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# RESEARCH ARTICLE

## Analyzing COVID-19 outbreak for Turkey and Eight Country with Curve Estimation Models, Box-Jenkins (ARIMA), Brown Linear Exponential Smoothing Method, Autoregressive Distributed Lag (ARDL) and SEIR Models

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## Türkiye ve Sekiz Ülke (G8) için COVID-19 salgınının Eğri Tahmini Modelleri, Box-Jenkins (ARIMA), Brown Doğrusal Üstel Düzeltme Yöntemi, Gecikmesi Dağıtılmış Otoregresif (ARDL) ve SEIR Modelleri ile analizi

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**Öz**

**Amaç:** Bu çalışma, COVID-19 salgınının Türkiye, Almanya, Birleşik Krallık, Fransa, İtalya, Rusya, Kanada ve Japonya gibi belirli ülkelerde yayılması konusunda toplulukları ve hükümetleri bilgilendirmek için yapılmıştır.

**Gereç ve Yöntem:** Bu amaçla, seçilen ülkeler için 100. vakadan sonra 19.07.2020'ye kadar olan COVID-19 salgını sayıları Eğri Tahmin Modelleri, Box-Jenkins (ARIMA), Brown Doğrusal Üstel Düzeltme Yöntemi, Otoregresif Dağılımlı Lag (ARDL) ve SEIR Modelleri kullanılarak tahmin edilmiştir.

**Bulgular:** Oluşturulan ARDL ve SEIR modellerinin değerlendirmelerinde, Fransa ve İtalya'nın pandemik büyüme oranlarının yüksek olduğu; Kanada düşük pandemik büyüme oranına sahipken. Ayrıca pandeminin dönüm noktasının 72. günde gerçekleştiğini gözlemledi. Salgında bir değişiklik olmazsa ve hükümetler aynı stratejilerle devam ederse, salgının 2020 Ekim ayı başlarında (21 Eylül - 10 Kasım arası) yeniden başlayacağı ve ortalama 155 gün (145-168 gün arası) etkili olacağı tahmin ediliyor.

**Öneri:** Gözlemlenen ve tahmin edilen günlük kümülatif yeni vakaların tutarlı olduğu görülmektedir. Sonuç olarak, bu çalışmada kullanılan modellerin G8 ülkesinde ve Türkiye'de COVID-19 salgınını iyi karakterize ettiği söylenebilir.

**Anahtar kelimeler:** COVID-19, Eğri kestirimi modelleri, ARIMA, Üstel Düzgünleştirme yöntemleri, ARDL, SEIR, Box-Jenkins Modelleri

**Abstract**

**Aim:** This study is conducted to inform communities and governments about the spread of the COVID-19 pandemic in selected countries: Turkey, Germany, the United Kingdom, France, Italy, Russian, Canada, and Japan.

**Materials and Methods:** For this purpose, the numbers of the COVID-19 epidemic after the 100th case up to 7/19/2020 for selected countries have been estimated by using Curve Estimation Models, Box-Jenkins (ARIMA), Brown Linear Exponential Smoothing Method, Autoregressive Distributed Lag (ARDL) and SEIR Models.

**Results:** In the evaluations of the ARDL and SEIR models established, it is determined that France and Italy have high pandemic growth rates; while Canada has a low pandemic growth rate. It has also observed that the turning point of the pandemic occurred on the 72nd day. If there is no change in the outbreak and governments continue with the same strategies, it is predicted that the epidemic will begin again in early October 2020 (from September 21 to November 10) and will be effective for an average of 155 days (between 145 and 168 days). It is seen that the observed and predicted daily cumulative new cases are consistent.

**Conclusion:** As a result, it can be said that the models used in this study well-characterized outbreak of the COVID-19 in the eight major Western countries and Turkey.

**Keywords:** COVID-19, Curve Estimation Models, ARIMA, Exponential Smoothing Methods, ARDL, SEIR, Box-Jenkins Models

## Introduction

Coronavirus disease 2019 named COVID-19 by the World Health Organization (WHO) was first reported in Wuhan, China, in December 2019. It has spread to more than 190 countries around the world and is declared a worldwide pandemic by WHO (WHO 2020). COVID-19 has posed a major threat to global public health as it can cause the death of people, especially for those with chronic diseases and the elderly.

Epidemiological studies have shown that this virus is transmitted from human to human (Huang et al 2020). For this reason, the countries exposed to COVID-19 have taken several measures such as curfew, obligation to wear a mask, isolation, etc. to prevent the spread of this outbreak, and these measures have different effects. By modelling the COVID-19 spread situations of these countries, it can be helped with which policy about the measures countries should follow. Thus, various studies have been conducted using different mathematical and economic models to estimate or predict the probable evolution of this pandemic.

Yonar and Tekindal (2020) estimated and forecasted the number of COVID-19 epidemic cases of the selected G-8 countries and Turkey with the data between 1/22/2020 and 3/22/2020 by using the curve estimation models, Box-Jenkins (ARIMA) and Brown/Holt linear exponential smoothing methods. Benvenuto et al. (2020) used the Auto-Regressive Integrated Moving Average (ARIMA) model prediction on the Johns Hopkins epidemiological data, which were collected from the official website of Johns Hopkins University, to predict the epidemiological trend of the prevalence and incidence of COVID-2019. Zhang et al. (2020) estimated the reproductive number of COVID-19 in the early stage of the outbreak on the ship. Also, they made a prediction of daily new cases for the next ten days by using the "early R" and "projections" packages in R. Fanelli and Piazza (2020) analyzed the temporal dynamics of the coronavirus disease 2019 outbreak in China, Italy, and France in the time window 01/22/2020–03/15/2020 by utilizing the susceptible- infected-recovered-deaths (SIRD) model.

This study is presented to inform communities and governments about the spread of COVID-19 pandemic in selected G8 countries: Germany, the United Kingdom, France, Italy, Russian, Canada, Japan, and Turkey. The countries which are considered here have been selected due to their strong economies and high living standard. The United States is excluded from the study because it has a very different attitude from the other countries during the pandemic. We also selected Turkey to evaluate the progress of the pandemic with together other countries. For this purpose, the number of the COVID-19 epidemic course after the 100th case up to 7/19/2020 has been estimated by using curve estimation models, the Box-Jenkins (ARIMA) and Brown Linear Exponential Smoothing Method, Autoregressive Distributed Lag (ARDL) and finally SEIR.

The rest of the paper is organized as follows. In Section 2, the data is introduced and curve estimation models, the Box-Jenkins (ARIMA), Brown Linear Exponential Smoothing Method, ARDL and finally SEIR models are explained. In Section 3, results are given. Finally, the conclusions are presented in Section 4.

## Material and Methods

### *Data set*

The data in this study sets involve the number of positive COVID-19 pandemic cases after 100th case up to 7/19/2020 in selected G-8 countries: Turkey Germany, United Kingdom, France, Italy, Russia, Canada and Japan (JHU 2020).

In this study, the data is modelled via some curve estimation models to estimate the number of positive COVID-19 cases. Then, the forecasts of the COVID-19 positive cases are made by using the Box-Jenkins (ARIMA), Brown linear exponential smoothing methods and ARDL models. Besides, the evaluation of cases is discussed by using the SEIR model separately for each country.

The analyses are conducted by IBM Corp. Released 2017. IBM SPSS Statistics for Windows, Version 25.0. Armonk, NY: IBM Corp, RStudio Team (2015). RStudio: Integrated Development for R. RStudio, Inc., Boston, and EViews Illustrated for Version 8 Copyright © 1994–2013 IHS Global Inc. (Griffiths et al 2008).

### *Curve Estimation Models*

Some curve estimation models:

linear $\hat{y} = b_0 + b_1 x$

logarithmic $\hat{y} = b_0 + (b_1 Ln\,(x))$

inverse $\hat{y} = b_0 + \left(\frac{b_1}{x}\right)$

quadratic $\hat{y} = b_0 + b_1 x + b_{11} x^2$

cubic $\hat{y} = b_0 + b_1 x + b_{11} x^2 + b_{111} x^3$

are used to model the considered data. The best model structure is determined by using the coefficient of determination (R squared ($R^2$)) of the models (Farebrother 1976, Robinson 1988, Akın et al 2020a).

