The Behavior of Stock Market Index During the Coronavirus Pandemic in Turkey

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Received: 23 November 2021; Accepted: 1 September 2022.

Summary

Recently, the coronavirus (COVID-19) pandemic has affected the economic situation all over the world. The objective of this research is to examine the effect of coronavirus spreading and vaccination rate on the stock market index in Turkey. To do that, we have applied several statistical methods, namely ridge, lasso, principal components, and partial least squares (PLS) regression versus elastic-net regression based on empirical mode decomposition, which can overcome the non-stationary problem and nonlinearity characteristics. The result of using the elastic net regression method based on empirical mode decomposition shows significant effects of coronavirus spreading on the stock market, and it varies based on the intrinsic mode function coefficients and frequencies. The findings of this research could assist practitioners and policymakers to design important strategies in the light of varying stock market dynamics during the coronavirus pandemic.

Keywords: Borsa Istanbul, Elastic-Net Regression, Coronavirus, Predictability.

JEL Classification: C22; E58; G12.

1. Introduction

Stock markets are sensitive to economic situations, policies, crises, and pandemics. Furthermore, values of stock market vary in financial markets, although they might be affected directly or indirectly by the developments of trading shares or the updating of financial indicators, whether negatively or positively.

Countries around the world have been facing an unexpected health pandemic that resulted to a black swan event worldwide at the end of 2019. The Covid-19 virus was detected in Wuhan City, Hubei Province of China in December 2019. A few weeks later, COVID-19 was declared to be a global pandemic on March 11, 2020 by the World Health Organization (WHO). Curbs to counter the transmission of the COVID-19 virus have been adopted by international and regional authorities worldwide, such as the actions of lockdowns, quarantines, transport limitations, social distancing, school closures, and postponing or cancelling mainstream events, such as the Olympic Games. Despite these efforts, the deterioration in economic and financial indicators was inevitable along with destructive and unprecedented consequences that have negative effects on the economic situation and international trading as the main backbone of economic activities. In addition, numerous restrictions in accessing borders between countries shuttered supply chains, which resulted in the slowing down of global economic activities. As a result of economic situation uncertainties and fears of the black swan event, panic prevailed among investors, industries, and companies, which distorted the usual consumption patterns with different trends in the market.

The significant contribution of this research is to use the elastic net regression method based on empirical mode decomposition to tackle the non-stationary and nonlinearity characteristics of the variables and to tackle multicollinearity problems (Abdullah S., Al-Jawarneh, Mohd Tahir Ismail, Ahmad M. Awajan, & Ahmed R. M. Alsayed, 2020) against the common methods, namely ridge and lasso regression, principal component regression (PCR), and partial least squares regression (PLS) to examine behaviors and trends of the stock market index with the infected and death cases of COVID-19 and vaccinated cases in Turkey.

This study contains the following: Section 2 illustrates the background and relevant literature reviews of the Turkish stock market, Section 3 provides details of the datasets and methods, Section 4 presents the findings, and Section 5 concludes the study.

2. Background and Literature Review

The first death case of coronavirus in Turkey was registered on March 17, 2020 by the Ministry of Health in Turkey (MHT). To date, the pandemic caused more than 50,000 deaths and more than five million confirmed cases (MHT, 2021).

Although the poverty rate has increased because of the 2018 crisis, the true extent of the impact of COVID-19 on poverty in Turkey may be much more than it was first anticipated. The Turkey's official unemployment rate hovered at 12% to 13% during the pandemic.

Policymakers have adapted some policies in responses against the COVID-19 pandemic to maintain economic activities in the second half of 2020 as follows: Turkey has begun to take fiscal, monetary, and administrative precautions to decrease the negative effects on the economy, the state, corporations, households, and individuals; and Turkey implemented notable mitigation policies to deal with the crisis, which consisted of the increased unemployment insurance benefits, social transfers, and unpaid leave subsidies amounting to a welfare shield of about $6.2 billion. These mitigation policies fostered a significant job recovery in the country. As of September 2020, the country has regained 72% of the lost jobs with the help of the Unemployment Insurance Fund, which contributed monthly allowances to approximately five million laid off employees.

First, Turkish stock market exchange is established in 1985, called the Istanbul Stock Exchange. However in 2013, Borsa Istanbul 100 was established with the merger of the Istanbul Stock Exchange, Istanbul Gold Exchange, and Futures and Options Exchanges, and thus XU100 was constructed. Through the compensation of those stock exchanges, the Borsa Istanbul has been growing positively. For example, comparing the market values of the year 2013 with 2020, the market value of Turkish lira reached to 1233 billion in June 2020, whereas it was only 505.9 billion in the year 2013. Also, a total traded value has reached Turkish lira to 2336.8 billion as of the end of June 2020, whereas it was 816.8 billion in 2013. Moreover, average traded value was at 18.8 billion as of the end of June 2020, whereas it was 3.3 billion in 2013. In addition, an increasing traded volume since May 2020 was seen in the Borsa Istanbul Stock Exchange (BIST

100) equity market. Furthermore, there are varieties of indices in BIST. However, BIST 100 is the main index, symbolized as XU100 (International Monetary Fund, 2020).

