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IMPACT OF THE CORONAVIRUS COVID-19 ON ENTERPRISES SECTOR IN POLAND – EVIDENCE FROM THE WARSAW STOCK EXCHANGE INDEX

Abstract

The Covid-19 coronavirus pandemic created many doubts and unknowns in all areas of the activity of enterprises, not only for those smaller and more turbulent-prone entities but also for seemingly stronger players on the market. The fundamental question is what is the economic impact of the Covid-19 pandemic on these companies. In this work we analyze the relationship between the impact of the coronavirus Covid-19 pandemic and the returns of the stock prices of selected companies, mainly those included in the Warsaw Stock Exchange WIG 20 Index.

We use two classical models of the evolution of stock prices – the geometric Brownian motion model and the jump-diffusion model, proposed by Merton. We estimate these models for two periods – the pre-pandemic period and a period that encompasses also the time of the Covid-19 pandemic. We compare the impact on the returns with the impact of the pandemic on enterprises from different sectors reported in the literature.

The results of the conducted research show that returns of companies operating in the financial sectors (banking and insurance) and fuel companies have changed the most. In the case of companies from the IT sectors as well as the food industry, most of the returns in 2020 were not far from the returns in 2019, but from time to time also here the market was characterized by greater fluctuations.

Keywords: *pandemic, Covid-19 coronavirus, enterprises, Warsaw Stock Exchange, WIG-20, geometric Brownian motion model, Merton's jump-diffusion model*

Introduction

Pandemics are one of the greatest potential negative global risks, especially in the modern, highly globalized world. They can cause high morbidity and mortality and have negative socio-economic consequences (Chakraborty and Maity, 2020; Wolf and Fornaro, 2020; Tokic 2020; Brada, Gajewski and Kutan, 2021). The literature often emphasizes that the coronavirus will cause a protracted global recession, while other authors tone their emotions, arguing that the new virus will be stopped relatively quickly and the global economy will quickly recover (McKibbin and Fernando, 2020; Baker, Bloom, Davis and Terry, 2020; Barrios and Hochberg, 2020, Goodell, 2020). The coronavirus pandemic has affected all sectors of the economy, causing one of the biggest economic crises in recent decades. It has resulted in a fall in consumer spending (Baker, Farrokhnia, Meyer, Pagel and Yannelis, 2020; Zaremba, Aharon, Demir, Kizys and Zawadka, 2021). The tourism, transport, and entertainment sectors have been hit hardest by the epidemic. Other sectors of the economy are also experiencing disruption, which may lead to shortages of certain goods and result in higher prices of others (Wolf and Fornaro, 2020; Loayza and Pennings, 2020). Wójcik and Ioannou confirm that financial institutions (like banks and insurance companies) have been the most badly affected sector after the health care sector (Wójcik and Ioannou, 2020). "One way to gauge the potential impact of the pandemic on the financial sector is to compare sectoral stock market indices. Not surprisingly, there are large differences between the performance of different sectors, even though all indices declined. Health care did best, losing 10 per cent globally since the start of the stock market fall on 20 February. On the other end of the spectrum, affected by falling oil and gas prices, the energy sector globally lost 33 per cent. Real estate transactions are not popular in conditions of fundamental uncertainty, and almost impossible with lockdowns, with stocks in the industry falling by 24 per cent globally. Financials (made of banking, insurance, and diversified financial firms) have been the second most badly affected sector with a fall of 27 per cent" (Wójcik and Ioannou, 2020).