*Auto-Regressive Integrated Moving-Average (ARIMA)*

ARIMA is the essential aspect of the Box-Jenkins method and examines the autoregressive time series, which has a moving average (Akın et al 2020b, Çevrimli 2020, Öztemiz 2020) This method is preferred to examine the non-stationary time series. ARIMA model selection depends on the nature of the considering data among the various model options (Tekindal et al 2016, Arıkan et al 2018, Özen 2019, Yonar et al 2020) The expression of ARIMA (p, d, q) model can be defined as follows:

$$Y_t = \phi_1 Y_{t-1} + \phi_2 Y_{t-2} + \cdots + \phi_p Y_{t-p} + \alpha_1 - \theta_1\alpha_{t-1} - \alpha_2 - \theta_2\alpha_{t-2} - \cdots - \alpha_q - \theta_q\alpha_{t-q} \quad (1)$$

Here: $\phi_p$ are the parameter values for autoregressive operator, $\alpha_q$ are the error term coefficient, $\theta_q$ are the parameter values for moving average operator, $Y_t$ is the time series of the original series differenced at the degree d (Brockwell et al 2002, Gujarati and Porter 2003, Yenice and Tekindal 2015, Yonar et al 2020).

*Brown Linear Exponential Smoothing Method*

This model is a special case of Holt linear exponential smoothing method and is used for prediction in time series. This procedure depends on choosing the coefficients of the curve and also trend, which are the smoothing parameters that are equal (Tekindal et al 2019).

In this method, estimates are obtained using the equations below (Kaymaz 2018, Ateş 2020).

$$Y'_t = \alpha Y_t + (1-\alpha)(Y'_{t-1}) \quad (2)$$

$$Y''_t = \alpha Y'_t + (1-\alpha)(Y''_{t-1}) \quad (3)$$

$$a_t = Y'_t + (Y'_t - Y''_t) = 2Y'_t - Y''_t \quad (4)$$

$$b_t = \frac{\alpha}{1-\alpha}(Y'_t - Y''_t) \quad (5)$$

$$\hat{Y}_{t+m} = a_t + b_t m \quad (6)$$

where $\alpha$ is the smoothing constant in the range of [0,1] (Yonar et al 2020, Akın et al 2020b)

*Autoregressive Distributed-Lag (ARDL) models*

Autoregressive Distributed Lag (ARDL) models, which introduced by (Pesaran and Shin 1998) and developed by (Pesaran et al 2001), include lags of both the dependent variable and independent variables.
ARDL concept has been developed to eliminate the problem caused by the inability to perform cointegration analysis in time series with different degrees of stationarity and has been used to explain the dynamic (autoregressive) relationship between variables.

This model is used to examine the existence of relationships in the long and short term by eliminating the differences occurring in the stationary degrees of the series.

With the ARDL, regardless of whether the series is stationary at the level or first difference, the cointegration relationship between the series can be examined, and it also gives good results when the number of observations is low (Narayan and Narayan 2004, Pesaran et al 2001)

The ADRL consists of two stages. In the first stage, whether there is a long-run relationship between the series in the study is tested. In the second stage, short and long-run parameter estimates are examined. The reason why the ARDL is very popular is that it gives very consistent results in the analyzes of short and long series, regardless of stationarity.
ARDL is based on OLS and can be used in small and large samples. ARDL approach, with the use of Unrestricted Error Correction Model (UECM), provides more reliable results in the short and long term compared to the Engle-Granger causality analysis test and Johansen - Engle-Granger causality analysis (Palamalai and Kalaivani 2013).

The ARDL cointegration model is as follows,

$$y_t = \delta + \beta_1 y_{t-1} + \cdots + \beta_q y_{t-p} + \alpha_0 x_t + \alpha_1 x_{t-1} + \cdots + \alpha_q x_{t-q} + \varepsilon_t \quad (7)$$

or

$$y_t = \delta + \sum_{i=1}^{p} \beta_i y_{t-i} + \sum_{i=0}^{q} \alpha_j x_{t-q} + \varepsilon_t \quad (8)$$

Here; *p* denotes the lag on *y* and *q* denotes the lag on *x*.

Application stages of the ARDL test respectively (Huang et al 2020)

Step 1. Stationarity of variables is tested by using unit root tests. The purpose of this is to test whether the stationarity levels of the series are I.

Step 2. A model based on the Unrestricted Vector Autoregressive (VAR) is installed. By choosing the lowest value of Akaike (AIC) and Schwarz Information Criteria (SIC), the most appropriate lag length is detected for ARDL model.

Step 3. The F statistic is compared with the table value for the cointegration relation determination, and it is tested as given; if F statistic value is higher than the upper limit, the basic hypothesis, which states that there is no cointegration relation, is rejected, and if this value is less than the lower limit, the basic hypothesis cannot be rejected.

Step 4. If the basic hypothesis is rejected and it is concluded that there is cointegration, ARDL short-run and long-run (UECM) comments are made in this stage.

*SEIR Model*

Susceptible-Exposed-Infectious-Recovered (SEIR) model, which is originated by Kermack and McKendrick in the early 20th century, is a kind of compartmental model and provides a basic model for the research of different kinds of the epidemic (Kermack and McKendrick 1927).

The model has four elements which are called as Susceptible(S), Exposed(E), Infectious(I) and Recovered(R). Susceptible (S) is represented the individuals in the entire population; Exposed (E) is the number of individuals who contact Infectious(I) but they are in the incubation period; Infectious(I) is the number of individuals with infections, and Recovered(R) is the number of recovered from the infected individuals (Zhou and Cui 2011).

An SEIR model is evaluated in two parts. The first part is the transmission dynamic, which is including population inputs, basic reproductive number ($R_0$), and transmission time. Population inputs (size of population and number of initial infections), basic reproductive number ($R_0$) and transmission times (length of the incubation period, duration patient is infectious) are the dynamics of the model, and the calculations of these are based on differential equations for *S(t)*, *E(t)*, *I(t)* and *R(t)* are given,

$$dS(t)/dt = -\beta S\, I/N \quad (9)$$

$$dE(t)/dt = \beta S\, I/N - \kappa E \quad (10)$$

$$dI(t)/dt = \kappa E - \curlyvee I \quad (11)$$

$$dR(t)/dt = \curlyvee I \quad (12)$$

$$N(t)=S(t)+E(t)+I(t)+R(t) \quad (13)$$

where, $\beta$,$\kappa$ and $\curlyvee$ are the provides transition each other the compartments (Roda et al 2020). These parameters are determined through Effective Basic Reproduction Number ($R_t$) and basic Reproduction number ($R_0$), which is the number of secondary infections each infected individual produces. They represent the proportion of a specific population with respect to the total population and given as follows (Diaz et al 2018, Legrand et al 2007):

$$\beta = R_t/(Duration\ patient\ is\ infectious) \quad (14)$$

$$\kappa = 1/(Length\ of\ incubation\ period) \quad (15)$$

$$\curlyvee = 1/(Duration\ patient\ is\ infectious) \quad (16)$$

The second part of the SEIR model includes Clinical Dynamics, which are Mortality Statistics, Recovery Times, and Care Statistics. Mortality Statistics are the Case fatality rate and time from the end of incubation to death. Recovery Times are the length of hospital stays and recovery time for mild cases. Care statistics are hospitalization rates and time to hospitalization. For detailed information about all these Transmission and Clinical Dynamics parameter, values of the epidemic used in Table 4, see Epidemic Calculator (available: gabgoh.github.io/COVID), which is introduced by Gabriel Goh and also (WHO 2020, JHU 2020).

**Results**

Firstly, curve estimation models are examined to model the data included the number of positive COVID-19 cases, and the results are given in Table 1. According to the results, Cubic estimation models are determined as the best model with the highest $R^2$ for all countries. Furthermore, curve estimation graphs given in Fig.1 also supports these results.

