

## STRUCTURAL BREAKS IN FARM AND RETAIL PRICES OF BEEF MEAT IN POLAND

**Mariusz Hamulczuk**

Department of Agricultural Economics and International Economic Relations  
Warsaw University of Life Sciences – SGGW  
e-mail: mariusz\_hamulczuk@sggw.pl

**Abstract:** The aim of this study was to analyze the dynamics of monthly prices in the beef marketing chain in Poland in the years 1997-2012. The study showed that in the time series of farm and retail prices of beef meat in Poland structural break points occurred. They are mainly associated with appearance of BSE disease and the Polish accession to the European Union. The farm and retail price series are non-stationary and farm prices Granger-cause retail prices. The estimates of the long-run parameters depend on the assumptions about deterministic variables existence in the Engel-Granger cointegration equation, including structural breaks among them.

**Keywords:** food chain, beef prices, structural break, price transmission, cointegration

### INTRODUCTION

Price development in the agri–food sector is the subject of many studies. The interest of researchers has increased recently due to dynamic evolution of food prices, increase of price volatility as well as food security problems [Abbot et al. 2011, Prakash 2011, Roache 2010]. Specific areas subjected to detailed analysis are the issues of margins' changes and price transmission along food marketing chain. That interest is reinforced by a rapid concentration in the retail trade observed in the last decade. As a result the problems of inefficiency in the market pricing and the market power are quite often raised in the public discussion and in research [Mc Corrison 2002, Seremak Bulge 2012, Kuosmanen, Niemi 2009, Lloyd et al. 2006]. Market power, if confirmed, constitutes a justification for the introduction of different agricultural policy instruments or antitrust regulations.

Economists, who study market efficiency, often focus on vertical price transmission in the marketing chain of food products. It is expected that under competitive market assumption retail prices reflect changes in farm prices, not reversely. Furthermore, retail prices need to respond with the same speed and amplitude (symmetrically) to decreases and increases in the farm prices [Meyer & von Cramon-Taubadel 2004]. Numerous methods have been employed to analyze the nature of vertical price transmission, such as: ARDL models, VAR models, cointegration methods or threshold autoregressive methods. The overview of the methods applied can be found in the works by Meyer & von Cramon-Taubadel [2004] or Frey & Manera [2007].

One of the most important assumptions about models is stability of their parameters over time. Existence of the structural changes in the data has negative influence on the results (bias them, loss of power of tests) of statistical analysis performed with the use of methods which do not take into account structural breaks [Perron 2005]. The presence of structural breaks in the cointegrating relationship between price series in vertical marketing chain leads to over-rejection of null hypothesis of symmetric transmission when standard tests for asymmetric price transmission are applied [von Cramon-Taubadel & Meyer 2001].

It can be assumed that a structural break has occurred if at least one of models' parameters has changed at the break date within the sample period. Structural break could be assumed as immediate or it might seem more reasonable to allow a structural change to take effect over period of time. Structural breaks may be limited to the level shift (LS), trend change (TC) or regime change (RC) when there is allowance for change of structural parameters in different regimes. In a given model there could be one structural break or the combination of a few ones of the same or different categories. In empirical research authors mostly focus on the simple case of an immediate structural break for simplicity and parsimony [Hansen 2001, Zeileis et al. 2003]. One of the research problems is testing for structural breaks in the univariate or the multivariate cases (one break and multiple breaks tests). Timing of structural breaks may be known a priori or the dates need to be estimated therefore many researches concentrate on dating structural breaks. In general, incorporation of structural breaks into a model is challenging task and rarely happens that all mentioned problems are simultaneously studied [Perron 2005, Gregory & Hansen 1996, Carrion-i-Sylvestre & Sansó-i-Rosselló 1996].

