | 32.35663 | 0.0000 |

*Test allows for unequal cell variances

| Method | df | Value | Probability |
|---|---|---|---|
| Bartlett | 7 | 235.9899 | 0.0000 |
| Levene | (7, 1528) | 35.38760 | 0.0000 |
| Brown-Forsythe | (7, 1528) | 8.216307 | 0.0000 |

Source: Own calculations

**Table 5. Boxed milk price correlations by retail chains**

| Correlation coefficient<br>Prob. | PMB_A | PMB_CB | PMB_CO | PMB_CP | PMB_IN | PMB_M | PMB_P | PMB_T |
|---|---|---|---|---|---|---|---|---|
| PMB_A | 1.000000 | | | | | | | |
| PMB_CB | 0.792196 | 1.000000 | | | | | | |
| | 0.0000 | ----- | | | | | | |
| PMB_CO | 0.793244 | 0.792738 | 1.000000 | | | | | |
| | 0.0000 | 0.0000 | ----- | | | | | |
| PMB_CP | 0.717274 | 0.886134 | 0.716938 | 1.000000 | | | | |
| | 0.0000 | 0.0000 | 0.0000 | ----- | | | | |
| PMB_IN | 0.523590 | 0.714224 | 0.485004 | 0.753766 | 1.000000 | | | |
| | 0.0000 | 0.0000 | 0.0000 | 0.0000 | ----- | | | |
| PMB_M | 0.749284 | 0.938864 | 0.757751 | 0.954177 | 0.741629 | 1.000000 | | |
| | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | ----- | | |
| PMB_P | 0.728320 | 0.904312 | 0.732180 | 0.985268 | 0.748245 | 0.966770 | 1.000000 | |
| | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | ----- | |
| PMB_T | 0.784374 | 0.778264 | 0.756222 | 0.708769 | 0.515102 | 0.712098 | 0.710495 | 1.000000 |
| | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | ----- |

Source: Own calculations

**Table 6. Storable milk price correlations by retail chains**

| Correlation coefficient<br>Prob. | PMS_A | PMS_CB | PMS_CO | PMS_CP | PMS_IN | PMS_M | PMS_P | PMS_T |
|---|---|---|---|---|---|---|---|---|
| PMS_A | 1.000000 | | | | | | | |
| PMS_CB | 0.720853 | 1.000000 | | | | | | |
| | 0.0000 | ----- | | | | | | |
| PMS_CO | 0.814976 | 0.730327 | 1.000000 | | | | | |
| | 0.0000 | 0.0000 | ----- | | | | | |
| PMS_CP | 0.696954 | 0.844545 | 0.764920 | 1.000000 | | | | |
| | 0.0000 | 0.0000 | 0.0000 | ----- | | | | |
| PMS_IN | 0.674708 | 0.713791 | 0.762160 | 0.809494 | 1.000000 | | | |
| | 0.0000 | 0.0000 | 0.0000 | 0.0000 | ----- | | | |
| PMS_M | 0.705143 | 0.848049 | 0.732196 | 0.944375 | 0.762679 | 1.000000 | | |
| | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | ----- | | |
| PMS_P | 0.651308 | 0.820561 | 0.742794 | 0.969756 | 0.807707 | 0.949195 | 1.000000 | |
| | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | ----- | |
| PMS_T | 0.850965 | 0.765885 | 0.812001 | 0.739593 | 0.727342 | 0.728574 | 0.701305 | 1.000000 |
| | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | ----- |

Source: Own calculations

**Table 7. Boxed milk price changes correlations by retail chains**

| Correlation coefficient<br>Prob. | DPMB_A | DPMB_CB | DPMB_CO | DPMB_CP | DPMB_IN | DPMB_M | DPMB_P | DPMB_T |
|---|---|---|---|---|---|---|---|---|
| DPMB_A | 1.000000 | | | | | | | |
| DPMB_CB | -0.018458 | 1.000000 | | | | | | |
| | 0.7999 | ----- | | | | | | |
| DPMB_CO | 0.064618 | 0.054531 | 1.000000 | | | | | |
| | 0.3745 | 0.4537 | ----- | | | | | |
| DPMB_CP | -0.041516 | 0.250422 | -0.108943 | 1.000000 | | | | |
| | 0.5685 | 0.0005 | 0.1336 | ----- | | | | |
| DPMB_IN | -0.030839 | 0.034368 | 0.019201 | 0.022890 | 1.000000 | | | |
| | 0.6719 | 0.6369 | 0.7921 | 0.7533 | ----- | | | |
| DPMB_M | 0.093901 | 0.334190 | -0.001001 | 0.236582 | 0.072013 | 1.000000 | | |
| | 0.1963 | 0.0000 | 0.9890 | 0.0010 | 0.3222 | ----- | | |
| DPMB_P | 0.008738 | 0.187410 | -0.115833 | 0.706580 | -0.077570 | 0.185753 | 1.000000 | |
| | 0.9045 | 0.0094 | 0.1106 | 0.0000 | 0.2861 | 0.0101 | ----- | |
| DPMB_T | 0.129348 | 0.087856 | 0.041489 | 0.109473 | -0.170182 | 0.037620 | 0.175244 | 1.000000 |
| | 0.0745 | 0.2268 | 0.5688 | 0.1317 | 0.0186 | 0.6054 | 0.0153 | ----- |