The forecasts of the COVID-19 positive cases are made by using the Box-Jenkins (ARIMA) and Brown linear exponential smoothing methods. The results of the analyzed have been given in Table 2 with the model fit statistics and p values. ARIMA models have been determined separately for each country except for France and Canada, as seen in Table 2. Brown Linear Exponential Smoothing Method models are also preferred for France and Canada. In addition, the graphs of ARIMA and Brown linear exponential smoothing models are given in Fig.2 for each country.

Autoregressive Distributed Lag Bound Test (ARDL) approach for cointegration is used for short-term modelling in the presence of structural breakage and the most suitable models are determined as shown in Table 3. In addition, the graphs of ARDL models are given in Fig.3 for each country.

The evaluation of cases is also discussed by using the SEIR model separately for each country. The parameters of the dynamics model for Covid-19 cases are given in Table 4. Moreover, the graphs of SEIR models are given in Fig. 4 for each country. For detailed information about all these Transmission and Clinical Dynamics parameter, values of the epidemic used in Table 4, gabgoh.github.io/COVID, which is introduced by Gabriel Goh and also (WHO 2020, JHU 2020).

Table 1. Model summary and parameter estimates of countries

| Dependent Variable | Equation | Model Summary and Parameter Estimates | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Model Summary | | | | | Parameter Estimates | | | |
| | | $R^2$ | F | df1 | df2 | p | Constant | $\beta_1$ | $\beta_2$ | $\beta_3$ |
| TURKEY | Linear | 0.926 | 2241.150 | 1 | 178 | 0.001 | -49290.939 | 1533.786 | | |
| | Logarithmic | 0.604 | 271.601 | 1 | 178 | 0.001 | -196308.485 | 67851.853 | | |
| | Inverse | 0.086 | 16.750 | 1 | 178 | 0.001 | 98181.362 | -270162.348 | | |
| | Quadratic | 0.939 | 1362.088 | 2 | 177 | 0.001 | -28184.069 | 837.956 | 3.844 | |
| | Cubic | 0.981 | 3006.912 | 3 | 176 | 0.001 | 18163.499 | -2192.911 | 45.591 | -0.154 |
| GERMANY | Linear | 0.891 | 1453.810 | 1 | 178 | 0.001 | -28964.193 | 1512.021 | | |
| | Logarithmic | 0.689 | 394.690 | 1 | 178 | 0.001 | -199024.702 | 72854.411 | | |
| | Inverse | 0.117 | 23.504 | 1 | 178 | 0.001 | 118017.154 | -316270.793 | | |
| | Quadratic | 0.907 | 867.285 | 2 | 177 | 0.001 | -53264.523 | 2313.131 | -4.426 | |
| | Cubic | 0.959 | 1382.539 | 3 | 176 | 0.001 | -1399.898 | -1078.519 | 42.290 | -0.172 |
| UNITED KINGDOM | Linear | 0.925 | 2204.175 | 1 | 178 | 0.001 | -65383.083 | 2217.559 | | |
| | Logarithmic | 0.627 | 298.818 | 1 | 178 | 0.001 | -285860.300 | 99980.370 | | |
| | Inverse | 0.093 | 18.181 | 1 | 178 | 0.001 | 148317.634 | -405702.799 | | |
| | Quadratic | 0.928 | 1138.617 | 2 | 177 | 0.001 | -51491.902 | 1759.607 | 2.530 | |
| | Cubic | 0.989 | 5043.933 | 3 | 176 | 0.001 | 29186.747 | -3516.315 | 75.200 | -0.268 |
| FRANCE | Linear | 0.892 | 1470.068 | 1 | 178 | 0.001 | -35152.922 | 1584.027 | | |
| | Logarithmic | 0.666 | 355.361 | 1 | 178 | 0.001 | -207730.234 | 74998.822 | | |
| | Inverse | 0.109 | 21.667 | 1 | 178 | 0.001 | 118444.929 | -319388.690 | | |
| | Quadratic | 0.899 | 791.781 | 2 | 177 | 0.001 | -52277.397 | 2148.570 | -3.119 | |
| | Cubic | 0.958 | 1353.079 | 3 | 176 | 0.001 | 5616.824 | -1637.381 | 49.029 | -0.192 |
| ITALY | Linear | 0.893 | 1480.828 | 1 | 178 | 0.001 | -29419.360 | 1846.349 | | |
| | Logarithmic | 0.714 | 443.994 | 1 | 178 | 0.001 | -243342.505 | 90449.538 | | |
| | Inverse | 0.126 | 25.589 | 1 | 178 | 0.001 | 150520.023 | -400499.584 | | |
| | Quadratic | 0.921 | 1029.867 | 2 | 177 | 0.001 | -68168.809 | 3123.803 | -7.058 | |
| | Cubic | 0.971 | 1958.573 | 3 | 176 | 0.001 | -6029.222 | -939.771 | 48.914 | -0.206 |
| RUSSIA | Linear | 0.833 | 890.110 | 1 | 178 | 0.001 | -202158.106 | 4630.106 | | |
| | Logarithmic | 0.45 | 145.359 | 1 | 178 | 0.001 | -567904.354 | 186296.209 | | |
| | Inverse | 0.053 | 9.953 | 1 | 178 | 0.001 | 238505.539 | -674704.180 | | |
| | Quadratic | 0.983 | 5260.638 | 2 | 177 | 0.001 | 29994.225 | -3023.268 | 42.284 | |
| | Cubic | 0.986 | 4123.318 | 3 | 176 | 0.001 | 66156.791 | -5388.093 | 74.857 | -0.120 |
| CANADA | Linear | 0.922 | 2098.261 | 1 | 178 | 0.001 | -27185.948 | 818.559 | | |
| | Logarithmic | 0.592 | 258.011 | 1 | 178 | 0.001 | -104458.739 | 35929.440 | | |
| | Inverse | 0.083 | 16.084 | 1 | 178 | 0.001 | 51444.088 | -141882.250 | | |
| | Quadratic | 0.939 | 1352.697 | 2 | 177 | 0.001 | -14134.162 | 388.280 | 2.377 | |
| | Cubic | 0.990 | 5565.918 | 3 | 176 | 0.001 | 13226.057 | -1400.922 | 27.022 | -0.091 |
| JAPAN | Linear | 0.919 | 2018.919 | 1 | 178 | 0.001 | -4194.800 | 152.233 | | |
| | Logarithmic | 0.634 | 308.245 | 1 | 178 | 0.001 | -19596.356 | 6926.708 | | |
| | Inverse | 0.097 | 19.023 | 1 | 178 | 0.001 | 10497.202 | -28525.697 | | |
| | Quadratic | 0.921 | 1028.723 | 2 | 177 | 0.001 | -3397.006 | 125.933 | 0.145 | |
| | Cubic | 0.955 | 1237.257 | 3 | 176 | 0.001 | 761.539 | -146.013 | 3.891 | -0.014 |
| | Compound | 0.813 | 775.363 | 1 | 178 | 0.001 | 35.741 | 1.047 | | |
| | Power | 0.934 | 2515.815 | 1 | 178 | 0.001 | 0.027 | 2.690 | | |
| | S | 0.314 | 81.494 | 1 | 178 | 0.001 | 8.250 | -16.458 | | |
| | Growth | 0.813 | 775.363 | 1 | 178 | 0.001 | 3.576 | 0.046 | | |
| | Exponential | 0.813 | 775.363 | 1 | 178 | 0.001 | 35.741 | 0.046 | | |

