COVID-19 SHOCK: THE SHORT-TERM IMPACT ON THE EUROPEAN AND AMERICAN FINANCIAL MARKETS

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Abstract: *The new coronavirus has very seriously shaken the behavior of global financial markets. Globally, the COVID-19 shock is considered severe, even compared to the Great Financial Crisis that took place in 2007-2008. Considering the persistence of the virus, this study is designed to investigate the short-term impact of COVID-19 upon financial markets of Europe and the United States (US) in the entire year of 2020. In the research we used daily data from the period 1st January - 31st December 2020 and linear regression. The stock markets indices selected in the sample were: European stock indices DAX30, FTSE100 and CAC40 and the American stock indices DJI and S&P500. The study's results showed that there is a significant relationship between the number of new daily cases of COVID-19 and the considered stock market indices. But there is a much stronger correlation between oil prices and stock indices than between the number of COVID-19 new cases and stock indices. We conclude that the market has been intensely agitated at a terrible level. The American, London, French and German stock markets reacted negatively to the increase in confirmed cases of COVID-19 and to the price of oil. So, the market reaction with respect to the number of COVID-19 new daily cases is significant.*

Keywords: COVID-19 pandemic, European stock indices, US stock indices, oil prices, financial markets behaviour.
JEL classification: G01, G09, G14 and G41.

1. Introduction

The coronavirus disease (COVID-19) has affected the global economy and also, has led to massive losses on international capital markets: in the period of February 24th-28th, 2020, the FTSE100 index decreased by 13%, while the S&P500 and DJIA indices decreased by 11-12%, this being the largest decrease since the financial and economic crisis of 2007-2008 (Dias et al., 2020); also, important share indexes lost about 10% of their value in only one day (on Monday, March 9th, 2020), this being the highest daily loss since the terrorist attack of September 11th, 2001. The losses were not so large, even in the well-known financial market crisis and in Lehman's bankruptcy (Daube, 2020). UK stock markets have proved that short-term health management system deficiencies imperatively impact the London stock (Shehzad et al., 2020). Capital markets tend to have an overreaction to data

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and information accessed in the short term, and sometimes, the reactions are the result of the uncertainty heard by investors during a global outbreak (Dias et al., 2020).
Considering the rapid spread of COVID-19, changes in stock prices reflect market expectations of a number of effects, including changes in final demand (people buy more from some items and less from others), changes in intermediate demand and restrictions on supply (e.g. supply chain interruptions). As a result, the economic circle around the world has been disrupted. In particular, sales of online travel agencies (Online Travel Agencies), airlines and hotels fell unexpectedly (World Economic Forum, 2020). Due to the global financial system and the unstable political climate, oil price shocks are spreading rapidly in the capital markets. The pandemic has had a very negative influence on the global economy, as well as on the social and cultural life of people (Moore and Kolencik, 2020; Thompson, 2020).
This study examines the effect of the recent pandemic disease upon the stock markets, and, in particular, the COVID-19 effect upon the main stock markets in Germany, France, the United Kingdom and the United States. The implications of our study are important for the main players of the stock market to understand and predict the behavior of stock market returns during a pandemic disease. Stock markets data are available much faster than official data on, for example, unemployment, GDP growth or government debt. Indeed, they are updated second by second, as investors react instantly to the latest events, with stock exchanges being a valuable and timely source of information.
Our aim is to investigate the impact of COVID-19 upon financial markets through stock indices in Germany (DAX30), France (CAC40), Great Britain (FTSE100) and the USA (DJI and S&P500) for the period January 1st - December 31st, 2020, using an explanatory analysis and also an econometric analysis based on 252 daily values considered for each variable. Regarding the independent variables, we used the price of crude oil WTI (WTI) and the number of new global daily cases of COVID-19 (Cov).
To the existing literature in the field, this study will be very useful for the financial sector and is a support for investors in the capital markets. This paper adds a main contribution to the literature: together with the daily increase in confirmed cases of COVID-19, the evolution of the crude oil price as an independent variable was added, because the price of oil affects asymmetrically many crude oil companies and countries and, in our days, the price of oil has a significant influence on the inflation rate and, consequently, on the prices of goods and services in worldwide economy.
The study's results showed a significant connection between the number of COVID-19 new cases and the European and American stock indices DAX30, FTSE100, DJI and S&P500. But there is a much stronger correlation between oil prices and stock indices than between the number of COVID-19 new cases and stock indices.

2. Literature review

Stock indices react very quickly to various events. Previous studies have identified several major events that have affected stock markets, for example disasters (Kowalewski and Śpiewanowski, 2020, Lee and Chen, 2020), sports (Buhagiar et al., 2018), some news (Hussain and Ben Omrane, 2020, Li, 2018), environmental events (Alsaifi et al., 2020; Guo et al., 2020) and some political events (Bash and Alsaifi, 2019; Shanaev and Ghimire, 2019).
Stock market indices may also react to pandemic diseases. For example, the epidemic of severe acute respiratory syndrome (SARS) (Chen et al., 2007, 2009) and the epidemic of Ebola virus disease (EVD) (Ichev and Marinč, 2018).
Corbet et al. (2021) examines the associations between the indices of the Chinese stock market and Bitcoin yields during the time of the COVID-19 pandemic. Analysing all the shares of the firms included in the Hang Seng Index (HIS) and Shanghai Stock Exchange Composite Index (SHCOMP) during the pandemic COVID-19 (January 10th - March 16th,

2020), Al-Awadhi et al. (2020) found that this pandemic negatively interacts with stock market returns, i.e. stock returns are significantly negative as the number of confirmed daily cases increases. Their tests suggest that despite the pandemic, some sectors of the economy performed better than others during the COVID-19 outbreak, especially in the information technology and medicine production sectors.

Based on the GARCH model, Onali (2020), investigated the COVID-19 cases for the period April 8th, 2019 - April 9th, 2020 and their impact on the US stock market, selecting DJI and S&P500 indices. Their results suggest that changes in the number of COVID-19 cases in the US and other six countries severely affected by the COVID-19 crisis do not impact US stock market returns, apart from the number of cases reported for China.

Using daily data from 20th January to 20th May 2020 and ten industry groups in the United Kingdom, Sherif (2020) found a strong and statistically significant relationship of the COVID-19 pandemic with the performance of the conventional stock market index, and that the disease interacts negatively and insignificantly with the Dow Jones faith-based ethical (Islamic) index compared to its counterpart from UK.

