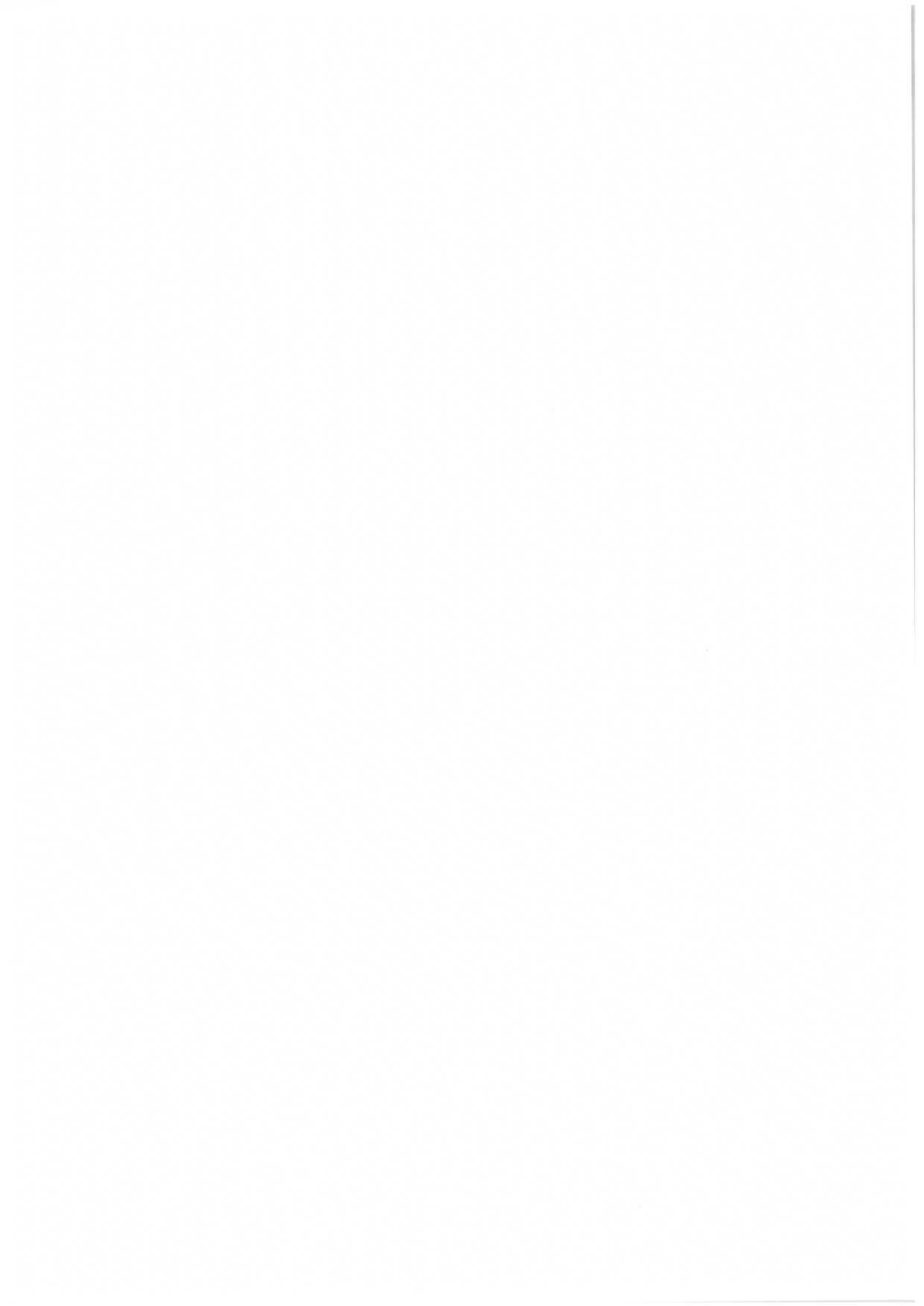


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**IV**  
**SKEWNESS IN RETURN RATE**  
**DISTRIBUTION MODELLING**

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#### 4.1. Introduction

The appropriate modelling of return rate distribution for specific financial instruments is one of the most commonly analysed concepts related to capital market. The results of the modelling are often used as an element in a number of tools and methods used to prepare analyses, diagnoses and forecasts related to specific phenomena on financial markets. In the light of previous research, the *a priori* adoption of certain assumptions as to the form of the return rate distribution density function including, in particular, the assumption that it takes the form of a standard Gaussian function (as in the case of Markovitz model or CAMP model) seems a very risky thing to do. Additionally, it is indicated that typical properties of a return rate include the leptokurtic and fat-tailed distribution of return rates, autocorrelation, clustering, leverage effect, volatility long memory process and skewness (Pionek, 2005).