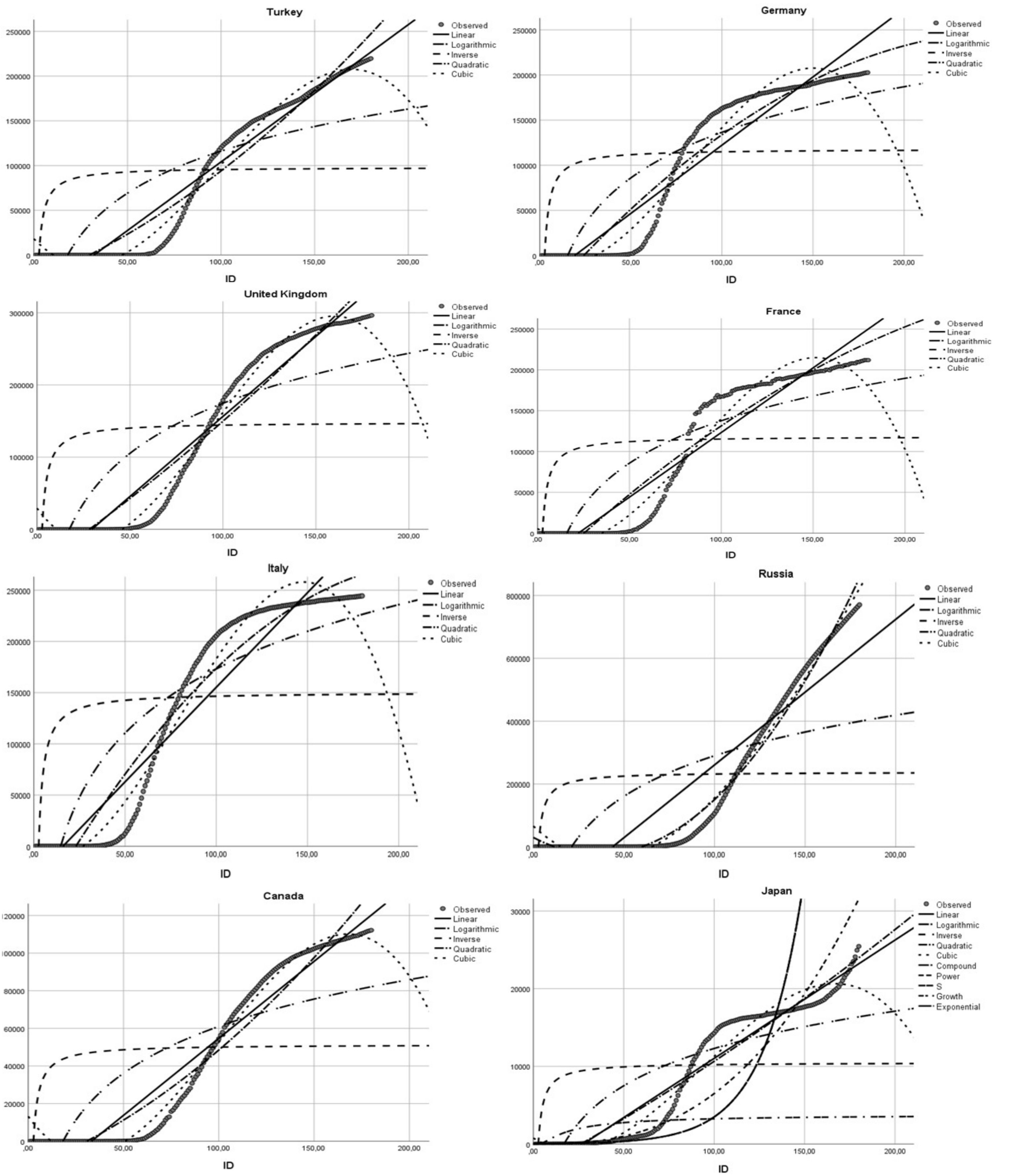



Figure 1. Curve estimation graphs of the countries

Table 2. ARIMA models and Brown linear exponential smoothing models of countries

| | | Model Fit statistics | | | | | | | | Ljung-Box Q(18) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Model Type | Stationary R-squared | R-squared | RMSE | MAPE | MAE | MaxAPE | MaxAE | Normalized BIC | Statistics | DF | p |
| Turkey | ARIMA(2,2,2) | 0.125 | 0.9999917 | 240.908 | 5.506 | 126.019 | 110.413 | 1247.530 | 11.056 | 31.217 | 15 | 0.008 |
| Germany | ARIMA(0,2,3) | 0.069 | 0.9999575 | 543.505 | 4.356 | 305.953 | 100.000 | 2691.744 | 12.654 | 87.629 | 16 | 0.001 |
| United Kingdom | ARIMA(0,2,4) | 0.408 | 0.9999937 | 303.867 | 4.510 | 182.364 | 100.000 | 1006.209 | 11.550 | 31.588 | 14 | 0.005 |
| France | Brown | 0.460 | 0.9993747 | 2185.372 | 5.133 | 807.132 | 80.001 | 22806.561 | 15.408 | 52.757 | 17 | 0.001 |
| Italy | ARIMA(0,2,7) | 0.201 | 0.9999897 | 325.497 | 3.348 | 199.368 | 103.576 | 1261.594 | 11.629 | 78.279 | 16 | 0.001 |
| Russia | ARIMA(1,2,1) | 0.120 | 0.9999980 | 375.866 | 5.178 | 207.311 | 100.000 | 1819.567 | 11.975 | 30.007 | 14 | 0.008 |
| Canada | Brown | 0.440 | 0.9999696 | 244.998 | 4.403 | 124.956 | 97.769 | 1616.646 | 11.031 | 44.138 | 17 | 0.001 |
| Japan | ARIMA(1,2,4) | 0.259 | 0.9999357 | 66.600 | 2.852 | 34.015 | 48.046 | 397.107 | 8.485 | 28.943 | 15 | 0.016 |

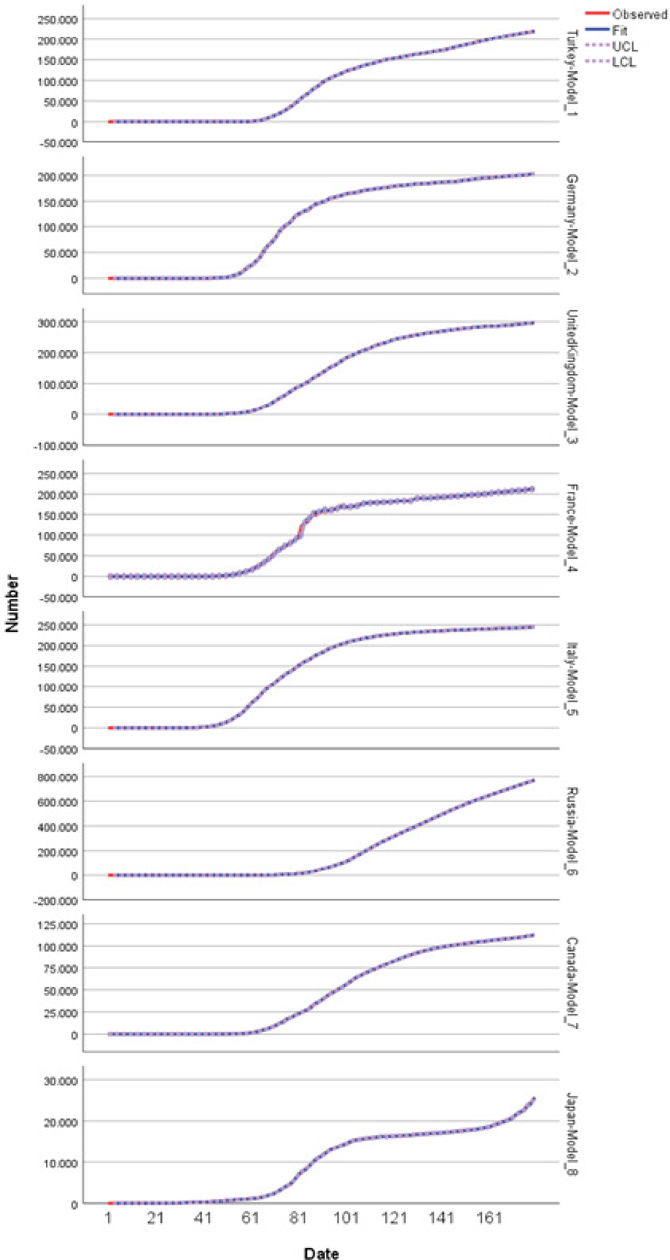
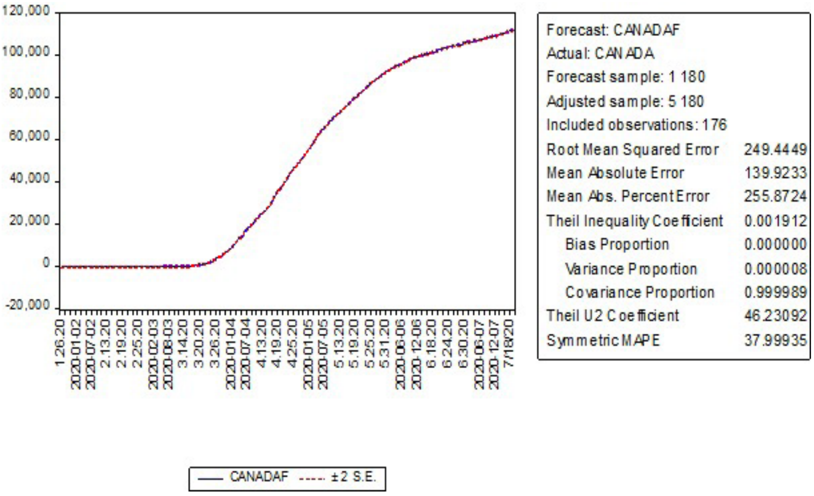
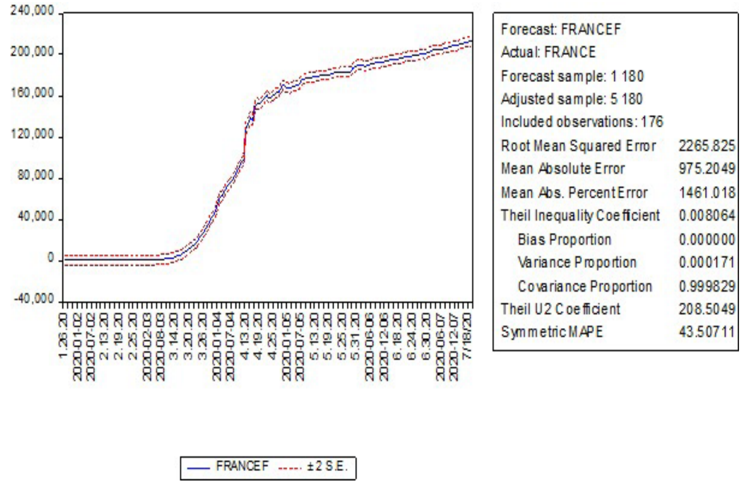