The Polish economy has undoubtedly suffered as a result of the Covid-19 pandemic, although it is worth noting that, as emphasized by many authors (Pandey and Kumari, 2021; Korzeb and Niedziółka, 2020) in "the final analysis, it should feel the effects of the pandemic less than other European countries" (Kochański & Partners, 2020). Firstly, because in comparison with Germany, for example, the Polish economy is less dependent on exports and has less economic links to China. Secondly, the tourism and leisure sector account for smaller percentage of GDP compared with the countries of southern Europe. Finally, the higher rate of economic growth in Poland in comparison with Germany or other Western countries creates less risk before a possible recession occurs (Pandey and Kumari 2021; Ashraf 2020). At the same time, the pandemic has further accelerated the already rapid digitalization of economic and social life. The new digital world has made the COVID-19 pandemic's impact on the global economy different from that of previous epidemics (Ding, Guan, Chan and Liu, 2020; Nicola, Alsafi, Sohrabi, Kerwan, Al-Jabir, Iosifidis, Agha, and Agha, 2020). The new technology sector is a provider of innovative solutions that will be standard in a new, changed reality. Limited economic activity also generates lower tax revenues. The government is increasing spending on the fight against the pandemic, thereby resulting in a greater budget deficit and public debt (Wolf and Fornaro, 2020). However, the impact is relatively large as confirmed in this paper.

This paper aims to analyze the impact of COVID 19 pandemic on the enterprise sector in Poland mainly on the example of companies from index WIG-20. The WIG20 index has been calculated since April 16th, 1994, based on the value of the share portfolio of the 20 largest and most liquid companies on the Warsaw Stock Exchange Main Market. It is a price type index, which means that only the prices of shares included in it are taken into account in its calculation, while dividend income is not taken into account. The WIG20 index cannot include more than five companies from one stock exchange sector. The value of the index at the beginning of the analyzed period, i.e. on January 2nd, 2019, was 2301.62 points. Since then, a downward trend has been observed, resulting in reaching the minimum value of the index on March

15th, 2020 (1365.97 points). Since that date, the index has gradually recovered, reaching 1772.89 points on 13 November 2020 (STOOQ, GPW). The data that support the findings of this study are in a public repository (https://www.gpw.pl/; https://stooq.pl/db/).

Ashraf discovers that stock markets respond negatively to the increase in COVID-19 confirmed cases and he suggests that stock markets react more strongly to the growth in the number of confirmed cases than to the number of deaths (Ashraf, 2020). The increase in COVID-19 cases contributes to the decline in the Prague PX, Budapest BUX, Warsaw WIG20, and Bratislava SAX stock indices (Carlsson-Szlezak, Reeves and Swartz, 2020) though the Polish capital market is gradually stabilizing. This can be seen both in stock exchange indices and in the approach and activity of the business. A similar pattern can also be observed in western countries. The French and Italian stock exchanges suffered the most as a result of the pandemic, which, together with the Spanish one, have the greatest difficulties in returning to pre-pandemic levels. The United States and Germany have been the best at emerging from the crisis. The relatively small response of the US stock exchange to the pandemic seems puzzling, especially when compared to the avalanche of unemployment and the risk of a severe economic collapse. He et al. examine the COVID-19 impact on the stock market in advanced economies and also affirm that countries in Asia experience more negative abnormal returns as compared to the countries in Europe (He, Liu, Wang and Yu, 2020). The high resilience of the Chinese stock exchange, which has recorded relatively small losses despite the collapse of the global supply chain, of which China is a key element, is also surprising (Fernandes, 2020; Baker, Farrokhnia Meyer, Pagel and Yannelis, 2020; McKibbin and Fernando, 2020; Baker, Bloom, Davis and Terry, 2020; Wolf and Fornaro, 2020). Sansa reveals that there is a significant relationship between COVID-19 confirmed cases and Chinese and US stock markets. He et al. confirmed that the COVID-19 pandemic has a negative but short-term impact on stock markets (Sansa, 2020). In Poland, the clothing and pharmaceutical sectors experienced biggest falls, by as much as 50%, in mid-March. The smallest losses were in the construction sector (14%), real estate and new technologies (18% each). The worst situation seems to be in the banking sector, which is still in crisis, and which – in mid-March, noting a loss of 36% – deepened in the fall of 2020 to 46% (Kochański & Partners, 2020). Worrying signals are also coming from the real estate sector, which, despite a relatively small loss in the value of the stock index, has been slow to make up for the losses, and since mid-March, its level has been constantly fluctuating between – 13% and – 21% around the values at the beginning of the year. Many authors stress that "financial markets now ascribe significant disruptive potential to Covid-19, and those risks are real. But the variations in asset valuations underline the significant uncertainty surrounding this epidemic, and history cautions us against drawing a straight line between financial market sell-offs and the real economy" (Carlsson-Szlezak, Reeves and Swartz, 2020). Thus the fundamental question arises about the extent and economic impact of the Covid19 pandemic on large companies. In this paper we analyze the relationship between the impact of the coronavirus Covid-19 pandemic and the returns of the stock prices of selected companies, mainly those included in the Warsaw Stock Exchange WIG 20 Index. Those companies were selected that represent particularly important sectors that will be affected by COVID pandemic (KGHM – metal mining sector, Orlen, Lotos – refining and energy sector, mBank, Pekao, PZU – financial sector, CD PROJECT, Cyfrowy Polsat, TEN SQUARE GAMES – new technology sector, Eurocash, Dino – food retail sector and LPP – clothing retail sector). We use two classical models of the evolution of stock prices – the geometric Brownian motion model and the jump-diffusion model, proposed by Merton. We estimate these models for two periods – pre-pandemic period and a period which encompasses also the time of the Covid-19 pandemic. Comparing estimated return distributions for companies representing different sectors of the economy we infer how severe was the impact of the pandemic on the returns. Then, we compare the impact on the returns with the reports on the impact of the pandemic on these sectors.