The main objective of the study is to assess the extent to which inclusion of the possibility of skewness in the density function affects the quality of return rate distribution modelling. Three basic distribution types shall be used to this end, i.e. normal distribution, Student's t-distribution and GED distribution. Additionally, the significance of skewness for modelling normal and logarithmic return rate shall be determined, as well as differences in return rate distribution skewness on both mature and developing capital markets. For this purpose, return rates on the S&P500 and WIG indices shall be subjected to modelling.

#### 4.2. Methodological grounds

Skewness of each symmetrical distribution with known density function  $f(x)$  can be obtained through the appropriate conversion of the distribution to the left or to the right from the modal value. Then, each half of the distribution obtained constitutes a fragment of the base symmetrical distribution with different properties (Pionek, 2005). In general, the density function  $h(x)$  for skew distribution can be presented as follows (Arellano-Valle, R. B. et al., 2005):

$$h(x|\alpha) = \frac{2}{a(\alpha)+b(\alpha)} \left[ f\left(\frac{x}{a(\alpha)}\right) I_{(x \geq 0)} + f\left(\frac{x}{b(\alpha)}\right) I_{(x < 0)} \right] \quad (II.1)$$

where  $\alpha$  is the skewness (asymmetry) parameter, and  $a(\alpha)$  and  $b(\alpha)$  are the functions which introduce asymmetry to the distribution.

Assuming that the density function for a normal symmetrical distribution (*norm*) is described by the formula:

$$f(x) = \frac{1}{\sigma\sqrt{2\pi}} \exp\left(\frac{-(x-\mu)^2}{2\sigma^2}\right) \quad (\text{II.2})$$

normal skew distribution (*snorm*) can be presented as (Azzalini, 1985):

$$f(x) = \frac{2}{\sigma} \phi\left(\frac{x-\mu}{\sigma}\right) \Phi\left(\alpha \cdot \frac{x-\mu}{\sigma}\right) \quad (\text{II.3})$$

or

$$f(x) = \frac{1}{\sigma\pi} \cdot e^{-0.5 \cdot \left(\frac{x-\mu}{\sigma}\right)^2} \cdot \int_{-\infty}^{\alpha \cdot \left(\frac{x-\mu}{\sigma}\right)} e^{-\frac{t^2}{2}} dt \quad (\text{II.4})$$

where  $\mu$  – location parameter,  $\sigma$  – scale parameter,  $\alpha$  – skewness parameter,  $\phi(x)$  – density function for standardised normal distribution,  $\Phi(x)$  – cumulative distribution function (CDF) for normal distribution.

The standard, symmetrical form (*t-stud*) of Student's t-distribution is described with the following density function:

$$f(x) = \frac{\Gamma\left(\frac{n+1}{2}\right)}{\Gamma\left(\frac{n}{2}\right)\sqrt{n\pi}} \left(1 + \frac{x^2}{n}\right)^{-\frac{n+1}{2}} \quad (\text{II.5})$$

while the skew Student's t-distribution (*st-stud*) can be presented as (Jones, 2003):

$$f(x) = \frac{1}{2^{a+b-1} \cdot B(a,b) \cdot (a+b)^{0.5}} \cdot \left(1 + \frac{x}{(a+b+x^2)^{0.5}}\right)^{a+0.5} \cdot \left(1 - \frac{x}{(a+b+x^2)^{0.5}}\right)^{b+0.5} \quad (\text{II.5})$$

where  $\Gamma(\cdot)$  – gamma function,  $B(\cdot, \cdot)$  – beta function,  $a, b > 0$ . If  $a=b$ , then the function (II.5) is converted into standard Student's t-function with "2\*a" degrees of freedom; if  $a < b$ , function negatively skewed function is obtained; while if  $a > b$ , positively skewed function is obtained.

The GED density function, also known as the GGD (*Generalized Gaussian Distribution*), is described with the use of the following formula (Purczyński, 2003):

$$f(x) = \frac{\lambda \cdot s}{2\Gamma\left(\frac{\lambda}{s}\right)} \exp(-\lambda^s |x - \mu|^s) \quad (\text{II.6})$$

where:

$$\lambda = \frac{1}{\sigma} \left[ \frac{\Gamma\left(\frac{\lambda}{s}\right)}{\Gamma\left(\frac{\lambda}{s}\right)} \right]^{0.5} \quad (\text{II.7})$$

The skew GED (sGED) function, in turn, is described as follows (Theodossiou, 2000):

$$f(x) = \frac{C}{\sigma} \cdot \exp\left(-\frac{1}{[1-\text{sign}(x-\mu+\delta\sigma)\lambda]^2 \Theta^2 \sigma^2} \cdot |x - \mu + \delta\sigma|^2\right) \quad (\text{II.8})$$

where:

$$C = \frac{k}{2\Theta} \Gamma\left(\frac{1}{k}\right)^{-1},$$

$$\Theta = \Gamma\left(\frac{1}{k}\right)^{0.5} \Gamma\left(\frac{3}{k}\right)^{-0.5} S(\lambda)^{-1},$$

$$\delta = 2\lambda AS(\lambda)^{-1},$$

$$S(\lambda) = \sqrt{1 + 3\lambda^2 - 4A^2\lambda^2},$$

$$A = \Gamma\left(\frac{2}{k}\right) \Gamma\left(\frac{1}{k}\right)^{-0.5} \Gamma\left(\frac{3}{k}\right)^{-0.5},$$

s- shape parameter,  $\lambda$  – scale parameter.

