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PREDICTING THE SPREAD OF COVID-19 PANDEMIC IN TURKEY WITH S.I.R. MODEL

ABSTRACT

The novel Coronavirus is also known as COVID-2019 (Sars-Cov-2) have been emerged and firstly identified in Wuhan, Hubei Province, China and now continues to spread fears and anxious all over the world. On March 11, the World Health Organization classified this new coronavirus type as a "pandemic" (epidemic). It has spread to more than 180 countries and territories and the number of people who died worldwide due to the coronavirus has exceeded 160 thousand. Sustained transmission of the Covid-19 around the World has urged many governments to take various measures in fighting coronavirus outbreak. The spread of Covid-19 can be critically reduced by the social distancing and other no pharmaceutical interventions (NPIs) in the absence of the vaccines. World Health Organization reported that infection of Covid-19 occurs mainly through direct contact between people.

This article presents the classical mathematical S.I.R. model to estimate how long Covid-19 survive on and to provide more information about measures applied in Turkey. Our results present basic implications for Turkey economy facing severe threats from COVID-19 crisis.

Keywords: COVID-19, SIR model, Turkish Economy
JEL Codes: B23, CO2, I15

1. INTRODUCTION

Human beings have struggled with significant infectious diseases throughout their history, and were able to obtain medical remedies even though they have suffered massive damages to these pandemics. The world population has reached over 7 billion people due to advances in medicine and public health. The life expectancy in the world has been extended and increased from 46 years in 1950 to 71 in 2015. However, several epidemic outbreaks occurred in human history, and have caused hazardous impacts on economies, social life and political systems and even in the world plagues and epidemics have devastated life throughout its existence, often changing the course of history. With the emergence of a novel coronavirus (Covid-19), global epidemics have been taken again to the World agenda. New coronavirus disease officially was named Covid-19 by The World Health Organization after the first case in China in late 2019. The Covid-19 disease has been recognized as a global pandemic by the World Health Organization, with deaths exceeding 1.00,000 and more than 44 million during October of 2020.

The world economy has been severely hit by the coronavirus pandemic due to the lockdowns and job losses in several countries. In the existing literature, there are many studies on the potential effects of Covid19 epidemic on world economies. Among the selected studies, Boissay & Rungcharoenkitkul (2020) estimated that the world economy is expected to shrink by 4% in the following years. Maliszewska, Mattoo & Van Der (2020) predicted that the slowdown in GDP growth across developed and developing regions will be 1.8 and 2.5 % respectively. Regardless of economic status, the COVID-19 crisis has converted all countries into a more fragile world system. The economic environment caused by the Covid-19 pandemic, such as the decrease in demand, disruptions in supply chains, contraction in production volume and disruptions in the tourism sector, have been the main determinants of the slowdown in the global economy (Kartal, 2020: 229).

National lockdowns, international or domestic travel restrictions, reduced business activity, the volatility of the oil and financial markets have increased the cost of the pandemic on the economies of the country. The links between public health and economy have gradually become more important during the Covid-19 pandemic. Decision making on the supply or demand side is very difficult during the pandemic periods. Because people suffer difficult times to make a sound decision about the degree of investment, financial, consumption, savings activities. Stable and healthy decisions are directly related to the duration of the pandemic and effects of covid-19 containment measures.

The relations between public health and economic sustainability has played a critical role especially during the period of the epidemics. Because people are going to have difficulties in deciding their correct investments about the property and financial products. During epidemic times, it is very difficult to make economic decisions in the direction of demand and supply. Satisfactory results of these decisions depend on the duration of these epidemics (Toda, 2020: 1).

In order to prevent the spread of the Covid-19, many countries have already implemented many various containment measures such as workplace closures, stay-at-home orders, closure of public travels, restrictions on internal and external movements, school closures. In order to obtain successful results from all these measures, the performance and accuracy of different mathematical forecasting are very essential for dealing with the economic recession.