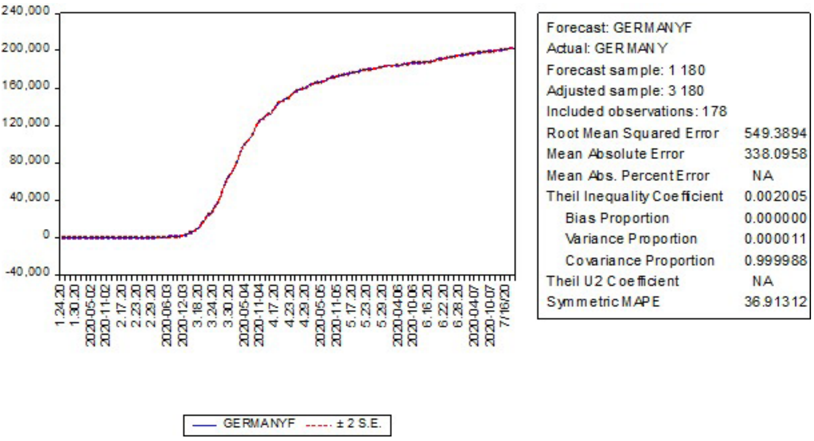

Figure 2. ARIMA models and Brown linear exponential smoothing models' graphs of the countries

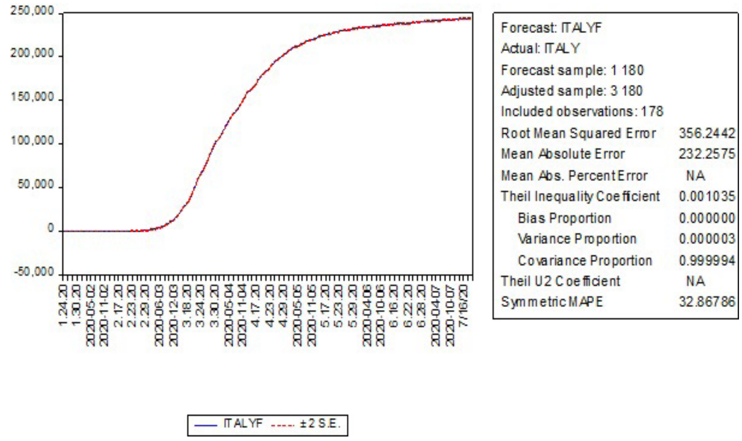
Table 3. Results from long-term ARDL review of countries

