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How Are Structural Breaks Related to Stock Return Volatility Persistence? Evidence from China and Japan

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Abstract

This study empirically examines the effects of structural breaks on equity return volatility persistence by using Chinese and Japanese equity index return data. Applying standard GARCH models and two kinds of structural break dummy variables, we derive the following findings. First, we reveal that for both Chinese and Japanese equity index returns, the values of GARCH parameters of standard GARCH models decline when the first structural break dummies are incorporated. Second, our analyses further clarify that for both Chinese and Japanese equity index returns, the values of GARCH parameters of standard GARCH models again decline when different kinds of structural break dummies are incorporated.

Keywords

GARCH Model, Equity Return Volatility Persistence, Structural Break, Structural Break Dummies

1. Introduction

In economics and finance, structural breaks are recently being much important, while well-known volatility persistence of equity returns is also important in financial time-series modeling (e.g., Narayan *et al.* [1]; Chen *et al.* [2]; Chatzikonstanti and Venetis [3]; Tsuji [4] [5] [6]). In particular, what is the effect of equity returns' structural breaks on their volatility persistence? Moreover, how are equity returns' structural breaks related to their volatility persistence? In this paper, to answer these important research questions, we investigate the effects of equity return structural breaks on their volatility persistence by using Chinese and Japanese equity index return data. Incorporating two kinds of structural break dummies into the standard univariate GARCH models, this paper derives the following interesting findings. 1) First, this study reveals that for both Chinese and Japanese equity index returns, the values of GARCH parameters of standard GARCH models decline when the first structural break dummies are incorporated. 2) Second, our analyses further clarify that for both Chinese and Japanese equity index returns, the values of GARCH parameters of standard GARCH models again decline when different kinds of structural break dummies are incorporated.

As we document later, these interesting findings are very robust; and thus, the findings from our research are highly useful and valuable for economic and financial modeling of various kinds of time-series. Hence, our results derived in this paper make an important contribution to the research in the fields of economics and finance. Regarding the rest of this paper, Section 2 reviews recent related research; in Section 3, our data and variables are explained; and in Section 4, our methodology is documented. After that, Section 5 explains our main empirical results and finally, Section 6 concludes the paper.

2. Literature Review

This section reviews recent literature employing structural break analyses very concisely. First, Narayan *et al.* [1] tested structural breaks in the US, the UK, and Japanese equity prices, and they suggested that the structural breaks have slowed down the growth rates of the US, the UK, and Japanese equity markets. Chen *et al.* [2] examined the effect of structural breaks on the linkage of spot–futures oil prices, and they suggested that the structural breaks caused some effects on the issues of cointegrating relations, market efficiency, arbitrage, causalities, and oil futures volatility forecasting performance.

Using stock market data, Chatzikonstanti and Venetis [3] investigated whether the observed long memory characteristic of equity returns is spurious and whether it is explained by the presence of structural breaks; and they suggested that once the structural breaks are considered, the equity return volatility persistence was eliminated. Güloğlu *et al.* [7] examined the volatility spillovers among five Latin American equity markets, and they suggested that when the structural breaks of variances are taken into consideration, volatility spillover effects among the five equity markets were not strong.

Recently, Smith [8] estimated the US equity premium from economic fundamentals under structural breaks, and they found that the US equity premium fell from 8.16% in 1951 to 1.15% in 1985. Using the US equity market data, Hood and Malik [9] suggested that their out-of-sample tests incorporating both time-varying nature and structural breaks in volatility yielded more accurate Value-at-Risk forecasts than several alternative benchmark methods.

As the above brief literature review shows, recent studies advocated the importance of structural breaks. Hence, this study quantitatively examines Chinese and Japanese equity returns by taking structural breaks into account and employing two kinds of structural break dummy variables in the following sections.

3. Data and Variables

In this section, we explain our main variables. All data we use in this study are from Thomson Reuters. Our first variable is LRCHI, denoting daily log returns of the Shanghai A-share index in China; our second variable is LRTPX, denoting daily log returns of the Tokyo Stock Price Index (TOPIX) in Japan. Our sample period as to these two percentage log returns spans from January 4, 2000 to August 2, 2018.

Figure 1 plots the price evolution of the Shanghai A-share index and the TOPIX from January 3, 2000 to August 2, 2018. Further, Table 1 exhibits the summary statistics of the above Chinese and Japanese equity index returns. Table 1 indicates that for both returns, their mean values are almost zero, their values of skewness are negative, and their values of kurtosis are clearly higher than the value of three for normal distributions.

4. Methods

We next explain our methodology. In this study, we use the standard GARCH model and two kinds of structural break dummy variables. Namely, for Chinese and Japanese equity returns, we estimate the standard GARCH model without and with two kinds of dummy variables that capture structural breaks for each equity index return.