The functions above shall be used in the attempt to model daily (D), weekly (W) and monthly (M) distributions of return rates, where the normal rate of return shall be calculated as:

$$R_t = \frac{P_t - P_{t-1} + D_t}{P_{t-1}} \quad (\text{II.9})$$

and logarithmic rate of return  $R^*_t$  as:

$$R^*_t = \ln \frac{P_t + D_t}{P_{t-1}} \quad (\text{II.10})$$

where:

$P^t$  – price of the security in  $t$  period;

$P^{t-1}$  – price of the security in  $t-1$  period;

$D^t$  – value of dividend paid in  $t$  period.

This means that the following shall be subjected to modelling:

- normal daily rate of return in the period of 252 index listings ( $R^t_{D\_252}$ );
- logarithmic daily rate of return in the period of 252 index listings ( $R^{*t}_{D\_252}$ );
- normal daily rate of return in the period of 126 index listings ( $R^t_{D\_126}$ );
- logarithmic daily rate of return in the period of 126 index listings ( $R^{*t}_{D\_126}$ );

- normal weekly rate of return in the period of 52 index listings ( $R^t_{W_52}$ );
- logarithmic weekly rate of return in the period of 52 index listings ( $R^{*t}_{W_52}$ );
- normal monthly rate of return in the period of 36 index listings ( $R^t_{M_36}$ );
- logarithmic monthly rate of return in the period of 36 index listings ( $R^{*t}_{M_36}$ );
- normal monthly rate of return in the period of 60 index listings ( $R^t_{M_60}$ );
- logarithmic monthly rate of return in the period of 60 index listings ( $R^{*t}_{M_60}$ ).

The above-mentioned rates of return will be modelled starting from the first index listing, in which such modelling is possible (e.g. for the daily rate of return in the period of 252 index listings, the first model was obtained for listing no. 254 for the index, while the second model, for listing no. 255, was based on return rates from listings 3 to 254 etc.), until the final listing in 2015. This means that, in the case of the S&P500 index, for each of the distributions analysed, 11353 models were obtained for daily return rates in the period of 252 listings and 11479 for 126 listings, 490 models were obtained for monthly return rates in the period of 60 listings and 514 for 36 listings and 2185 models were obtained for weekly return rates. When it comes to the WIG index, in turn, the number of models obtained equalled 5062 and 5188, 194 and 218 and 943 respectively.

The main research hypothesis adopted in the study (H1) is as follows: adjustment for skewness in modelling return rate distribution significantly increases the probability that the output distribution will consistent with the assumed one. Additionally, two auxiliary hypotheses have been proposed: (H2) probability that the distribution obtained shall be consistent with the assumed one does not differ significantly, in terms of statistics, for developed and developing markets; (H3) probability that the distribution obtained shall be consistent with the assumed one is highly dependent on the assumed time of estimations and type of the return rate modelled.

### 4.3. Research results

In order to verify the hypothesis concerning the impact of adjustment for skewness on the quality of modelling the return rate distribution,



parameters have been calculated for all the previously mentioned distribution variants. In the next step, a chi-squared test was used to verify the number of the obtained  $n$  distributions for which there are no grounds to reject the hypothesis that they are consistent with the theoretical distribution analysed ( $p$ -value=0.05). Then, based on this very same test,  $p$ -value was determined for two indicators of the structure, at which it can be assumed that there is a statistically significant difference in probability that the distribution obtained will be consistent with the assumed one, between the symmetrical and the skew variant of the given distribution. The results are presented in Table 3.1.

