Analysis of Structural Breaks in BET Index

Valentin EPURE, Ph.D. Student,

School of Advanced Studies of the Romanian Academy (SCOSAAR)

Abstract

In the paper, we analyse the dynamics of the BET index between 1997 and 2017. The fluctuations in the BET dynamics have led to the construction of an econometric model with breaks in trend. Stability tests indicated as plausible a regression model with a linear trend and five breakpoints: 30 August 2002, 29 August 2005, 26 August 2008, 24 August 2011 and 11 September 2014. The model explains 95% of variation in BET index from the mean.

Keywords: Bucharest Exchange Trading (BET) Index, stability tests, multiple structural breaks.

JEL Classification: C12, C52, E44, G17

1. Introduction

The Bucharest Stock Exchange (BVB) base index, namely the Bucharest Exchange Trading Index (BET), was launched on 19 September 1997, with a starting value of 1,000 points. In its nearly 20 years of history, the BET index has recorded an oscillating evolution. The BET index dynamics is shown in the following figure.

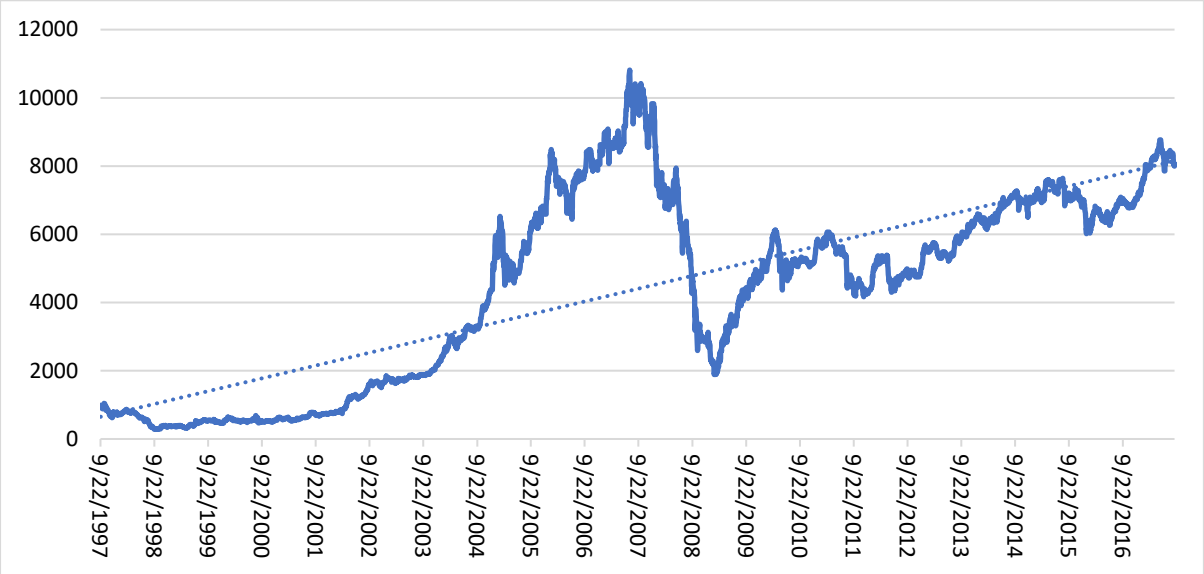

Figure 1. The evolution of the BET index, 1997 - 2017

Source: Bucharest Stock Exchange, BET Index,
http://www.bvb.ro/FinancialInstruments/Indices/IndicesProfiles.aspx?i=BET

After a period of relatively calm evolution (1997-2001), the BET index exploded in an exponential course from 2002 until the beginning of the financial crisis: the maximum value of 10813.59 points was reached on 7 July 2007, which represented a growth in 10 years (1997-2017) for nearly 11 times compared to the starting level. The next 10 years were much more turbulent, starting with a collapse between July 2007 and February 2009, of over 5.7 times: from 10813.59 points to 1887.14 points (25 February 2009).

The resumption of the BET index growth after 2009 was achieved under conditions of increased volatility. The high volatility of the BET index was the characteristic of the evolution between 2005 and 2009, and this characteristic was maintained in the post-crisis period.