Structural breaks are evident in many economic phenomena. Agricultural prices that are affected by numerous factors, such as weather conditions, animal diseases or changes in agricultural policies, are regarded as those in which the structural changes may occur frequently [Wang & Tomek 2007]. In transition economies like Poland the probability of structural breaks is even higher than in the developed countries. The aim of this paper is to analyze the dynamics of monthly farm and retail prices of beef meat in Poland. Our empirical research is focused on detecting structural breaks in the individual price series as well as in the long-run equilibrium relationship between retail and farm prices. Knowing type and date

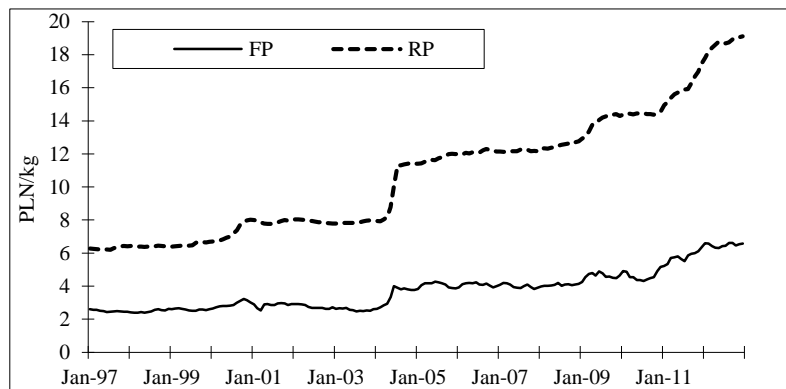
of structural breaks we can learn more about the relationships between prices in the food chain. It can be also helpful in establishing and estimating the cointegration equation and error correction model more accurately.

## DATA AND METHODS APPLIED

### Data

Statistical data used in the analysis were monthly information about farm prices (procurement) for live weight beef (FP) and retail prices of sirloin (RP) in Poland (Figure 1). Price series data covered the period from January 1997 to December 2012 (192 observations) and was expressed in PLN/kilo. The source of information was Central Statistical Office in Poland.

Figure 1. Farm prices of live weight beef (FP) and retail prices (RP) of beef sirloin expressed in PLN/kilo



Source: CSO Poland (GUS)

Graphical insight into the data indicates on a high correlation between farm and retail prices. In addition, a widening gap between them is observable over the analyzed period. Beef market belongs to those agri-food markets which were the most influenced by the Poland's accession to the EU. During a few months since May 2004 prices of beef meat on different food chain levels rose by over 50% due to the removal of all trade barriers and restrictions. Less clear is impact of the BSE (Bovine Spongiform Encephalopathy) crisis on prices in 2000-2001.

### Methods

The key method applied in the research for data analyzing and structural break detection was TRAMO-SEATS procedure. It belongs to so-called ARIMA-based-method approaches [Gomez & Maravall 2001]. TRAMO (Time series Regression with ARIMA noise, Missing values, and Outliers) is a procedure for estimation and forecasting of regression models with errors that follow

nonstationary ARIMA processes, while there may be missing observations in the series, as well as infection of outliers and other deterministic effects. Automatic procedure enable to detect and locate additive outliers, transitory changes and level shifts. Other structural changes, like RAMP effect revealing in linear change during a few periods, can be predefined manually. The regression effect is included if the  $t$ -value for a given regression variable is higher than 3.5. The model for variable  $y$  (in logs or original form) can be written as follows [Marraval 2008]:

$$y_t = R_t' \beta + x_t \quad (1)$$

where:  $R_t'$  – matrix with  $n$  regression variables for calendar effects, structural changes and outliers, intervention variables and constant;  $\beta$  is a vector of  $n$  regression parameters;  $x_t$  – stochastic component following ARIMA process:

$$\phi(B)\delta(B)x_t = \theta(B)a_t \quad (2)$$

where:  $B$  – backward operator;  $\delta(B)$  – stationary AR polynomial in  $B$ ;  $\phi(B)$  – non-stationary AR polynomial in  $B$  (unit roots);  $\theta(B)$  – invertible MA polynomial in  $B$ , at white-noise innovations.