Ruiz Estrada et al. (2020) investigated ten stock markets (S&P500, TWSE, SHE, Nikkei 225, DAX, HIS, UK-FTSE, KRX, SGX and Malaysia) and the impact of the pandemic on their performance, considering an epidemic period of 150 days, to assess the determinants of capital market behavior in the event of an infectious disease. Their results show that the epidemic could be disastrous for the economies of all countries and could cause damage similar to the 1929 crisis on the ten stock markets analyzed. Also, Chikri et al. (2020) proved that stock market values are very sensitive to the positive and negative shocks that occurred through COVID-19, and that the financial market has negative reactions related to the evolution of the epidemic.

A negative impact on US and European stock markets generated by the spread of COVID-19 was found in the results of He et al. (2020). Although the disease spread in China has gradually stabilized, it has begun to appear in other countries. During that global spread, China's stock market suffered a blow due to the spread effect. The impact of COVID-19 on the EU and US stock markets had a decreasing effect on the Asian stock markets, especially on the stock market of China.

Khan et al. (2020) investigated the impact upon stock markets of the COVID-19 pandemic, based on efficient market theory and intertemporal asset price theory, using pooled OLS, t-test and Mann-Whitney test. They found that the main stock market indices of the countries included in the study were negatively affected by COVID-19.

Zeren and Hizarci (2020) investigated the relationships between COVID-19 deaths and the number of daily COVID-19 illnesses versus investor behavior in the stock markets of China, South Korea, Italy, France, Germany and Spain. The study shows that the number of COVID-19 deaths affected all six markets analyzed, while the number of diseases did not affect the stock markets of Italy, France and Germany. Contrary to these, Sansa (2020) showed that there is a significant relationship between COVID-19 illnesses and financial markets from China and the USA (SHE and DJI) in the period March 1st - March 25th of 2020.

Arouri and Nguyen (2010) studied the impact of changes in oil prices on European shares and found that there is a significant connection between oil prices and European capital markets. Lee and Chiou (2011) developed a two-step methodology to examine the impact of oil shocks on stock markets and found that when there are registered significant fluctuations in oil prices (WTI), these unexpected asymmetric price changes lead to negative effects on S&P500 returns, but the results are not similar when there are lower oil price fluctuations. The stock markets have a strong reaction to the COVID-19 because of its potential to upset cross-border supply chains (Baker et al., 2020). Mazur et al. (2021) investigated the US stock market performance during the March 2020 collapse triggered by COVID-19 and found that stocks of companies from sectors such as natural gas, healthcare,

food and software registered high positive returns, while stocks of the companies acting in the oil, entertainment, hospitality and real estate sectors were reducing dramatically.
So, the main questions in this paper are:
1. Do the cases of COVID-19 diseases affect the indices of the European and American stock markets (DAX30, FTSE100 and CAC40, and respectively DJI and S&P500)?
2. Does the price of oil affect the indices of the European and American stock markets (DAX30, FTSE100 and CAC40, and respectively DJI and S&P500)?

3. Data and Methodology

In this study we used as dependent variables, the rates of the European FTSE100, DAX30, CAC40, and American DJI and S&P500 stock markets indices and, as independent variables the Crude Oil Price (WTI) and the number of global new daily COVID-19 cases (Cov). The explanatory and econometric analysis was based on the data from 1st of January to 31st of December 2020, in order to investigate the short-term relation between the stock market indices and the independent variables WTI and Cov. For each variable, 252 daily values were considered. The data used in the study were collected from https://www.cnbc.com and https://www.bloomberg.com/, and the statistical package EViews was used for econometric analysis. A summary of statistics for these variables is given in Table 1.

Table 1. Descriptive statistics for variables analysed

Variable	Mean	Std. Dev.	Min.	Max.
DAX30	12303,65	1227.33	8441.71	13789.00
FTSE100	6268.58	610.77	4993.89	7674.56
CAC40	5063	544.9	3754.84	6111.24
DJI	26779.68	2485.02	18591.92	30303.36
S&P500	3201.59	311.18	2237.39	3722.47
WTI	39.35	11.31	-37.63	63.27
Cov	215082	194637.57	0	729899

Source: Authors' analysis

Examining the data shown in Table 1 we found that the average rate of CAC40 is 5063, the minimum value being 3754.84. Related to the evolution of the crude oil price (WTI), we can see that it touched an historical minimum of -37.63. This happened on the date of April 20th (Figure 1). With an initial value of 0 cases, the new daily COVID-19 cases come to a maximum value of 729899 (Figure 2), with a daily average of 215082.

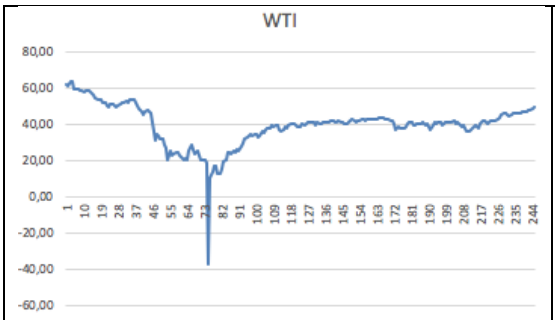


Figure 1: Evolution of the oil price for 2020
Source: Source: https://www.cnbc.com and https://www.bloomberg.com/

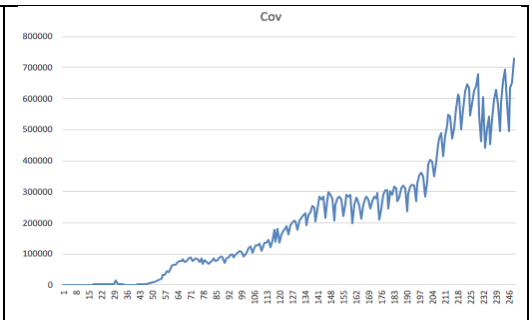


Figure 2: Evolution of the number of new daily cases of COVID-19 for 2020
Source: Source: https://www.cnbc.com and https://www.bloomberg.com/

A graphic representation of the stock indices evolution with 252 values (daily calculated starting at 1st of January until 31st of December 2020) is presented in Figure 3. As we observe, the trend is decreasing at the beginning, until April 20th, and increasing during the next eight months. This leads us to consider the possibility of a structural break in the evolution of these values.

