Extreme value analysis of Taiwan stock market

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Abstract

The modern extreme value theory focuses on the analysis of exceedances over some high thresholds where exceedance times and the excesses are modeled simultaneously. In this paper, we employ this new extreme value theory approach to analyze Taiwan Stock Exchange Weighted Index and the return series of Taiwan Semiconductor Manufacturing stock. We identify variables that can explain the extreme movements as described by parameters of the intensity function. In particular, we examine the impact of U.S. Stock Markets on the extreme value of Taiwan Stock Market.

The empirical analysis confirms the effect of extreme values of U.S. market on Taiwan market. There are extreme-value spillover effect from the U.S. market to Taiwan market, especially from the high-tech dominated NASDAQ market. Domestic explanatory variables such as duration from the prior extreme events, time trend, volatility indicator, and trading behavior of the previous trading day all have some effects on the intensity of exceedance for the positive returns. The effect on the negative returns does not show any clear pattern.

1 Introduction

Extreme quantiles assess the probability of occurrence for a very large or small value and these tail quantiles are essential component of risk management. Conventional extreme value analysis focus on the asymptotic behavior of maximum (or minimum) value of an independent and identically distributed random variables: $X_{(n)} = max\{X_1, \cdots, X_n\}$ (or $x_{(n)} = min\{X_1, \cdots, X_n\}$) , where $X_1, \cdots, X_n$ are the iid variables under investigation. The limiting distribution of the properly normalized statistics is found to be of three types which can be combined into a single Generalized Extreme Value distribution

$$H(x; \mu, \sigma, k) = exp[-(1 - k(x - \mu)/\sigma)^{1/k}],$$

where $x > 1 - k(x - \mu)/\sigma > 0$, μ, σ and k are respectively location, scale, and shape parameter.

While the maximal or minimal value are important quantities, other *large (small)* observations are more important as they occur more frequently and also have huge impact on the risk management. Modern extreme value theory focus on analysis of exceedances over some high thresholds. Exceedance times and the excesses are modeled simultaneously. See Davidson and Smith (1990) the reference therein.

This paper employs the new extreme value model to analyze Taiwan stock market. We focus on analysis of variables which can explain the parameters of intensity function. In particular, we examine the impact of US stock market on Taiwan extreme value. We also use the concepts of cluster to correct the serial dependence among consecutive returns.

The empirical analysis found that duration, trend, volatility indicator, and trading behavior of previous day have effects on the intensity of exceedance.

The rest of the paper is organized as below. A brief review of more extreme value theory is provided in Section 2. Section 3 contains description of data used and empirical results. A simple conclusion is put in Section 4.

2 Models, Estimation and Diagnostically Checking

In this section, we briefly introduce the model setup, estimation method, and model checking for the threshold exceedance modeling approach. For more details, see Tsay (2001), or Smith (1989). This new approach focus on exceedances of the variable over some pre-specified threshold and when it exceeds. Let η be the given threshold and r_t be the return at time t. Suppose on $t_i, i = 1, \cdots, N, r_{t_i} < \eta$. This new approach focus on modeling $(t_i, r_{t_i} - \eta)$.

$$Pr(r \leq x + \eta | r > \eta) = \frac{Pr(r \leq x + \eta) - Pr(r \leq \eta)}{1 - Pr(r \leq \eta)} \sim 1 - [1 - \frac{kx}{\alpha - k(\eta - \beta)}]^{1/k} \quad (1)$$

where $x > 0$ and $1 - k(\eta - \beta)/\alpha > 0$ The proposed models are two dimensional homogeneous Poisson and inhomogeneous Poisson process. The former model is:

$$\Delta[(0, T)x(y, \infty)] = (1 - k_t \frac{y_t - \mu_t}{\sigma_t})_+^{1/k_t}, \quad y > r$$

$$k_t = \beta_1' x_t, ln(\sigma_t) = \beta_2' x_t, \mu_t = \beta_3' x_t$$

where x_+ denotes $max(x, 0)$. The model reduces to two-dimensional homogeneous Poisson process when $\mu_t = \mu, \sigma_t = \sigma, k_t = k, t = 1, \cdots, T$.