SEATS model (Signal Extraction in ARIMA Time Series) allows for decomposition of the series into trend, seasonal, cyclical and irregular components, and provide forecasts for these components. TRAMO-SEATS procedures are implemented in *DEMETRA+* software.

Augmented Dickey Fuller test (ADF) was used in order to verify presumption about existence of unit root in the price series. Two types of data were tested: initial series as well as series transformed via TRAMO procedure for reducing effect of structural brakes. Null hypothesis states that time series is non-stationary (unit root) against the alternative of stationarity. ADF test statistic is based on  $t$ -statistic of coefficient  $\varphi$  from OLS estimation of the following formula [Enders 2010]:

$$\Delta y_t = \mu_t + \varphi y_{t-1} + \sum_{i=1}^p \delta_i \Delta y_{t-i} + \varepsilon_t \quad (3)$$

where:  $y_t$  – analyzed price series;  $\mu_t$  – deterministic term (none, constant, trend);  $p$  is the number of lags ensuring white noise properties of random component  $\varepsilon_t$ ;  $\delta_i$  are coefficients describing the short-run persistence of  $\Delta y_t$ . The number of lags  $p$  was determined with the use of Akaike's Information Criterion (AIC).

The concept of Granger causality was employed to evaluate the nature of relation between producer and consumer prices. A variable  $x$  is said to Granger-cause  $y$  if we can better forecast  $y$  using lagged values of  $x$  rather when ignoring them. Test formula presented below was applied for original data and for time series data linearized for structural break effects [Enders 2010]:

$$y_t = a_0 + \sum_{j=1}^k \alpha_j y_{t-j} + \sum_{j=1}^k \beta_j x_{t-j} + \varepsilon_t \quad (4)$$

where:  $a_0, \alpha_j, \beta_j, \gamma_j$  are model parameters;  $y$  and  $x$  are analyzed variables;  $k$  – the greatest lag length;  $\varepsilon_t$  – white noise. Null hypothesis, stating no Granger causality, assumes that  $\beta_1 = \beta_2 = \dots = \beta_k = 0$  against alternative of statistical significance of these coefficients. Determining number of lag length we applied Vector Autoregression Model (VAR) and AIC.

To test existence of the long-term relationship the Engle-Grangers (EG) cointegration framework was applied. The nonstationary time series are cointegrated if there is a stationary  $I(0)$  linear combination of these series. The linear combination of two series is referred to as a long-run equilibrium relationship and can be written as follows [Engle Granger 1987]:

$$RP_t = \gamma_0 + \gamma_1 FP_t + u_t \quad \text{or} \quad RP_t = \gamma_0 + \gamma_1 FP_t + \gamma_2 t + u_t \quad (5)$$

where:  $\gamma_0, \gamma_2$  – constant and trend parameter;  $\gamma_1$  – parameter of the long-run impact;  $u_t$  – residuals form EG relationship called as an error correction term ECT.

After testing for structural breaks the basic EG models (5) were extended for set of structural break dummies  $D_i$ :

$$RP_t = \gamma_0 + \gamma_1 FP_t + \gamma_3 D_i + u_t \quad \text{or} \quad RP_t = \gamma_0 + \gamma_1 FP_t + \gamma_2 t + \gamma_3 D_i + u_t. \quad (6)$$

## STRUCTURAL BREAKS IN UNIVARIATE PRICE SERIES

Statistical analysis of farm and retail prices was carried out with the use of TRAMO-SEATS method. For each price series two models were estimated: the first one was chosen on pure automatic procedure (denoted as *auto*) implemented in *DEMETRA+* (denoted as RCA3 variant) and the second was selected via automatic procedure with predefined RAMP effects (denoted as *autoRAMP*). RAMP effect is a combination of a few successive LS changes and can be applied when structural change is time-distributed. All studies were carried out on logs of price series. A stable seasonality pattern was confirmed only in farm price series. However, the impact of seasonality on farm prices is relatively low and the amplitude of seasonal variation is around 5 pp.