Recently, several research have been conducted to study the impact of the COVID-19 pandemic on economic situations. Ning Zhang, Aiqun Wang, Naveed-Ul Haq, and Safia Nosheen (2021) examined the stock market volatility before and during the COVID-19 pandemic in China and its association with the other developed countries using the TGARCH model. The data contained closing stock market returns for the period from January 5, 2015 to April 4, 2020. The data are divided into three parts—full, before, and during the COVID-19 pandemic. The findings show that there is no significant impact of return volatility coming from developed countries toward China's stock market during the COVID-19 pandemic, but it has a significant impact before the pandemic period. Although China has a significant impact on explaining the volatility of countries, such as Sweden, the Netherlands, and the UK, no significant impact on Switzerland's stock returns was observed, but a persistent positive leverage effect was detected, which indicates that a positive shock has less effect on Switzerland's stock returns as compared to a negative shock. This means that the good shock generates less volatility than the bad shock. Ahmed Alsayed, Tiziana Balbi, Giuseppe Gerardi, Giancarlo Manzi, and Martina Viggiano (2022) examined the economic situation in the villages during the pandemic lockdowns. Jens Klose and Peter Tillmann (2021) studied the response of financial markets to detailed data sets of policy announcements following the pandemic outbreak. They collected daily data during the working days, Mondays to Fridays, from February 17, 2020 to April 24, 2020 for 29 European countries. The dependent variables include the stock prices and bond yields, whereas the explanatory variables include the growth rate of COVID-19 cases, the policy announcements, announcements of fiscal policies at the national European level, announcements of the Federal Reserve, and Google Mobility Report data summarizing the effective lockdown. They applied the fixed effects panel data and the log differences of confirmed COVID-19 cases, as the log difference used is between days t-1 and t-2 because these are the confirmed cases real-time. Their findings show that the estimated coefficient on the growth rate of domestic cases is negative and is statistically highly significant. However, the response of bond yields is much more heterogeneous across the countries. Moreover, the markets respond to the evolution of COVID-19 cases with a drop in stock prices and an increase in government bond yields. Some measures were effective in calming financial markets. Hence, investors distinguish among policy announcements, as the effects of policies on asset prices depend on the exposure of countries to the pandemic. A country that is affected with a high growth rate of COVID-19 cases could experience an increase in bond yields on days of fiscal policy announcements, whereas the same announcements leave yields of less affected countries unchanged. Stephanie Ettmeier, Chi Hyun Kim, and Alexander Kriwoluzky (2020) studied the impact of the pandemic on corporate bond yields in main European economies. They estimated a term-structure model to obtain corporate bond yields for different maturities. The spread of COVID-19 has shown to affect long term rates, implying that the economic consequences are considered long-lasting. Policy interventions reduce the firm's refinancing conditions if they are coordinated across governments or when there is coordination between monetary and fiscal policies. In addition, several studies have approved that the environmental quality could affect economic situations (Ahmed R. M. Alsayed, Zaidi Isa, Sek Siok Kun, & Giancarlo Manzi, 2020), whereas the effect is increased during the pandemic, as the infected and death cases are influenced by environmental factors (Ahmed Alsayed, 2021).

However, there are few research that show interest in studying the behavior of stock market index in Turkey during the pandemic. Güneysu, Yusuf. (2022), Faheem Aslam, Paulo Ferreira, Khurrum Shahzad Mughal and Beenish Bashir (2020) studied the volatility spillover among 12 European stock markets during the period from December 2019 to May 2020. They applied the Diebold and Yilmaz (2012) measurement by using the static and rolling windows to characterize 5-minute volatility spillovers. The main findings supported that 77.80% of intraday volatility forecast error variance in 12 European markets comes from spillovers. Faheem Aslam, Yasir Tariq Mohmand, Paulo Ferreira, Bilal Ahmed Memon, Maaz Khan & Mrestyal Khan (2020) examined the effects of COVID-19 on 56 global stock indices during the period from October 2019 to August 2020 by using a complex network method. The results show that the structural change in the form of node changes reduced the connectivity and significant differences in the topological characteristics of the network because of COVID-19. Erhan Mugaloglu, Ali Yavuz Polat, Hasan Tekin, & Edanur Kılıç (2021) measured the economic uncertainty in Turkey by using the principal component analysis and structural vector autoregressions (SVAR) for the novel economic uncertainty index before and during the COVID-19 pandemic in Turkey for data spanning from January 2011 to July 2020. The findings supported that the uncertainty was rising to extremely high levels during the outbreak, and the SVAR output implied significant decline in economic activities in Turkey. Özcan Öztürk, Muhammet Yunus Şişman, H. Uslu, & F. Çıtak

(2020) examined the effects of the daily COVID-19 confirmed cases with the Turkish stock market as a dependent variable by applying the fixed-effect panel data model during the period from January 2, 2020 to April 15, 2020. At a sectoral level, other sectors of stock exchange markets were considered in the analysis as control variables, namely the Turkey's daily credit default swap, volatility index, and Chicago board options exchange. The main findings revealed that the number of COVID-19 cases has significantly affected all sectors in Turkey at different levels. Ahmed Alsayed (2022) investigated the effects of coronavirus epidemic on the stock market, foreigner exchange rate, and credit default swap in Turkey by applying the developed machine-learning algorithm. The results supported the existence of the significant effect of the coronavirus spreading on the Turkish stock market index. Mustafa Tevfik Kartal, Özer Depren, & Serpil Kilic Depren (2020) examined the causes of the main stock exchange index changes in Turkey during the COVID-19 period. They included 14 variables categorized as follows: three at the global level, six at the country level, and five at the market level by performing two machine-learning algorithms, namely the random forest and support vector machine for the daily data between February 1, 2020 and May 15, 2020, considering two periods in the analysis—pre- and during pandemic. The findings illustrated that the support vector machine outperformed the random forest technique in estimating the models in both pre-pandemic and pandemic periods, as the estimated model showed a significant role for most of the variables in the study including the volatility index and credit default swap spreads.

