

# Modeling the volatility of daily listed real estate returns during economic crises: Evidence from Generalized Autoregressive Conditional Heteroscedasticity models Appendix

**Table S1.** Parameter estimation comparisons on the subset covering 90% of the full sample, ARMA(2, 0)-GARCH-type models.

(a) Original GARCH models

	GARCH (1,1)	EGARCH (1,1)	GJRGARCH (1,1)	APARCH (1,1)	FIGARCH (2,1)	IGARCH (1,2)
<b><u>Mean Equation</u></b>						
$\hat{\mu}$	0.001 (0.000)	0.001 (0.000)	0.001 (0.000)	0.001 (0.000)	0.001 (0.000)	0.001 (0.000)
$\hat{\theta}_1$	0.053 (0.022)	0.063 (0.012)	0.060 (0.015)	0.064 (0.015)	0.055 (0.014)	0.053 (0.015)
$\hat{\theta}_2$	0.025 (0.019)	0.034 (0.012)	0.032 (0.016)	0.036 (0.018)	0.026 (0.015)	0.026 (0.016)
$\hat{\tau}$	-	-	-	-	-	-
<b><u>Variance Equation</u></b>						
$\hat{\omega}$	-	-0.191 (0.006)	-	-	-	-
$\hat{\alpha}$	0.103 (0.275)	-0.062 (0.012)	0.054 (0.013)	0.094 (0.012)	0.315/ 0.085 (0.085) (0.037)	0.119 (0.044)
$\hat{\beta}$	0.883 (0.293)	0.979 (0.001)	0.876 (0.033)	0.903 (0.014)	0.640 (0.080)	0.830/0.359 (0.051)/(NA)
$\hat{\gamma}$	-	0.179 (0.017)	0.094 (0.041)	0.396 (0.072)	-	-
$\hat{\delta}$	-	-	-	1.066 (0.164)	0.436 (0.064)	-

(b) Modified GARCH-m models

	GARCH (1,1)-m	EGARCH (1,1)-m	GJRGARCH (1,1)-m	APARCH (1,1)-m	FIGARCH (2,1)-m	IGARCH (1,2)-m
<b><u>Mean Equation</u></b>						
$\hat{\mu}$	0.001 (0.001)	0.001 (0.000)	0.001 (0.000)	0.001 (0.000)	0.001 (0.000)	0.001 (0.000)
$\hat{\theta}_1$	0.053 (0.022)	0.060 (0.014)	0.060 (0.015)	0.062 (0.012)	0.055 (0.014)	0.053 (0.015)
$\hat{\theta}_2$	0.025 (0.019)	0.032 (0.015)	0.031 (0.016)	0.034 (0.013)	0.025 (0.015)	0.026 (0.017)
$\hat{\tau}$	-0.004 (0.120)	-0.062 (0.030)	-0.029 (0.052)	-0.053 (0.010)	-0.012 (0.048)	-0.015 (0.045)
<b><u>Variance Equation</u></b>						

$\hat{\omega}$	-	-0.173 (0.011)	-	-	-	-
$\hat{\alpha}$	0.103 (0.299)	-0.063 (0.012)	0.054 (0.015)	0.098 (0.011)	0.316/0.086 (0.085)/(0.037)	0.118 (0.044)
$\hat{\beta}$	0.883 (0.318)	0.981 (0.001)	0.877 (0.038)	0.91 (0.013)	0.642 (0.079)	0.830/0.051 (0.358)/(NA)
$\hat{\gamma}$	-	0.178 (0.021)	0.095 (0.042)	0.403 (0.070)	-	-
$\hat{\delta}$	-	-	-	1.048 (0.145)	0.437 (0.064)	-

Notes: 1. Based on the daily sector return series for the period from January 2003 to August 2019.

2. Bollerslev–Wooldridge robust standard errors are presented in parentheses.

3. Equations (1), (2), and (3) are applied.

**Table S2.** Parameter estimation comparisons of five subsample periods: pre-GFC, GFC, EDC, post-EDC, and COVID-19.

Pre-GFC			GFC			EDC		Post-EDC		COVID-19	
Parameters	GARCH	GARCH-M	GARCH-M	MAPARCH	MIGARCH	GARCH	GJR-GARCH	GARCH	GJR-GARCH	GARCH	GARCH
<b><u>Mean Equation</u></b>											
$\hat{\mu}$	0.001 (0.000)	0.001 (0.000)	-0.006 (0.003)	-0.007 (0.001)	-0.006 (0.002)	0.001 (0.000)	0.000 (0.001)	0.001 (0.000)	0.001 (0.001)	0.001 (0.001)	0.001 (0.000)
$\hat{\theta}_1$	0.956 (0.037)	0.954 (0.053)	0.046 (0.046)	0.055 (0.166)	0.046 (0.047)	-0.580 (0.149)	-0.489 (0.105)	0.054 (0.024)	0.065 (0.023)	0.26 (0.071)	0.358 (0.025)
$\hat{\phi}_1$	-0.942 (0.042)	-0.939 (0.063)	-	-	-	0.669 (0.148)	0.597 (0.105)	-	-	-0.21 (0.21)	-0.277 (0.031)
$\hat{\phi}_2$	-	-	-	-	-	0.108 (0.044)	0.114 (0.0373)	-	-	-	-
$\hat{\tau}$	-	-	0.276 (0.161)	0.281 (0.053)	0.246 (0.122)	-	-	-	-	-	-
<b><u>Variance Equation</u></b>											
$\hat{\alpha}$	0.094 (0.016)	0.153 (0.046)	0.133 (0.020)	0.074 (0.170)	0.146 (0.038)	0.099 (0.080)	0.006 (0.029)	0.110 (0.010)	0.018 (0.008)	0.166 (0.060)	-0.118 (0.048)
$\hat{\beta}$	0.842 (0.026)	0.847 (NA)	0.844 (0.029)	0.921 (0.117)	0.856 (NA)	0.881 (0.104)	0.906 (0.017)	0.826 (0.014)	0.820 (0.029)	0.790 (0.0449)	0.963 (0.011)
$\hat{\gamma}$	-	-	-	0.579 (1.531)	-	-	0.135 (0.0425)	-	0.158 (0.029)	-	0.206 (0.139)
$\hat{\delta}$	-	-	-	1.031 (0.422)	-	-	-	-	-	-	-

Notes: For the pre-crisis period, mean equation order ARMA (1, 1) and SSTD distribution are applied; GFC period applied ARMA (1, 0) and GED; EDC period used ARMA (1, 2) and SGED; post-EDC period used ARMA(1,0) and NIG; COVID-19 period used ARMA (1, 1) and NIG according to Table 2 and Table 3.