An application of automatic TRAMO procedure for farm and retail prices allows us to estimate models which are presented in Table 1. The visualization of aggregated impact of structural changes on farm and retail prices is presented in Figure 2. We concentrated on dating and recognizing of structural breaks' types. According to automatic TRAMO procedure, breaks are restricted to additive outliers (OA), level shifts (LS) and temporal changes (TC). In case of farm prices statistically significant structural breaks were in 2001 (BSE crisis), in 2004 (EU integration) and in March 2011 (Table 1). Most of them are LS type structural breaks. One can notice an estimated positive impact of BSE crisis on farm prices which is not in line with experts' expectations. It seems that the consequence of BSE should have resulted in the decrease of prices paid for farmers as the demand for beef decreased and restrictions on beef meat import from Poland were imposed by the EU. BSE crisis started in November 2000 and its impact was

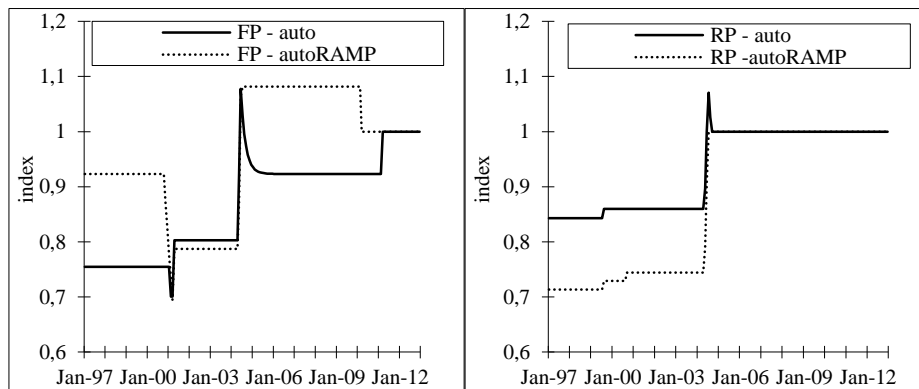
spread over time which is not reflected in the model. Instead of that the correction of previous declines in prices is estimated (LS[2001.4]) as dominant structural break.

Table 1. TRAMO models for farm and retail prices (all parameters are statistically significant with p-values less than 0.001)

FP - auto		FP - autoRAMP		RP - auto		RP - autoRAMP	
ARIMA model [(0,1,1)(0,1,1)] BIC = -332.3		ARIMA model [(1,1,0)(0,1,1)] BIC = -336.7		ARIMA model [(1,1,1)(0,0,0)] BIC = -433.8		ARIMA model [(2,1,0)(0,0,0)] BIC = -480.2	
Parameter	Value	Parameter	Value	Parameter	Value	Parameter	Value
LS[2001.2]	-0.075	rp:2000.10-2001.03	-0.285	LS[1999.8]	0.020	LS[1999.8]	0.022
LS[2001.4]	0.137	LS[2001.4]	0.126	LS[2004.5]	0.042	LS[2000.9]	0.021
LS[2004.5]	0.139	rp:2004.04-2004.07	0.318	LS[2004.6]	0.110	rp:2004.04-2004.07	0.295
TC[2004.6]	0.154	AO[2004.6]	0.089	AO[2004.7]	0.068	AO[2004.5]	-0.039
LS[2011.3]	0.080	LS[2010.3]	-0.079	AO[2004.8]	0.026	x	x
Th(1)	0.351	Phi(1)	-0.264	Phi(1)	-0.751	Phi(1)	-0.458
BTh(1)	-0.770	BTh(1)	-0.815	Th(1)	-0.105	Phi(2)	-0.218

Source: own calculations

Figure 2. Deterministic components effect on FP and RP



Source: own calculations

To overcome this problem RAMP effect (*rp* variable) was introduced from September 2000 to March 2001 for a better description of the BSE crisis. In addition, an effect of Poland's accession to the EU, which distributed over time, was presumed by means of *rp* variable. The result (dotted line in left chart of Figure 2 and in Table 1) seems to be quite different from previous one. In *autoRAMP* model the negative impact of BSE crisis on prices was estimated. Moreover, the permanent effect of EU integration on prices was estimated. There is

also a difference in the dating breaks at the end of the time series – instead of LS break in March 2011 (*auto*) there is LS in March 2010 (*autoRAMP*).