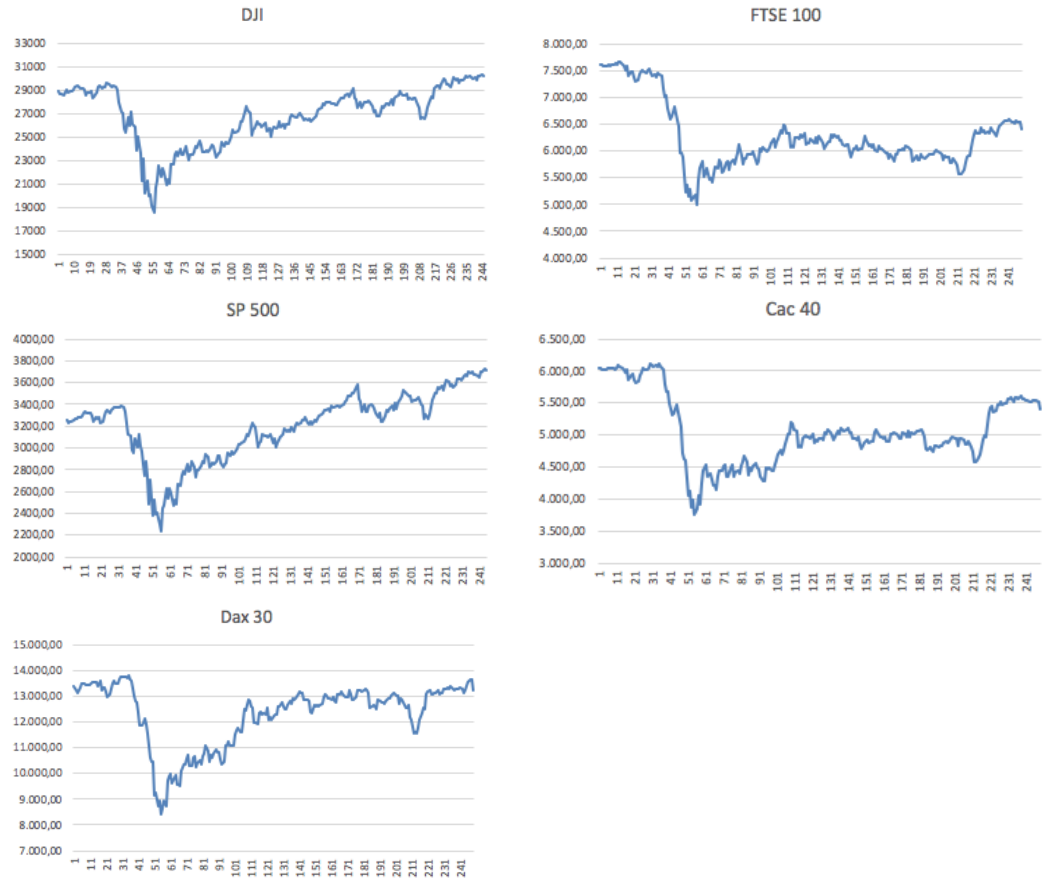


Figure 3: The indexes evolutions for the considered period
Source: https://www.cnbc.com and https://www.bloomberg.com/

In our study, we will consider three dummy variables in order to indicate the absence or presence of some categorical effect that may be expected to shift the outcome:
• the appearance of the pandemic: March 6-16 (D1);
• announcements regarding the discovery of the vaccine: November 2-9 (D2);
• consolidation of Joe Biden's victory in the US elections: November 23-24 (D3).
The selected model for examining the impact of chosen independent variables on stock market indices is multiple regression, expressed as a linear relationship:

$$y_i = \beta_1 x_{1i} + \beta_2 x_{2i} + \ldots + \beta_p x_{pi} + u_i, \quad (1)$$

where i=1,…,n, and y_i represents the values of the explained variable Y and x_{1i}, x_{2i},…,x_{pi} are the values of the independent variables X_1,…,X_p. The coefficients β_1, β_2,…, β_p are the parameters used in the regression model, and u_i are the residual variable values.

4. Results and discussions

4.1. Interpretation of the obtained results

In this section, we outlined the components of the multiple regression model, including key indicators and tests that assess the validity and quality of the associated equation. Following the creation of the group based on the previously discussed variables, we established the equation for the multiple regression model, incorporating the relevant values for each stock market index (FTSE, DAX, CAC40, DJI and S&P500) as dependent variables, and Crude Oil Price (WTI), the number of global new daily COVID-19 cases (Cov) and the dummy variables (D1, D2, D3) as independent variables, defining also the constant C, related to the effect of other external factors affecting the stock indices that were not included in this analysis. The parameter estimates in the regression model were determined using the least squares method.

The values obtained, which reflect both the coefficients of the variables in the regression model and the results from the tests, are shown in Table 2.

Table 2: Estimations results

Dependent Variable: DAX30				
Explanatory variable	Coefficient	Std. Error	t-Statistic	Prob.
WTI	80.6167	3.6023	22.3793	0.0000
Cov	-0.0019	0.0002	-7.5102	0.0000
D1	-1448.9643	248.6901	-5.8264	0.0000
D2	389.0101	209.8603	1.8537	0.0650
D3	72.9149	457.6089	0.1593	0.8735
C	8796.8073	153.2374	57.4064	0.0000
R-squared	0.737880			
Adjusted R-squared	0.732396			
Prob(F-statistic)	0.000000			

Dependent Variable: FTSE100				
Explanatory variable	Coefficient	Std. Error	t-Statistic	Prob.
WTI	41.3322	1.8949	21.8126	0.0000
Cov	-0.0014	0.0001	-10.4427	0.0000
D1	-566.9693	130.8158	-4.3341	0.0000
D2	278.6913	110.3905	2.5246	0.0122
D3	325.4571	240.7111	1.3521	0.1776
C	4926.9997	80.6058	61.1246	0.0000
R-squared	0.721169			
Adjusted R-squared	0.715126			
Prob(F-statistic)	0.000000			

Dependent Variable: CAC40				
Explanatory variable	Coefficient	Std. Error	t-Statistic	Prob.
WTI	39.2237	1.7089	22.9530	0.0000
Cov	-0.0003	0.0001	-2.9536	0.0025
D1	-437.2471	117.9746	-3.7063	0.0003
D2	181.8965	99.5544	1.8271	0.0689