2. Identification of structural breaks in BET dynamic series

To identify the structural breaks in BET series dynamics, we apply Bai-Perron stability tests (2003) in which, multiple structural breaks can be automatically detected from data. We use two estimations for the dynamic model of the BET index: a model in which the regression is made against

the average series (the constant) and a model in which the regression is built against a linear trend in a long-term evolution.

2.1. Identification of structural breaks in the model with a single (constant) regressor

The regression model is as follows:

$$BET_t = a_0 + e_t.$$

In the previous model, BET is the daily BET index series, e_t is the error variable, and a_0 is the average of the BET series, on long-term (1997-2017) - ie a_0 = 4400 points.

The results of the stability tests (numbers of determined breaks and estimated break dates) are summarized in the following table and are detailed in Annex A.1.

Table 1. Breakpoint tests for BET index in model with a constant as regressor

Multiple breakpoint tests	*Numbers of determined breaks*	*Estimated break dates:*
1. Bai-Perron tests of L+1 vs. L sequentially determined breaks	4	10/25/2001 10/22/2004 6/26/2008 9/23/2013
2. Bai-Perron tests of 1 to M globally determined breaks	4	1/08/2002 1/05/2005 7/11/2008 9/23/2013
3. Bai-Perron tests of L+1 vs. L globally determined breaks	4	1/08/2002 1/05/2005 7/11/2008 9/23/2013
4. Compare information criteria for 0 to M globally determined breaks	4	1/08/2002 1/05/2005 7/11/2008 9/23/2013

Source: calculations in EViews, based on Bucharest Stock Exchange data, BET Index, http://www.bvb.ro/FinancialInstruments/Indices/IndicesProfiles.aspx?i=BET

All stability tests indicate a number of four interruptions, for the model in which the BET index is regressed comparative to a constant (average process on long-term).

The last three tests select the same estimates periods of interruptions in the long-term trend: 8 January 2002 - 5 January 2005, 11 July 2008 and 23 September 2013. These data represent the first date of the subsequent regime (this is a convention in defining break dates of EViews - the software used to solve the models).

Bai-Perron tests of L+1 vs. L sequentially determined breaks identifies, from the previous list, only 23 September 2013 and approximately the mid of 2008 (26 June 2008, compared to 11 July in the last three tests). The first two break dates are estimated as about two months earlier (the end of October in the first test, compared to the beginning of January in the other three).

2.2. Identification of structural breaks in the linear trend model

The linear regression model is: (Jula and Jula 2017):

$$BET_t = a_0 + a_1 t + e_t.$$

In the previous model,

BET – is the daily BET index series,

t – symbolizes (means) time,

e_t – is the error variable,

a_0 and a_1 – are the coefficients of the model.

The estimation for the model is:

$$BET_t = \underset{(49.6510)}{650.1533} + \underset{(0.0165)}{1.4401} + u_t$$

where u_t symbolizes the residues from the regression model (in brackets, below estimators is the standard error).

The results of the stability tests (numbers of determined breaks and estimated break dates) are summarized in the following table and are detailed in Annex A.2.

Table 2. Breakpoint tests for BET index in model with a linear trend

Multiple breakpoint tests	*Numbers of determined breaks*	*Estimated break dates:*
1. Bai-Perron tests of L+1 vs. L sequentially determined breaks	5	11/05/2001 12/09/2004 8/15/2008 8/15/2011 8/12/2014
2. Bai-Perron tests of 1 to M globally determined breaks	5	8/30/2002 8/29/2005 8/26/2008 8/24/2011 9/11/2014

Multiple breakpoint tests	*Numbers of determined breaks*	*Estimated break dates:*
3. Bai-Perron tests of L+1 vs. L globally determined breaks	5	8/30/2002 8/29/2005 8/26/2008 8/24/2011 9/11/2014
4. Compare information criteria for 0 to M globally determined breaks	5	8/30/2002, 8/29/2005 8/26/2008 8/24/2011 9/11/2014

Source: calculations in EViews, based on Bucharest Stock Exchange data, BET Index, http://www.bvb.ro/FinancialInstruments/Indices/IndicesProfiles.aspx?i=BET

All stability tests indicate a number of five interruptions, for the model where the BET index is evaluated compared to a linear trend, on long-term.