The corresponding likelihood function becomes:

$$L = (\Pi_{i=1}^{N_\eta} \frac{1}{T} g(r_{t_i}; k_t, \sigma_t, \mu_t)) \times exp[-\frac{1}{T} \sum_{t=1}^{N} S(\eta; k_t, \sigma_t, \mu_t) dt]$$

where

$$g(z; k, \alpha, \beta) = \begin{cases} \frac{1}{\alpha}[1 - \frac{k(z-\beta)}{\alpha}]^{1/k-1} & \text{for } k \neq 0 \\ \frac{1}{\alpha} exp[-\frac{(z-\beta)}{\alpha}] & \text{for } k = 0 \end{cases}$$

$$S(r; k, \alpha, \beta) = [1 - \frac{k(r - \beta)}{\alpha}]_+^{1/k}$$

To verify the adequacy of the proposed model, three key assumptions have to be checked. Firstly, duration between two consecutive events are independently and exponentially distributed. QQ-plot of the test statistics

$$z_{t_i} = \sum_{t=t_{i-1}+1}^{t_i} S(\eta; k_t, \alpha_t, \beta_t)$$

could be checked against the straight line 1 through the origin with slope one. Secondly, the distribution of the excess, $r_t - \eta$, over the threshold follows a generalized Pareto distribution and appropriate QQ-plot of the test statistics is:

$$w_{t_i} = \begin{cases} \frac{-1}{k_{t_i}} \ln(1 - k_{t_i} \frac{r_{t_i} - \eta}{\phi_{t_i}})_+ & \text{if } k_{t_i} \neq 0 \\ \frac{r_{t_i} - \eta}{\phi_{t_i}} & \text{if } k_{t_i} = 0 \end{cases}$$

Lastly, sample autocorrelation of z_{t_i}, w_{t_i} could be used to check the independence assumption.

3 Data

We employ the models above to analyze Taiwan Stock Exchange Weighted Index (TAIEX) and Taiwan Semiconductor Manufacturing (TSM). The American Deposit Receipt (ADR) of TSM is traded in NYSE and prices in both market are supposed to be closely related. NYSE seems to have a stronger effect on Taiwan stock market recently. We would like to examine the spillover effects by including NASDAQ and TSM-ADR as exogenous variables for TAIEX and TSM respectively.

In Taiwan stock market, there is a price limit each stock. Price of each stock is only allowed to fluctuate within the band of 7% higher and lower than the closing price of previous trading day. See Cho, Russell, Tiao and Tsay (2002) for an analysis of the effect of these price limits.

All Taiwan stock data are daily closing price taken from the Taiwan Stock Exchange Corporation. The sample period is (1990/1/4 ~ 2001/12/14) for TAIEX and (1994/9/17 ~ 2001/12/14) for TSM respectively. It is worth noting that TSM was initially offered to the market on September 5, 1994. For the first nine trading days, TSM opened at price ceiling and stay there until when the market closed. To avoid the possible biases, we remove the first 10 returns from the sample. The corresponding sample size are 3327 and 1983 for TAIEX and TSM respectively. NASDAQ and TSM-ADR are daily closing price taken from yahoo. The sample period for NASDAQ is (1990/1/4 ~ 2001/12/14) the same as TAIEX while TSM-ADR is (1997/10/9 ~ 2001/12/14) the earliest possible. In the study of the effect from US market to Taiwan market, price at time t in Taiwan is matched against time $t-1$. Sample size for the matched samples are 2835 and 956.

In the empirical analysis, return r_t is defined as

$$r_t = \frac{P_t - P_{t-1}}{P_{t-1}} * 100.0$$

For both TSM and TSM-ADR, dividend adjusted prices are used to compute returns. The descriptive statistics for four series are put in Table (1).

Table 1: Descriptive Statistics for four returns

Stock	TSM	TSM-ADR	TAIEX	NASDAQ
Total Obs	1983	955	3327	2835
Obs > 0.0	861	434	1643	1574
Obs < 0.0	890	489	1684	1258
Obs = 0.0	232	32	0	3
Mean	0.145743	0.177644	0.001241	0.064131
Median	0.000000	-0.233630	-0.020280	0.129180
Maximum	6.993010	26.24614	6.798070	14.17320
Minimum	-6.986900	-23.87944	-6.802250	-9.668510
Std. Dev.	2.696118	4.811875	1.939517	1.625186
Skewness	0.0259194	0.609331	-0.073109	0.155976
Kurtosis	3.488337	5.969174	5.012922	10.71560

With the only exception of NASDAQ, there are more negative returns than positive returns. As is clear from Table (1), there are 11.7% (232) zero returns which is much larger than 3.4% (32) zero returns for TSM-ADR. This can be explained by the discreteness of price in Taiwan stock market. Over the whole sample period, the price of TSM mostly fell within the range between 50NT$ and 500NT$, and the tic-size was 0.5NT$. With such a large tic-size, the chance for TSM price to remain unchanged is much bigger than TSM-ADR with small tic-size and TAIEX and NASDAQ which latter are indexes. In addition, the range, standard deviation, and kurtosis of TSM are all smaller than those of TSM-ADR that seems to suggest that price ceiling and floor might help to stabilize the market though the two sample periods are not the same. The time series plots are put in Figures (1).