D3	385.2672	217.0824	1.7748	0.0772
C	3590.1150	72.6934	49.3871	0.0000
R-squared	0.712428			
Adjusted R-squared	0.706203			
Prob(F-statistic)	0.000000			

Dependent Variable: DJI				
Explanatory variable	Coefficient	Std. Error	t-Statistic	Prob.
WTI	150.6651	6.9708	21.6139	0.0000
Cov	0.0051	0.0004	11.5345	0.0000
D1	-2342.2761	426.3921	-5.4932	0.0000
D2	268.7009	492.8633	0.5452	0.5861
D3	1020.3123	982.0743	1.0389	0.2999
C	19867.6219	294.5303	67.4553	0.0000
R-squared	0.762468			
Adjusted R-squared	0.757498			
Prob(F-statistic)	0.000000			

Dependent Variable: S&P500500				
Explanatory variable	Coefficient	Std. Error	t-Statistic	Prob.
WTI	15.1740	0.7882	19.2510	0.0000
Cov	0.0010	0.0000	19.3910	0.0000
D1	-283.2743	48.2143	-5.8753	0.0000
D2	65.9206	55.7306	1.1828	0.2380
D3	104.5966	111.0481	0.9419	0.3472
C	2411.3758	33.3040	72.4049	0.0000
R-squared	0.806322			
Adjusted R-squared	0.802270			
Prob(F-statistic)	0.000000			

Source: Authors' analysis

One key assumption of any time series model is that the underlying process remains consistent across all observations in the sample. Therefore, it is essential to thoroughly analyze time series data that includes periods of significant change, as seen in the stock indices in Figure 3. A particularly useful tool for this analysis is the Chow test. The null hypothesis for this test posits that there is no break point, meaning the data can be represented by a single regression line. We assumed there was no structural break between the first four months and the last eight months of the period. However, upon applying the Chow test, we found that the null hypothesis is rejected, indicating that the regression is not stable across the examined data sets. Due to this structural break, we will proceed to estimate the model for January 1st – April 20th (section 4.3), respectively April 21st – December 31st, 2020 (section 4.4).

4.2. An overview of the entire considered period

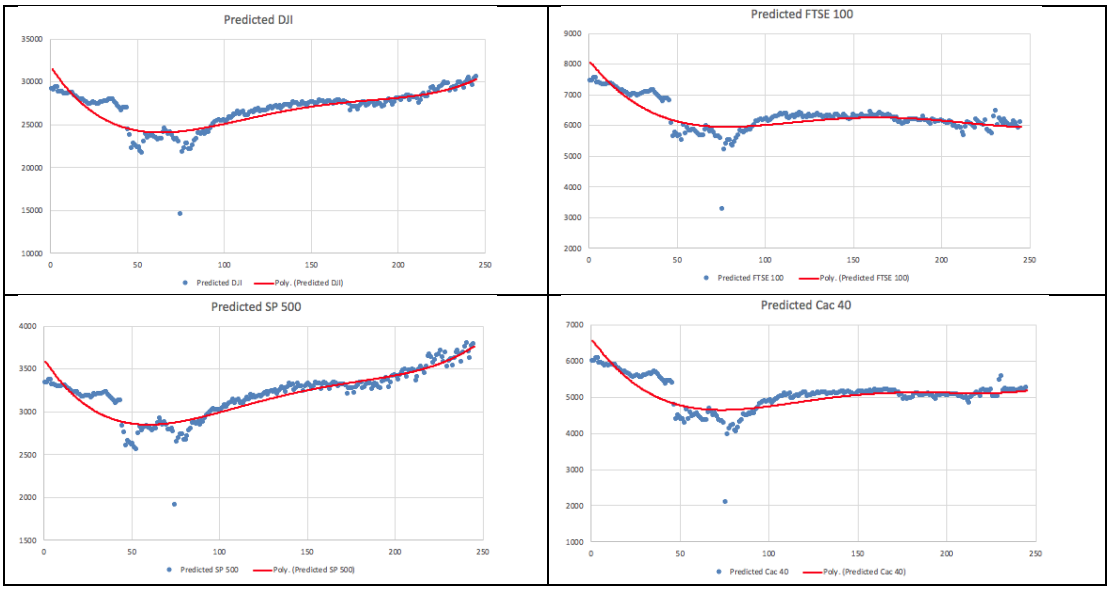
Table 2 reveals a linear relationship between each independent variable (FTSE, DAX, CAC40, DJI, and S&P500) and its explanatory factors, all statistically significant at the 1% significance level (Prob(F-statistic) = 0.000). The signs of WTI and Cov coefficients are the expected ones, the sign of WTI being positive for all the stock indices and the sign of Cov is negative in the case of European stock indices. This means that if the first component

increases, the stock market values will also increase. And if the Cov variable increases, the values of the European stock market indices will decrease. The signs of dummy variables are also those expected for all five variables, so we have mathematical confirmation that the appearance of the pandemic has led to a sharp decline in all stock indices. The presence of non-zero values of D2 and D3 leads, as expected, to an increase in the dependent variables. All these considered variables explain the level of each stock index in percentages between 71.24% (R-squared = 0.712428 for CAC40) and 80.63% (R-squared = 0.806322 for S&P500).

Thus, based on the values presented, we can conclude that the linear multiple regression model is appropriate for the correlation and the interdependence between the stock indices and the considered independent variables: WTI Crude Oil Price (WTI), the number of global new daily COVID-19 cases (Cov) and D1, D2, D3. However, as previously noted, this regression is not stable according to the Chow test. Therefore, we will divide the January-December period into two segments and analyse each part separately in the following subsections.