Interaction between health and economy is so essential is that good health system would contribute to sound economic growth in many countries. Several analyses have been conducted to provide the roadmap and control the spread of the disease with different epidemiological models (Atkeson, 2020: 23). S.I.R. is one of those models that compute the infected population and provide information about the outbreak of the pandemic for public health experts to prevent an epidemic by reducing the ambiguities of their policies in all countries.

In this study, we present the S.I.R. model over the March and October in 2020 to predict the peak and the end of the Covid-19 pandemic in Turkey. The main aim of this paper is to estimate the peak date for the infected and recovery population in order to prepare information and help all measures about the Covid-19 in the upcoming months.

2. LITERATURE REVIEW

Empirically, there are several studies about epidemic forecasting by applying different statistical methods. and the data set. In Table 1, we summarize the literature by presenting a few basic research with their statistical model.

Table 1. Summary of Literature on the Forecasting and Prediction Models in the Epidemics

Model	Explanations	Strengths And Weaknesses,	Studies
Time Series Modelling	ARIMA models as a form of Box-Jenkins model are used. ARIMA models assume that future values can be predicted based on trend with the average of historical values.	ARIMA models generally estimate a constant averages of observed periodic values average. But it is not good at revealing the non-linear patterns and seasonality effects of data in the time series models of epidemics.	Dehesh, et al. (2020), Benvenuto et al., (2020), Yonar et al., (2020) -Li et al. (2020)
Analogue And Numerical Weather Prediction	Developed by Lorenz in 1969, the analogues method is a nonparametric meteorological forecasting method. It is used to predict the behavior of the epidemic data.	Considering the geographical differences makes it better performance comparing to the ARIMA models. However, it catches vectors from similar diseases and fails to explain clearly the determinability of human differences in the outbreaks of the epidemic.	Viboud et al. (2012) Buczak, et al. (2018) Chen (2020)
Compartmental models	These models provide analyzes through inter- compartments by dividing the threatened population such as the Susceptible-Infected-Recovered.	The advantage of these models is that they filter the patients through classifying with simple mathematical analysis. On the other hand, they have a few unrealistic assumptions that they accept population as constant and homogeneous against external factors. And also they don't consider some factors such as age, social status, gender, health equipment and system, the incubation period.	Toda-(2020) Dhanwant et al. (2020) Boudrioua et al. (2020) Atkeson, (2020)

Table 1. Summary of Literature on the Forecasting and Prediction Models in the Epidemics (*Cont.*)

Model	Explanations	Strengths And Weaknesses,	Studies
Agent-based model (ABM)	In this modeling, agent (micro) behaviors analyze its interaction with other things and environment (macro) levels. These model evaluate the macro-level effects of agents by developing simulations through various scenarios.	These models can reveal the social consequences of individuals' behavior through simulations. These models are so real, flexible, and time saver because complex systems explain their behavior. Models generally use humans as factors, but people make subjective preferences with irrational behavior, which makes a social case difficult to be understood.	-Longini, et. al. (2004), -Khalil, et. al. (2010) - Ajelli, et. al. (2015)
Metapopulation models	It considers the spatial structure of populations in determine the spread of epidemics. Its basic assumption is that the population is clustered and localized. This localization consists of relatively patch isolations or sub-populations related to migration	The strength side of these models is that they are dynamic and include the ecology of living species. Thus, it is possible to combine the separate effects of patch area and insulation. Biological system change is the weakness of this model.	-Calvetti, et al. 2020 -Costa et.al (2020) -Aleta and Moreno (2020) -Yin (2020) -Chinazzi et al., (2020)

3. METHODOLOGY, DATA AND EMPIRICAL RESULTS

3.1. Methodology

S.I.R. model is the most known acronym that stands its initials susceptible, infected, and recovered. The ultimate aim of this model is to provide insights with specific mathematical equations and make predictions about the pandemic, to plan effective control strategies and policies (Cooper, Mondal & Antonopoulos, 2020: 2).