We construct two structural break dummies after detecting structural break points by ICSS algorithm. The identified break point numbers and time periods are exhibited in Table 2. As this table shows, for both LRCHI and LRTPX, there are 11 break points.

We first employ Ewing and Malik [10]-type structural break dummies and denote the structural break dummy variables for LRCHI as CDUM1 (k), and those for LRTPX as JDUM1 (j), where $k = 1, \ldots, 11$ and $j = 1, \ldots, 11$. For example, CDUM1 (1) takes one from the first structural break point (December 8, 2006) onwards and zero elsewhere; and JDUM1 (1) takes one from the first structural break point (November 29, 2002) onwards and zero elsewhere. Further, we denote our second structural break dummy variables for LRCHI as

Table 1. Summary statistics of Chinese and Japanese equity index returns: From January 4, 2000 to August 2, 2018.

	LRCHI	LRTPX
Mean	0.0143	0.0004
Max.	9.3998	12.8646
Min.	−9.2608	−10.0071
SD	1.5254	1.3392
Skewness	−0.3596	−0.3661
Excess kurtosis	5.4723	6.6833

Notes. SD denotes the standard deviation value. Max. and Min. denote maximum and minimum values, respectively.

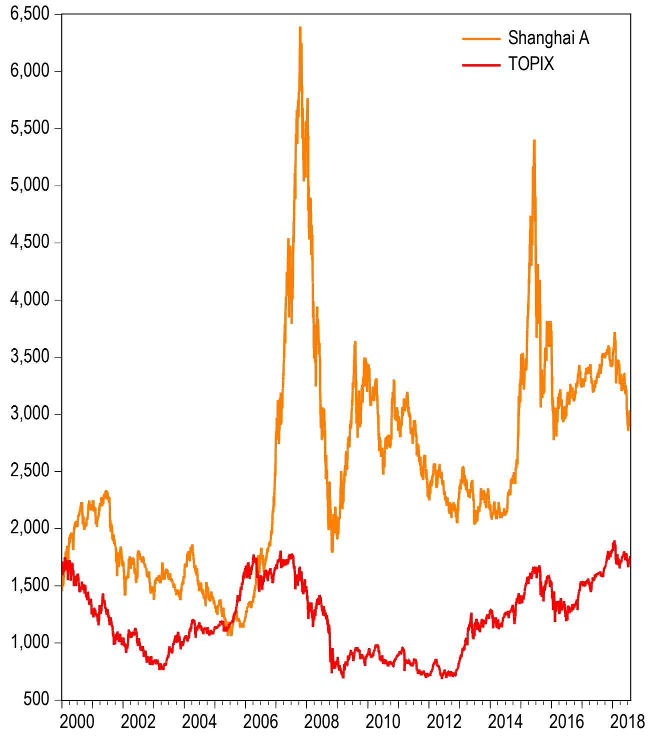

Figure 1. Price evolution of the Shanghai A-share index and the TOPIX.

Table 2. Structural breaks of Chinese and Japanese equity returns.

Series	Break points	Time periods
LRCHI	11	January 4, 2000 - December 7, 2006 December 8, 2006 - December 12, 2008 December 15, 2008 - November 17, 2010 November 18, 2010 - July 23, 2013 July 24, 2013 - November 20, 2014 November 21, 2014 - June 15, 2015 June 16, 2015 -August 28, 2015 August 31, 2015 - January 1, 2016 January 4, 2016 - March 2, 2016 March 3, 2016 - August 15, 2016 August 16, 2016 - January 26, 2018 January 29, 2018 - August 2, 2018
LRTPX	11	January 4, 2000 - November 28, 2002 November 29, 2002 - June 7, 2004 June 8, 2004 - September 19, 2005 September 20, 2005 - May 15, 2006 May 16, 2006 - July 28, 2006 July 31, 2006 - August 9, 2007 August 10, 2007 - September 15, 2008 September 16, 2008 - May 19, 2009 May 20, 2009 - March 14, 2014 March 17, 2014 - August 18, 2015 August 19, 2015 - July 12, 2016 July 13, 2016 - August 2, 2018

Notes. Break points and time periods are detected by ICSS algorithm. The sample period is from January 4, 2000 to August 2, 2018.

CDUM2 (m), and those for LRTPX as JDUM2 (n), where $m = 1, \ldots, 11$ and $n = 1, \ldots, 11$. Specifically, CDUM2 (1) takes one for January 4, 2000 to December 7, 2006, and zero elsewhere; while JDUM2 (1) takes one for January 4, 2000 to November 28, 2002, and zero elsewhere.