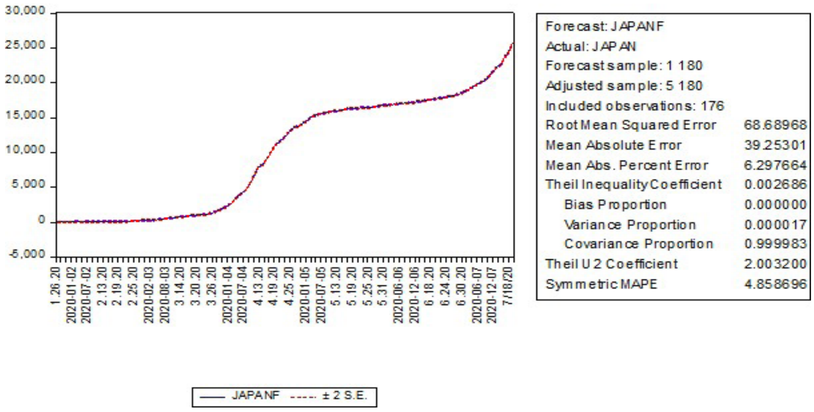
| Dependent Variable ARDL | Variable | Coefficient | Std. Error | t-Statistic | p | Substituted Coefficients | Cointegrating Equation | AIC |
|---|---|---|---|---|---|---|---|---|
| Turkey<br>ARDL(4) | TURKEY(-1) | 2.0440 | 0.0749 | 27.2561 | 0.001 | TURKEY = 2.0440*TURKEY(-1) -<br>1.2990*TURKEY(-2) + 0.4503*TURKEY(-<br>3) - 0.1957*TURKEY(-4) + 56.5268 | D(TURKEY) = 56.52688 -<br>0.0003*TURKEY(-1) +<br>1.0444*D(TURKEY(-1)) -<br>0.2545*(TURKEY - (155993.6511 ) +<br>0.1957*D(TURKEY(-3)) ) | 13.9275 |
| | TURKEY(-2) | -1.2990 | 0.1699 | -7.6449 | 0.001 | | | |
| | TURKEY(-3) | 0.4503 | 0.1700 | 2.6486 | 0.0088 | | | |
| | TURKEY(-4) | -0.1957 | 0.0752 | -2.6017 | 0.0101 | | | |
| | C | 56.5268 | 31.528 | 1.7928 | 0.0748 | | | |
| GERMANY<br>ARDL(2) | GERMANY(-1) | 1.9388 | 0.0254 | 76.2191 | 0.001 | GERMANY = 1.9388*GERMANY(-1) -<br>0.9394*GERMANY(-2) + 135.5760 | D(GERMANY) = 135.5759 -<br>0.0006*(GERMANY - (225189.6964) +<br>0.9394*D(GERMANY(-1)) ) | 15.4892 |
| | GERMANY(-2) | -0.9394 | 0.0254 | -36.9692 | 0.001 | | | |
| | C | 135.5760 | 74.915 | 1.8097 | 0.0721 | | | |
| UNITED_KINGDOM<br>ARDL(4) | UNITED_KINGDOM(-1) | 2.0743 | 0.0758 | 27.3545 | 0.001 | UNITED_KINGDOM =<br>2.0743*UNITED_KINGDOM(-1) -<br>1.3024*UNITED_KINGDOM(-2) +<br>0.3573*UNITED_KINGDOM(-3) -<br>0.1295*UNITED_KINGDOM(-4) +<br>90.2648 | D(UNITED_KINGDOM) = 90.2648 -<br>0.0003*UNITED_KINGDOM(-1) +<br>1.0746*D(UNITED_KINGDOM(-1)) -<br>0.2277*(UNITED_KINGDOM -<br>(264946.8923 ) +<br>0.1295*D(UNITED_KINGDOM(-3)) ) | 14.7912 |
| | UNITED_KINGDOM(-2) | -1.3024 | 0.1737 | -7.4958 | 0.001 | | | |
| | UNITED_KINGDOM(-3) | 0.3573 | 0.1738 | 2.0554 | 0.0414 | | | |
| | UNITED_KINGDOM(-4) | -0.1295 | 0.0759 | -1.7061 | 0.0898 | | | |
| | C | 90.264 | 51.086 | 1.7668 | 0.0790 | | | |
| FRANCE<br>ARDL (4) | FRANCE(-1) | 1.1601 | 0.0742 | 15.6247 | 0.0000 | FRANCE = 1.1601*FRANCE(-1) +<br>0.0799*FRANCE(-2) - 0.0022*FRANCE(-<br>3) - 0.2392*FRANCE(-4) + 589.5037 | D(FRANCE) = 589.5036 -<br>0.0014*FRANCE(-1) +<br>0.1615*D(FRANCE(-1)) +<br>0.24149*(FRANCE - (409411.8568 ) +<br>0.2392*D(FRANCE(-3)) ) | 18.3460 |
| | FRANCE(-2) | 0.0799 | 0.1156 | 0.6911 | 0.4904 | | | |
| | FRANCE(-3) | -0.0022 | 0.1157 | -0.0195 | 0.9844 | | | |
| | FRANCE(-4) | -0.2392 | 0.0741 | -3.2243 | 0.0015 | | | |
| | C | 589.5037 | 297.4996 | 1.9815 | 0.0491 | | | |
| ITALY<br>ARDL (2) | ITALY(-1) | 1.9738 | 0.0156 | 126.002 | 0.001 | ITALY = 1.9738*ITALY(-1) -<br>0.9743*ITALY(-2) + 106.8514 | D(ITALY) = 106.8514 -0.0005*(ITALY -<br>(208919.4179 ) + 0.9743*D(ITALY(-<br>1)) ) | 14.6228 |
| | ITALY(-2) | -0.9743 | 0.0156 | -62.3257 | 0.001 | | | |
| | C | 106.8515 | 52.1330 | 2.0495 | 0.0419 | | | |
| RUSSIA<br>ARDL(4) | RUSSIA(-1) | 1.8348 | 0.0758 | 24.1814 | 0.001 | RUSSIA = 1.8348*RUSSIA(-1) -<br>0.5381*RUSSIA(-2) - 0.4221*RUSSIA(-3)<br>+ 0.1250*RUSSIA(-4) + 74.9737 | D(RUSSIA) = 74.9737 -<br>0.0003*RUSSIA(-1) +<br>0.8352*D(RUSSIA(-1)) +<br>0.2970*(RUSSIA - (232480.3246 ) -<br>0.1250*D(RUSSIA(-3)) ) | 14.7897 |
| | RUSSIA(-2) | -0.5381 | 0.1562 | -3.4437 | 0.0007 | | | |
| | RUSSIA(-3) | -0.4221 | 0.1565 | -2.6958 | 0.0077 | | | |
| | RUSSIA(-4) | 0.1250 | 0.0770 | 1.6237 | 0.1063 | | | |
| | C | 74.9737 | 43.5021 | 1.7234 | 0.0866 | | | |
| CANADA<br>ARDL (4) | CANADA(-1) | 1.2035 | 0.0706 | 17.0267 | 0.0000 | CANADA= 1.2035*CANADA(-1)<br>+0.1748*CANADA(-2)<br>+0.0039*CANADA(-3) -<br>0.38294*CANADA(-4)+ 55.1143 | D(CANADA) = 55.1143 -<br>0.0006*CANADA(-1) +<br>0.2042*D(CANADA(-1)) +<br>0.3790*(CANADA - (87879.4202 ) +<br>0.3829*D(CANADA(-3)) ) | 13.9331 |
| | CANADA(-2) | 0.1748 | 0.1160 | 1.5062 | 0.1338 | | | |
| | CANADA(-3) | 0.0039 | 0.1160 | 0.0338 | 0.9731 | | | |
| | CANADA(-4) | -0.38294 | 0.0709 | -5.4007 | 0.001 | | | |
| | C | 55.1143 | 31.968 | 1.7240 | 0.0865 | | | |
| JAPAN<br>ARDL (4) | JAPAN(-1) | 1.5843 | 0.0744 | 21.2742 | 0.001 | JAPAN=1.5843*JAPAN(-1)-0.5650*<br>JAPAN(-2)+ 0.3620* JAPAN(-3) -<br>0.3811*JAPAN(-4) +6.4449 | D(JAPAN) = 6.4449 + 0.0001*JAPAN<br>(-1) + 0.5842*D(JAPAN(-1)) +<br>0.0191*(JAPAN - (-34591.4868 ) +<br>0.3811*D(JAPAN(-3)) ) | 11.3538 |
| | JAPAN(-2) | -0.5650 | 0.1501 | -3.7645 | 0.0002 | | | |
| | JAPAN(-3) | 0.3620 | 0.1539 | 2.3522 | 0.0198 | | | |
| | JAPAN(-4) | -0.3811 | 0.0791 | -4.8177 | **0.001** | | | |
| | C | 6.4449 | 8.5569 | 0.7531 | 0.4524 | | | |