**Table 3.1. Statistics of the modelled return rate distribution**

Distribution	n	Number of good-fit distributions		p-value for two indicators of the structure used in the text
		symmetrical	skew	
T_stud_wig_Rt_D_252	5062	4450	4449	0.97569
T_stud_wig_R*t_D_252	5062	4454	4459	0.87830
T_stud_wig_Rt_D_126	5188	4573	4622	0.12986
T_stud_wig_R*t_D_126	5188	4572	4604	0.32595
T_stud_wig_Rt_M_60	194	168	168	1.00000
T_stud_wig_R*t_M_60	194	190	192	0.41057
T_stud_wig_Rt_W_52	943	806	822	0.28365
T_stud_wig_R*t_W_52	943	803	817	0.35435
T_stud_wig_Rt_M_36	218	190	189	0.88703
T_stud_wig_R*t_M_36	218	198	201	0.60616
T_stud_SP500_Rt_D_252	11353	10092	9980	0.02028
T_stud_SP500_R*t_D_252	11353	10094	9952	0.00339
T_stud_SP500_Rt_D_126	11479	10099	10196	0.04559
T_stud_SP500_R*t_D_126	11479	10102	10199	0.04537
T_stud_SP500_Rt_M_60	490	404	406	0.86601
T_stud_SP500_R*t_M_60	490	406	393	0.28455
T_stud_SP500_Rt_W_52	2185	1779	1893	0.00000
T_stud_SP500_R*t_W_52	2185	1787	1894	0.00001
T_stud_SP500_Rt_M_36	514	414	406	0.53452
T_stud_SP500_R*t_M_36	514	411	400	0.40051
norm_wig_Rt_D_252	5062	2915	3097	0.00023
norm_wig_R*t_D_252	5062	2906	3068	0.00106
norm_wig_Rt_D_126	5188	3836	4017	0.00003
norm_wig_R*t_D_126	5188	3826	3988	0.00022

norm_wig_Rt_M_60	194	119	119	1.00000
norm_wig_R*t_M_60	194	188	191	0.17687
norm_wig_Rt_W_52	943	701	771	0.00009
norm_wig_R*t_W_52	943	692	759	0.00024
norm_wig_Rt_M_36	218	134	152	0.06712
norm_wig_R*t_M_36	218	186	195	0.17961
norm_SP500_Rt_D_252	11353	6354	6407	0.47832
norm_SP500_R*t_D_252	11353	6353	6388	0.63970
norm_SP500_Rt_D_126	11479	7890	8317	0.00000
norm_SP500_R*t_D_126	11479	7883	8290	0.00000
norm_SP500_Rt_M_60	490	355	341	0.32424
norm_SP500_R*t_M_60	490	347	340	0.62357
norm_SP500_Rt_W_52	2185	1666	1813	0.00000
norm_SP500_R*t_W_52	2185	1664	1810	0.00000
norm_SP500_Rt_M_36	514	368	376	0.57486
norm_SP500_R*t_M_36	514	351	366	0.30737
GED_wig_Rt_D_252	5062	4705	693	0.00000
GED_wig_R*t_D_252	5062	4696	575	0.00000
GED_wig_Rt_D_126	5188	4881	2724	0.00000
GED_wig_R*t_D_126	5188	4879	2645	0.00000
GED_wig_Rt_M_60	194	169	82	0.00000
GED_wig_R*t_M_60	194	192	146	0.00000
GED_wig_Rt_W_52	943	873	742	0.00000
GED_wig_R*t_W_52	943	875	724	0.00000
GED_wig_Rt_M_36	218	193	149	0.00000
GED_wig_R*t_M_36	218	203	183	0.00265
GED_SP500_Rt_D_252	11353	10731	2034	0.00000
GED_SP500_R*t_D_252	11353	10753	1868	0.00000
GED_SP500_Rt_D_126	11479	10712	5365	0.00000
GED_SP500_R*t_D_126	11479	10710	5179	0.00000
GED_SP500_Rt_M_60	490	457	247	0.00000
GED_SP500_R*t_M_60	490	453	231	0.00000
GED_SP500_Rt_W_52	2185	1947	1746	0.00000
GED_SP500_R*t_W_52	2185	1945	1719	0.00000
GED_SP500_Rt_M_36	514	462	373	0.00000
GED_SP500_R*t_M_36	514	460	352	0.00000

Source: own work.



Two major conclusions can be drawn based on the results presented in Table 3.1.: (1) adjustment for skewness in modelling return rate distribution significantly increases the probability that the output distribution will be consistent with the assumed one; (2) skewness significance depends on the type of the adopted distribution modelling: for Student's t-distribution, adjustment for skewness had significant impact on the results obtained only in the case of daily and weekly return rates (both normal and logarithmic) for S&P500. When it comes to the remaining distributions analysed, such impact was observed in all cases.

Validity of the conclusions above is also confirmed by results of the Kolmogorov-Smirnov test ( $K_S$ ), used to verify the hypothesis that empirical distributions of the  $p$ -values obtained for the chi-squared goodness-of-fit test are identical when modelling both symmetrical and skew density functions of the distributions analysed (Table 3.2.).