5. Results

This section documents the main points of our empirical results. First, Table 3 displays the estimation results of standard GARCH models with no structural break dummy for Chinese and Japanese equity index returns. As Panel A of Table 3 indicates, for LRCHI, it is noted that the GARCH parameter takes a high value of 0.9384, and as Panel B of Table 3 indicates, for LRTPX, we also note that the GARCH parameter takes a high value of 0.8773.

Next, Table 4 displays the estimation results of standard GARCH models with Ewing and Malik [10]-type structural break dummies for Chinese and Japanese equity returns. As Panel A of Table 4 indicates, for LRCHI, the GARCH parameter takes 0.8538, and this value is rather lower than 0.9384, where structural breaks are ignored. In addition, as Panel B of Table 4 indicates, for LRTPX, the GARCH parameter takes 0.8072, and this value is clearly lower than 0.8773, where structural breaks are ignored.

Furthermore, Table 5 displays the estimation results of standard GARCH models with different structural break dummies for Chinese and Japanese equity returns. As Panel A of Table 5 indicates, for LRCHI, the GARCH parameter takes 0.8538, and this value is again rather lower than 0.9384, where structural breaks are ignored. In addition, as Panel B of Table 5 indicates, for LRTPX, the GARCH parameter takes 0.8072, and this value is again clearly lower than 0.8773, where structural breaks are ignored.

Table 3. Estimation results of GARCH models with no structural break dummy. (a) Panel A. China; (b) Panel B. Japan.

(a)

Variable	Coefficient	Standard error	*t*-statistic	*p*-value
Mean (LRCHI)	0.0210	0.0158	1.3284	0.1840
C	0.0104**	0.0046	2.2790	0.0227
A	0.0595***	0.0092	6.4950	0.0000
G	0.9384***	0.0096	97.4830	0.0000
Log likelihood		−8198.1810		

(b)

Variable	Coefficient	Standard error	*t*-statistic	*p*-value
Mean (LRTPX)	0.0491**	0.0209	2.3536	0.0186
C	0.0351***	0.0100	3.5235	0.0004
A	0.1058***	0.0148	7.1504	0.0000
G	0.8773***	0.0165	53.0645	0.0000
Log likelihood		−7686.0914		

Notes. In this table, C: constant term; A: ARCH parameter; G: GARCH parameter. *** and ** indicate the statistical significance of the estimates at the 1% and 5% levels, respectively.

Table 4. Estimation results of GARCH models with the first structural break dummies. (a) Panel A. China; (b) Panel B. Japan.

(a)

Variable	Coefficient	Standard error	*t*-statistic	*p*-value
Mean (LRCHI)	0.0283*	0.0171	1.6566	0.0976
C	0.1329	0.1272	1.0453	0.2959
A	0.0572*	0.0301	1.9047	0.0568
G	0.8538***	0.1063	8.0295	0.0000
CDUM1 (1)	0.4525	0.4228	1.0702	0.2846
CDUM1 (2)	−0.3558	0.3222	−1.1044	0.2694
CDUM1 (3)	−0.1074	0.1283	−0.8368	0.4027
CDUM1 (4)	−0.0479	0.0515	−0.9312	0.3518
CDUM1 (5)	0.3046	0.2831	1.0759	0.2820
CDUM1 (6)	1.1760	1.2707	0.9255	0.3547
CDUM1 (7)	−1.2315	1.3282	−0.9272	0.3538
CDUM1 (8)	0.3847	0.9038	0.4257	0.6703
CDUM1 (9)	−0.6041	0.9699	−0.6228	0.5334
CDUM1 (10)	−0.0733	0.0974	−0.7526	0.4517
CDUM1 (11)	0.1157	0.1253	0.9235	0.3558
Log likelihood		−8124.0989		

(b)

Variable	Coefficient	Standard error	*t*-statistic	*p*-value
Mean (LRTPX)	0.0516***	0.0188	2.7410	0.0061
C	0.1995***	0.0599	3.3282	0.0009
A	0.0978***	0.0154	6.3586	0.0000
G	0.8072***	0.0337	23.9579	0.0000
JDUM1 (1)	−0.0468	0.0421	−1.1115	0.2663
JDUM1 (2)	−0.1015**	0.0422	−2.4038	0.0162
JDUM1 (3)	0.0847**	0.0407	2.0818	0.0374
JDUM1 (4)	0.1451	0.1015	1.4290	0.1530
JDUM1 (5)	−0.1893*	0.1014	−1.8671	0.0619
JDUM1 (6)	0.2095***	0.0781	2.6832	0.0073
JDUM1 (7)	0.1994	0.1519	1.3129	0.1892
JDUM1 (8)	−0.3603**	0.1684	−2.1395	0.0324
JDUM1 (9)	−0.0547**	0.0263	−2.0789	0.0376
JDUM1 (10)	0.2193*	0.1124	1.9507	0.0511
JDUM1 (11)	−0.2383**	0.1144	−2.0830	0.0373
Log likelihood		−7631.5586		

Notes. In this table, C: constant term; A: ARCH parameter; G: GARCH parameter. ***, **, and * indicate the statistical significance of the estimates at the 1%, 5%, and 10% levels, respectively.