The last three tests select the same estimated data for breaks in the long-term trend (the first date of the subsequent regime): 30 August 2002, 29 August 2005, 26 August 2008, 24 August 2011 and 11 September 2014. Bai-Perron tests of L+1 vs. L sequentially determined breaks identifies the last three dates near those calculated in the global tests, but the first two are calculated earliest, with differences between 9 and 11 months.

3. Econometric modelling of BET index evolution

Based on results related to numbers of determined breaks and estimated break dates analysed in the previous chapter, we have built up econometric models to analyse the evolution of the BET index. Table 3 presents the results of the model estimation in which the BET index regression is performed compared to the average of the series (constant), and in Table 4 are presented the results of the estimation of the model in which the regression is built compared to a linear evolution trend (in a long term).

Table 3. BET index model with a constant as regressor – 4 breakpoints

Multiple breakpoint tests	*Estimated break dates:*	*Goodness of Fit*
Bai-Perron tests of L+1 vs. L sequentially determined breaks	10/25/2001 10/22/2004 6/26/2008 9/23/2013	R^2 = 0.8937 AIC = 16.480 SC = 16.487 HQ = 16.483

Multiple breakpoint tests	*Estimated break dates:*	*Goodness of Fit*
Bai-Perron tests of 1 to M globally determined breaks / Bai-Perron tests of L+1 vs. L globally determined breaks / Compare information criteria for 0 to M globally determined breaks	1/08/2002 1/05/2005 7/11/2008 9/23/2013	R^2 = 0.8959 AIC = 16.460 SC = 16.466 HQ = 16.462

Table 4. BET index model with a linear trend - 5 breakpoints

Break specification	*Estimated break dates:*	*Goodness of Fit*
Bai-Perron tests of L+1 vs. L sequentially determined breaks	11/05/2001 12/09/2004 8/15/2008 8/15/2011 8/12/2014	R^2 = 0.94986 AIC = 15.732 SC = 15.747 HQ = 15.737
Bai-Perron tests of 1 to M globally determined breaks / Bai-Perron tests of L+1 vs. L globally determined breaks / Compare information criteria for 0 to M globally determined breaks	8/30/2002 8/29/2005 8/26/2008 8/24/2011 9/11/2014	R^2 = 0.95081 AIC = 15.713 SC = 15.728 HQ = 15.718

Source: calculations in EViews, based on Bucharest Stock Exchange data, BET Index, http://www.bvb.ro/FinancialInstruments/Indices/IndicesProfiles.aspx?i=BET

Because the global test provides the same results on numbers of determined breaks and estimated break dates, the results of estimation are identical for 2-4 models in Table 1. In the first case (regression against to the average) the model calculated starting from assumptions of global tests is superior (Jula & Jula, 2017): the coefficient of determination (R^2) is higher and the values of the information criteria (AIC - Akaike info criterion, SC - Schwarz criterion and HQ - Hannan-Quinn criterion) are lower.

The situation is similar in the case of models built on the assumption of linear trend, too: the results of estimation are identical for models 2-4 in Table 2, and global models are superior to the model for sequential determination of the number of breaks.

Moreover, the criteria for assessing the quality of models are superior to models with a linear trend, compared to models with a constant trend.

The best specification is the one obtained by applying a global breaks determination criterion, starting from the linear trend model. Consequently, we choose the linear trend model and five breakpoints to describe the evolution of the BET index.

BET = @before("8/30/2002")·(467.72828 + 0.26220·t) +

+ @during("8/30/2002 – 8/26/2005")·(-6712.45866 + 5.79061·t) +

+ @during("8/29/2005 – 8/25/2008")·(4518.69601 + 1.38403·t) +

+ @during("8/26/2008 – 8/23/2011")·(-8071.77131 + 3.89649·t) +

+ @during("8/24/2011 – 9/10/2014")·(-7742.84976 + 3.28461·t) +

+ @after("9/11/2014")·(1546.55604 + 1.17532·t).

