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# Structural Changes in Wheat Market

**Abstract.** Time series analysis is based on the assumption of stationarity. Stationarity implies the parameters are constant over time. Structural break occurs when at least one of the parameters changes at some date. Structural breaks can lead to huge forecasting errors and unreliability of the model. Modelling structure breaks is very popular in the literature of macroeconomics and finance. However, there are still too few publications about structural breaks in agricultural market.
The goal of research is to identify structural breaks in wheat prices time series. A few structural break tests are applied. It has been shown that there is at least one significant structural break in the analysed time series. Both Quandt-Andrews and Bai-Perron tests show that there is a significant breakpoint in 12.09.2007. The estimated break date is associated with the beginning of global financial crisis. It may imply that wheat prices have become more prone to changes in global financial market.

**Key words:** agricultural commodity, wheat market, structural breaks, Bai-Perron test

## Introduction

First decade of 21st century has brought on incredible structural changes to the commodity market. Commodity markets, including agricultural commodities, have become more like financial markets (Domanski, Heath, 2007). During 2007–2008 and 2010–2011 commodities' prices, including agricultural commodities, have increased substantially. Baffes and Haniotis (2010) claim that economic factors cannot fully explain the recent increase in commodity prices. They find the investors' activity in commodity futures market as one of the main driving forces behind the sharp prices rise of agricultural commodities. High activity of speculators has pushed up commodities' prices beyond fundamental levels. Furthermore, growing interest of speculators in the commodity futures market increases price volatility in this market (Czech, 2013). Nowadays, the researchers need to apply models and techniques which have been used so far mainly for financial time series data. There are a few main issues that arise with agricultural commodity's prices time series. One among others is the problem of structure breaks that may affect any or all of the models parameters.

Fundamental econometric models are based on the assumption that parameters are constant over time. Structural changes occur if at least one parameters in the model has changed at some date (*break date*). This change may involve a change in mean or a change in other parameters of the process that produce the series. Being able to identify when the structure of time series changes can give researchers insights into the analysed problem. In order to determine when and whether there is a significant change in data, one can apply structural break tests.

It is generally known that the identification and modelling structural breaks is important to generate the precise estimates of the model and its forecast. Modelling structure breaks is very popular issue in literature concerning empirical macroeconomics

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and finance. For instance, Malik (2003) or Rapach and Strauss (2008) detect structural breaks in the exchange rate market, Bai and Perron (2003) in the US interest rate market or Aggarwal, Inclan and Leal (1999) in the securities market. The application of structural break tests on commodities' time series is not as popular as on macroeconomic and financial time series. The problem was analysed by Jin and Miljkovic (2010), Zainudin and Shaharudin (2011), Narayan et al. (2013) among others. Jin and Miljkovic find six structural breaks in the US relative farm prices. Zainudin and Shaharudin (2011) investigate the spot and future palm oil prices time series. They identify two significant structural breaks in analysed data. Narayan et al. (2013) detect significant structural breaks in the gold, oil and silver market. It needs to be emphasized that identification of structure breaks is essential in the volatility clustering modelling. Structure breaks have an impact on the accuracy of volatility parameters estimation. Detecting structural breaks is also the first step to build econometric models with regime-changes.

The primary goal of research is to identify structural breaks in the wheat prices time series. The paper is organized as follows: section 2 depicts literature reviews concerning the methods of identifying structural breaks in time series data, section 3 discusses analysed wheat prices' data and examines the results of applied breakpoint tests, and section 4 contains conclusions.

## Methodology

Structural change will be discussed in the context of simplest dynamic model, the first-order autoregressive model (1):

$$y_t = \alpha + \beta y_{t-1} + \varepsilon_t \tag{1}$$

where $\varepsilon_t$ is a time series of serially uncorrelated shocks, $\alpha, \beta$ are the parameters of the model. Time series $y_t$ is being modelled as a regression on its own past. The explanatory variables $y_{t-1}$ are lagged values of observed endogenous variables $y_t$. The well-known assumption of stationarity implies that model parameters $\alpha, \beta$ are constant over time. Structural break is said to occur if at least one of these parameters has changed at some date in the sample period. This date is popularly called as the break date.