On the other hand, using advance statistics techniques could provide significant information to have a clear idea of the effects; Philip Arestis, Hüseyin Şen, and Ayşe Kaya (2021) assessed the comparative effectiveness of both monetary and fiscal policy on the growth in Turkey by applying the Autoregressive Distributed Lag cointegration technique. The finding shows that both monetary and fiscal policies are effective in promoting output growth but with different levels. Ahmed Alsayed and Giancarlo Manzi (2019) applied the developed Monotonic Dependence Coefficient to detect the behavior of GDP growth. Ahmed R. M. Alsayed, Zaidi Isa, & Sek Siok Kun (2018) applied various advanced diagnostic outlier's methods to detect the extreme values of economic growth and energy consumptions in developed countries. Zaidi Isa, Ahmed R. M. Alsayed, & Sek Siok Kun (2017) applied an inversed function regression to minimize the error term of the estimation model. Ahmed Alsayed and Giancarlo Manzi (2018) used several robust estimators to tackle the changing the heterogeneity of GDP per capita during the economic crisis. Zaidi Isa, Ahmed R. M. Alsayed, & Sek Siok Kun (2015) applied the fixed effect model to control the variation of energy consumption at various economic level in selected developing countries. Paulo Ferreira (2017) studied the integration of the stock market between Brazil and Portugal by applying the non-linear statistical methods; detrended moving-average cross-correlation analysis, detrended fluctuation analysis, and detrended cross-correlation analysis, while the data is split into six different periods. The study concluded that the integration of the stock market between these two countries increased over time, but it has decreased in 2013.

3. Materials and Methods

3.1. Data

The data is collected from the beginning of the pandemic in Turkey on March 11, 2020, until July 9, 2021, for several variables; the number of daily confirmed cases, total cases, death cases, and vaccinated cases which are obtained from the Republic of Turkey Ministry of Health (MHT, 2021). Although the dataset of the stock market index (XU100) is extracted from the Central Bank of the Republic of Turkey (Central Bank of the Republic of Turkey, 2021). We have considered the changing of the stock market values by removing the two zeros from the index in July 2020 (Daily Sabah, 2020), more details about the XU100 are attached in the appendix.

Figure 1 shows that the XU100 index declined sharply at the beginning of the pandemic, then it started to increase slowly in early April 2020. Moreover, Figure 2 shows the daily new cases per million, total deaths per million, new deaths per million, and total vaccinations per hundred. From Figure 2, clearly you can note that the number of new cases in Turkey is stable from the beginning of the pandemic until December 2020, then it increased sharply. Figures 1 and 2 suggest that stock market prices are negatively related to new daily confirmed cases caused by Covid-19, as the stock market prices started to decline during the increase of the confirmed cases (early of April 2020, early of December 2020, early of April 2021). In addition, Table 1 provides a descriptive statistic for all variables in this research. We can note that the output of the Robust Jarque-Bera test, which is used to check the normality, indicates significant results which mean that the data are not normally distributed for all variables.