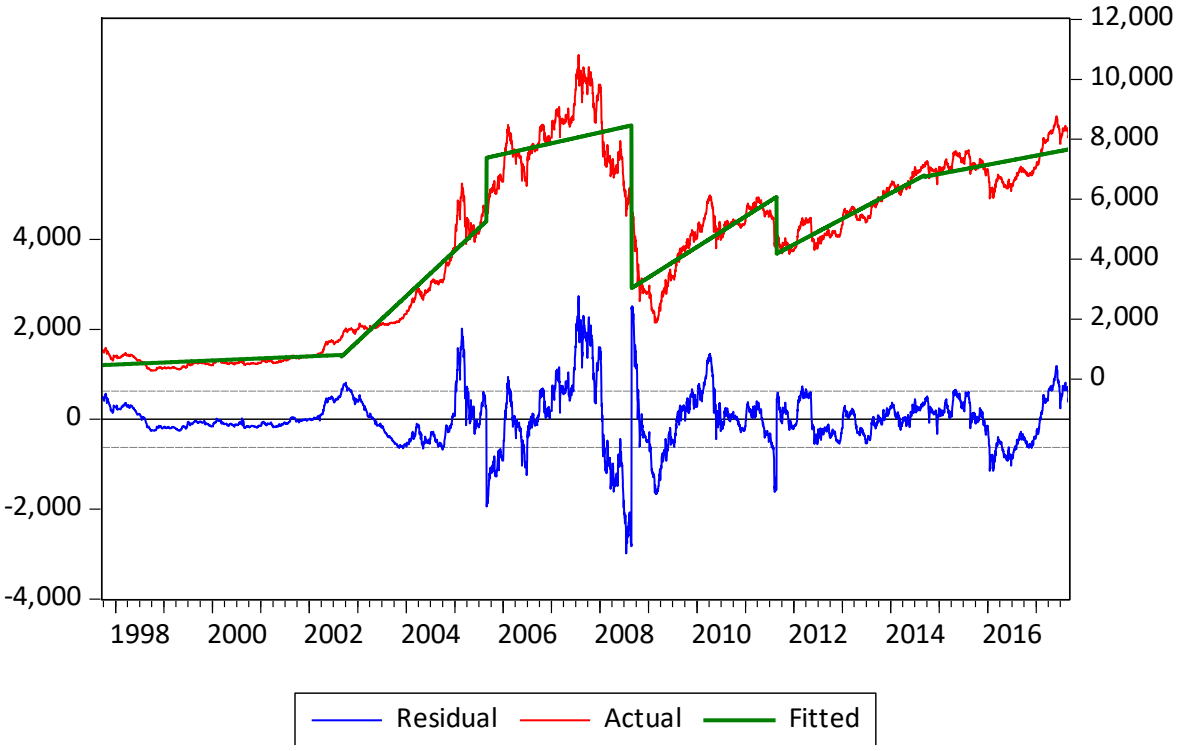

Figure 2. BET regression linear model with breaks in trend

The model is presented in detail in Annex 3. From the econometric point of view, the model is significant (F-statistic = 9131.481 and Prob(F-statistic) < 0.000001). Also, for the coefficient significance tests, the probabilities associated with the null hypothesis (H_0 - the coefficients are not significantly different of zero) are below the standard limit of 0.01. The model explains over 95% of the BER index variation as against the average.

Conclusions

BET index dynamics have registered significant fluctuations in the nearly 20 years after launching: a relatively slight increase in the first five years (1997-2002), an exponential increase in the next five years (2002-2007), followed by a collapse in the crisis period (2007-2009) and a resumption

of post-crisis growth. These differentiated dynamics in sub-periods led to searching for an evolution model with breaks in trend. Applying different methods for identifying breakpoints in two different models (regression from the series average, respectively linear trend) have led to construction the best model in this class: a BET linear regression model with 5 breakpoints: 30 August 2002, 29 August 2005, 26 August 2008, 24 August 2011 and 11 September 2014. The model is econometrically significant and explains over 95% of the BET index variation from the mean.

References

Albu, Lucian-Liviu. 2008. "Trends in Structural Changes and Convergence in UE." *Romanian Journal of Economic Forecasting* (Institute for Economic Forecasting) 9 (1): 91-101.

Alexandru, Antoniade Ciprian, and Nicoleta Caragea. 2015. "The Capital Markets Research Based on the Financial Quantitative Models." *Eco-Economics Review* (Ecological University of Bucharest, Economics Faculty and Ecology and Environmental Protection Faculty) 1 (1): 3-16.

Alexandru, Antoniade-Ciprian, Nicoleta Caragea, and Ana-Maria Dobre. 2013. "Innovative methods to analyze the stock market in Romania. Studying the volatility of the Romanian stock market with the ARCH and GARCH models using the "R" software." Edited by Asociația Generală a Economiștilor din România - AGER. *Theoretical and Applied Economics* 11 (588): 83-100.