The pandemics represent several threats to humankind and drive economic and social cost triggered by social interactions. Mathematical models in pandemics play a key role in learning about spreads of pandemics to prepare, mıtıgate and respond in the event of such a disaster (Rhodes, Lancaster & Lees, 2020: 2).

The original SIR model, developed by Kermack and McKendirck in 1927 has followed assumptions: (Capitanelli, 2020):

- No external interactions can in among the community. So the individual can be infected only once.
- the population size is fixed (i.e., no deaths or migration),
- the population is completely homogeneous (no variations about the resistance of disasters).

In this model, the population is divided into three groups:

The susceptible (S): people remain healthy but have the risks of infections.

Infected (I): People whose test is positive are likely to infect someone else.

Recovered (R): People who defeat the virus and develop immunity.

SIR model developed by Kermack and McKendrick (1927) can be expressed by the following three nonlinear differential equations with $S_{(t)}$ (the number of susceptible individuals in t, day), $I_{(t)}$ (the number of infected individuals in t, day), $R_{(t)}$ (the number of recovered individuals in t, day) (Carvalho and Goncalves, 2016: 1).

$$-\beta S I \quad (1)$$

$$\beta S I - \gamma I \quad (2)$$

$$\gamma I, \quad (3)$$

$$R_0 = \frac{\beta S}{\gamma}. \quad (4)$$

where β is the population's infection rate and γ is the recovery rate, R_o is the basic preproduction number.

Reproduction value is so important indicator and represents two main roads for the spread of the pandemic:

- If the $R_0 > 1$, then a pandemic has the potential to spread more people.
- If the $R_0<1$, then a pandemic will eventually end.

3.2. Data and Empirical Results

Since the coronavirus firstly outbreaks on December 20 in China have now spread to more than 183 countries over the world, and then WHO declared the novel coronavirus outbreak (2019-nCoV) as a pandemic in March 2020. In Turkey, the total number of infections has increased from 1 to more than 100,000 in about seven months as shown in Table 3.1. All data used in this paper is taken from the database of the Ministry of Health in Turkey.

As explained previously, two epidemic variables namely infection rate β(t) and removal rate γ(t) are the two very critical indicators that have to be calculated.

Table 3.1. Epidemiological data of the Covid-19 for Turkey

Date	I(t)	R(t)	β(t)	γ(t)	Date	I(t)	R(t)	β(t)	γ(t)
03/12/20	1	0	0.0000	0.0000	04/24/20	104922	24321	0.0416	0.3946
03/13/20	5	0	0.0000	0.0000	04/25/20	107783	28272	0.0322	0.2094
03/14/20	6	0	0.1667	0.0000	04/26/20	110140	31929	0.0188	0.1218
03/15/20	18	0	0.6667	0.0000	04/27/20	112271	36675	0.0288	0.5129
03/16/20	47	1	0.6383	0.0000	04/28/20	114663	41785	0.0241	0.1534
03/17/20	98	1	0.5102	0.0000	04/29/20	117599	47105	0.0269	0.0725
03/18/20	191	2	0.4921	0.0000	04/30/20	120214	52044	0.0187	0.1472
03/19/20	359	3	0.4680	0.0000	05/01/20	122402	57050	0.0185	0.0347
03/20/20	670	4	0.4642	0.0000	05/02/20	124385	61579	0.0122	0.2375
03/21/20	947	9	0.2967	0.0000	05/03/20	126055	66532	0.0167	0.2641
03/22/20	1236	21	0.2395	0.0000	05/04/20	127669	71611	0.0137	0.0762
03/23/20	1529	30	0.1897	0.0000	05/05/20	129501	76789	0.0150	0.0568
03/24/20	1872	37	0.1822	0.0000	05/06/20	131754	81770	0.0157	0.0897
03/25/20	2433	44	0.2306	00000	05/07/20	133731	86609	0.0138	0.0683
03/26/20	3629	59	0.3318	0.0000	05/08/20	135579	90069	0.0035	0.7413
03/27/20	5698	118	0.3709	0.0203	05/09/20	137125	93203	0.0089	0.2122
03/28/20	7402	162	0.2282	0.0082	05/10/20	138667	96461	0.0121	0.0824
03/29/20	9217	220	0.1985	0.0039	05/11/20	139781	99605	0.0072	0.1095
03/30/20	10827	314	0.1521	0.0137	05/12/20	141485	102767	0.0122	0.0117
03/31/20	13531	441	0.2024	0.0089	05/13/20	143124	105651	0.0096	0.1727
04/01/20	15679	594	0.1387	0.0042	05/14/20	144759	108021	0.0078	0.3125
04/02/20	18135	755	0.1359	0.0033	05/15/20	146467	110172	0.0102	0.1241
04/03/20	20921	893	0.1322	0.0047	05/16/20	148077	112217	0.0102	0.0615
04/04/20	23934	1271	0.1360	0.0773	05/17/20	149445	114086	0.0080	0.1308
04/05/20	27069	1600	0.1141	0.0147	05/18/20	150603	115732	0.0062	0.1813
04/06/20	30217	1959	0.1053	0.0089	05/19/20	151625	117078	0.0048	0.2906