**Table 3.2. Results of the Kolmogorov-Smirnov ( $K_S$ ) test of equality of empirical CDFs of the obtained  $p$ -values (chi-squared goodness-of-fit test), for modelling symmetrical and skew variants of the distribution**

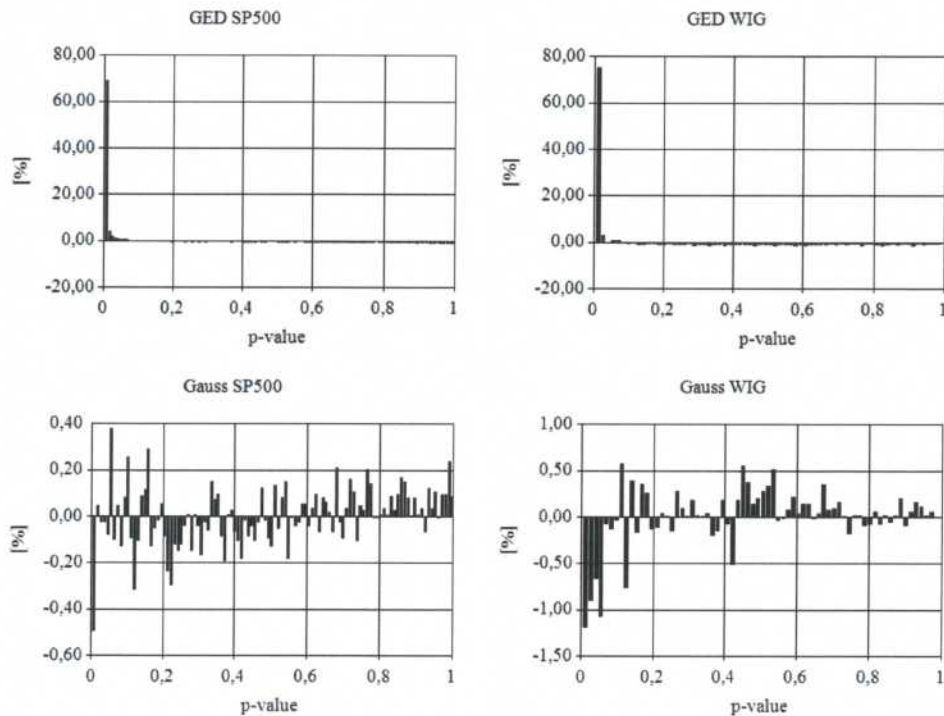
Distribution	$K_S$	p-value	Distribution	$K_S$	p-value
T_stud_wig_Rt_D_252	1.79870	0.00310	norm_SP500_Rt_D_252	1.86705	0.00188
T_stud_wig_R*t_D_252	1.79870	0.00310	norm_SP500_R*t_D_252	1.74711	0.00446
T_stud_wig_Rt_D_126	2.26754	0.00007	norm_SP500_Rt_D_126	3.09977	0.00000
T_stud_wig_R*t_D_126	2.44423	0.00001	norm_SP500_R*t_D_126	3.10839	0.00000
T_stud_wig_Rt_M_60	0.75955	0.61111	norm_SP500_Rt_M_60	0.54249	0.93016
T_stud_wig_R*t_M_60	1.21529	0.10426	norm_SP500_R*t_M_60	0.86327	0.44539
T_stud_wig_Rt_W_52	3.29105	0.00000	norm_SP500_Rt_W_52	3.86752	0.00000
T_stud_wig_R*t_W_52	2.99187	0.00000	norm_SP500_R*t_W_52	3.81956	0.00000
T_stud_wig_Rt_WM_36	1.76793	0.00386	norm_SP500_Rt_M_36	1.88337	0.00166
T_stud_wig_R*t_WM_36	1.38567	0.04298	norm_SP500_R*t_M_36	1.68624	0.00678
T_stud_SP500_Rt_D_252	1.58602	0.01307	GED_wig_Rt_D_252	39.93917	0.00000
T_stud_SP500_R*t_D_252	1.30067	0.06786	GED_wig_R*t_D_252	41.07206	0.00000
T_stud_SP500_Rt_D_126	3.27337	0.00000	GED_wig_Rt_D_126	23.47052	0.00000
T_stud_SP500_R*t_D_126	3.06219	0.00000	GED_wig_R*t_D_126	24.85461	0.00000
T_stud_SP500_Rt_M_60	0.73396	0.65421	GED_wig_Rt_M_60	5.16497	0.00000
T_stud_SP500_R*t_M_60	1.08498	0.18974	GED_wig_R*t_M_60	5.51943	0.00000
T_stud_SP500_Rt_W_52	3.75069	0.00000	GED_wig_Rt_W_52	3.84340	0.00000
T_stud_SP500_R*t_W_52	3.50871	0.00000	GED_wig_R*t_W_52	4.67192	0.00000
T_stud_SP500_Rt_M_36	1.77605	0.00364	GED_wig_Rt_M_36	4.39593	0.00000