Anghelache, Gabriela. 2000. *Bursa și piața extrabursieră.* București: Editura Economică.

Bai, Jushan, and Pierre Perron. 2003. "Computation and Analysis of Multiple Structural Change Models." *Journal of Applied Econometrics* 18 (1): 1-22.

Bai, Jushan, and Pierre Perron. 2003. "Critical Values for Multiple Structural Change Tests." *Econometrics Journal* 6: 72-78.

Bai, Jushan, and Pierre Perron. 1998. "Estimating and Testing Linear Models with Multiple Structural Changes." *Econometrica* 66: 47-78.

Bucharest Exchange Trading. 2014. "Manualul Indicelui BET." Accessed January 2015. https://bvb.ro/info/indices/Manual%20BET_RO.pdf.

Buneci, Bogdan. 2014. *Concurența. Analiză economică și instituțională.* București: Editura Mustang.

Jula, Dorin, and Nicolae Marius Jula. 2013. "Economic Growth and Structural Changes in Regional Employment." *Romanian Journal of Economic Forecasting* (Institute for Economic Forecasting) 16 (2): 52-69.

Jula, Dorin, and Nicolae-Marius Jula. 2017. "Foreign Direct Investments and Employment. Structural Analysis." *Romanian Journal of Economic Forecasting* XX (2): 30-45.

Jula, Nicoleta, and Dorin Jula. 2017. *Modelare economică. Modele econometrice și de optimizare.* București: Editura Mustang.

Liu, Jian, Shiying Wu, and James V Zidek. 1997. "On Segmented Multivariate Regression." *Statistica Sinica* 7: 497-525.

Perron, Pierre. 2006. *Dealing with Structural Breaks.* Vol. 1: Econometric Theory, in *Palgrave Handbook of Econometrics*, edited by Terence C Mills and Kerry Patterson, 278-352. New York: Palgrave Macmillan.

Annexes

Annex 1. Multiple breakpoint tests for BET index in model with a constant as regressor

All the multiple breakpoint tests were performed in EViews. We used for BET index in model with a constant as regressor the following parameters and specification:

Sample: 9/22/1997 5/29/2017

Included observations: 5209

Breaking variables: C

Break test options: Trimming 0.15, Max. breaks 5, Sig. level 0.05

Critical values: Bai-Perron (Econometric Journal, 2003). * Means "significant at the 0.05 level".

1.1. Bai-Perron tests of L+1 vs. L sequentially determined breaks

Sequential F-statistic determined breaks:		4	
Break Test	F-statistic	Scaled F-statistic	Critical Value
0 vs. 1 *	15776.21	15776.21	8.58
1 vs. 2 *	1054.611	1054.611	10.13
2 vs. 3 *	2807.976	2807.976	11.14
3 vs. 4 *	836.0999	836.0999	11.83
4 vs. 5	0.000000	0.000000	12.25

Break dates:	Sequential	Repartition
1	10/22/2004	10/25/2001
2	6/26/2008	1/04/2005
3	9/23/2013	7/14/2008
4	10/25/2001	9/23/2013

1.2. Bai-Perron tests of 1 to M globally determined breaks

Sequential F-statistic determined breaks:	5
Significant F-statistic largest breaks:	5
UDmax determined breaks:	1
WDmax determined breaks:	4

Breaks	F-statistic	Scaled	Weighted	Critical

		F-statistic	F-statistic	Value
1 *	15776.21	15776.21	15776.21	8.58
2 *	10269.17	10269.17	12203.53	7.22
3 *	11644.58	11644.58	16763.51	5.96
4 *	11195.26	11195.26	19249.56	4.99
5 *	8743.129	8743.129	19185.69	3.91

UDMax statistic*	15776.21	UDMax critical value**	8.88
WDMax statistic*	19249.56	WDMax critical value**	9.91

Estimated break dates:
1: 10/22/2004
2: 12/21/2004, 6/25/2008
3: 12/21/2004, 7/11/2008, 9/23/2013
4: 1/08/2002, 1/05/2005, 7/11/2008, 9/23/2013
5: 1/08/2002, 1/05/2005, 6/30/2008, 6/28/2011, 6/25/2014