Five domestic explanatory variables are: (1) duration from previous exceedance defined as number of trading days, inclusive, from the previous exceedance of the series under study; (2) yearly trend defined as year - t_0 +1 where t_0 denotes the year that data begins; (3) fourth quarter indicator defined as 1 provided the day belong to 4-th quarter and 0 otherwise; (4) indicator for behavior of the previous trading day defined as defined as 1 if the return exceeds threshold at time $t - 1$ but in opposite direction and 0 otherwise; and (5) volatility indicator defined as number of days during previous 5 trading days with the absolute return exceeding the threshold. It is worth mentioning that we have once attempted to fit an GARCH models to TSM and TAIEX returns and then used conditional variance as a proxy of volatility. The experiment failed. Surprisingly, we found out that the kurtosis of the standardized residual of the MA(1)-GARCH(1,1) (=4.2448) is higher than that of original returns for TSM (=3.635094) and only marginally smaller for TAIEX. For the case of TSM, the abnormality can be explained by the price discreteness. See Lin, Chang and Lei (2002) for similar findings. The foreign explanatory variables are indicator variables for TSM-ADR and NASDAQ defined as 1 if it exceeds 2.0 and 0 otherwise. We have tried other threshold levels but found similar results.

Exponential distribution of duration between exceedance, generalized Pareto distribution of excess, and independence of these two are three fundamental assumptions behind extreme value analysis. See Smith and Shively (1995) and Tsay (2001) for details.

4 Empirical Results

In this section, analyze the empirical results of the extreme value analysis of Taiwan stock returns. Three threshold levels, 2.0, 2.5 and 3 are analyzed since smaller thresholds might not display the '*tail* behavior and larger thresholds results leave too few observations.

4.1 Homogeneous models

Considering that a single event might cause exceedance of threshold for several consecutive days and violate the assumption of independence, we further analyze the data with cluster. Exceedances over a given threshold in consecutive days belong to the same cluster and cluster maximum or minimum is used for statistical analysis.

Estimation results for TSM with homogeneity is reported in Table (2). From the table, we make the following observations: (1) estimation results with and without cluster give similar estimation results. Thus, we shall focus on the case without cluster in the sequel. (2) there are more exceedances at positive returns than negative returns at all three thresholds. This is consistent with the fact that the mean of the returns over the whole sample period is significantly positive with t-value being 2.40. (3) parameter estimates are stable across different threshold levels, which suggests stability of the model. (4) shape parameter are all significantly negative implying that Pareto distribution fits Taiwanese stock data well. (5) there exist asymmetry between positive returns and negative ones as the corresponding parameter estimates differ from each other.

The diagnostic checking statistics for three fundamental assumptions for both positive and negative returns with threshold being 2 are plot in Figure (2, 4). From the figures, we observe significant lag 1 or 2 autocorrelation for z_t and the QQ-Plots for w_z, z_t are all far off straight line. Using clustered data does not solve the problem as is seen in Figures (3, 5). Similar results are obtained for different threshold levels. See Tsay (2001) for similar findings. This justifies introducing explanatory variables into the models, which we shall next turn to.

4.2 Inhomogeneous models

As stated in Section 3, matching TSM with TSM-ADR would cut the sample from 1983 to 955. To make full use of all available data, we estimate two cases, one with domestic explanatory variables for full sample and the other with TSM-ADR for matched sample. Different sample periods might make direct comparison difficult but almost half sample observations would be lost otherwise.

We first estimate the model with all explanatory variables, remove insignificant variables and then re-estimate the model. The estimation results are summarized in Table (**??**) from which, we make following observations First, constant terms for all three equations are significantly, as they should be. Second, while all variables have some explanatory power for σ_t, and k_t for positive returns with threshold level, 2 and 2.5, they are all insignificant for threshold level 3. As for negative returns, they are all insignificant except for μ_t at threshold level 2.5. The QQ-plots and ACF plots as in Figures **??** show no significant improvements to confirm the results.