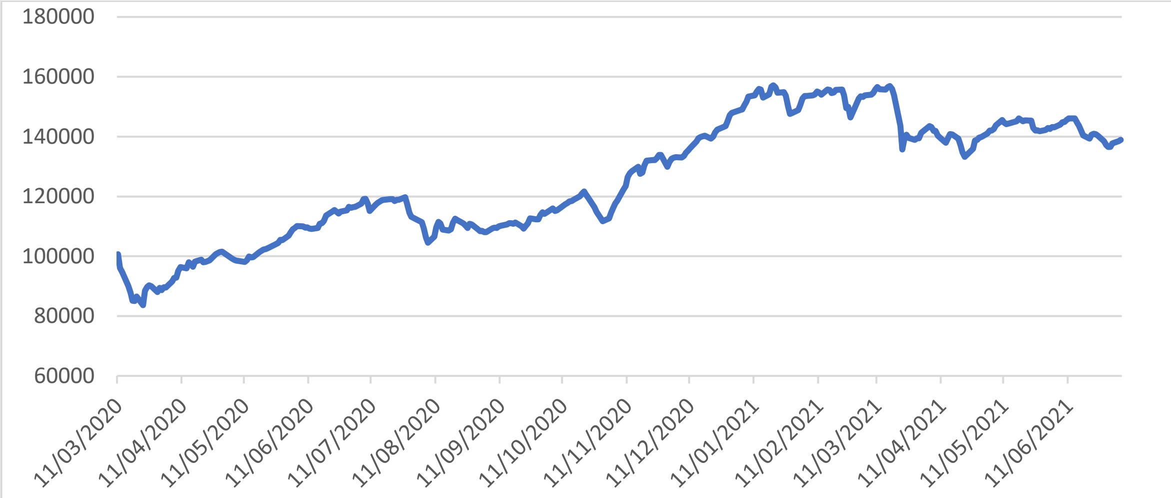


Figure 1 Turkish Stock Market Trend XU100

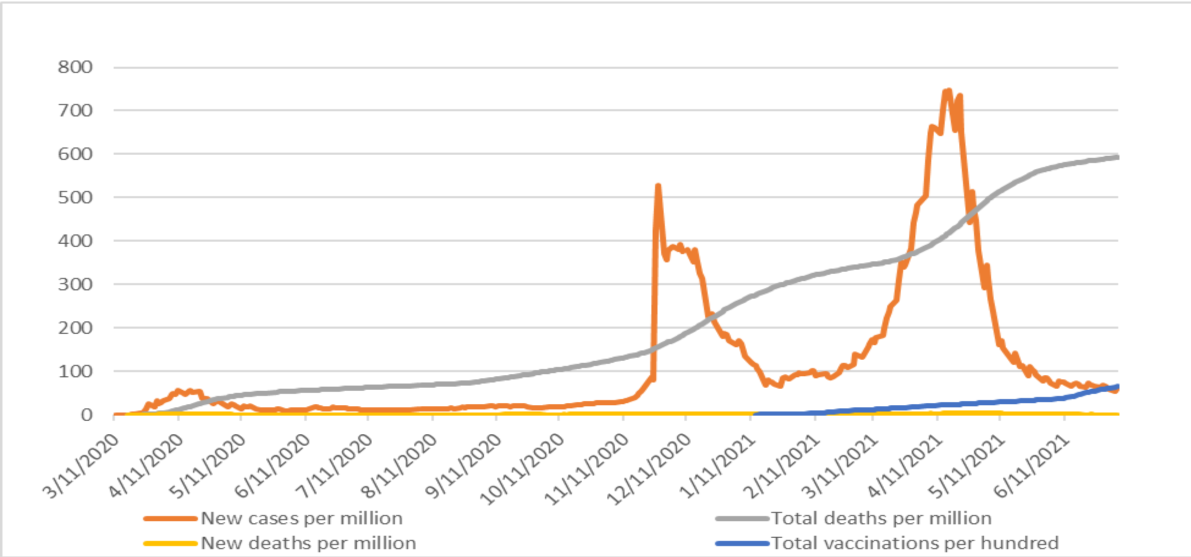


Figure 2 The Trend of Covid-19 Pandemic Cases in Turkey

Table 1 Descriptive Statistics.

Variable	XU100	Total cases per million	New cases per million	Total deaths per million	New deaths per million	Vaccinations per hundred*
Mean	125808.06	20079.63	116.03	215.90	1.23	22.93
Median	122295.00	4705.19	48.67	132.15	0.88	21.45
Standard Dev.	20127.21	22152.10	163.73	183.49	1.03	17.07
Kurtosis	-1.20	-0.74	4.26	-0.78	0.82	-0.30
Skewness	-0.11	0.85	2.17	0.73	1.21	0.65
Minimum	83645.10	0.01	0.00	0.01	0.00	0.33
Maximum	157140.00	64676.59	747.96	592.80	4.67	65.22
Count	329	329	328	325	325	119
Robust JB-test	18.53**	41.72**	35.22**	28.89**	160.03**	7.84**

* The vaccination in Turkey is started on 14th January 2021. ** Significant level at less than 0.05 regard to Jarque-Bera (JB) test which implies that all series are not normally distributed.

Source: Authors' calculations

3.2. Statistical Methods

In this study, we apply shrinkage methods and dimension reduction methods because they are the most suitable techniques to handle the multicollinearity and heterogeneity issue by controlling the variance either by shrinking their coefficients toward zero or by using a subset of the original variables (Gareth James, Daniela Witten, Trevor Hastie, & Robert Tibshirani, 2013). In addition to that, we apply the elastic-net regression based on empirical mode decomposition which could tackle the multicollinearity and nonstationary problems (Al-Jawarneh, Ismail, Awajan, & Alsayed, 2020).

Firstly, we apply two well-known shrinkage methods, namely, ridge regression and lasso regression which stands for least absolute shrinkage and selection operator. These techniques shrink the less contribution of regression coefficients towards zero. The shrinking method estimates the coefficients of the model but not the intercept, with minimizing their variance by applying a tuning parameter (lambda $\lambda \geq 0$). The increase in λ lead to a decrease in Mean Square Error (MSE) which helps to improve the prediction accuracy, but the bias is slightly increasing. However, the best λ is determined by cross-validation where the MSE is the smallest. In addition, ridge regression includes all predictors in the final model, as it shrinks all of the coefficients towards zero but not exactly to zero, while the lasso regression filters the predictors and eliminates the less relevant predictors by performing variable selection, it sets some of the estimated coefficients to exactly zero when the tuning parameter λ is sufficiently large. As λ value increases, the estimation of coefficients shrinks toward zero and forces to become zero for unimportant estimated coefficients (i.e., as $\lambda \rightarrow \infty$, nonzero coefficients $\rightarrow 0$) (James, Witten, Hastie, & Tibshirani, 2013).

The OLS estimation minimize the sum of squares as the following:

$$\hat{\beta}_{ols} = argmin_{\beta} \, \|\boldsymbol{y} - \hat{\boldsymbol{y}}\|^2 \qquad (1)$$

However, $\hat{\beta}_{\text{ridge}}$ and , $\hat{\beta}_{\text{lasso}}$ are chosen to minimize the penalized sum of squares as the following:

$$\sum_{i=1}^{n}(y_i - \beta_0 \sum_{j=1}^{p} \beta_j \; x_{ij})^2 + \lambda \sum_{j=1}^{p} \beta_j^2 \qquad (2)$$

$$\sum_{i=1}^{n}(y_i - \beta_0 \sum_{j=1}^{p} \beta_j \; x_{ij})^2 + \lambda \sum_{j=1}^{p} \left|\beta_j\right| \qquad (3)$$

Secondly, we apply dimension reduction methods called as the following: principal components regression (PCR) and partial least squares (PLS). These techniques aim to reduce the dimension of data to decline the variance of the estimated coefficients. These approaches work in two stages. First, transform the predictors, then the model is estimated for M predictors by using least squares estimation. PCR involves the construction of the first M principal components, then using these components as the predictors in the model by using the least squares. PCR performs well if the first M principal components are sufficient to capture most of the variability in the predictors, and the explicit relationship with the response variable. Including more principal components in the estimating model could result to an increase in the variance, but the bias is decreasing. On the other hand, PLS identifies a new set of components M in a supervised way that are linear combinations of the original features, then estimating the model by least squares. PLS sets the highest weight on the variables that are most strongly related to the response. PLS, instead of finding hyperplanes of maximum variance between the response and explanatory variables, finds a linear regression model by projecting the predicted variables and the observable variables to a new space (James, Witten, Hastie, & Tibshirani, 2013).