The most evident structural breaks in the retail price series are those connected with Poland's accession to the EU. Similarly to the farm prices, pure automatic model and the RAMP effect model differ in terms of break date and type of structural changes. Two additional LS in 2009 and 2011 are of a lesser importance and it is difficult to find any reasonable explanation for them.

## STRUCTURAL BREAKS IN THE LONG RUN RELATIONSHIP

The next step of this research paper is to analyze existence of structural breaks in the long run relationship between retail and farm prices of beef meat. Despite the occurrence of the structural changes in particular price series it might have happened that those breaks were not present in the long run relationship or nature of the change was different.

### Unit root and causality

Considering the model EG a question about stationarity and casual relations between variables appears. In order to test presumption about existence of unit root the ADF test series was applied for natural logs of original price series as well as for price series linearized via automatic TRAMO procedure and via the automatic procedure with predefined RAMP breaks. As far as FP data is concerned, it was seasonally adjusted via TRAMO-SEATS method. The results obtained (details available on request) indicate the existence of unit root in all price series being considered. The first difference of all price series can be regarded as stationary.

The presumption about Granger non-causality was tested on the basis of pairs of the following price series (all in natural logs): initial data, price series linearized via *auto* TRAMO procedure and prices linearized through *autoRAMP* TRAMO procedure. The Granger-causality test has low power in analyzing data with structural breaks therefore analysis was performed also on pairs of linearized data. The obtained result (details available on request) shows that farm prices become a Granger-cause for retail prices, which is in line with expectations. The null hypothesis stating that past farm prices are not helpful in forecasting current retail prices was rejected for all pairs of price series ( $p < 0.01$ ).

### Dating structural breaks in the long run relationship

Two of the Engle-Granger cointegration models were estimated on the basic of logs of farm and retail prices (eq. 5). Estimates of models' residuals are as follows:  $u_{1t} = RP_t - (0.90 + 1.11 \cdot FP_t)$  and  $u_{2t} = RP_t - (1.25 + 0.56 \cdot FP_t + 0.003 \cdot t)$ .

There are substantial difference in parameters estimates of the long run relationship. The second model presents more reliable findings. Model with trend is also preferable because trend represent (proxy) other inputs which contribute to the retail prices. Standard error of residuals in the model with constant and trend is

0.041 whereas in model with constant  $s_e=0.075$ . Nevertheless, estimates of both models may not be reliable if there are structural breaks.

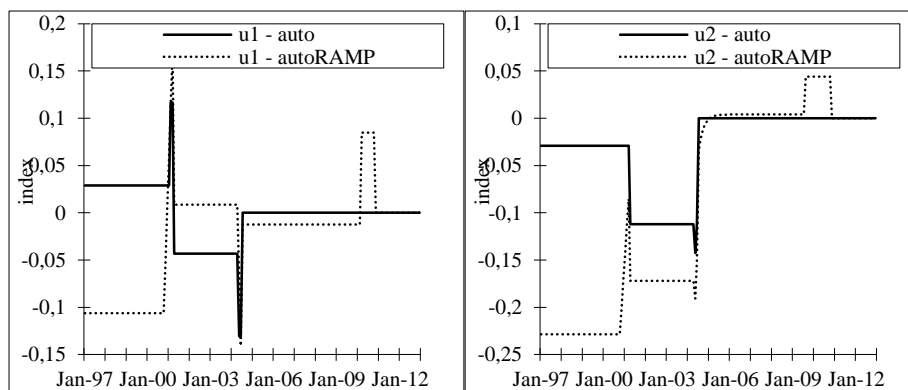
ARIMA models with dummies for structural brakes according to TRAMO methodology were fitted for residuals from above cointegration equations ( $u_{1t}$  and  $u_{2t}$ ) to verify presumption about structural breaks in the cointegration relationships. Two models for each residual were estimated as of initial price series: via automatic procedure (*auto*) and via automatic procedure with predefined RAMP effects (*autoRAMP*). The results are present in Table 2 and in Figure 3.