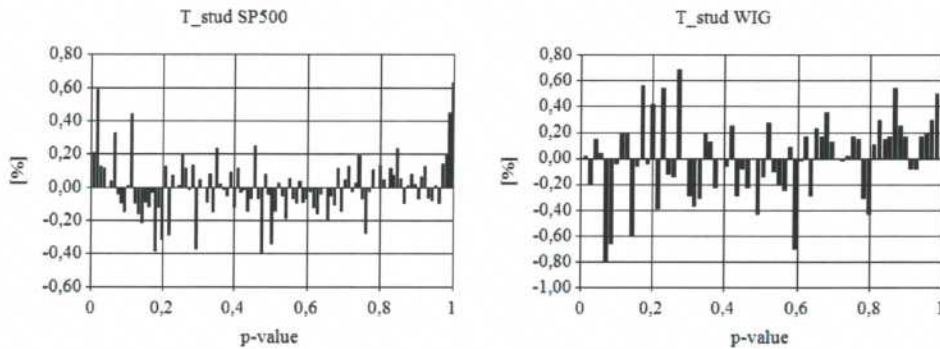
T_stud_SP500_R*t_M_36	1.71374	0.00562	GED_wig_R*t_M_36	2.15018	0.00019
norm_wig_Rt_D_252	2.21465	0.00011	GED_SP500_Rt_D_252	58.29782	0.00000
norm_wig_R*t_D_252	2.10935	0.00027	GED_SP500_R*t_D_252	59.27332	0.00000
norm_wig_Rt_D_126	3.26674	0.00000	GED_SP500_Rt_D_126	39.24750	0.00000
norm_wig_R*t_D_126	3.46187	0.00000	GED_SP500_R*t_D_126	40.23083	0.00000
norm_wig_Rt_M_60	0.55374	0.91901	GED_SP500_Rt_M_60	6.79710	0.00000
norm_wig_R*t_M_60	0.89184	0.40409	GED_SP500_R*t_M_60	7.37151	0.00000
norm_wig_Rt_W_52	3.40080	0.00000	GED_SP500_Rt_W_52	3.99267	0.00000
norm_wig_R*t_W_52	3.08112	0.00000	GED_SP500_R*t_W_52	4.79423	0.00000
norm_wig_Rt_WM_36	1.43170	0.03316	GED_SP500_Rt_WM_36	3.27168	0.00000
norm_wig_R*t_WM_36	1.31659	0.06243	GED_SP500_R*t_WM_36	3.58327	0.00000

Source: own work.

Figure 3.1., in turn, shows differences in the incidence of distributions consistent with the assumed distribution, for daily return rate modelling, given the estimation time encompassing 252 index listings (positive value denotes predominance of skew distributions, negative value denotes predominance of symmetrical distributions).

**Figure 3.1. Differences in the incidence of distributions consistent with the assumed ones when modelling symmetrical and skew variants of the distribution (estimation time: 252)**





Source: own work.

In order to verify the additional hypothesis (H2), i.e., that probability that the distribution obtained shall be consistent with the assumed one does not differ significantly, in terms of statistics, for developed and developing markets, the results of rate modelling for S&P500 and WIG were compared. The results obtained, however, are inconclusive. For daily return rate modelling, significant differences in the incidence of distributions consistent with the assumed ones were reported for each GED and normal distribution, while they were absent in the case of Student's t-distribution. When it comes to weekly return rate modelling, significant differences were observed for skew GEDs and Student's t-distributions. Details concerning the results of the test are presented in Table 3.3..

**Table 3.3. P-values for two structure indicators, for tests measuring equality of the incidence of distributions consistent with the assumed distribution for return rates on WIG and SP500 indices**

Distribution	p-value for two structure indicators in the test	Distribution	p-value for two structure indicators in the test
T_stud_Rt_D_252	0.97667	snorm_Rt_D_252	0.05344
T_stud_R*t_D_252	0.43913	snorm_R*t_D_252	0.08374
T_stud_Rt_D_126	0.61112	snorm_Rt_D_126	0.00000
T_stud_R*t_D_126	0.84074	snorm_R*t_D_126	0.00000
T_stud_Rt_M_60	0.22997	snorm_Rt_M_60	0.00452
T_stud_R*t_M_60	0.00000	snorm_R*t_M_60	0.00000
T_stud_Rt_W_52	0.68645	snorm_Rt_W_52	0.25327
T_stud_R*t_W_52	0.97378	snorm_R*t_W_52	0.09883
T_stud_Rt_M_36	0.01447	snorm_Rt_M_36	0.00695
T_stud_R*t_M_36	0.00000	snorm_R*t_M_36	0.00000