Methodology and Results

The geometric Brownian motion model

The classical model of the evolution of stock prices in continuous time is the geometric Brownian motion model (Black, F. and Scholes, 1973). If $\boldsymbol{S_t}$ denotes the price of a stock at time $\boldsymbol{t}$ then in the geometric Brownian motion model the evolution of $\boldsymbol{S_t}$ is described by the following stochastic differential equation

$$d\,S_t = \nu \cdot S_t\,dt + \sigma \cdot S_t\,dB_t\,, \qquad (1)$$

where B_t is a standard Brownian motion process and ν, σ are constants, called drift and (instantaneous) volatility respectively. Equation (1), given S_{t_0} at some starting time moment $t_0 \geq 0$ has the unique strong solution which is a geometric Brownian motion process, given by the following formula

$$S_t = S_{t_0} e^{\left(\nu - \frac{\sigma^2}{2}\right)(t-t_0)+\sigma(B_t - B_{t_0})} = S_{t_0} e^{\mu(t-t_0)+\sigma(B_t - B_{t_0})}, \qquad (2)$$

where $\mu = \text{v}-\frac{\sigma^2}{2}$. Formula (2) yields that S_t is a random variable with the log-normal distribution. More precisely, for $t \geq t_0 0$, $ln\ S_{tl}$ has normal distribution with mean $ln\ S_{t0} + \mu(t - t_0)$ and variance $\sigma^2(t - t_0)$, which will we denote by:

$$\ln S_t \sim N(\ln S_{t_0} + \mu(t - t_0), \sigma^2(t - t_0))$$

Another immediate consequence of Eq. (2) is that the logarithmic returns of the prices S_t (over time lag Δ) have also normal distribution.

$$\ln \frac{S_{t+\Delta}}{S_t} = \ln S_{t+\Delta} - \ln S_t = \mu\Delta + \sigma(B_{t+\Delta} - B_t) \sim N(\mu\Delta, \sigma^2\Delta). \quad (3)$$

The fact that $\mu\Delta + \sigma(B_{t+\Delta} - B_t) \sim N(\mu\Delta, \sigma^2\Delta)$ follows from the fact that for any $t \geq 0$, $B_{t+\Delta} - B_t \sim N(0, \Delta)$.

This is not supported by empirical data, which suggests that the distribution of logarithmic returns, especially for shorter time lags , has heavy tails and thus fails to be normal (Cont, 2001). In the next subsection we test normality of daily and weekly logarithmic returns of selected companies from WIG20 index in two periods 2019 and 2020.

Normality tests for logarithmic returns

Both – Shapiro-Wilk and Jarque-Bera normality tests reject the null hypothesis about the normality of daily logarithmic returns in 2019 at 99% confidence level (p-value <0,01) for seven out of twelve companies considered, while for weekly logarithmic returns in 2019 at 99% confidence level – only for two companies considered.