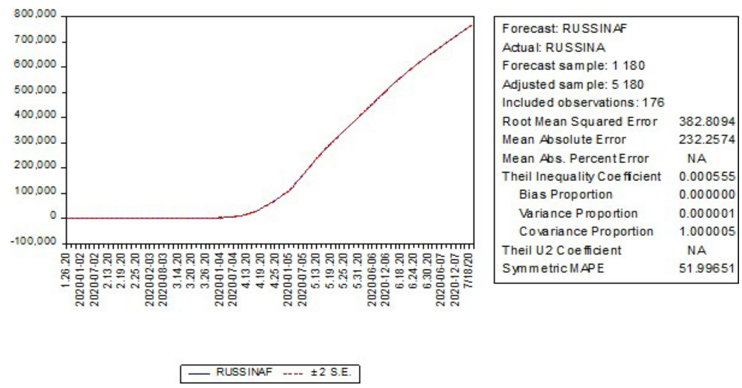


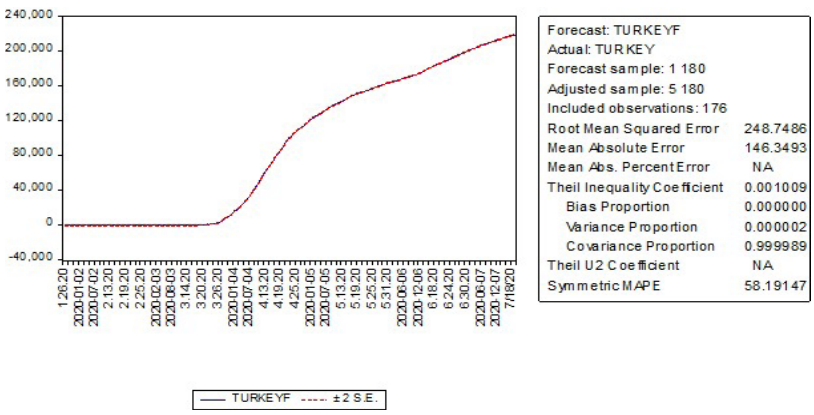



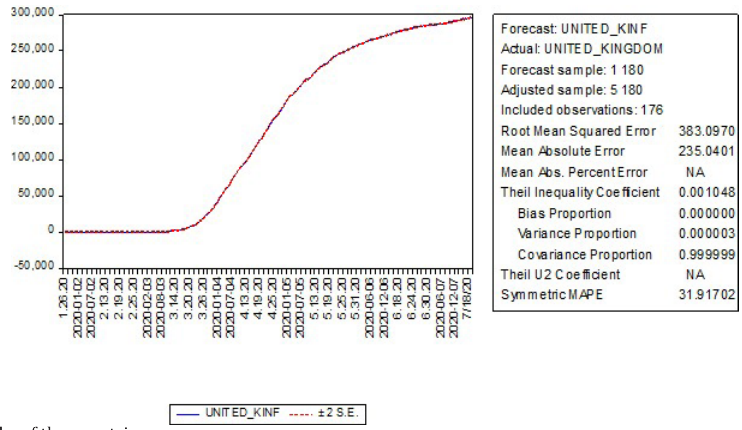




Figure 3. ARDL models' graphs of the countries

Table 4. Parameters of dynamics model for Covid-19 cases

| Dynamics | | Inputs | TURKEY | GERMANY | UNITED KINGDOM | FRANCE | ITALY | RUSSIA | CANADA | JAPAN |
|---|---|---|---|---|---|---|---|---|---|---|
| Transmission dynamics | Population Inputs | Size of population. | 82.639638 | 83.470180 | 55.395006 | 71.843450 | 60.611791 | 144.674941 | 37.798 | 128.315162 |
| | | Number of initial infections. | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| | Basic Reproduction Number $R_0$ | Measure of contagiousness: the number of secondary infections each infected individual produces. | 2.2 | 2.7 | 3.4 | 3.14 | 4.26 | 2 | 1.5 | 1.29 |
| | Transmission Times | Length of incubation period | 13.08 | 13.08 | 13.08 | 13.08 | 13.08 | 13.08 | 13.08 | 13.08 |
| | | Duration patient is infectious | 2.9 | 2.9 | 2.9 | 2.9 | 2.9 | 2.9 | 2.9 | 2.9 |
| Clinical Dynamics | Mortality Statistics | Case fatality rate | 0.25 | 0.44 | 15.35 | 14.13 | 14.13 | 0.17 | 0.17 | 0.03 |
| | | Time from end of incubation to death | 14 (Days) | 14 (Days) | 14 (Days) | 14 (Days) | 14 (Days) | 14 (Days) | 14 (Days) | 14 (Days) |
| | Recovery Times | Length of hospital stay | 14 (Days) | 14 (Days) | 14 (Days) | 14 (Days) | 14 (Days) | 14 (Days) | 14 (Days) | 14 (Days) |
| | | Recovery time for mild cases | 11.1 | 11.1 | 11.1 | 11.1 | 11.1 | 11.1 | 11.1 | 11.1 |
| | Care statistics | Hospitalization rate | 9.8 | 9.8 | 9.8 | 9.8 | 9.8 | 9.8 | 9.8 | 9.8 |
| | | Time to hospitalization | 14.14 | 14.14 | 14.14 | 14.14 | 14.14 | 14.14 | 14.14 | 14.14 |

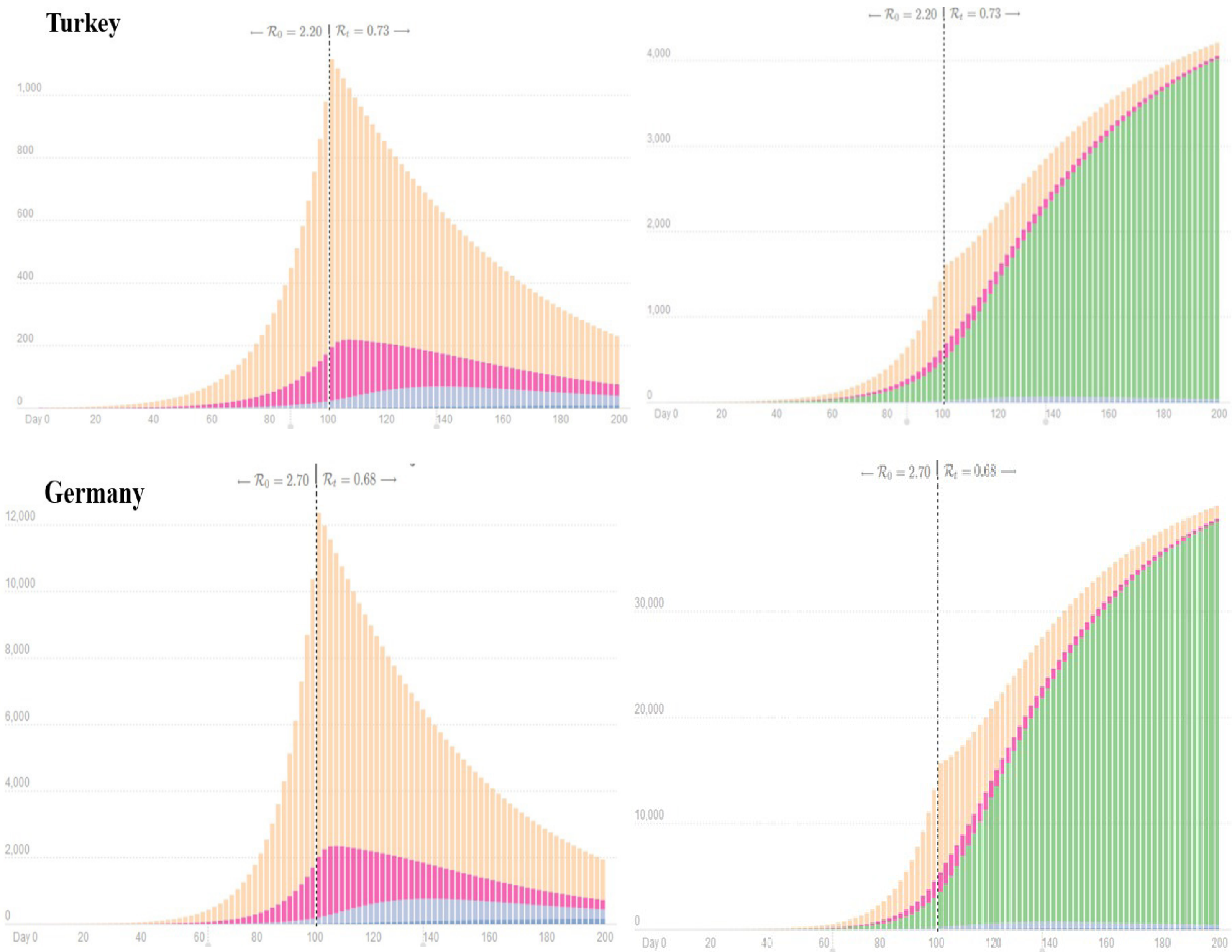



Figure 4. SEIR models graphs of the countries (Turkey-Germany)