Source: Own calculations

**Table 8. Storable milk price changes correlations by retail chains**

| Correlation coefficient<br>Prob. | DPMS_A | DPMS_CB | DPMS_CO | DPMS_CP | DPMS_IN | DPMS_M | DPMS_P | DPMS_T |
|---|---|---|---|---|---|---|---|---|
| DPMS_A | 1.000000 | | | | | | | |
| DPMS_CB | 0.044732 | 1.000000 | | | | | | |
| | 0.5389 | ----- | | | | | | |
| DPMS_CO | 0.102031 | -0.037409 | 1.000000 | | | | | |
| | 0.1602 | 0.6074 | ----- | | | | | |
| DPMS_CP | -0.015188 | 0.351941 | -0.118099 | 1.000000 | | | | |
| | 0.8348 | 0.0000 | 0.1037 | ----- | | | | |
| DPMS_IN | -0.020246 | 0.004917 | -0.097882 | 0.028761 | 1.000000 | | | |
| | 0.7810 | 0.9462 | 0.1779 | 0.6929 | ----- | | | |
| DPMS_M | 0.038480 | 0.286811 | -0.065566 | 0.345970 | -0.131561 | 1.000000 | | |
| | 0.5971 | 0.0001 | 0.3675 | 0.0000 | 0.0697 | ----- | | |
| DPMS_P | -0.046147 | 0.248606 | 0.000281 | 0.630915 | 0.077113 | 0.166322 | 1.000000 | |
| | 0.5261 | 0.0005 | 0.9969 | 0.0000 | 0.2890 | 0.0215 | ----- | |
| DPMS_T | -0.013051 | 0.041550 | 0.168430 | 0.093869 | -0.077374 | 0.090154 | 0.056779 | 1.000000 |
| | 0.8578 | 0.5682 | 0.0199 | 0.1965 | 0.2874 | 0.2149 | 0.4353 | ----- |

Source: Own calculations

**Table 9. Granger causality test results, boxed milk prices**

| Price of retail chain | Granger cause | Price of retail chain | Prob.[*] |
|---|---|---|---|
| Auchan | → | Cora | 0.0028 |
| CBA | → | Auchan | 0.0036 |
| | → | Match | 0.0250 |
| Cora | → | Auchan | 0.0355 |
| | → | Tesco | 0.0078 |
| COOP | → | Plus | 0.0426 |
| Interspar | → | CBA | 0.0235 |
| | → | Cora | 0.0264 |
| | → | COOP | 0.0147 |
| | → | Plus | 0.0537 |
| Match | → | CBA | 0.0023 |
| | → | COOP | 0.0189 |
| | → | Plus | 0.0057 |
| Plus | → | Match | 0.0119 |
| Tesco | → | Auchan | 0.0456 |
| | → | CBA | 0.0263 |

[*] Null hypothesis: price in retail chain X does not cause price in retail chain Y

Source: Own calculations

**Table 10. Granger causality test results, storable milk prices**

| Price of retail chain | Granger cause | Price of retail chain | Prob.* |
|---|---|---|---|
| Auchan | → | Cora | 0.0039 |
| | → | Plus | 0.0919 |
| | → | Tesco | 0.0000 |
| CBA | → | Tesco | 0.0073 |
| Cora | → | Auchan | 0.0658 |
| | → | CBA | 0.0313 |
| | → | Interspar | 0.0271 |
| | → | Plus | 0.0381 |
| COOP | → | Plus | 0.0635 |
| Interspar | → | Cora | 0.0358 |
| | → | Plus | 0.0140 |
| | → | Tesco | 0.0457 |
| Match | → | COOP | 0.0358 |
| | → | Plus | 0.0000 |
| Plus | → | CBA | 0.0759 |
| Tesco | → | Auchan | 0.0001 |

* Null hypothesis: price in retail chain X does not cause price in retail chain Y

Source: Own calculations

**Table 11. Granger causality tests between boxed and storable milk prices by retail chains**

| Price of product A | Granger cause | Price of product B | Prob.* |
|---|---|---|---|
| PMS_A | → | PMB_A | 0.0131 |
| PMB_A | → | PMS_A | 0.0005 |
| PMS_CB | → | PMB_CB | 0.0239 |
| PMB_CB | → | PMS_CB | 0.0502 |
| PMS_CO | → | PMB_CO | 0.0369 |
| PMB_CO | → | PMS_CO | 0.0005 |
| PMS_CP | → | PMB_CP | 0.1113 |
| PMB_CP | → | PMS_CP | 0.3031 |
| PMS_IN | → | PMB_IN | 0.8284 |
| PMB_IN | → | PMS_IN | 0.0192 |
| PMS_M | → | PMB_M | 0.0190 |
| PMB_M | → | PMS_M | 0.0060 |
| PMS_P | → | PMB_P | 0.0989 |
| PMB_P | → | PMS_P | 0.0000 |
| PMS_T | → | PMB_T | 0.2685 |
| PMB_T | → | PMS_T | 0.0000 |