This dramatically changes in 2020, where the normality of daily and weekly logarithmic returns is rejected at 99% confidence level by both tests for all but one or two companies (Cyfrowy Polsat and Eurocash for daily returns and Dino for weekly returns).

Table 1. Normality tests for daily logarithmic returns in the year 2019

Asset	Shapiro-Wilk test statistic's p-value	Jarque-Bera test statistic's p-value
KGHM	0.3343	0.7325
ORLEN	0.0024	<0.0001
LOTOS	0.1469	0.1252
MBANK	0.0237	0.0058
PEKAO	0.0160	0.0018
PZU S.A.	0.0692	0.0154
CD PROJECT	<0.0001	<0.0001
CYFROWY POLSAT	<0.0001	<0.0001
TEN SQUARE GAMES	0.0013	0.0075
EUROCASH	<0.0001	<0.0001
DINO	<0.0001	<0.0001
LPP	0.0034	0.0050

Source: Own calculations based on the stock prices of the Warsaw Stock Exchange

Table 2. Normality tests for weekly logarithmic returns in the year 2019

Asset	Shapiro-Wilk test statistic's p-value	Jarque-Bera test statistic's p-value
KGHM	0.0174	0.0255
ORLEN	0.0171	0.1873
LOTOS	0.1097	0.3173
MBANK	0.2357	0.2179
PEKAO	0.0981	0.1471
PZU S.A.	0.4211	0.5573
CD PROJECT	0.0511	0.0091
CYFROWY POLSAT	0.0331	0.0222
TEN SQUARE GAMES	0.2444	0.5121
EUROCASH	<0.0001	<0.0001
DINO	0.3263	0.4591
LPP	0.0002	0.0158

Source: Own calculations based on the stock prices of the Warsaw Stock Exchange

Table 3. Normality tests for daily logarithmic returns in the year 2020 (02.01.2020-13.11.2020)

Asset	Shapiro-Wilk test statistic's p-value	Jarque-Bera test statistic's p-value
KGHM	<0.0001	<0.0001
ORLEN	0.0009	<0.0001
LOTOS	<0.0001	<0.0001
MBANK	<0.0001	<0.0001
PEKAO	<0.0001	<0.0001
PZU S.A.	<0.0001	<0.0001
CD PROJECT	<0.0001	<0.0001
CYFROWY POLSAT	0.0133	0.0012
TEN SQUARE GAMES	<0.0001	<0.0001
EUROCASH	0.0047	0.0213
DINO	<0.0001	<0.0001
LPP	<0.0001	<0.0001

Source: Own calculations based on the stock prices of the Warsaw Stock Exchange

Table 4. Normality tests for weekly logarithmic returns in the year 2020 (02.01.2020-13.11.2020)

Asset	Shapiro-Wilk test statistic's p-value	Jarque-Bera test statistic's p-value
KGHM	<0.0001	<0.0001
ORLEN	0.0005	<0.0001
LOTOS	<0.0001	<0.0001
MBANK	<0.0001	<0.0001
PEKAO	<0.0001	<0.0001
PZU S.A.	<0.0001	<0.0001
CD PROJECT	<0.0001	<0.0001
CYFROWY POLSAT	<0.0001	<0.0001
TEN SQUARE GAMES	<0.0001	<0.0001
EUROCASH	<0.0001	<0.0001
DINO	0.0112	<0.0001
LPP	<0.0001	<0.0001

Source: Own calculations based on the stock prices of the Warsaw Stock Exchange

Merton's jump-diffusion model

Due to the limitations of the geometric Brownian motion model in modeling the distribution of logarithmic stock returns for shorter time lags , Robert Merton (Merton, 1976) enriched this model with the possibility of jumps, which occur according to a Poisson process , independent from the Brownian motion appearing in (1). The stock prices in the new model may be described by the following equation

$$S_t = S_{t_0} e^{\mu(t-t_0)+\sigma\left(B_t-B_{t_0}\right)+X_t-X_{t_0}}, \tag{4}$$

where is a compound Poisson process:

$$X_t = \Sigma_{k=0}^{N_t} Y_k \tag{5}$$

The process N_t which appears in Eq. (5) in the upper index of the summation operator is a homogeneous Poisson process with some intensity λ, independent from the Brownian motion B_t, and the variables Y_1, Y_2, appearing in Eq. (5) are independent from both processes N_t and B_t. The variables Y_1, Y_2, … model the size and direction of jumps of the process X_t which occur at random times modelled by the process N_t. The number of jumps which occur till time t is equal N_t and N_t has Poisson distribution with parameter $\lambda \cdot t$. More generally, the number of jumps which occur between times t and $t + \Delta$ is equal $N_{t+\Delta} - Nt$ and the difference $N_{t+\Delta} - Nt$ has Poisson distribution with parameter $\lambda \cdot t$.

For a general compound Poisson process one does not assume any specific distribution of the variables Y_1, Y_2, … however, Merton assumed that they are normally distributed.

The logarithmic returns in the Merton model are equal

$$\ln \frac{S_{t+\Delta}}{S_t} = \ln S_{t+\Delta} - \ln S_t = \mu\Delta + \sigma(B_{t+\Delta} - B_t) + \sum_{k=N_t+1}^{N_{t+\Delta}} Y_k. \quad (6)$$

If m and s^2 denote respectively the (common) mean and the variance of the variables Y_1, Y_2, … then the conditional distribution of $\ln \frac{S_{t+\Delta}}{S_t}$ given $N_{t+\Delta} - N_t = k$ (which occurs with probability $p_k = \frac{e^{-\lambda\cdot\Delta}(\lambda\cdot\Delta)^k}{k!}$) is normal with the mean $\mu \cdot \Delta + k \cdot m$ and variance $\sigma 2 \cdot \Delta + k \cdot s^2$. Thus, the distribution of $\ln \frac{S_{t+\Delta}}{S_t}$ is a mixture of the normal distributions: $N(\mu\cdot\Delta+k\cdot m, \sigma^2\cdot\Delta+k\cdot s^2)$, with weights .

Calibration of Merton's jump-diffusion model and the geometric Brownian motion model

To estimate the parameters of both models – that is the parameters μ and σ for the geometric Brownian motion model and parameters μ, σ, λ, m and s for Merton's jump-diffusion model we utilized the maximum likelihood approach. To distinct the parameters μ and σ in both models we will denote the parameters of the geometric Brownian motion model by μ_{gBm} and σ_{gBm} and the parameters of Merton's jump-diffusion model by $\mu_{Mj\text{-}d}$ and $\sigma_{Mj\text{-}d}$.

In the case of the geometric Brownian motion model it is possible to give explicit formulas for the maximum likelihood estimators of μ_{gBm} and σ_{gBm}. Namely, if $r_1, r_2, \dots, r_n$ are consecutive observations of the logarithmic returns then

$$\hat{\mu}_{gBm} = \bar{r} = \frac{1}{n}\sum_{i=1}^{n} r_i, \quad \hat{\sigma}_{gBm} = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(r_i - \bar{r})^2}. \tag{7}$$

In the case of Merton's model there are no explicit formulas for the maximum likelihood estimators of the model parameters. They were obtained as a result of the optimisation of the likelihood function:

$$\left(\hat{\mu}_{Mj-d}, \hat{\sigma}_{Mj-d}, \hat{\lambda}, \hat{m}, \hat{s}\right) = \arg \max_{(\mu,\sigma,\lambda,m,s)} \prod_{i=1}^{n} \left(\sum_{j=0}^{\infty} p_j \frac{\exp\left(-\frac{(r_i-\mu-j\cdot m)^2}{2(\sigma^2+j\cdot s^2)}\right)}{\sqrt{\sigma^2+j\cdot s^2}} \right). \tag{8}$$

The sum on the right side of Eq. (8) is infinite, but for shorter time lags one may assume that $\lambda \cdot \Delta \approx 0$ so the weights $p_4, p_5, \dots$ are very close to 0 and we set: if $j = 0, 1, 2$ then $p_j = \frac{e^{-\lambda \cdot \Delta}(\lambda \cdot \Delta)^k}{k!}$, $p_3 = 1 - p_0 - p_1 - p_2$ and $p_4 = p_5 = \cdots = 0$.