In Table 2, we can find the parameters estimated that measure the contribution of the independent variable to the dependent variable. Hence, the regression equations will be:

$$\begin{aligned}
DJI &= 150.66 * WTI + 0.0051 * Cov - 2342.27 * D_1 + 268.70 * D_2 + 1020.31 * D_3 \\
&\quad + 19867.62 \\
S\&P500 &= 15.17 * WTI + 0.0010 * Cov - 283.27 * D_1 + 65.92 * D_2 + 104.59 * D_3 \\
&\quad + 2411.37 \\
DAX30 &= 80.61 * WTI - 0.0019 * Cov - 1448.96 * D_1 + 389.01 * D_2 + 72.91 * D_3 \\
&\quad + 8796.80 \\
FTSE100 &= 41.33 * WTI - 0.0014 * Cov - 566.96 * D_1 + 278.69 * D_2 + 325.45 * D_3 \\
&\quad + 4926.99 \\
CAC40 &= 39.22 * WTI - 0.0003 * Cov - 437.24 * D_1 + 181.89 * D_2 + 385.26 * D_3 \\
&\quad + 3590.11
\end{aligned} \tag{2}$$



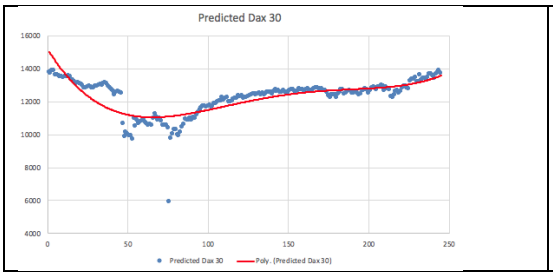


Figure 4: The graphic representations of the regression models for the year 2020
Source: Authors' analysis

As shown in Figure 4, the trend lines for the predicted stock index values do not follow a linear pattern. This observation supports the need for a separate analysis of each period January 1st – April 20th, respectively April 21st – December 31st, 2020.

4.3. The model for the January 1st – April 20th period

In Table 3 was presented the pairwise correlations of the stock indices (FTSE, DAX, CAC40, DJI and S&P500), Crude Oil Price (WTI) and the number of global new daily COVID-19 cases (Cov).

Table 3: Correlation matrixes between stock indices, oil prices and the number of cases of Covid

DJI					S&P500			
	DJI	*WTI*	*Cov*			*S&P500*	*WTI*	*Cov*
DJI	1				S&P500	1		
WTI	0,9076	1			WTI	0,8889	1	
Cov	-0,6603	-0,8408	1		Cov	-0,6408	-0,8408	1

DAX30					FTSE100			
	DAX30	*WTI*	*Cov*			*FTSE100*	*WTI*	*Cov*
DAX30	1				FTSE100	1		
WTI	0,9256	1			WTI	0,9560	1	
Cov	-0,6903	-0,8408	1		Cov	-0,7304	-0,8408	1

CAC40			
	CAC40	*WTI*	*Cov*
CAC40	1		
WTI	0,9482	1	
Cov	-0,7298	-0,8408	1

Source: Authors' analysis

We found strong correlations between the evolution of stock indices and the other two variables. Table 3 shows that there is a much stronger correlation between Crude Oil Price (WTI) and stock indices than between Cov and stock indices. Also, our calculations confirm a very close connection between the price of oil (WTI) and the evolution of the number of cases of COVID 19 (Cov), the correlation coefficient for these two variables being -0.8408.
As we can see in Figure 3, the values of all the five stock market indices considered had a downward trend between January and April. The regression model values for this period are presented in Table 4.

Table 4: Estimations results for January 1st – April 20th period

Dependent Variable: DJI				
Explanatory variable	Coefficient	Std. Error	t-Statistic	Prob.
WTI	254.2652	24.4528	10.3982	0.0000
Cov	0.0282	0.0117	2.4190	0.0182
D1	-875.7105	599.9717	-1.4596	0.0989
C	14699.4546	1315.2814	11.1759	0.0000
R-squared	0.863743			
Adjusted R-squared	0.857903			
Prob(F-statistic)	0.000000			

Dependent Variable: S&P500				
Explanatory variable	Coefficient	Std. Error	t-Statistic	Prob.
WTI	25.2955	2.7568	9.1757	0.0000
Cov	0.0028	0.0013	2.1052	0.0289
D1	-111.7313	67.6402	-1.6518	0.0830
C	1882.0809	148.2835	12.6924	0.0000
R-squared	0.835119			
Adjusted R-squared	0.828053			
Prob(F-statistic)	0.000000			

Dependent Variable: DAX30				
Explanatory variable	Coefficient	Std. Error	t-Statistic	Prob.
WTI	131.1758	11.1530	11.7615	0.0000
Cov	0.0124	0.0053	2.3107	0.0238
D1	-526.8214	306.6831	-1.7178	0.0703
C	6117.1249	596.5856	10.2536	0.0000
R-squared	0.888796			
Adjusted R-squared	0.880738			
Prob(F-statistic)	0.000000			

Dependent Variable: FTSE100				
Explanatory variable	Coefficient	Std. Error	t-Statistic	Prob.
WTI	68.5107	4.4093	15.5379	0.0000
Cov	0.0050	0.0021	2.3827	0.0199
D1	-270.7869	121.2449	-2.2334	0.0288
C	3679.9921	235.8557	15.6027	0.0000
R-squared	0.937345			
Adjusted R-squared	0.932805			
Prob(F-statistic)	0.000000			

Dependent Variable: CAC40				
Explanatory variable	Coefficient	Std. Error	t-Statistic	Prob.
WTI	57.8697	4.3310	13.3618	0.0000
Cov	0.0035	0.0021	1.6666	0.0801
D1	-278.5859	119.0919	-2.3393	0.0222
C	2783.7940	231.6675	12.0163	0.0000