We proceed the analysis by introducing TSM-ADR into the model. As the TSM-ADR serves an alternative piece of information competing with information contained in past domestic market returns, and also because the sample period is shorter than before, we fix the model by including both Days and TSM-ADR variables even when some of them are insignificant. Other explanatory variables are left out since they are almost always insignificant. The estimation results are reported in Table (4. Several findings can be found from the table. First, the estimates remains stable across different threshold levels. Second, TSM-ADR are all significant for both positive and negative results with all three threshold levels. Third, Days variable has no effect on σ_t, k_t and some effect on μ_t. The QQ- and ACF-Plots in Figures (8, 9) show significant improvements.

To conclude the analysis on TSM returns, the empirical results show significant effects of TSM-ADR on TSM. That is, the sharp rise or fall in TSM-ADR in previous day could stimulate TSM to rise or fall sharply. As for domestic explanatory variables, duration from previous exceedance, yearly trend, 4-th quarter indicator, indicator in previous trading day and volatility indicator might have effect on extreme values of positive return though without a clear pattern, they have virtually no effect on extreme value of negative returns.

Table 2: Estimation Results for TSM Returns: Homogeneous Model

	positive return					negative				
r	times	k	ln(σ)	u	Ψ	times	k	ln(σ)	u	Ψ
without cluster										
2	415	-0.9825	-2.3312	6.8944	4.9058	357	-0.2569	-0.2820	6.9405	2.0236
stdv		0.0536	-.1675	0.0210			0.0662	0.1840	0.2480	
2.5	333	-1.3410	-2.9268	6.9531	6.0249	263	-0.3621	-0.5034	6.8359	2.1746
stdv		1.0154	2.2108	2.4622			0.0909	0.2255	0.2074	
3	263	-1.1611	-2.5407	6.9251		200	-0.5365	-0.8643	6.7340	
stdv		0.0118	0.0116	0.0036			0.1447	0.3233	0.1368	
with cluster										
2	314	-1.0233	-2.0633	6.8689	5.1094	269	-0.4353	-0.5874	6.7316	2.6155
std		0.0138	0.0260	0.0334			0.0847	0.2101	0.1788	
2.5	259	-1.1149	-2.2742	6.9007	5.0091	209	-0.5905	-0.8973	6.6713	2.8706
stdv		0.0137	0.0230	0.0277			0.1184	2.2676	0.1188	
3	214	-1.0745	-2.1178	6.8810		164	-0.6543	-0.9700	6.7037	
stdv		0.0230	0.0265	0.0270			0.0385	0.0621	0.0989	

Table 3: Estimation Results for TSM Returns with Domestic Explanatory Variables

threshold	times	par	constant	duration	trend	4-th Q	Oppo	Days
			positive return					
2	415	μ_t	6.9470					
		stdv	0.0452					
		$\ln(\sigma)$	0.5894		-0.0538	1.2123	-0.6945	-0.6485
		stdv	0.0296		0.0054	0.0717	0.0491	0.0277
		k_t	0.0624	-0.0487		0.3097	-0.2374	-0.2498
		stdv	0.0200	0.0013		0.0344	0.0274	0.0084
2.5	333	μ_t	6.9065					
		stdv	0.0817					
		$\ln(\sigma)$	-1.0865	0.0331	-0.1929		0.9310	
		stdv	0.0893	0.0038	0.0286		0.1801	
		k_t	-0.4745		-0.0645		0.3200	-0.0333
		stdv	0.0165		0.0099		0.0912	0.0143
3	254	μ_t	6.897102					
		stdv	0.031374					
		$\ln(\sigma)$	-2.303656					
		stdv	0.015725					
		k_t	-1.041551					
		stdv	0.025213					
			negative return					
2	357	μ_t	6.9405					
		stdv	0.2480					
		$\ln(\sigma)$	-0.28820					
		stdv	0.1840					
		k_t	-0.2569					
		stdv	0.0662					
2.5	263	μ_t	5.8215		0.2217			
		stdv	0.3221		0.0576			
		$\ln(\sigma)$	-0.3628					
		stdv	0.1949					
		k_t	-0.3026					
		stdv	0.0767					
3	200	μ_t	6.736145					
		stdv	0.137079					
		$\ln(\sigma)$	-0.86775					
		stdv	0.324052					
		k_t	-0.536583					
		stdv	0.144679					