Thirdly, we apply the developed method, namely elastic-net (EN) regression approach based on empirical mode decomposition (EMD) algorithm (Al-Jawarneh, Ismail, Awajan, & Alsayed, 2020). EN estimation is a penalized least-squared estimator that includes two penalties, namely, L_1 penalty and L_2 penalty.

$$\hat{\beta}_{elestic} = (1 + \lambda_2)\left[argmin_{\,\beta}\|\boldsymbol{y} - \hat{\boldsymbol{y}}\|^2 + \lambda_1 \; \|\beta\| + \lambda_2 \; \|\beta\|^2\right] \qquad (4)$$

where parameters λ_1 and λ_2 are tuning parameters and positive numeric values.

Whereas, the EMD decomposes the nonstationary and nonlinear data into a finite set of linearly independent components called intrinsic mode functions (IMFs) (Norden E. Huang et al. 1998).

$$x_t = \sum_{i=1}^{n} IMF_{i,t} + \varepsilon_{n,t} \quad (5)$$

Where n represent the number of IMF, i represents the number of component, $\varepsilon_{n,t}$ represents the residual component.

The following equation shows the interested model of stock market index in this study

$$Ln(XU100)_t = \alpha + \beta_1 N.C.m_t + \beta_2 T.C.m_t + \beta_3 T.D.m_t + \beta_4 N.D.m_t + \beta_5 T.V.h_t + \varepsilon_t \quad (6)$$

where *ln XU100* represents the natural logarithm of the stock market index at day *t* in Turkey, *N.C.m* is the daily new confirmed cases per million caused by Covid-19, *T.C.m* is total cases per million, *T.D.m* is total death cases per million, *N.D.m* is new death cases per million, *T.V.h* is total vaccinated cases per hundred, and ε_t is the error term.

3.3. The Process of Analysis

The process of modelling the effects of the Covid-19 pandemic on the XU100 index in Turkey in this research is constructed as shown in Figure 3. Before performing the analysis, the standardization for each predictor and the response variable is made to ensure that all variables are on the same scale. In addition, to validate the estimated models, the dataset is divided into 70% for training data, and 30% for test data. Besides, the stationarity of data is checked by using the Augmented Dickey-Fuller and KPSS test. The best tuning parameters λ and M are determined by the cross-validation (C.V.) technique where the MSE is the smallest in the training data. Next step, we use the selected tuning parameters to predict values corresponding to the test dataset. Then, all estimated models for test data are compared based on the goodness of fit criteria. Final step is to estimate the models using those five methods by using the correspond selected tuning parameter for the whole dataset.

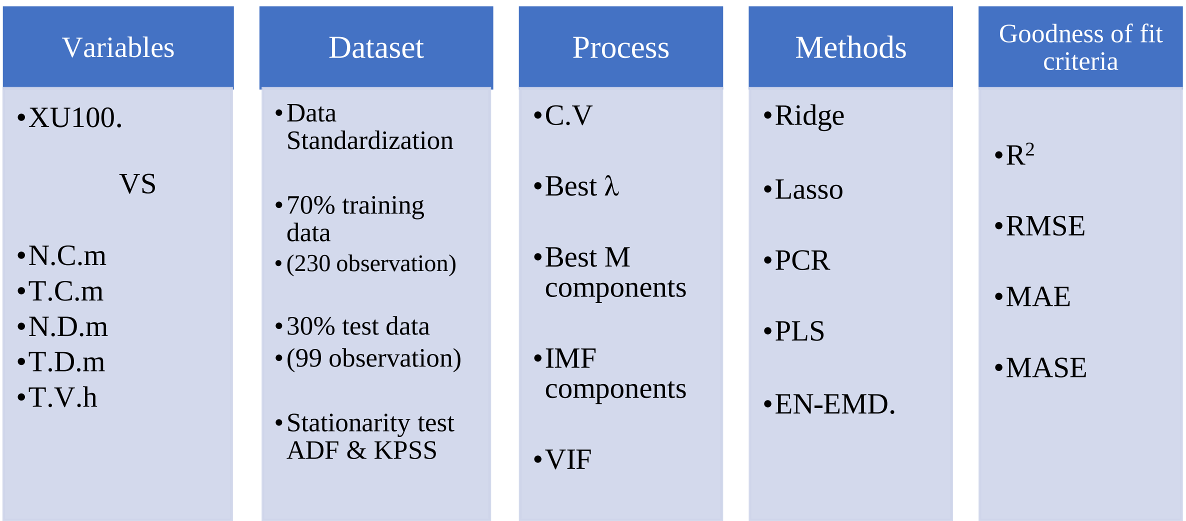
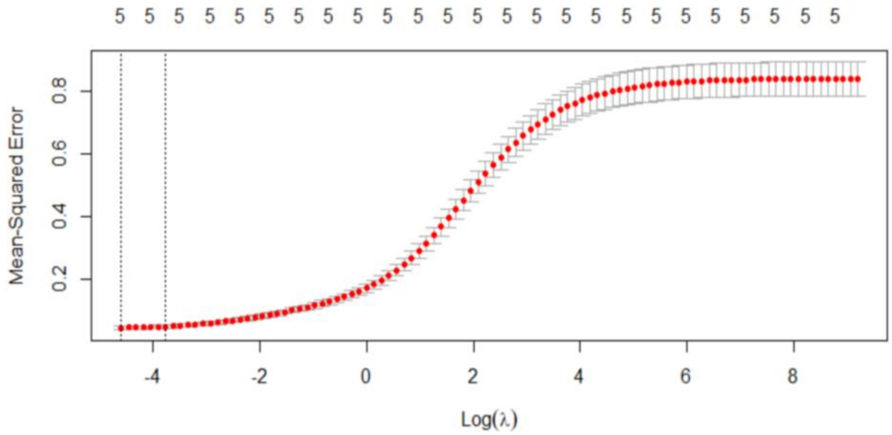