R-squared	0.921547			
Adjusted R-squared	0.915862			
Prob(F-statistic)	0.000000			

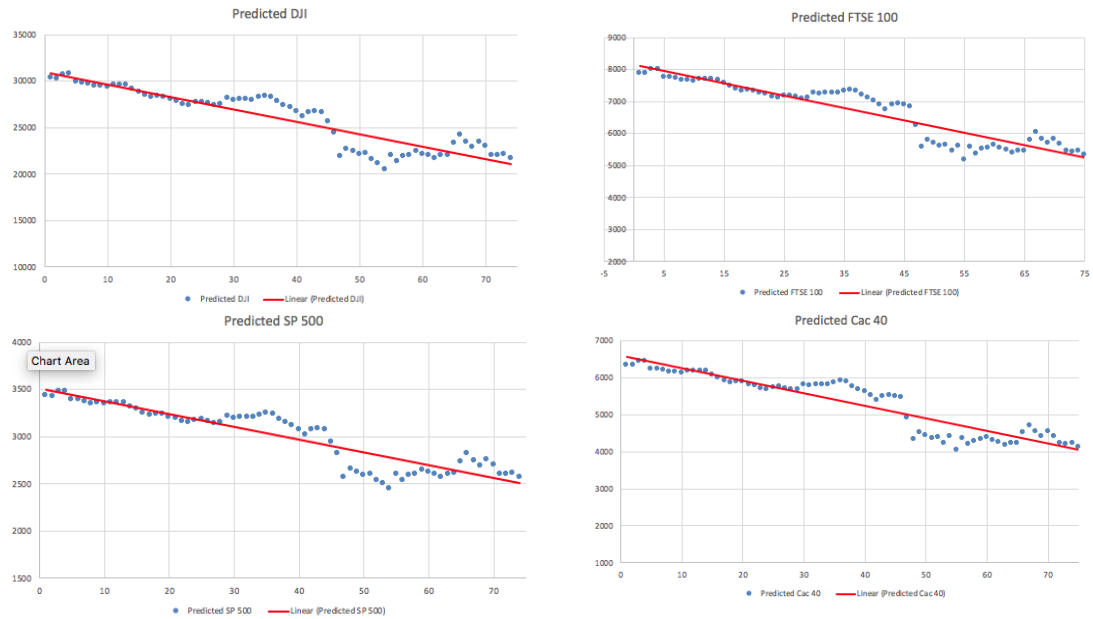
Source: Authors' analysis

Here, we present the components of the multiple regression models along with values for various indicators and tests that assess the reliability and quality of the equations associated with these models. Based on the results of these tests, we can conclude that the correlation and interdependence between the stock indices and the independent variables are effectively represented by linear multiple regression models. Also, we see here high values of R-squared, which means that the variables studied explain the level of each stock index in percentages between 83.51% (for S&P500) and 93.73% (for CAC40). The regression equation will be:

$$\begin{aligned} DJI &= 254.26 * WTI + 0.0282 * Cov - 875.71 * D_1 + 14699.45 \\ S\&P500 &= 25.29 * WTI + 0.0028 * Cov - 111.73 * D_1 + 1882.08 \\ DAX30 &= 131.17 * WTI + 0.0124 * Cov - 526.82 * D_1 + 6117.12 \\ FTSE100 &= 68.51 * WTI + 0.0050 * Cov - 270.78 * D_1 + 3679.99 \\ CAC40 &= 57.86 * WTI + 0.0035 * Cov - 278.58 * D_1 + 2783.79. \end{aligned} \quad (3)$$

We can say that an increase by one unit of WTI leads to an increase in stock indices between 25.29 units (for S&P500) and 254.26 units (for DJI). We can affirm that there was a correlation and interdependence between stock market indices and independent variables, which was also demonstrated by Sherif (2020) and Chikri et al. (2020). We also notice that the dummy variable D1 drastically influences negatively, as expected, the evolution of all stock indices.

Figure 3 illustrates the predicted stock index values based on equation (3) for 75 daily calculations from January 1 to April 20, 2020. In this figure, the trend line for each predicted index value shows a downward linear pattern.



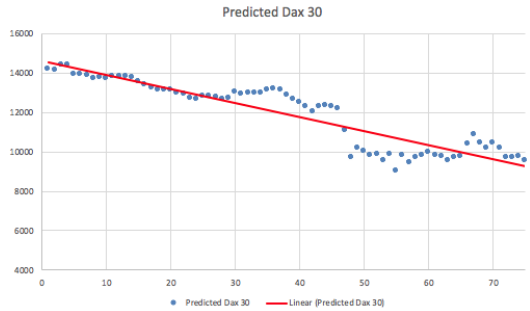


Figure 3: Graphic representations of the regression models for 1st of January until 20th of April 2020 period
Source: Authors' analysis

In order to strengthen and argue the evolution of the indices presented in Figure 3, we will give a synthesis of the events that took place worldwide between January 1st and April 20th, 2020. (Source: https://bfpg.co.uk/2020/04/covid-19-timeline and https://www.ecdc.europa.eu/en/covid-19/timeline-ecdc-response, https://www.economica.net):

- January 24th: In France was reported the first European case;
- January 28th: Germany also reported cases involving a person who visited China;
- January 30th: The initial outbreak of COVID-19 was designated a public health emergency of international concern by the World Health Organization (WHO) in 2020;
- February 22nd and in the next days: groups of cases were reported by the Italian authorities in several regions (Lombardy, Piedmont, Veneto, etc.). Over the next week, cases of COVID-19 were reported by several European countries.
- February 14th: The first coronavirus death in Europe was announced in France - a Chinese tourist of 80-year-old. This was the fourth death from the virus registered outside mainland China;
- February 24th: The Trump administration is requesting $1.25 billion from Congress for a coronavirus response, with 35 confirmed cases and no reported deaths in the US;
- March 8th: In the most affected regions, Italy issued a decree to install strict public health measures, including social distancing. On 11 March 2020, these measures were extended at national level. Then, similar public health measures were installed in Spain, France and many other European countries;
- March 11th: The US blocks travel from European countries other than the UK for 30 days, the WHO (2020) declares the virus a global pandemic and stock markets plunge;
- March 17th: France imposes a nationwide lockdown;
- April 8th: The expert opinion on the use of face masks in public by individuals who are not ill to reduce the transmission of COVID-19 was provided by the European Centre for Disease Prevention (ECDC). This opinion was translated into 26 languages;
- April 17th: US President Donald Trump announces that the US will be reopened in phases;
- April 20th: For the first time in history, oil prices fall below zero (negative) in US. The coronavirus pandemic has hit economic activity worldwide and reduced oil demand. Thus, a buyer ended up receiving money to buy oil. The WTI oil price, a benchmark for the US market, recorded a historic collapse of 305% on April 20th, 2020 and, for the first time in the history of statistics, turned negative.

4.4. The model for April 21st – December 31st 2020

We developed a multiple regression model using data from April 21 to December 31, during which stock index values showed an upward trend. This was done to assess whether the same independent variables exert a stronger influence on the stock market indices, akin to the previous model.

We will apply the same techniques mentioned earlier to analyse the specified period, and the same dependent and independent variables, measured in the statistical interval considered. Also, here are presented the dummy variables D2 representing the influence of the announcements regarding the discovery of the vaccine against COVID-19 (November 2-9), respectively D3 regarding the consolidation of Joe Biden's victory in the US elections (November 23-24).

By employing the same technique outlined earlier with EViews software, we obtained the coefficients for the model variables and the test results, which we present in Table 5. The R-squared statistic shows that between 77.42% (FTSE100) and 88.61% (S&P500) from the stock indices values is explained by the considered independent variables. Testing of the obtained models was realized by using the Fisher test, F-statistic, and its associated probability Prob(F-statistic). The econometric models of multiple regression using stock indices as dependent variables are correct and can be used in the analysis of Stock Market Index forecasts.