Table 4: Estimation Results for TSM returns with Domestic Explanatory Variables and TSM-ADR

threshold	times	par	constant	duration	trend	4-th Q	Oppo	Days	ADR-2
positive return									
2	229	μ_t	5.933731					0.75894	3.079983
		stdv	0.622182					0.251885	0.729877
		$\ln(\sigma)$	-0.312888					0.059666	0.107437
		stdv	0.189447					0.037504	0.108729
		k_t	-0.276703						
		stdv	0.057488						
2.5	184	μ_t	5.876119					0.941319	2.699249
		stdv	0.463521					0.211324	0.652492
		$\ln(\sigma)$	-0.463329					0.058976	0.002534
		stdv	0.189805					0.036907	0.117249
		k_t	-0.363638						
		stdv	0.064075						
3	150	μ_t	6.320513					1.082989	2.372857
		stdv	0.429221					0.254894	0.724005
		$\ln(\sigma)$	-0.325730					0.065711	0.091990
		stdv	0.182515					0.044209	0.138035
		k_t	-0.351940						
		stdv	0.065659						
negative return									
2	221	μ_t	8.470467					0.097643	1.540140
		stdv	0.690560					0.096679	0.296339
		$\ln(\sigma)$	0.538808						
		stdv	0.182984						
		k_t	-0.022470						
		stdv	0.055057						
2.5	164	μ_t	8.549176					0.08547	1.682538
		stdv	0.693315					0.119115	0.359415
		$\ln(\sigma)$	0.543721						
		stdv	0.190416						
		k_t	-0.029737						
		stdv	0.062333						
3	130	μ_t	8.507719					0.150162	1.498977
		stdv	0.725983					0.132024	0.382280
		$\ln(\sigma)$	0.570607						
		stdv	0.208693						
		k_t	-0.005965						
		stdv	0.073491						

Table 5: Estimation Results for TAIEX Returns: Homogeneous Model

	positive return					negative				
r	times	k	ln(σ)	u	Ψ	times	k	ln(σ)	u	Ψ
without cluster										
2	376	-0.2040	-0.1451	6.2103	1.7240	365	-0.2334	-0.1475	6.3845	1.8862
stdv		0.0631	0.1492	0.2057			0.0776	0.1805	0.2173	
2.5	264	-0.3327	-0.3490	6.1835	1.9308	254	-0.5700	-0.7380	6.2675	2.6256
stdv		0.0754	0.1485	0.1545			0.0881	0.1695	0.0978	
3	196	-0.41756	-0.465141	6.196538	1.9628	187	-0.787594	-1.00871	6.365034	3.0150
stdv		0.096286	0.161383	0.133944			0.0075533	0.131075	0.079379	
with cluster										
2	312	-0.2197	-0.1228	6.0949	1.7841	292	-0.2946	-0.1841	6.2714	2.0901
std		0.0708	0.1549	0.2097			0.0912	0.1915	0.2030	
2.5	218	-0.3943	-0.3726	6.0969	2.1071	205	-0.6911	-0.8017	6.2651	3.0506
stdv		0.0819	0.1450	0.1468			0.0911	0.1588	0.0928	
3	164	-0.494524	-0.490125	6.134234	2.162504	156	-0.859466	-0.96228	6.368604	3.2772
stdv		0.104109	0.156849	0.131479			0.082956	0.134059	0.806186	

Table 6: Estimation Results for TAIEX with Domestic Explanatory Variables

threshold	times	par	constant	duration	trend	4-th Q	Oppo	Days
positive return								
2	376	μ_t	4.6869		-0.0740			0.8274
		stdv	0.1646		0.0223			0.0644
		$\ln(\sigma)$	-0.8006					
		stdv	0.0661					0.065655
		k_t	-0.4117					
		stdv	0.0275					
2.5	264	μ_t	6.1835					
		stdv	0.1545					
		$\ln(\sigma)$	-0.3490					
		stdv	0.1485					
		k_t	-0.3327					
		stdv	0.0754					
3	196	μ_t	6.196538					
		stdv	0.133944					
		$\ln(\sigma)$	-0.465141					
		stdv	0.161383					
		k_t	-0.417560					
		stdv	0.096286					
negative return								
2	365	μ_t	5.9200	-0.0177	-0.1138		-0.8159	0.6446
		stdv	0.2803	0.0042	0.0284		0.2849	0.0826
		$\ln(\sigma)$	-0.4000					
		stdv	0.0706					
		k_t	-0.3388		0.0102			
		stdv	0.0315		0.0033			
2.5	254	μ_t	4.9984					
		stdv	0.1440					
		$\ln(\sigma)$	0.3171					
		stdv	0.0686					
		k_t	-0.3011					
		stdv	0.0302					
3	187	μ_t	6.665716					
		stdv	0.034538					
		$\ln(\sigma)$	-0.589801					-0.501822
		stdv	0.123006					0.055882
		k_t	-0.847353					
		stdv	0.069127					