* Null hypothesis: price of product A does not cause price of product B

Source: Own calculations

**Table 12. Perron unit root tests in the presence of structural breaks, boxed milk prices**

| Variable | Test statistic* | Lags | Breakpoint (t - statistic) |
|---|---|---|---|
| PMB_A | - 2.541 | 2 | 160 (38.83) |
| PMB_CB | 0.262 | 2 | 177 (- 94.95) |
| PMB_CO | - 2.349 | 2 | 160 (43.32) |
| PMB_CP | 0.057 | 10 | 144 (116.18) |
| PMB_IN | - 2.716 | 8 | 168 (83.05) |
| PMB_M | - 0.872 | 3 | 144 (132.28) |
| PMB_P | - 1.388 | 2 | 144 (130.93) |
| PMB_T | - 2.395 | 3 | 158 (44.76) |

* null hypothesis: unit root. 5% critical value is – 2.88

Source: Own calculations

**Table 13. Perron unit root tests in the presence of structural breaks, storable milk prices**

| Variable | Test statistic* | Lags | Breakpoint (t - statistic) |
|---|---|---|---|
| PMS_A | -2. 065 | 2 | 160 (42.30) |
| PMS_CB | - 1.677 | 0 | 22 (- 1.756) |
| PMS_CO | - 1.651 | 7 | 185 (50.62) |
| PMS_CP | - 1.376 | 6 | 144 (116.85) |
| PMS_IN | - 1.295 | 2 | 103 (66.97) |
| PMS_M | - 1.387 | 6 | 144 (81.11) |
| PMS_P | - 1.345 | 5 | 144 (107.02) |
| PMS_T | - 1.573 | 4 | 160 (49.63) |

* null hypothesis: unit root. 5% critical value is – 2.88

Source: Own calculations

**Table 14. Johansen cointegration test, boxed milk prices**

| No. of CI vectors | Eigen value | Trace statistic | 5% Crit. value | Prob.* |
|---|---|---|---|---|
| None | 0.338655 | 285.6265 | 169.5991 | 0.0000 |
| Maximum 1 | 0.286340 | 207.0653 | 134.6780 | 0.0000 |
| Maximum 2 | 0.238475 | 142.9690 | 103.8473 | 0.0000 |
| Maximum 3 | 0.192368 | 91.20702 | 76.97277 | 0.0028 |
| Maximum 4 | 0.114127 | 50.61367 | 54.07904 | 0.0984 |
| Maximum 5 | 0.089614 | 27.58905 | 35.19275 | 0.2602 |
| Maximum 6 | 0.042154 | 9.750509 | 20.26184 | 0.6643 |
| Maximum 7 | 0.008217 | 1.567608 | 9.164546 | 0.8611 |

*MacKinnon-Haug-Michelis (1999) p- values

Source: Own calculations

**Table 15. Johansen cointegration test, storable milk prices**

| No. of CI vectors | Eigen value | Trace statistic | 5% Crit. value | Prob.* |
|---|---|---|---|---|
| None | 0.329580 | 222.5254 | 169.5991 | 0.0000 |
| Maximum 1 | 0.258447 | 146.5537 | 134.6780 | 0.0083 |
| Maximum 2 | 0.189292 | 89.74196 | 103.8473 | 0.2942 |
| Maximum 3 | 0.093766 | 49.87102 | 76.97277 | 0.8572 |
| Maximum 4 | 0.070082 | 31.16395 | 54.07904 | 0.8767 |
| Maximum 5 | 0.053064 | 17.35871 | 35.19275 | 0.8707 |
| Maximum 6 | 0.026347 | 6.999293 | 20.26184 | 0.8973 |
| Maximum 7 | 0.010087 | 1.926261 | 9.164546 | 0.7923 |

*MacKinnon-Haug-Michelis (1999) p- values

Source: Own calculations

**Table 16. Panel cointegration tests between boxed and storable milk prices**

| Test / statistic | Test statistic | Prob.* |
|---|---|---|
| Kao | | |
| ADF | -1.968 | 0.024 |
| Pedroni | | |
| Panel v-Statistic | 3.296717 | 0.001 |
| Panel rho-Statistic | -39.37626 | 0.000 |
| Panel PP-Statistic | -17.23413 | 0.000 |
| Panel ADF-Statistic | -20.49216 | 0.000 |

* Null hypothesis: no cointegration

Source: Own calculations