To maximize the likelihood function we used procedure optim available in R statistical software. Obtained estimates of parameters of two models are presented in Table 5 and 6.

Table 5. Maximum likelihood estimators for the jump-diffusion model parameters based on the data from the year 2019

Asset	$\hat{\mu}_{Mj-d}$	$\hat{\sigma}_{Mj-d}$	$\hat{\lambda}$	$\hat{m}$	$\hat{s}$
KGHM	-0.0004	0.0190	0.0874	0.0075	0.0174
ORLEN	-0.0010	0.0141	0.1326	0.0011	0.0276
LOTOS	-0.0015	0.0175	0.0968	0.0146	0.0203
MBANK	-0.0006	0.0156	0.1254	0.0022	0.0255
PEKAO	0.0014	0.0090	0.6101	-0.0026	0.0122
PZU S.A.	0.0004	0.0110	0.1019	-0.0050	0.0163
CD PROJECT	0.0023	0.0171	0.0962	0.0027	0.0379
CYFROWY POLSAT	0.0003	0.0107	0.1241	0.0044	0.0339
TEN SQUARE GAMES	0.0010	0.0231	0.1755	0.0151	0.0349
EUROCASH	0.0008	0.0216	0.9735	0.0024	0.2930
DINO	0.0016	0.0186	0.0944	0.0503	0.9099
LPP	0.0006	0.0130	0.2047	-0.0003	0.0234

Source: Own calculations based on the stock prices of the Warsaw Stock Exchange

Table 6. Maximum likelihood estimators for the geometric Brownian motion model parameters based on the data from the year 2019

Asset	$\hat{\mu}_{gBm}$	$\hat{\sigma}_{gBm}$
KGHM	0.0003	0.0198
ORLEN	-0.0007	0.0174
LOTOS	0.0000	0.0191
MBANK	-0.0003	0.0182
PEKAO	-0.0001	0.0132
PZU S.A.	-0.0001	0.0123
CD PROJECT	0.0025	0.0208
CYFROWY POLSAT	0.0010	0.0165
TEN SQUARE GAMES	0.0039	0.0281
EUROCASH	0.0011	0.0679
DINO	0.0016	0.0241
LPP	0.0005	0.0169

Source: Own calculations based on the stock prices of the Warsaw Stock Exchange

Comparison of the distributions obtained from models calibrated to pre Covid-19 pandemic data and the empirical distribution of the returns from a period which encompasses also the time of the Covid-19 pandemic.

Results of the Kolmogorov-Smirnov and Anderson-Darling tests shows that the daily returns of KGHM and the fuel companies changed significantly in 2020 compared to 2019, similarly, the daily returns of PZU and banks (insurance and banking sectors) changed significantly in 2020 compared to 2019. Daily returns for IT companies are comparable for 2019 and 2020, although the 5% or 95% quantiles differ, this means that most of the quotes were not far from the 2019 quotes, but from time to time the market was also characterized by larger fluctuations. The situation for IT is similar for Eurocash and Dino. In addition, the Merton model better fits the daily returns in 2020 (higher p-value) for Eurocash than the geometric Brownian motion model. For Dino, the Merton model also fits quite well. In other industries, a better fitting model is the geometric Brownian motion model. This would indicate the presence of frequent abrupt price changes (and this is reflected in the highest estimated λ value for Eurocash) (see table 5).

Table 7. Results of the Kolmogorov-Smirnov and Anderson-Darling goodness of fit tests of the models obtained, applied to the data from the year 2020

Asset	Jump-diffusion model, K-S statistic's p-value	Geometric Brownian motion model, K-S statistic's p-value	Jump-diffusion model, A-D statistic's p-value	Geometric Brownian motion model, A-D statistic's p-value
KGHM	0.0069	0.0107	<0.0001	<0.0001
ORLEN	<0.0001	0.0003	<0.0001	<0.0001
LOTOS	<0.0001	<0.0001	<0.0001	<0.0001
MBANK	<0.0001	0.0001	<0.0001	<0.0001
PEKAO	<0.0001	<0.0001	<0.0001	<0.0001
PZU S.A.	0.0002	0.0006	NA	<0.0001
CD PROJECT	0.0208	0.1159	0.0001	0.0003
CYFROWY POLSAT	0.0024	0.2352	<0.0001	0.0033
TEN SQUARE GAMES	0.1099	0.2370	0.0097	0.0163
EUROCASH	0.0681	<0.0001	0.0041	<0.0001
DINO	0.4849	0.8409	0.0722	0.1032
LPP	0.0004	0.0019	<0.0001	<0.0001