04/07/20	34109	2291	0.1134	0.0072	05/20/20	152597	118193	0.0049	0.2325
04/08/20	38226	2642	0.1083	0.0019	05/21/20	153558	119223	0.0057	0.0926
04/09/20	42282	3034	0.0970	0.0079	05/22/20	154510	120371	0.0070	0.1239
04/10/20	47029	3413	0.1008	0.0032	05/23/20	155696	121894	0.0101	0.3120
04/11/20	52167	4050	0.1036	0.0508	05/24/20	156837	123018	0.0048	0.3497
04/12/20	56956	4628	0.800	0.0127	05/25/20	157824	124368	0.0077	0.2320
04/13/20	61049	5237	0.0677	0.0073	05/26/20	158772	125888	0.0071	0.1804
04/14/20	65111	6186	0.0677	0.0815	05/27/20	159807	127208	0.0053	0.1990
04/15/20	69402	7176	0.0626	0.0077	05/28/20	160989	128814	0.0092	0.2453
04/16/20	74203	8716	0.0723	0.1125	05/29/20	162130	130436	0.0072	0.0158
04/17/20	78556	10384	0.0572	0.0292	05/30/20	163113	131483	0.0025	0.5829
04/18/20	82339	12327	0.0494	0.0740	05/31/20	163952	132497	0.0049	0.0381
04/19/20	86316	13977	0.0428	0.0752					
04/20/20	90990	15554	0.0507	0.0148					
04/21/20	95601	17161	0.0487	0.0074					
04/22/20	98684	18837	0.0320	0.0230					
04/23/20	101800	20966	0.0352	0.1460					

Table 3.1. provides the epidemiological data showing the spread of the Covid-19 pandemic in Turkey for 10 weeks. The rest of the epidemiological data is not present here due to space constraints. I(t) represents the cumulative infected rate, R(t) captures the cumulative recovery rate which includes both dead and recovers cases. β(t) is the number of individuals contracting the disease per unit of time, in our case per day, thus the daily infection rate. The rate at which infected cases for either recovered case or recorded death and are no longer a carrier of the disease is represented by the parameter γ(t). The estimations of β(t) and γ(t) should always be decreasing (monotonic) or remain constant. This generates an important constraint on estimating infection rates and recovery rates. Consequently, the number of infected cases in the SIR model would be bell-shaped and curve following the epidemic transmission model (Ang, 2007:123). In reality, in the long run the parameter β(t) should be monotonically decreasing with time. This is to ensure that the pandemic comes to a natural end, otherwise, the pandemic will not end until all the susceptible population are infected. Moreover, in order not to significantly underestimate the epidemic transmissibility, the decreasing rate for β(t) should not be sharp. Fitting different subsets of data helps to obtain a good estimate for the parameter β(t).

The parameter γ(t) records small values at the onset of the pandemic due to the fact that the number of infected cases during the early days have not recovered or died yet, hence γ(t) varies slowly with time. Considering the significantly small variations in γ(t), it implies a long pandemic duration in Turkey.