Table 7: Estimation Results for TAIEX with Domestic Explanatory Variables and NASDAQ

threshold	times	par	constant	duration	trend	4-th Q	Oppo	Days	ADR-2
positive return									
2	376	μ_t	5.250111		-0.113635			0.733636	5.156196
		stdv	0.382036		0.036476			0.10128	2.38758
		$\ln(\sigma)$	-0.044287		-0.006262			-0.18406	1.392284
		stdv	0.018886					0.065655	0.535109
		k_t	-0.046785		0.00354			-0.107826	0.32265
		stdv	0.093056		0.007526			0.025928	0.15248
2.5	264	μ_t	5.298014		-0.095707			0.830601	4.751153
		stdv	0.549134		0.045352			0.185719	2.047421
		$\ln(\sigma)$	0.235415		-0.024368			-0.267178	1.24426
		stdv	0.317675		0.023228			0.101186	0.46828
		k_t	0.091356		-0.006442			-0.144029	0.28889
		stdv	0.127293		0.009201			0.037637	0.134759
3	179	μ_t	6.021421		-0.133741			0.701838	4.861943
		stdv	0.553217		0.048297			0.196179	1.225591
		$\ln(\sigma)$	0.393126		-0.019768			-0.383273	1.064774
		stdv	0.282795		0.024553			0.123195	0.317387
		k_t	0.105386		-0.000227			-0.176721	0.214285
		stdv	0.123701		0.011045			0.04617	0.118679
negative return									
2	365	μ_t	5.097677					1.021002	4.007384
		stdv	0.318552					0.151896	2.710242
		$\ln(\sigma)$	0.03565					0.021883	0.804105
		stdv	0.16185					0.065002	0.757002
		k_t	-0.08204					-0.029516	0.193164
		stdv	0.068077					0.025024	0.234948
2.5	254	μ_t	5.359907					1.138085	2.75393
		stdv	0.353074					0.168757	1.442473
		$\ln(\sigma)$	0.203214					-0.085054	0.242459
		stdv	0.176018					0.079212	0.530965
		k_t	-0.015992					-0.081775	-0.008694
		stdv	0.082273					0.032212	0.175904
3	176	μ_t	5.581158					1.25726	2.867664
		stdv	0.332864					0.206353	1.440601
		$\ln(\sigma)$	0.183059					-0.09122	0.299884
		stdv	0.14163					0.084932	0.507015
		k_t	-0.080485					-0.061705	-0.00586
		stdv	0.07221					0.030704	0.183647

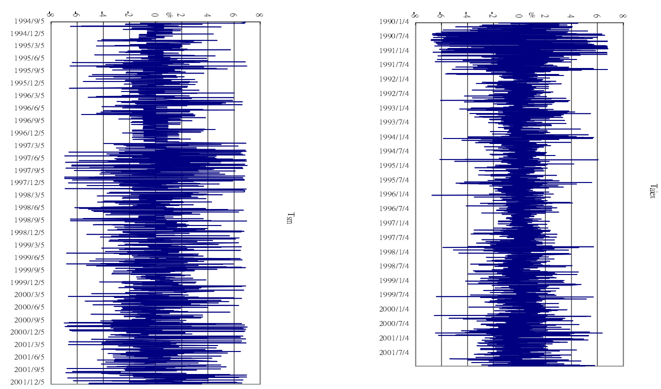

Figure 1: Time Series Plots for TAIEX and TSM Returns

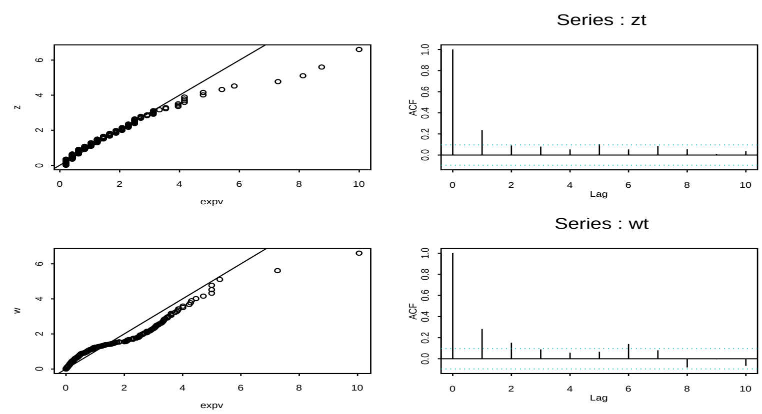

Figure 2: QQ-plot and ACF for TSM: homogeneous model, positive returns, threshold=2