Source: Own calculations based on the stock prices of the Warsaw Stock Exchange

Comparing of the 5% and 95% empirical quantiles of daily returns with obtained in Jump-diffusion model and Geometric Brownian motion model shows that indeed the largest daily changes in stock prices in 2020 were often much larger than in 2019 and the models estimated based on 2019 data do not predict the possibility of such large changes (see table 8 and 9).

Table 8. Comparison of the 5% empirical quantiles of daily returns with quantiles obtained in two models considered

Asset	Jump-diffusion model, 5% quantile	Geometric Brownian motion model, 5% quantile	Empirical 5% quantile in the year 2019	Empirical 5% quantile (02.01.2020-13.11.2020)
KGHM	-0.0315	-0.0324	-0.0347	-0.0452
ORLEN	-0.0275	-0.0294	-0.0309	-0.0516
LOTOS	-0.0305	-0.0315	-0.0317	-0.0506
MBANK	-0.0285	-0.0302	-0.0300	-0.0586
PEKAO	-0.0225	-0.0220	-0.0223	-0.0494
PZU S.A.	-0.0205	-0.0204	-0.0200	-0.0410
CD PROJECT	-0.0285	-0.0317	-0.0286	-0.0510
CYFROWY POLSAT	-0.0205	-0.0262	-0.0223	-0.0377
TEN SQUARE GAMES	-0.0395	-0.0424	-0.0361	-0.0506
EUROCASH	-0.0375	-0.1107	-0.0358	-0.0531
LPP	-0.0255	-0.0273	-0.0301	-0.0554
DINO	-0.0335	-0.0382	-0.0318	-0.0461

Source: Own calculations based on the stock prices of the Warsaw Stock Exchange

Table 9. Comparison of the 95% empirical quantiles of daily returns with quantiles obtained in two models considered

Asset	Jump-diffusion model, 95% quantile	Geometric Brownian motion model, 95% quantile	Empirical 95% quantile in the year 2019	Empirical 95% quantile (02.01.2020-13.11.2020)
KGHM	0.0335	0.0329	0.0336	0.0581
ORLEN	0.0255	0.0280	0.0262	0.0471
LOTOS	0.0315	0.0314	0.0293	0.0597
MBANK	0.0285	0.0296	0.0297	0.0625
PEKAO	0.0205	0.0216	0.0185	0.0464
PZU S.A.	0.0195	0.0201	0.0194	0.0391
CD PROJECT	0.0345	0.0367	0.0300	0.0530
CYFROWY POLSAT	0.0235	0.0281	0.0232	0.0360
TEN SQUARE GAMES	0.0505	0.0501	0.0494	0.0665
EUROCASH	0.0385	0.1130	0.0374	0.0476
LPP	0.0265	0.0283	0.0287	0.0432
DINO	0.0365	0.0414	0.0414	0.0491

Source: Own calculations based on the stock prices of the Warsaw Stock Exchange

Conclusions

The results of the conducted research show that returns of companies operating in the financial sectors (banking and insurance) and fuel companies have changed the most. In the case of companies from the IT sectors as well as the food industry, most of the returns in 2020 were not far from the returns in 2019, but from time to time also here the market was characterized by greater fluctuations. For most of the analyzed sectors, a better fitting model is the geometric Brownian motion model. In the case of companies from the food sector, the Merton model gives a better or comparable geometric Brownian motion model fit. The empirical research conducted on the example of companies listed on the Warsaw Stock Exchange confirms the validity of the theses contained in the literature (Wolf and Fornaro, 2020; Loayza and Pennings, 2020; Wójcik and Ioannou, 2020; Carlsson-Szlezak, Reeves and Swartz, 2020).

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