Figure 3 Flow Chart of the Analysis Process

4. Results and Discussion

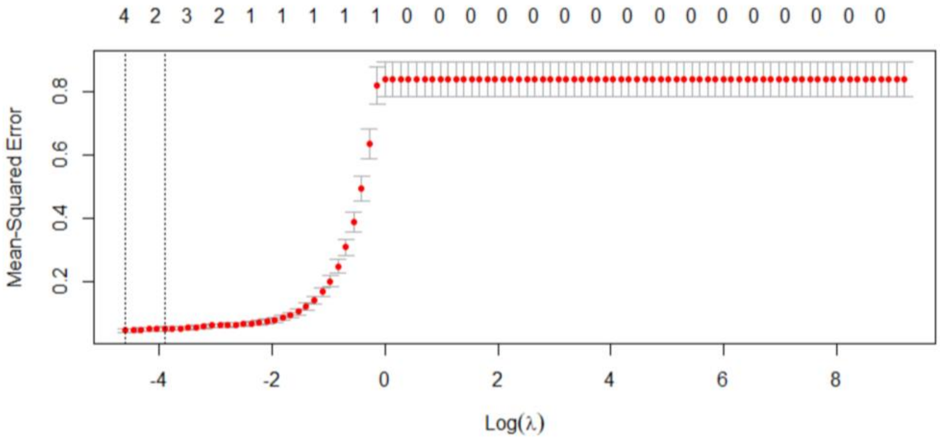
Firstly, the results of the C.V. technique of the training dataset which is used to select the best parameter value of λ where it minimizes the MSE for ridge and lasso regression are shown in Figure 4 and Figure 5, respectively. MSE values are in the red line of different values for the natural logarithms of λ at the lower horizontal axis, while the upper horizontal axis reports the corresponding number of non-zero estimated coefficients. Further, the leftmost vertical dashed-line corresponds to the minimum λ, while the rightmost vertical dashed-line indicates the λ for the first standard deviation of the MSE. The best λ value which makes the minimum of MSE is achieved for ridge regression at 0.014, while for lasso regression at 0.433.

In addition to that, Figure 6 and Figure 7 illustrate the C.V. technique which is used to select the best number of M components where it minimizes the MSEP for PCR and PLS. The minimum MSEP for PCR and PLS is found at the 5th component equal to 0.2098 and 0.2096, respectively. The blue lines show the component with the lowest MSEP with the corresponding component.