1.3. Bai-Perron tests of L+1 vs. L globally determined breaks

Sequential F-statistic determined breaks:	4
Significant F-statistic largest breaks:	4

Break Test	F-statistic	Scaled F-statistic	Critical Value
0 vs. 1 *	15776.21	15776.21	8.58
1 vs. 2 *	1054.611	1054.611	10.13
2 vs. 3 *	2893.360	2893.360	11.14
3 vs. 4 *	1182.105	1182.105	11.83
4 vs. 5	0.000000	0.000000	12.25

Estimated break dates:
1: 10/22/2004
2: 12/21/2004, 6/25/2008
3: 12/21/2004, 7/11/2008, 9/23/2013
4: 1/08/2002, 1/05/2005, 7/11/2008, 9/23/2013
5: 1/08/2002, 1/05/2005, 6/30/2008, 6/28/2011, 6/25/2014

1.4. Compare information criteria for 0 to M globally determined breaks

Schwarz criterion selected breaks:	4
LWZ criterion selected breaks:	4

Breaks	# of Coefs.	Sum of Sq. Resids.	Log-L	Schwarz* Criterion	LWZ* Criterion
0	1	4.11E+10	-48756.73	15.88396	15.88772

1	3	1.02E+10	-45126.79	14.49352	14.50480
2	5	8.32E+09	-44593.69	14.29212	14.31092
3	7	5.34E+09	-43436.46	13.85109	13.87741
4	9	4.28E+09	-42864.58	13.63480	13.66864
5	11	4.38E+09	-42920.25	13.65946	13.70082

* Minimum information criterion values displayed with shading

Estimated break dates:

1: 10/22/2004

2: 12/21/2004, 6/25/2008

3: 12/21/2004, 7/11/2008, 9/23/2013

4: 1/08/2002, 1/05/2005, 7/11/2008, 9/23/2013

5: 1/08/2002, 1/05/2005, 6/30/2008, 6/28/2011, 6/25/2014

Annex 2. Multiple breakpoint tests for BET index in model with a linear trend

All the multiple breakpoint tests were performed in EViews. We used for BET index linear trend model the following parameters and specification:

Sample: 9/22/1997 5/29/2017

Included observations: 5209

Breaking variables: C, t

Break test options: Trimming 0.15, Max. breaks 5, Sig. level 0.05

Critical values: Bai-Perron (Econometric Journal, 2003). * Means "significant at the 0.05 level".

2.1. Bai-Perron tests of L+1 vs. L sequentially determined breaks

Sequential F-statistic determined breaks:			5
Break Test	F-statistic	Scaled F-statistic	Critical Value
0 vs. 1 *	4072.616	8145.233	11.47
1 vs. 2 *	3170.907	6341.814	12.95
2 vs. 3 *	426.7017	853.4033	14.03
3 vs. 4 *	325.1182	650.2364	14.85
4 vs. 5 *	108.7937	217.5874	15.29

Break dates:	Sequential	Repartition
1	8/15/2008	11/05/2001
2	12/09/2004	8/18/2005
3	11/05/2001	7/01/2008
4	8/15/2011	8/15/2011
5	8/12/2014	8/12/2014

2.2. Bai-Perron tests of 1 to M globally determined breaks

Sequential F-statistic determined breaks:	5
Significant F-statistic largest breaks:	5
UDmax determined breaks:	2
WDmax determined breaks:	2

Breaks	F-statistic	Scaled F-statistic	Weighted F-statistic	Critical Value
1 *	4072.616	8145.233	8145.233	11.47
2 *	6569.374	13138.75	15456.56	9.75
3 *	5315.977	10631.95	14587.14	8.36
4 *	4486.755	8973.511	14315.18	7.19
5 *	3773.193	7546.385	14796.08	5.85

UDMax statistic*	13138.75	UDMax critical value**	11.70
WDMax statistic*	15456.56	WDMax critical value**	12.81

Estimated break dates:
1: 8/15/2008
2: 10/25/2004, 6/25/2008
3: 11/30/2001, 1/04/2005, 6/26/2008
4: 8/30/2002, 8/29/2005, 8/26/2008, 8/24/2011
5: 8/30/2002, 8/29/2005, 8/26/2008, 8/24/2011, 9/11/2014