Table 2. TRAMO models for residuals from EG cointegration model (all parameters are statistically significant with p-values less than 0.001)

$u_{1t}$ - auto		$u_{1t}$ - autoRAMP		$u_{2t}$ - auto		$u_{2t}$ - autoRAMP	
ARIMA model [(0,1,1)(0,1,1)] BIC = -758.4		ARIMA model [(0,1,0)(1,0,0)] BIC = -852.3		ARIMA model [(0,1,1)(0,1,1)], BIC = -993.3		ARIMA model [(1,1,0)(0,1,0)] BIC = -1005.4	
Parameter	Value	Parameter	Value	Parameter	Value	Parameter	Value
LS[2001.2]	0.088	rp:2000.10-2001.03	0.274	LS[2001.4]	-0.083	rp:2000.10-2001.03	0.143
LS[2001.4]	-0.160	LS[2001.4]	-0.159	LS[2004.5]	-0.030	LS[2001.4]	-0.087
LS[2004.5]	-0.087	rp:2004.04-2004.07	-0.224	LS[2004.7]	0.112	rp:2004.04-2004.07	0.176
LS[2004.7]	0.130	TC[2004.7]	0.203	x	x	TC[2004.5]	-0.077
x	x	LS[2010.3]	0.097	x	x	LS[2009.8]	0.040
Th(1)	0.236	LS[2010.11]	-0.085	Th(1)	0.220	LS[2010.11]	-0.044
BTh(1)	-0.827	BPhi(1)	-0.277	BTh(1)	-0.857	BPhi(1)	-0.836

Source: own calculations

Figure 3. Deterministic components effect on residuals from long-run cointegration relationships  $u_{1t}$  and  $u_{2t}$



Source: own calculations



Estimates of structural breaks differ considerably among the models. More reasonable seems to be those obtained according to *autoRAMP* models. Also the AIC criterion indicates better performance of *autoRAMP* models.

In the final step new cointegration models with structural breaks according to formula 6 were estimated. Deterministic variables included in models are listed in Table 2. The long run equilibrium estimates for models with constant and deterministic variables obtained by *auto* and *autoRAMP* procedures are 0.83 and 0.75 respectively. Estimated coefficients from models with constant, trend and dummies for structural breaks are almost the same for *auto* and *autoRAMP* procedures: 0.49 and 0.50. Comparing above long run equilibrium coefficients with coefficients estimated according equation 5 we can conclude that inclusion of dummy variables for structural breaks changes long run parameters especially in models without trend. Furthermore, it has also affects estimates of ECT and thus may have impact on estimates of transmission model (long and short adjustments).

## SUMMARY

The study allows us to formulate the following conclusions:

- The time series of the farm and retail beef prices are non-stationary.
- Farm prices of beef appeared to be the Granger-cause for the retail prices of beef cuts.
- There were structural breaks of different nature present in the time series of farm and retail prices as well as in the long-run cointegration relationship between these prices. The most evident structural breaks are mainly due to the BSE crisis and Poland's accession to the EU.
- Timing and the nature of the structural breaks estimated on the basis of automatic procedures may be far from reality if structural changes are spread out over time.
- The inclusion of variables for different structural regimes change estimates of the long-term relationship and the nature of the ECT process. It may strongly affects estimates of error correction models for beef prices in Poland.
- To enlarge the field of analysis we can, among other things, estimate error correction models (VECM or EG) with structural breaks and price transmission models (including asymmetric models). Ones can also apply models, which cover other types of structural breaks: trend change and/or transitory change.

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