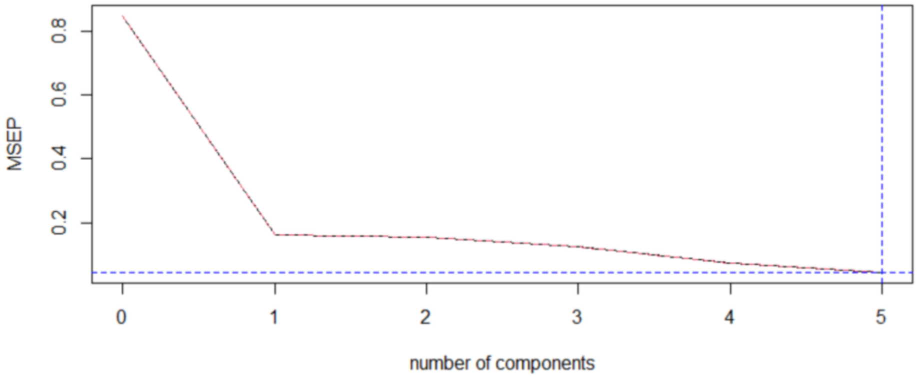
Source: Authors' calculations

Figure 4. Cross-Validation Technique for Ridge Model



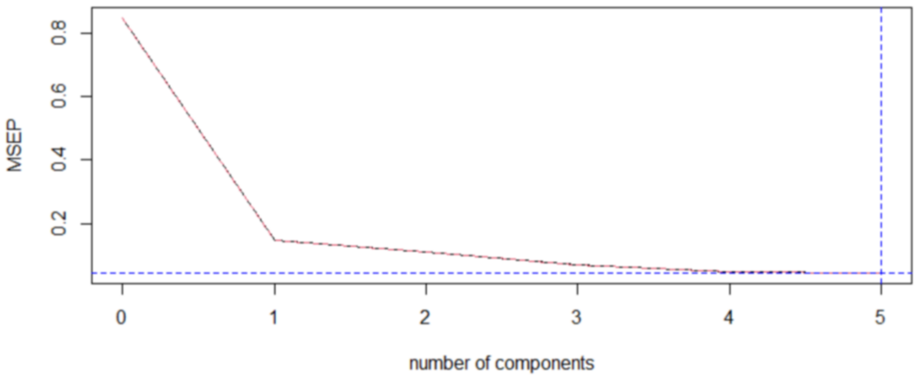
Source: Authors' calculations

Figure 5 Cross-Validation Technique for Lasso Model



Source: Authors' calculations

Figure 6 The Number of Component Principal Component Regression



Source: Authors' calculations

Figure 7 The Number of Component Partial Least Squares Regression

Moreover, Table 2 illustrates the goodness of fit criteria for the performance of the applied methods; RMSE, R^2, and MAE. The results show that the lasso regression has the smallest error value in terms of RMSE and MAE, but not the highest value of R^2. However, OLS, PCR, and PLS have similar values of criteria performance as no dimension reduction occurs by PCR and PLS, so the results do not suggest removing any variable from the final estimated model. Although lasso regression estimation outperforms other methods, the results, by using the estimation of the whole data, provide that the variable of *total cases per million* is not significant towards the changing of XU100, so it shrunk to zero and removed from the model as shown in Table 3.

However, *new cases per million* and *total death per million* have a positive significant impact on the XU100 index, the *new death per million* and *total vaccinated cases per hundred* have a negative impact on the values of the XU100 index. This finding could be interpreted as the registration of the *new cases* was very low until the declaration by the Turkish Health Ministry on November 24, 2020. As the declaration illustrates that the recording of the *new cases* to include the outpatients with the inpatients. Additionally, daily death cases from Covid-19 were recorded in low number in Turkey after November 24, 2020 because the Turkish Health Ministry excluded the number of Covid-19 patients who died during the hospitalized period if they have a negative test, from the daily Covid-19 death cases (MHT, 2021). The finding of our empirical study is in line with the studies of Mustafa Tevfik Kartal, Özer Depren, and Serpil Kilic Depren (2020), and Faheem Aslam, Paulo Ferreira, Khurrum Shahzad Mughal and Beenish Bashir (2020). While the study of Özcan Öztürk, Muhammet Yunus Şişman, H. Uslu, and F. Çıtak (2020) show that the Covid-19 pandemic has a negative impact on almost all economic sectors.

Table 2 The Accuracy of the Estimated Models by Using Test Data-99 observations.

Criteria	OLS	Ridge	Lasso	PCR	PLS
R^2	0.401	0.389	0.386	0.401	0.401
RMSE	5.868	4.807	**3.385**	5.868	5.868
MAE	4.914	4.003	**2.799**	4.914	4.914

Source: Authors' calculations

Table 3 The Estimated Coefficients Using the Whole Dataset-329 observations

Coefficients	OLS	Ridge	Lasso	PCR	PLS
Intercept	-1.479	---	---	---	---
β_1	-0.115	0.04	---	-0.816	-0.816
β_2	0.136	0.09	0.05	0.099	0.099
β_3	2.405	1.71	1.78	2.594	2.594
β_4	-0.233	-0.17	-0.13	-0.148	-0.148
β_5	-4.377	-1.06	-1.08	-1.083	-1.083

Where β_1, β_2, β_3, β_4, & β_5, indices to the *total cases per million, new cases per million, total death per million, new death per million, total vaccinated cases per hundred,* respectively.
Source: Authors' calculations

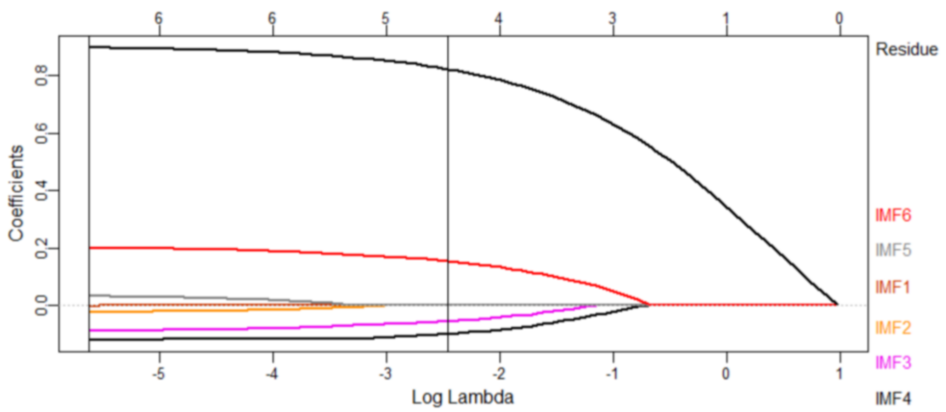
Furthermore, by applying the statistical stationarity test of the *Augmented Dickey-Fuller* and *KPSS test* for all variables, the results show that the *new cases per million* is nonstationary as it does not have a constantly changing rate over time. In addition, the time-series data of the stock market index often have an autocorrelation. For that reason, we apply the developed EMD-EN approach. The result of the analysis shows that the new cases variable decomposed into seven components of IMFs, then we test the multicollinearity by using VIF as shown in Table 4. The test supports that there is no multicollinearity among all constructed IMFs and residue components as all components have values of VIF less than 10. Along with, Figure 8 provides the relationship between the log (λ) and the estimated coefficients by EMD-EN. We can note clearly that the residue component has greater significant effects on XU100 than the other IMFs.

On the other hand, Table 5 provides the estimated coefficients of the IMFs and residual components and the goodness of fit; RMSE, R^2, MAE, and MASE which prove the accuracy of the estimated model by EMD-EN. The results show that EMD-EN has a high R^2 value of 0.892, which indicates that the estimated model by EMD-EN has high reliability and prediction accuracy. Interestingly, the first four high frequencies of IMFs coefficients gradually affect the XU100 negatively but IMF_5 and IMF_6 affect it positively and relatively higher than that in the first four high frequencies of IMFs.