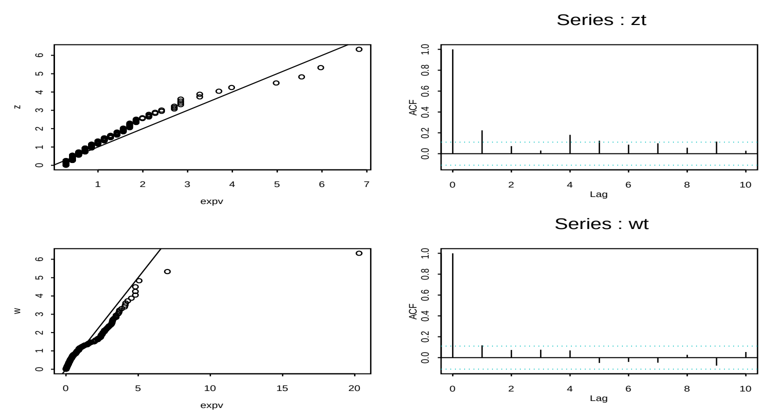

Figure 3: QQ-plot and ACF for TSM: homogeneous model, positive returns, threshold=-2,clustered

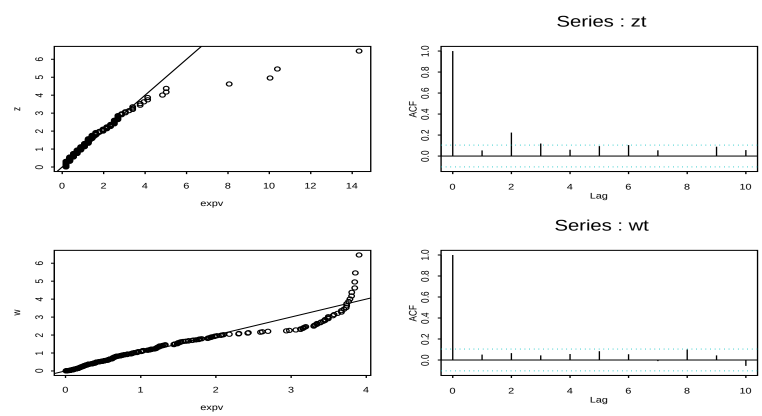

Figure 4: QQ-plot and ACF for TSM: homogeneous model, negative returns, threshold=2

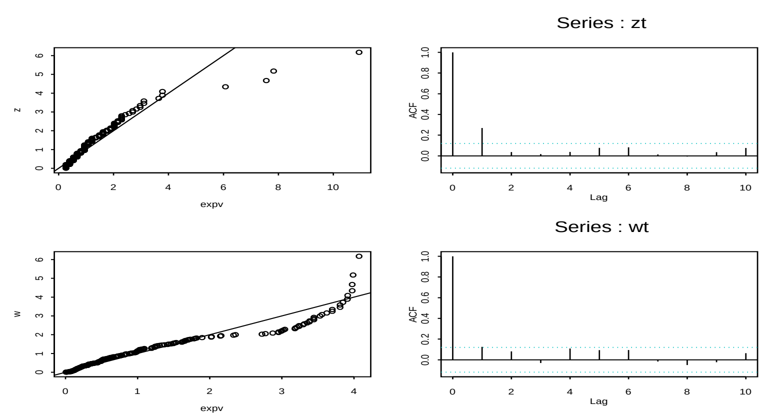

Figure 5: QQ-plot and ACF for TSM: homogeneous model, negative returns, threshold=2,clustered