The researchers of structural changes look for systematic methods to identify and understand structural breaks. The classical test for structural change is introduced by Chow (1960). In his test the sample is split into two sub periods, then after parameter estimation for each sub periods, the equality of two sets of parameters test is applied. However, there is an important limitation of the test. In the Chow test, researcher must know in advance the break date. It needs to be emphasized that the choice of exact break date is hard and problematic. Moreover, results are highly sensitive to the choice of break date and as a result different researchers may come to different conclusions. Therefore, there are two main disadvantages of the Chow test (Hansen, 2001). First of all, the Chow test may occur to be uninformative because the true break date can be missed. Moreover, the Chow test may be misleading, when the test indicates the break date while, in fact, none exist.

It is believed that better approach to find proper breakpoints is to treat the break date as unknown. Such idea was developed by Quandt (1960). He suggested taking the largest Chow statistic over „all” possible break dates. The estimated largest Chow statistic is called Quand’t statistic. The conventional solution is to consider all break dates in the interior τ percent to (1-τ) percent of the sample, where the trimming parameter τ is typically between 5 percent and 15 percent. For many years, however, the Quandt statistic had no practical application, because there were no proper critical values for the Quandt’s test. In the 1990’s this problem was simultaneously solved by several scientists. Andrews (1993), Andrews and Ploberger (1994) provide tables of critical values, Hansen (1997) provides method to calculate p-value for Quandt’s test.

Another disadvantage of both Chow’s and Quandt’s tests is the fact that they are able to detect only one break date. Dufour (1982) extended Chow’s test. He applied non-parametric methods to detect multiple changes in regression coefficients that occur at unknown time. Another interesting approach applied to detect multiple structural changes is the test developed by Bai and Perron (1998, 2003). They proposed a sequential method which starts by testing for the single break date existence. If the null hypothesis that there is no structural break is rejected, then the sample is split into two subsamples. It needs to be emphasized that the sample is divided on the basis of estimated break date. This sequence test is carried out until each subsample test fails to find evidence of a structural break.

## Research results

In order to identify structural breaks in wheat commodity market the first-order autoregressive model is built. Daily futures prices data for wheat from January 1995 to December 2015 (5 479 observations) provided by Thomson Reuters DataStream are applied to analysis. Figure 1 presents wheat prices from January 1995 to December 2015 in US dollars per bushel.

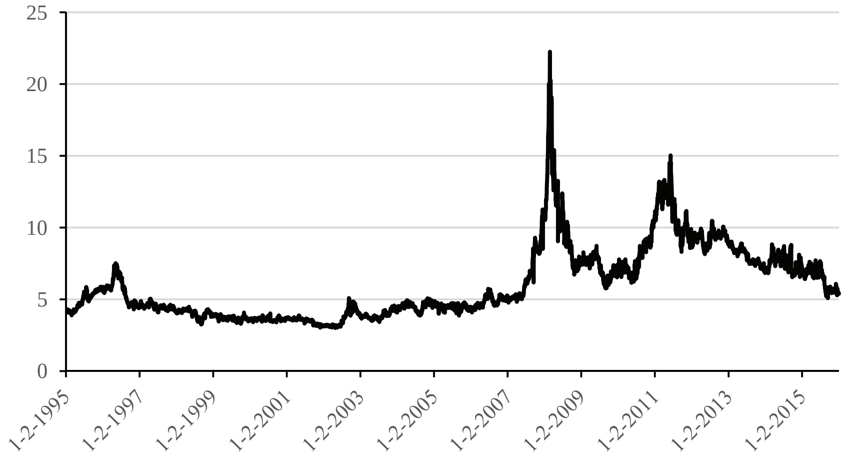


Fig. 1. Daily wheat prices from 01.1995 to 12.2015 (in US dollars per bushel)

Source: own calculations.

Figure 1 shows that the volatility of wheat prices increased substantially since the end of 2007. It needs to be emphasized that the period of extreme wheat prices' growth covers with the period of the beginning of global financial crisis. Before the end of 2007 wheat market was more stable, that is the volatility of wheat prices was much lower than in the next period. Based on figure 1 we can expect that there is some structural break in analysed wheat prices time series.