Table 4 Results of Variance Inflation Factors Multicollinearity Test

IMF1	IMF2	IMF3	IMF4	IMF5	IMF6	Residue
1.68	1.93	1.46	1.86	1.18	1.33	1.45

Source: Authors' calculations



Source: Authors' calculations

Figure 8 Coefficients Estimation by EMD-EN Model at Alpha 0.34.

Table 5 Estimated Coefficients for the IMF Components and Goodness of Fit Criteria.

Components	Coefficients	Criteria	Value
IMF_1	-0.002	RMSE	0.329
IMF_2	-0.024	MAE	0.270
IMF_3	-0.089	MAPE	0.385
IMF_4	-0.119	MASE	4.979
IMF_5	0.032	R^2	0.892
IMF_6	0.199		
Residue	0.897		

Source: Authors' calculations

5. Conclusion

The coronavirus pandemic has serious effects on financial markets. This research examined the impacts of the coronavirus pandemic on the stock market index in Turkey by applying several statistics techniques; ridge and lasso regression, principal component regression, partial least squares regression, and elastic-net regression based on empirical mode decomposition, using data over the period from March 11, 2020 until July 9, 2021. The findings show that the lasso estimation model outperformed other methods in terms of RMSE and MAE. However, Covid-19 factors such as *new cases per million* and *total death cases per million* have a positive significant impact on the XU100 index, while the *new death per million* and *total vaccinated cases per hundred* have a negative impact on the XU100 index.

In conclusion, from this study, some recommendations could be implemented. Investors and policymakers should pay attention to the economic issues besides the Covid-19 factors to improve and encourage investment in the Turkish market. Policy makers should give priority to the most important variables to sustain certainty in the financial market. Even though the overall economic impacts of the Covid-19 pandemic are complicated to be fully modelled, further research incorporating new significant information is important to provide solid policy implications for investors and decision-makers.

Conflicts of Interest: no conflict of interest.
Funding: no grant or funding for this research.

Authorship contribution statement; all authors work together.

Consent for publication: The authors are willing to permit the Journal to publish the article.

Availability of data and materials: The used data of this study are available in Bloomberg website and the Central Bank of Republic of Turkey at https://evds2.tcmb.gov.tr/index.php?/evds/serieMarket and Turkish Ministry of Health at https://covid19.saglik.gov.tr.

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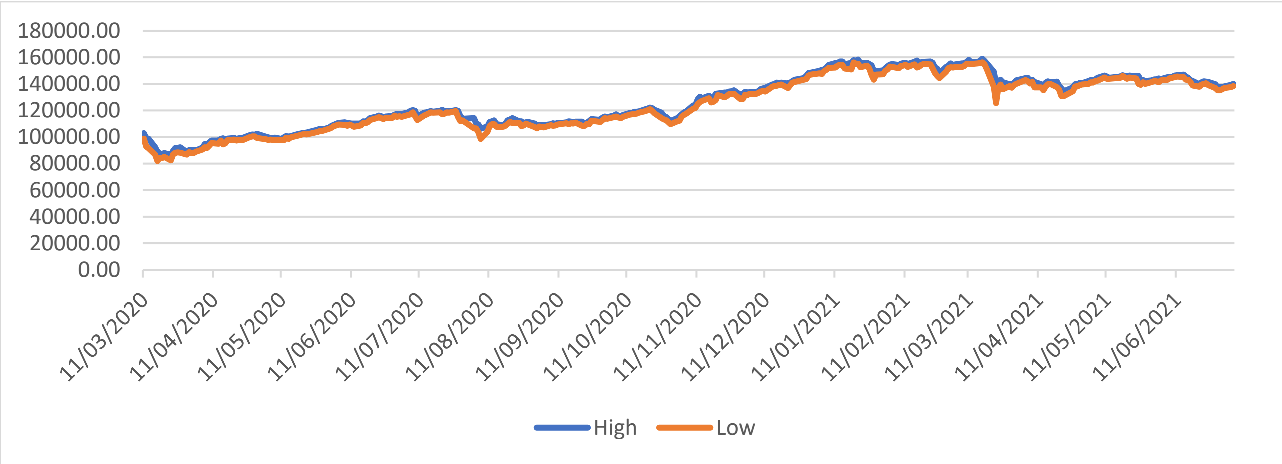
Appendix

Table A1 Descriptive Statistics of the Lowest and Highest Value of the Stock Market Prices During The Period of The Study

	XU100	Low	High
Mean	125808.06	18182.84	17968.05
Median	122295.00	123530.00	121120
Standard Dev.	20127.21	20141.47	20065.01
Kurtosis	-1.20	-1.229176	-1.16491
Skewness	-0.11	-0.09588	1.031754
Minimum	83645.10	86587.20	81936.4
Maximum	157140.00	158950.00	156210
Count	329	329	329

Source: Authors' calculations



Source: Authors' calculations

Figure A1 Turkish Stock Market Trend for the XU100 Lowest and Highest Value of the Stock Market Prices During The Period of The Study

Table A2 Augmented Dickey-Fuller and KPSS stationary tests for the Variables at level

Variable	ADF	P-value	KPSS	P-value
total cases per million	-1.305	0.75	1.88	0.01
new cases per million	-1.593	0.12	1.91	0.01
total death per million	-1.601	0.23	2.01	0.01
new death per million	-1.217	0.34	1.79	0.02
total vaccinated per hundred	-1.353	0.79	2.14	0.01

*The results shows nonstationary trend for all variables.