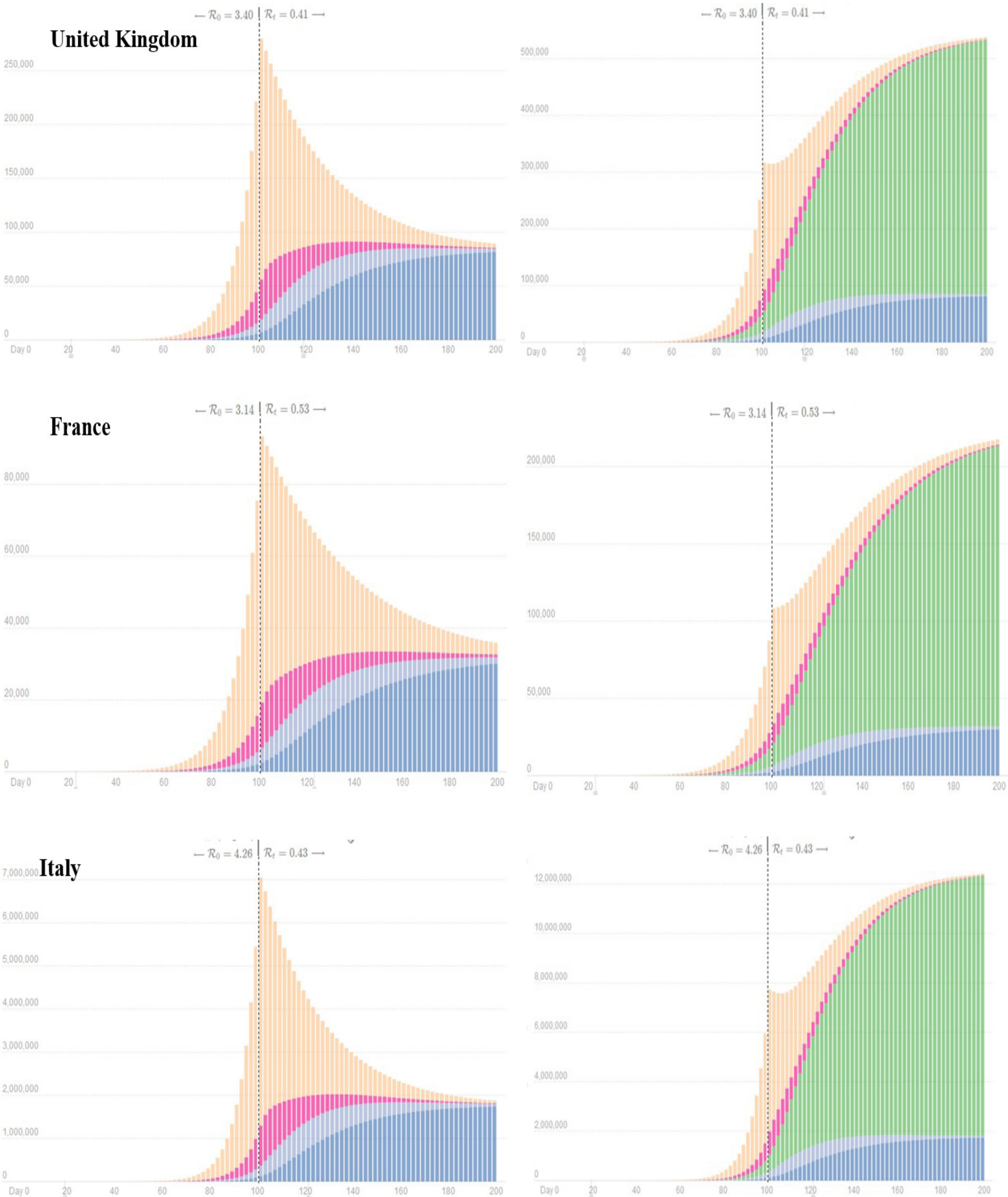



Figure 4. SEIR models graphs of the countries (UK-France-Italy))

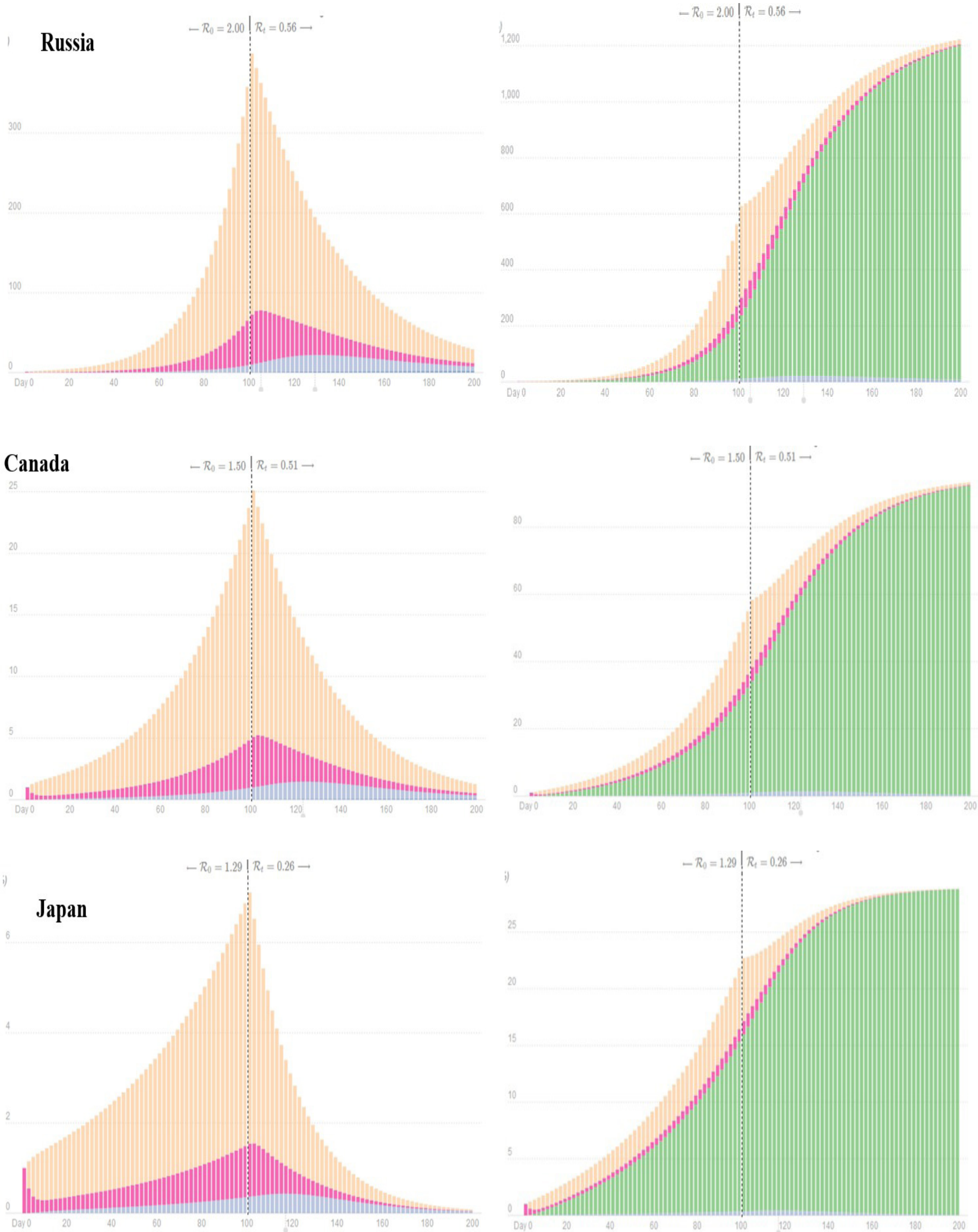



Figure 4. SEIR models graphs of the countries (Russia-Canada-Japan)

## Conclusion

In this study, we proposed a curve estimation model, ARIMA, Brown Exponential smoothing methods, ARDL, and SEIR that is a dynamic model, to analyze COVID-19 pandemic for selected countries: Turkey, Germany, United Kingdom, France Italy, Russia, Canada, and Japan. There are separate studies on the considered models in the literature, but in this study, we used all methods for selected countries, and thus COVID-19 cases have been evaluated from a wide range.
The conducted analyses allowed us to identify the spread, duration, and growth rate of the COVID-19 outbreak and reveal the predicted the turning point of the pandemic. It was determined by the ARDL and SEIR analyzes that France and Italy had the highest pandemic growth rate, and Canada had the lowest pandemic growth rate among selected nine countries. It was also seen the turning point of the pandemic appears to occur on the 72nd day (between 56-78 days) on average. If the strategies with the pandemic prevention of current governments remain unchanged, outbreaks will likely begin again in early October 2020 (from September 21 to November 10) and last an average of 155 days (ranging from 145 to 168 days). The results of other methods with the SEIR model, which also gives us the evaluation between compartments, are supported by each other.
There are many questions about the coronavirus epidemic that the scientific world cannot answer; one of them is why it caused so many deaths, especially in Europe (France / Italy). There are quite different approaches in the evaluations related to the epidemic in the literature, the most important of which are; Countries adopting different strategies against the epidemic, the attitudes of people against the measures related to the epidemic, the insufficient health services of the countries, the differences in the functioning of the test-follow-up, quarantine and isolation system in the countries, the differences in the genetic and immune systems of the individuals (such as obesity, high blood pressure, genetics and epigenetics factor), geographical conditions, the density of the elderly population (especially in Europe).
In future studies, evaluations can be made for different scenarios by using these methods. Furthermore, the fact that the results of the study were obtained using more than one method will be a reference for future predictions and studies.

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During this study, any pharmaceutical company which has a direct connection with the research subject, a company that provides and / or manufactures medical instruments, equipment and materials or any commercial company may have a negative impact on the decision to be made during the evaluation process of the study. or no moral support.

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