sT_stud_Rt_D_252	0.06737	GED_Rt_D_252	0.00000
sT_stud_R*t_D_252	0.08592	GED_R*t_D_252	0.00000
sT_stud_Rt_D_126	0.75750	GED_Rt_D_126	0.00000
sT_stud_R*t_D_126	0.82179	GED_R*t_D_126	0.00000
sT_stud_Rt_M_60	0.18624	GED_Rt_M_60	0.05478
sT_stud_R*t_M_60	0.00000	GED_R*t_M_60	0.00000
sT_stud_Rt_W_52	0.00602	GED_Rt_W_52	0.43636
sT_stud_R*t_W_52	0.02195	GED_R*t_W_52	0.23921
sT_stud_Rt_M_36	0.03129	GED_Rt_M_36	0.24842
sT_stud_R*t_M_36	0.00032	GED_R*t_M_36	0.00002
norm_Rt_D_252	0.00000	sGED_Rt_D_252	0.00008
norm_R*t_D_252	0.00000	sGED_R*t_D_252	0.00000
norm_Rt_D_126	0.00000	sGED_Rt_D_126	0.06280
norm_R*t_D_126	0.00000	sGED_R*t_D_126	0.07091
norm_Rt_M_60	0.05637	sGED_Rt_M_60	0.00923
norm_R*t_M_60	0.00000	sGED_R*t_M_60	0.00092
norm_Rt_W_52	0.44885	sGED_Rt_W_52	0.00280
norm_R*t_W_52	0.13720	sGED_R*t_W_52	0.00115
norm_Rt_M_36	0.39706	sGED_Rt_M_36	0.58582
norm_R*t_M_36	0.00000	sGED_R*t_M_36	0.12479

Source: own work.

Nevertheless, there is an argument for falsification of the additional hypothesis (H2), i.e., the results of the Kolmogorov-Smirnov (K\_S) test of equality of the  $p$ -value distribution. Only in 8 out of the 60 distributions analysed did the result ( $p$ -value=0.05) indicate that  $p$ -value distributions for the chi-squared goodness-of-fit test, for S&P500 and WIG index, do not differ in a statistically significant way (Table 3.4.).

**Table 3.4. Results of the Kolmogorov-Smirnov (K\_S) test of equality of empirical CDFs of the obtained  $p$ -values for the chi-squared goodness-of-fit test, for SP500 and WIG index return rate modelling**

Distribution	K_S	p-value	Distribution	K_S	p-value
T_stud_Rt_D_252	1.87982	0.00170	snorm_Rt_D_252	6.05133	0.00000
T_stud_R*t_D_252	1.78762	0.00335	snorm_R*t_D_252	6.30134	0.00000
T_stud_Rt_D_126	2.19446	0.00013	snorm_Rt_D_126	3.51597	0.00000
T_stud_R*t_D_126	2.06942	0.00038	snorm_R*t_D_126	3.51505	0.00000
T_stud_Rt_M_60	1.60839	0.01133	snorm_Rt_M_60	2.33034	0.00004
T_stud_R*t_M_60	5.00161	0.00000	snorm_R*t_M_60	4.90796	0.00000