Table 5: Estimations results for April 21st – December 31st period

Dependent Variable: DJI				
Explanatory variable	Coefficient	Std. Error	t-Statistic	Prob.
WTI	114.2322	10.2494	11.1452	0.0000
Cov	0.0063	0.0005	13.9958	0.0000
D2	567.8065	310.0999	1.8310	0.0689
D3	1262.1687	601.9709	2.0967	0.0375
C	20910.4130	333.1148	62.7724	0.0000
R-squared	0.841437			
Adjusted R-squared	0.837593			
Prob(F-statistic)	0.000000			

Dependent Variable: S&P500				
Explanatory variable	Coefficient	Std. Error	t-Statistic	Prob.
WTI	14.6315	1.2382	11.8166	0.0000
Cov	0.0009	0.0001	16.1479	0.0000
D2	56.2838	37.4626	1.5024	0.1349
D3	103.7750	72.7230	1.4270	0.1555
C	2470.8809	40.2430	61.3990	0.0000
R-squared	0.868150			
Adjusted R-squared	0.864953			
Prob(F-statistic)	0.000000			

Dependent Variable: DAX30				
Explanatory variable	Coefficient	Std. Error	t-Statistic	Prob.
WTI	91.5969	5.2785	17.3529	0.0000
Cov	0.0008	0.0002	3.2268	0.0015
D2	53.0574	130.9241	0.1691	0.2440

D3	43.0150	270.8267	0.1588	0.8740
C	8744.4466	169.3577	51.6330	0.0000
R-squared	0.798977			
Adjusted R-squared	0.794190			
Prob(F-statistic)	0.000000			

Dependent Variable: FTSE100				
Explanatory variable	Coefficient	Std. Error	t-Statistic	Prob.
WTI	14.6731	2.7831	5.2722	0.0000
Cov	0.0002	0.0001	0.8481	0.1976
D2	84.3282	69.0313	1.2216	0.1236
D3	180.9965	142.7966	1.2675	0.1670
C	5502.1028	89.2958	61.6166	0.0000
R-squared	0.774287			
Adjusted R-squared	0.757008			
Prob(F-statistic)	0.000000			

Dependent Variable: CAC40				
Explanatory variable	Coefficient	Std. Error	t-Statistic	Prob.
WTI	20.7879	2.5232	8.2387	0.0000
Cov	0.0008	0.0001	7.2171	0.0000
D2	95.2342	62.5839	1.5217	0.1300
D3	269.5908	129.4597	2.0824	0.0388
C	3920.7866	80.9558	48.4312	0.0000
R-squared	0.785793			
Adjusted R-squared	0.778312			
Prob(F-statistic)	0.000000			

Source: Source: Authors' analysis

Therefore, based on the results of these tests, we can conclude that there is a correlation and the interdependence between the stock indices values and considered independent variables – Crude Oil Price (WTI), the number of global new daily COVID-19 cases (Cov) and the dummy D3 and D3 – is represented very well using the model of linear multiple regression. The regression equations will be:

$$\begin{aligned} DJI &= 114.23 * WTI + 0.0063 * Cov + 567.80 * D_2 + 1262.16 * D_3 + 20910.41 \\ S\&P500 &= 14.63 * WTI + 0.0009 * Cov + 56.28 * D_2 + 103.77 * D_3 + 2470.88 \\ DAX30 &= 91.59 * WTI + 0.0008 * Cov + 53.05 * D_2 + 43.01 * D_3 + 8744.44 \\ FTSE100 &= 14.67 * WTI + 0.0002 * Cov + 84.32 * D_2 + 180.99 * D_3 + 5502.10 \\ CAC40 &= 20.78 * WTI + 0.0008 * Cov + 95.23 * D_2 + 269.59 * D_3 + 3920.78 \end{aligned} \quad (4)$$

We observe that the signs of the coefficients are the same in this case. Hence, we can affirm that a growth with one unit of WTI leads to the growth of the DJI with 114.23 units and 10000 new COVID-19 cases lead to a growth of CAC40 with eight units.
An evaluation of these functions given by (4), obtained from the values of the independent variables of the analyzed period, is represented in Figure 4.