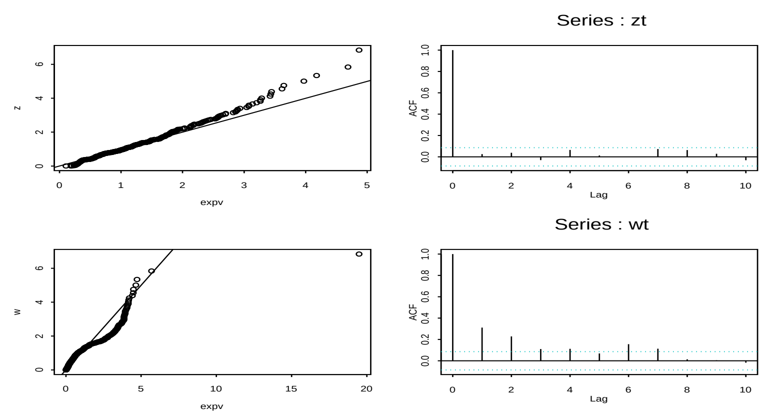

Figure 6: QQ-plot and ACF for TSM: inhomogeneous model with domestic explanatory variables, negative returns, threshold=2

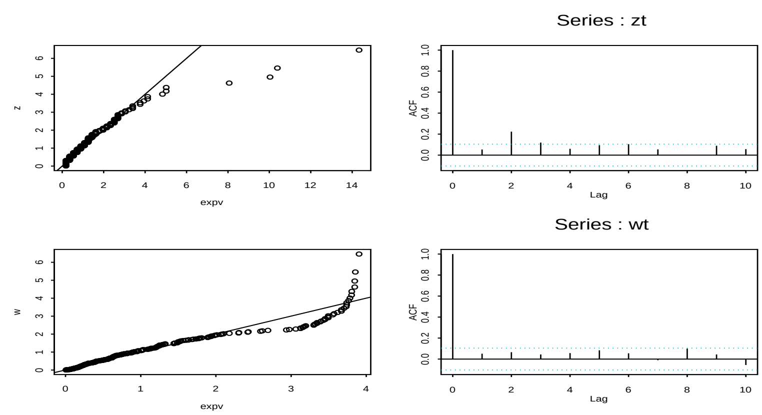

Figure 7: QQ-plot and ACF for TSM: inhomogeneous model with domestic explanatory variables, negative returns, threshold=2

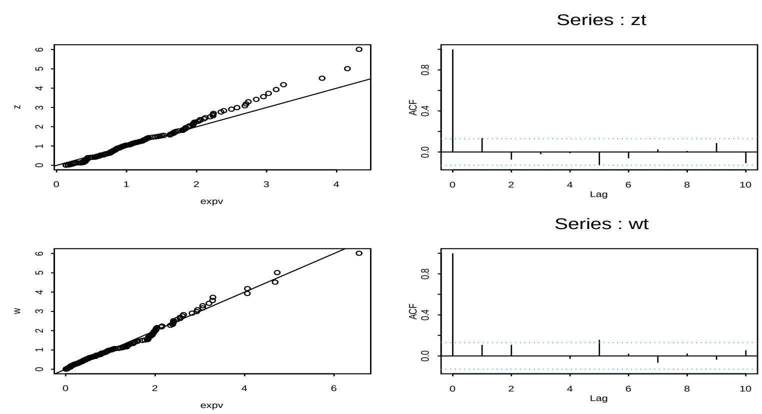

Figure 8: QQ-plot and ACF for TSM: inhomogeneous model with TSM-ADR, positive returns, threshold=2

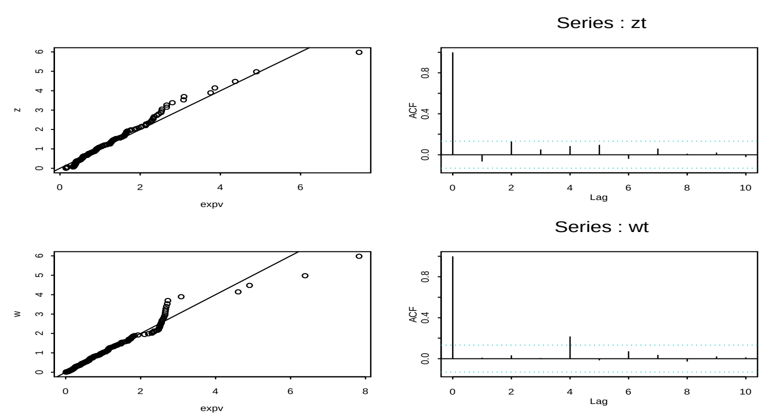

Figure 9: QQ-plot and ACF for TSM: inhomogeneous model with TSM-ADR, negative returns, threshold=2

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