As above, regarding our main concern of this study: the changes in the values of volatility persistence parameters of GARCH models, they always decrease when we take structural breaks into consideration. These results can be found for both Chinese and Japanese equity index returns regardless of types of dummy variables; thus, we emphasize that the above results are highly robust. Hence, from our results, we understand that when structural breaks are ignored, volatility persistence of international equity returns may be overestimated in, at least, univariate GARCH models.

Table 5. Estimation results of GARCH models with the second structural break dummies. (a) Panel A. China; (b) Panel B. Japan.

(a)

Variable	Coefficient	Standard error	*t*-statistic	*p*-value
Mean (LRCHI)	0.0283	0.0193	1.4661	0.1426
C	0.1465	0.1277	1.1472	0.2513
A	0.0572*	0.0331	1.7272	0.0841
G	0.8538***	0.1150	7.4266	0.0000
CDUM2 (1)	−0.0136	0.0577	−0.2357	0.8137
CDUM2 (2)	0.4389	0.4915	0.8930	0.3719
CDUM2 (3)	0.0830	0.1442	0.5757	0.5648
CDUM2 (4)	−0.0243	0.0583	−0.4179	0.6760
CDUM2 (5)	−0.0723	0.0650	−1.1119	0.2662
CDUM2 (6)	0.2324	0.2299	1.0106	0.3122
CDUM2 (7)	1.4085	1.4299	0.9850	0.3246
CDUM2 (8)	0.1769	0.1936	0.9134	0.3610
CDUM2 (9)	0.5617	0.9883	0.5683	0.5698
CDUM2 (10)	−0.0425	0.0624	−0.6802	0.4964
CDUM2 (11)	−0.1157	0.1016	−1.1390	0.2547
Log likelihood		−8124.0989		

(b)

Variable	Coefficient	Standard error	*t*-statistic	*p*-value
Mean (LRTPX)	0.0516***	0.0177	2.9218	0.0035
C	0.0666***	0.0212	3.1407	0.0017
A	0.0978***	0.0159	6.1298	0.0000
G	0.8072***	0.0346	23.3567	0.0000
JDUM2 (1)	0.1329***	0.0403	3.3001	0.0010
JDUM2 (2)	0.0861*	0.0468	1.8394	0.0659
JDUM2 (3)	−0.0154	0.0179	−0.8629	0.3882
JDUM2 (4)	0.0693*	0.0358	1.9339	0.0531
JDUM2 (5)	0.2143	0.1319	1.6251	0.1041
JDUM2 (6)	0.0251	0.0255	0.9828	0.3257
JDUM2 (7)	0.2346***	0.0902	2.6020	0.0093
JDUM2 (8)	0.4340**	0.1810	2.3975	0.0165
JDUM2 (9)	0.0737***	0.0250	2.9492	0.0032
JDUM2 (10)	0.0190	0.0211	0.9011	0.3675
JDUM2 (11)	0.2383**	0.1172	2.0335	0.0420
Log likelihood		−7631.5586		

Notes. In this table, C: constant term; A: ARCH parameter; G: GARCH parameter. ***, **, and * indicate the statistical significance of the estimates at the 1%, 5%, and 10% levels, respectively.

6. Conclusions

This study empirically examined the effects of structural breaks on equity return volatility persistence by using Chinese and Japanese equity index return data. Using standard GARCH models and two kinds of structural break dummy variables, we derived the following findings. First, this study found that for both Chinese and Japanese equity index returns, the values of GARCH parameters of standard GARCH models declined when Ewing and Malik [10]-type structural break dummies are incorporated. Second, our analyses further clarified that for both Chinese and Japanese equity index returns, the values of GARCH parameters of standard GARCH models again declined when different kinds of structural break dummies are incorporated.

As above, all our results demonstrated that when structural breaks are ignored, the volatility persistence of international equity returns may be overestimated at least in univariate GARCH models. We note that GARCH models are also important in economics and finance (e.g., Tsuji [11] [12] [13] [14] [15]); and we consider that the findings from our study are highly valuable for modeling of various kinds of economic and financial time-series since many economic and financial time-series have structural breaks. However, it is also noted that the structural break dummies we used in this study might be somewhat difficult to incorporate into multivariate models directly. Thus, we should recognize the importance of developing suitable and reasonable structural break modeling for multivariate economic and financial time-series, and it is one of our important future works.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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