2.3. Bai-Perron tests of L+1 vs. L globally determined breaks

Sequential F-statistic determined breaks:	5
Significant F-statistic largest breaks:	5

Break Test	F-statistic	Scaled F-statistic	Critical Value
0 vs. 1 *	4072.616	8145.233	11.47
1 vs. 2 *	3170.907	6341.814	12.95
2 vs. 3 *	377.0853	754.1705	14.03
3 vs. 4 *	262.0105	524.0210	14.85
4 vs. 5 *	117.1359	234.2719	15.29

Estimated break dates:
1: 8/15/2008
2: 10/25/2004, 6/25/2008
3: 11/30/2001, 1/04/2005, 6/26/2008
4: 8/30/2002, 8/29/2005, 8/26/2008, 8/24/2011
5: 8/30/2002, 8/29/2005, 8/26/2008, 8/24/2011, 9/11/2014

2.4. Compare information criteria for 0 to M globally determined breaks

Schwarz criterion selected breaks:	5
LWZ criterion selected breaks:	5

Breaks	# of Coefs.	Sum of Sq. Resids.	Log-L	Schwarz* Criterion	LWZ* Criterion
0	2	1.67E+10	-46411.32	14.98508	14.99260
1	5	6.52E+09	-43958.11	14.04809	14.06689
2	8	2.76E+09	-41722.88	13.19480	13.22488
3	11	2.34E+09	-41294.31	13.03518	13.07654
4	14	2.12E+09	-41026.85	12.93742	12.99006
5	17	2.02E+09	-40912.01	12.89826	12.96218

* Minimum information criterion values displayed with shading

Estimated break dates:
1: 8/15/2008
2: 10/25/2004, 6/25/2008
3: 11/30/2001, 1/04/2005, 6/26/2008
4: 8/30/2002, 8/29/2005, 8/26/2008, 8/24/2011
5: 8/30/2002, 8/29/2005, 8/26/2008, 8/24/2011, 9/11/2014

Annex 3. Econometric model for BET index

BET index model linear trend model with L+1 vs. L globally determined breaks is the following:

Dependent Variable: BET
Method: Least Squares with Breaks
Sample (adjusted): 9/22/1997 9/07/2017
Included observations: 5209 after adjustments
Break type: Bai-Perron tests of L+1 vs. L globally determined breaks
Breaks: 8/30/2002, 8/29/2005, 8/26/2008, 8/24/2011, 9/11/2014
Selection: Sequential evaluation, Trimming 0.15, Sig. level 0.05
Allow heterogeneous error distributions across breaks

Variable	Coefficient	Std. Error	t-Statistic	Prob.
9/22/1997 - 8/29/2002 -- 1289 obs				
C	467.7283	11.49954	40.67366	0.0000
@TREND	0.262203	0.015461	16.95889	0.0000
8/30/2002 - 8/26/2005 -- 781 obs				
C	-6712.459	146.0438	-45.96197	0.0000
@TREND	5.790615	0.086209	67.16961	0.0000

Variable	Coefficient	Std. Error	t-Statistic	Prob.
8/29/2005 - 8/25/2008 -- 781 obs				
C	4518.696	457.0197	9.887311	0.0000
@TREND	1.384030	0.185005	7.481039	0.0000
8/26/2008 - 8/23/2011 -- 781 obs				
C	-8071.771	367.9643	-21.93629	0.0000
@TREND	3.896491	0.113260	34.40291	0.0000
8/24/2011 - 9/10/2014 -- 796 obs				
C	-7742.850	183.4362	-42.21004	0.0000
@TREND	3.284608	0.045449	72.26943	0.0000
9/11/2014 - 9/07/2017 -- 781 obs				
C	1546.556	402.1242	3.845966	0.0001
@TREND	1.175320	0.083372	14.09735	0.0000
R-squared	0.950806	Mean dependent var		4400.230
Adjusted R-squared	0.950702	S.D. dependent var		2810.879
S.E. of regression	624.1035	Akaike info criterion		15.71281
Sum squared resid	2.02E+09	Schwarz criterion		15.72792
Log likelihood	-40912.01	Hannan-Quinn criter.		15.71809
F-statistic	9131.481	Durbin-Watson stat		0.030721
Prob(F-statistic)	0.000000			