The process of structural break testing should be begun with estimating the proper econometric model. Following Hansen (2001) the first-order autoregressive model (1) is built. Estimation of coefficients of model (1) requires variables to be stationary. The Augmented Dickey-Fuller (ADF) (1979) test is conducted for testing the null hypothesis of a unit root versus the alternative of a stationarity. Table 1 presents ADF test of futures wheat prices time series. Let $w_t$ be the natural logarithm of the wheat time series variable and $dw_t$ be the first difference of $w_t$.

Table 1. Augmented Dickey-Fuller test results

| Variable | Intercept | Intercept and trend |
|---|---|---|
| $w_t$ | -2,44 | -2,88 |
| $dw_t$ | -61,53*** | -61,53*** |

Note: *** $H_0$ of a unit root is rejected at 1%, ** 5%, and * 10% significance level.

Source: Thomson Reuters DataStream, own calculations.

The ADF test indicates that the hypothesis of a non-stationary level cannot be rejected for $w_t$ time series. However, $dw_t$ time series (the first difference of $w_t$) occurs to be stationary at least at 1% significance level. Therefore, it implies that the first-order autoregressive model (1) should be built on the basis of stationary variable $dw_t$. The variable $dw_t$ is the observed endogenous variable of the model (1). Moreover, model (1) consists of constant regressor and first order lagged values of observed endogenous variables. Table 2 presents the estimated coefficients of model (1) for the wheat prices time series.

Table 2. First-order autoregressive model (1) for wheat prices time series

| Coefficient | Value | t-statistic |
|---|---|---|
| constant ( $\alpha$ ) | 0,01 | 0,14 |
| $dw_{t-1}$ ( $\beta$ ) | -0,14 | -10,77*** |

Note: *** $H_0$: coefficient is equal zero is rejected at 1%, ** 5%, and * 10% significance level.

Source: own calculation.

On the basis of the results presented in table 2 it can be noticed that intercept coefficient is not significant. The null hypothesis that coefficient $\beta$ equals zero has been rejected at 1% significance level. The estimated model (1) is applied to identify structure breaks in the wheat market from 01.1995 to 12.2015.

First, we start from tests that identify single break date. As it is hard to detect exact break date, it is good to begin with Quandt (1960) test which treats the break date as unknown. The trimming percentage of 15 is employed. The trimming value implies that regimes are restricted to have at least 15 observations. The calculations has been made in

Eviews 8 econometric software. As many as 3836 break dates has been compared. The results of Quandt test is presented in Table 3.

Table 3. Quandt-Andrews unknown breakpoint test

| Statistics | Value | Probability |
|---|---|---|
| Maximum (max F) (12.09.2007) | 10,83 | 0,00 |
| Exponential (exp F) | 2,69 | 0,00 |
| Average (ave F) | 3,14 | 0,01 |

Source: own calculations.

The highest value of the Chow test has been estimated for date 12.09.2007. The maximum (max F), average (ave F) and exponential (exp F) test statistics are applied. P-values presented in the third column indicate that the null hypothesis of no break is rejected. It is shown that the estimated breakpoint date is significant.

Another, more advanced and complex, way to detect structure breaks is the sequential Bai-Perron test. The merit of the test is the fact that it can identify more than one breakpoint. Before we conduct the test, there are some assumptions that should be made. First, the maximum number of breaks is 5, trimming percentage is 15 and significance level for sequential testing is 0,05 (denoted by *).

Table 4 displays scaled F-statistic and the Bai-Perron critical values (Bai and Perron 2003). F-statistic is scaled by the number of varying regressors. Assumed significance level is 0,05. The sequential Bai-Perron test shows that there is only one breakpoint in 12$^{th}$ September 2007, which is consistent with the results of Quandt-Andrews test. A null hypothesis of zero breakpoint is rejected in favour of an alternative of 1 breakpoint ($m$=1). However, with this series, there is no evidence for a second break.

Table 4. Sequential Bai-Perron test

| Break test | Scaled F-statistic | Bai-Perron critical value |
|---|---|---|
| 0 vs. 1* | 22,66 | 11,47 |
| 1 vs. 2 | 6,35 | 12,95 |
| Break date | 12.09.2007 | |

* significant at a 0,05 level

Source: own calculations.