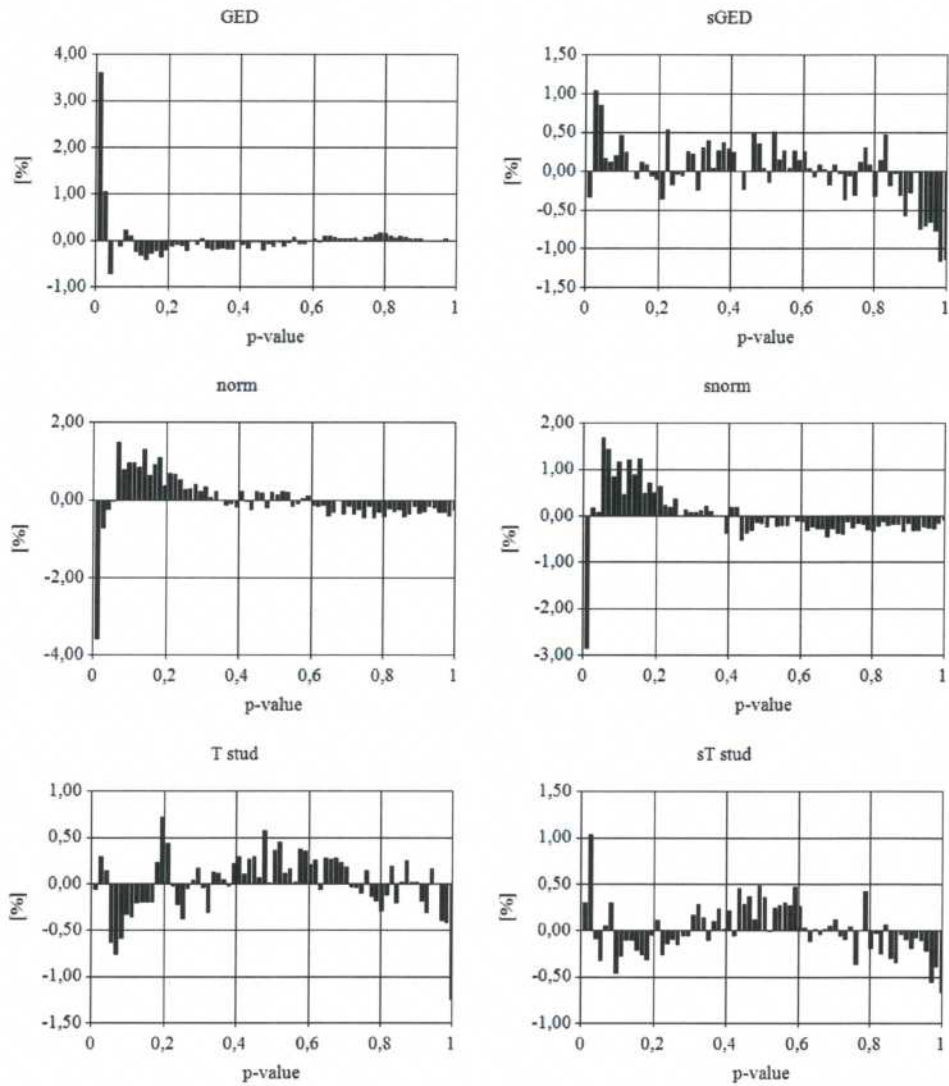
T_stud_Rt_W_52	1.12291	0.16054	snorm_Rt_W_52	2.15601	0.00018
T_stud_R*t_W_52	1.16569	0.13202	snorm_R*t_W_52	2.22648	0.00010
T_stud_Rt_M_36	2.59381	0.00000	snorm_Rt_M_36	1.57607	0.01391
T_stud_R*t_M_36	3.94457	0.00000	snorm_R*t_M_36	3.07158	0.00000
sT_stud_Rt_D_252	2.17393	0.00016	GED_Rt_D_252	5.85846	0.00000
sT_stud_R*t_D_252	2.29730	0.00005	GED_R*t_D_252	5.29639	0.00000
sT_stud_Rt_D_126	2.75000	0.00000	GED_Rt_D_126	4.17679	0.00000
sT_stud_R*t_D_126	2.73156	0.00000	GED_R*t_D_126	3.74895	0.00000
sT_stud_Rt_M_60	2.41832	0.00002	GED_Rt_M_60	2.01335	0.00060
sT_stud_R*t_M_60	5.17387	0.00000	GED_R*t_M_60	3.69417	0.00000
sT_stud_Rt_W_52	1.07727	0.19616	GED_Rt_W_52	1.14976	0.14212
sT_stud_R*t_W_52	1.13971	0.14880	GED_R*t_W_52	1.46205	0.02782
sT_stud_Rt_M_36	2.02669	0.00054	GED_Rt_M_36	2.14385	0.00020
sT_stud_R*t_M_36	2.66602	0.00000	GED_R*t_M_36	1.95481	0.00096
norm_Rt_D_252	5.18463	0.00000	sGED_Rt_D_252	4.09063	0.00000
norm_R*t_D_252	5.38824	0.00000	sGED_R*t_D_252	4.59241	0.00000
norm_Rt_D_126	3.10792	0.00000	sGED_Rt_D_126	2.86745	0.00000
norm_R*t_D_126	3.05065	0.00000	sGED_R*t_D_126	3.00894	0.00000
norm_Rt_M_60	2.24781	0.00008	sGED_Rt_M_60	1.69044	0.00659
norm_R*t_M_60	5.60017	0.00000	sGED_R*t_M_60	5.46260	0.00000
norm_Rt_W_52	2.04769	0.00046	sGED_Rt_W_52	1.26132	0.08301
norm_R*t_W_52	2.10164	0.00029	sGED_R*t_W_52	1.22193	0.10094
norm_Rt_M_36	1.05661	0.21418	sGED_Rt_M_36	2.53776	0.00001
norm_R*t_M_36	3.35163	0.00000	sGED_R*t_M_36	2.70756	0.00000

Source: own work.

Differences in empirical CDFs of the  $p$ -value for the chi-squared goodness-of-fit test are mainly due to the fact that lower values are far more frequently obtained for the WiG index than for S&P500, which is shown by Figure 3.2 (positive bar value means that for the specific  $p$ -value, the probability to obtain a distribution fitting well the assumed distribution is higher for WIG than for S&P500).



**Figure 3.2. Differences in the incidence of distributions consistent with the assumed ones when modelling return rates for SP500 and WIG indices (estimation time: 252 daily return rates)**



Source: own work.

#### 4.4. Conclusion

Based on the deductions made in the article, the following conclusions may be drawn:

- admitting the potential occurrence of skewness when modelling return rates (e.g. on market indices) essentially increases the probability that the distribution obtained shall be consistent with the assumed one,
- the significance of skewness is highly dependent on the type of the distribution assumed in the modelling,
- due to problems connected with modelling rates of return on market indices, mature capital markets (e.g. American) do not differ significantly from developing markets (e.g. Polish).

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# MODERN CONDITIONS OF DEVELOPMENT

## Economics and Management

Editors

Joanna Rosak-Szyrocka

Aneta Sokół



Univerza v Mariboru

University of Maribor

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**MODERN CONDITIONS OF DEVELOPMENT**  
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