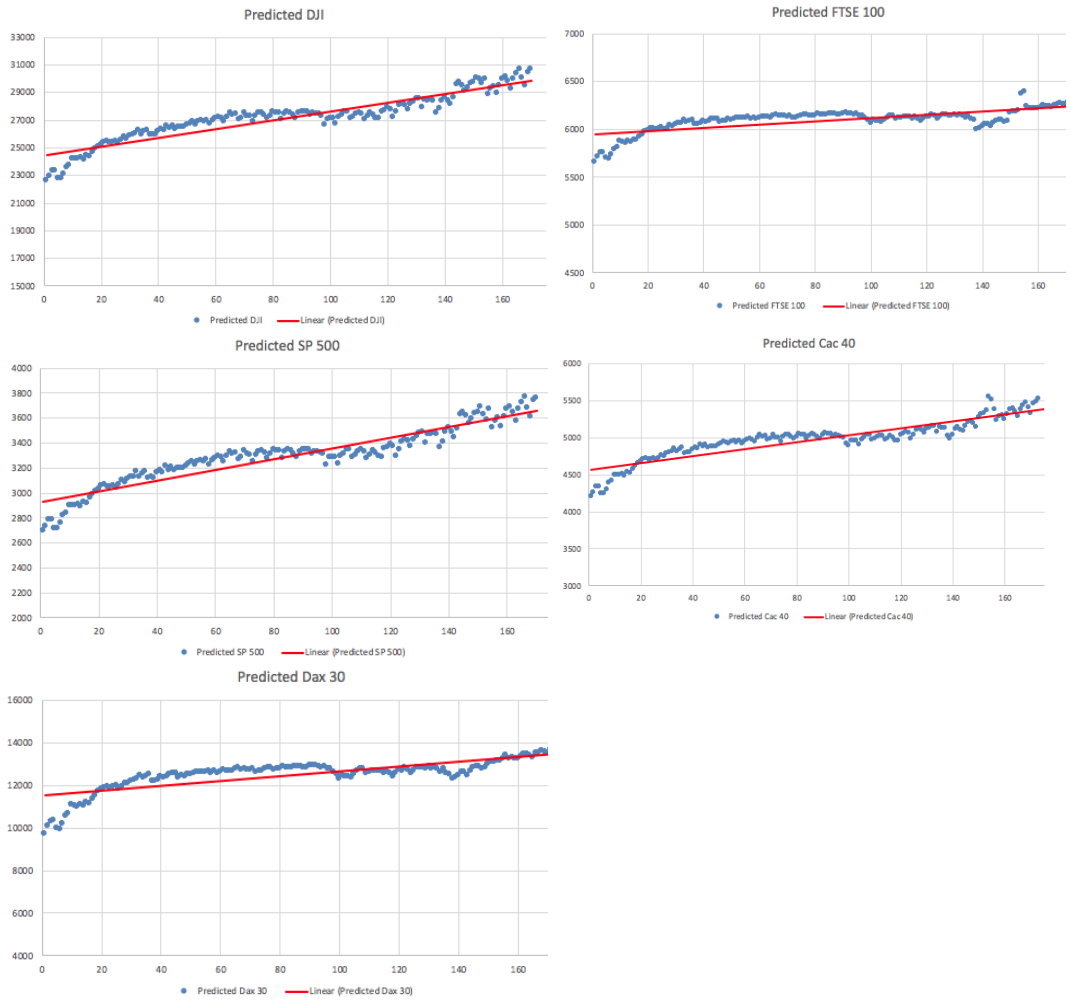


Figure 4: The graphic representation of the regression models for the April 21st –December 31st period
Source: Authors' analysis

The trend lines for predicted stock indices values are upward linear ones. Below we give the summary of events that took place worldwide between April 21st and December 31st, 2020 (Source: https://bfpg.co.uk/2020/04/covid-19-timeline and https://www.ecdc.europa.eu/en/covid-19/timeline-ecdc-response):

- April 22nd: UK human COVID-19 vaccine trials start;
- April 23rd: The United Nations Aviation agency reports that international air passenger traffic could decrease by up to 1.2 billion travelers, or two-thirds, by September 2020;
- June 17th: The European Commission introduced its strategy to expedite the development, manufacturing, and distribution of COVID-19 vaccines;
- June 29th: the number of confirmed cases of COVID-19 worldwide exceeded 10 million;
- July 24th: Cases in Europe, including France, Spain and Germany, rise sharply;

- October 19th: the number of confirmed COVID-19 cases worldwide exceeded 40 million;
- November 9th: Pfizer announces that its vaccine is 90% effective;
- November 16th: Moderna claims research shows that its vaccine is 94.5% effective;
- November 18th: New data show that the Pfizer vaccine to be 95% effective;
- December 1st: BioNTech/Pfizer and Moderna file for EU approval of the COVID-19 vaccine;
- December 30th: the number of confirmed COVID-19 cases worldwide exceeded 80 million.

5. Conclusions

With the emergence and spread of COVID-19 worldwide, uncertainty has increased. Depending on this situation, all countries were negatively affected in the first period by foreign investment outflows from stock exchanges, and the main stock market indices collapsed. COVID-19 uncertainty and related economic losses have made the market seriously volatile and impulsive.

In this study we tried to measure the impact of COVID-19 and the price of oil on the American, French, German and London stock exchanges, between January 1st, 2020 - December 31st, 2020, using the method of multiple regression.

We used, as dependent variables, the rates of the European stock indices DAX30, FTSE100 and CAC40 and the American DJI and S&P500. Regarding the independent variables, we have considered the price of crude oil (WTI) and the number of new global daily cases of COVID-19 (Cov). Also, three dummy variables (D1, D2, D3) were involved. The study used explanatory and econometric analysis based on the data from January 1st to December 31st 2020, in order to investigate the relation between the evolution of each of the five stock indices considered and those two independent variables.

Because the regression was not stable in the period analyzed, we divided the study into two periods: January 1st - April 20th, 2020 and April 21st - December 31st, 2020. Comparing the stock indices from the two periods, we conclude that all analysed indices (DJI, S&P500, DAX30, FTSE100 and CAC40) are strongly influenced by the price of oil (WTI) for both periods analysed. It is interesting to note the decrease in the impact on the evolution of stock market indices of the Cov variable. This finding leads to the idea that in the first period (January 1st - April 20th, 2020) the shock was so huge, and the countries were completely unprepared to manage the pandemic situation and the behaviour of investors on the stock markets was the same on both continents.

Starting with the second period (April 21st – December 31st, 2020), there is a comeback of stock market indices. This fact is also argued by the registration of a higher value for this period compared to the first period (January 1st – April 20th, 2020) of the constant variable C that measures the impact of other exogenous variables that influence the evolution of stock indices, variables that are not considered in this paper.

Regarding the dummy variables, D1 drastically negatively influences the evolution of the stock indices. At the opposite pole are the dummy variables D2 and D3, which positively influence the evolution of stock indices, but not with the same intensity as D1.

We conclude that the stock market was intensely agitated at a terrible level in 2020. The American, London, French and German stock markets reacted negatively to the increase in confirmed cases of COVID-19, but also to the price of oil. The market's reaction to the number of COVID-19 diseases is significant.

The main contribution of the paper to the existing literature in the field is the use of the evolution of the crude oil price as an independent variable, together with the daily increase in confirmed cases of COVID-19, because the price of oil has a significant influence on the inflation rate and, consequently, on the prices of the goods and services in worldwide

economy. Thus, the study is useful for the financial sector and is a support for investors in the capital markets.
Also, the relevance of this study for future economic and financial developments is given by the analysis of the effect of a pandemic disease on the stock markets. This paper analyzes the effect of COVID-19 on the main stock markets in Germany, France, the United Kingdom and the United States.
The results of this research are useful for the main players of the stock market, who can understand and predict the behavior of stock market returns during a pandemic disease. Stock markets data are updated second by second, and investors must react instantly to the latest events, the stock exchanges being a valuable and timely source of information, while macroeconomic official data affected by a pandemic disease, like unemployment, GDP growth or government debt, is available later.
However, there are some limitations when it comes to measuring the impact of the crisis. This study included data for only 6 stock market indices from Europe and US, and does not include small firms, non-listed firms, tertiary sector firms and even the public sector, which could be affected quite differently. This study considered only cases confirmed as COVID-19 variables and no deaths. In the future, researchers may consider other factors, in order to have a wide range of scenarios.

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