The Bai Perron test presented above requires the specification of the number of breaks ($m$) under the alternative hypothesis. Bai and Perron (1998) proposed another form of multiple breakpoint test where we test the null hypothesis of no structural break against the hypothesis of $M$ globally optimized breaks. In the test the maximum number of breaks is assumed to be 5, trimming percentage is 15% and significance level is 0,05. Test results are presented in table 5.

Table 5 displays scaled F-statistic, weighted F-statistics and the Bai-Perron critical values (Bai and Perron, 2003). Estimation procedure of above test statistics is described in the paper written by Bai and Perron (1998). The Bai-Perron test of 1 to M globally determined breaks is performed from 1 to the maximum number of breaks until we cannot reject the null hypothesis. In each case the individual test statistic (both scaled and weighted) exceeds the critical value. Therefore, the multiple breakpoint test indicates that there are as many as 5 breakpoints.

Table 5. Bai-Perron test of 1 to M globally determined breaks

| Breaks | Scaled F-statistic | Weighted F-statistics | Critical Value |
|---|---|---|---|
| 1* | 22,66 | 22,66 | 11,47 |
| 2* | 11,35 | 13,36 | 9,75 |
| 3* | 12,71 | 17,44 | 8,36 |
| 4* | 14,95 | 23,85 | 7,19 |
| 5* | 10,49 | 20,58 | 5,85 |
| | | | |
| $UD_{max}$ | 22,66 | $UD_{max}$ critical value** | 11,70 |
| $WD_{max}$ | 23,85 | $WD_{max}$ critical value** | 12,81 |

* significant at a 0,05 level.
** Bai-Perron (2003) critical values for $UD_{max}$ and $WD_{max}$.

Source: own calculations.

However, the application of scaled and weighted maximized statistics indicates different number of breakpoints.[2] The maximized value of scaled F-statistic ($UD_{max}$) clearly exceeds the critical value. A null hypothesis of no breaks is rejected in favour of an alternative hypothesis of a single break. The break date is 12.09.2007, exactly the same as in previous tests. The value of maximized weighted statistics ($WD_{max}$) is also higher than critical value which indicates that the null hypothesis is rejected. In that case however, the $WD_{max}$ test statistics indicates that there are 4 breakpoints. The null hypothesis of 3 breakpoints is rejected in favour of hypothesis of 4 breakpoints. The estimated break dates are as follows: 14.10.1998, 10.07.2002, 12.09.2007 and 04.11.2010. It needs to be emphasized that the results based on $WD_{max}$ test statistics are different than before, but one break date (12.09.2007) appears in each test.

All results reported up to this point show that there is at least one breakpoint in the analysed wheat prices' time series. 12$^{th}$ September 2007 is found to be a break date. It needs to be stressed that September 2007 is the time of the crisis in American housing market. The subprime mortgage crisis transformed very quickly into global financial crisis. The estimated break date shows that financial crisis has affected not only the shares or foreign exchange market but also the commodity market. Moreover, it doesn't concern only the most actively traded commodity like oil, but also soft commodities including wheat.

## Conclusions

The preceding analysis can be summarized as follows:

- From a perspective of generating the precise estimates of a model and its forecast, the identification of structural breaks is extremely important,
- The problem of structural breaks in food commodity market cannot be ignore, it can lead to inaccurate forecasts, misleading or worse policy recommendation,
- The results show that structural breaks exist in wheat prices time series. Both Quandt-Andrews and sequential Bai-Perron tests show that there is one significant breakpoint in 12.09.2007. The results of the Bai-Perron test of 1 to M globally determined breaks

[2] The test which is based on maximized scaled or weighted statistic is called a double maximum test (Bai and Perron 1998).

are not clear and unambiguous. The maximized value of scaled F-statistic ($UD_{max}$) indicates the existence of one break date (12.09.2007). The value of maximized weighted statistics ($WD_{max}$), however, indicates that there are as many as 4 breakpoints,

- All conducted tests show that there is structural break in 12.09.2007. It needs to be emphasized that the estimated date is covering with the time of the beginning of global financial crisis. It may suggest that wheat prices have become more and more sensitive to changes in global financial markets.

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