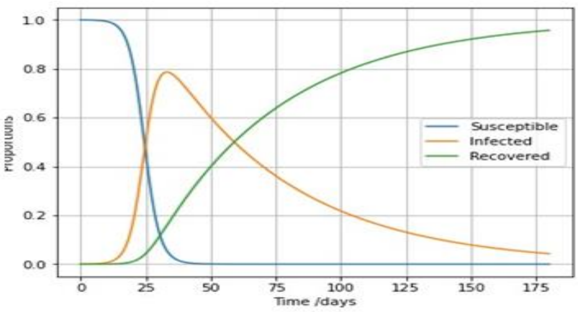

Figure 3.1. Susceptible, Infected and Recovered as a function of time (in days) for Turkey[1]

1 The time-evolution of influenza over 200 days

To predict the peak day for the number of infected cases, Figure 1 shows the proportions of Susceptible population, Infected cases and Recovery for the first 200 days in Turkey. The peak infection rate of the pandemic occurred on April 12, 2020, with the cumulative number of infected case of 56956 and rate of infection, β(t) of 0.8. The expected monotonically decreasing behavior of (Infected rate) β(t), is seen after the 30 days from the start date of the pandemic in Turkey. Moreover, as expected the monotonical increase for the recovery rate, γ(t) is seen to be increasing over time. Even though this increase started with very small values at the start of the pandemic, it gathers momentum as the infection rate, β(t) approached its peak and then begins to decline. The implications of this are that the spread of the pandemic would come to a natural end since the rate at which infected cases for either recovered or die and are no longer a carrier of the disease is monotonically increasing as the number of individuals contracting the disease per unit of time is monotonically decreasing. The time period covered was from 12 March 2020 to 5 October 2020. For most of the data timeline, we estimated the basic reproductive number for COVID-19 bigger than 1. The result of the reproductive ratio means that pandemic will continue to spread till the large proportion of the population is immunized in Turkey.

4. CONCLUSION

In this article, we performed the SIR model to predict the spread of the COVID-19 pandemic in Turkey between the period of March 12 and October 5 2020. According to the results of the SIR model, the infection rate (β(t)) has the highest value on 12th April in 2020, the peak for infection occurred 30 days after the start date of infection. A cumulated number of infected cases was 56956 and the cumulative number of recovered was at 4628. The covid-19 pandemic in Turkey is observed to be responding to measure put in place to help check the spread of the coronavirus. Our analysis suggests that, during the early days of the pandemic breakout, there was a sharp increase in the rate of infection reaching its peak in 30 days, which then begins to exhibit the monotonically decreasing behavior expected by the rate of infection. Thus, as the number of individuals contracting the disease per unit of time is monotonically decreasing, the rate at which infected cases for either recovered or dead and are no longer a carrier of the disease monotonically increases, the spread of the pandemic would come to a natural end. But, Turkey should reconsider imposing new lockdown restrictions and both local and state authorities are trying to keep the growth rate of the epidemic under control to prevent the possibility of the *2nd wave* of COVID-19.

REFERENCES

AJELLI, M., GONCALVES, B., BALCAN, D., COLIZZA, V., HU, H., RAMASCO, J., MERLER, S. & VESPIGNANI, A. (2015). Comparing large-scale computational approaches to epidemic modeling: Agent-based versus structured metapopulational models. *BMC Infectious Diseases, 10* (190): 1-13

ALETA, A. & MORENO, Y. (2020). Evaluation of the potential incidence of COVID-19 and effectiveness of containment measures in Spain: A data-driven approach. *BMC Medicine, 18*(157).

ANG, K. C. (2007). A simple stochastic model for an epidemic-numerical experiments with MATLAB. *Electron. J. Math. Technol., 1*(2):117-128

ATKESON, A. (2020). What will be the economic impact of covid-19 in the US? Rough estimates of disease scenarios. https://www.nber.org/papers/w26867

BENVENUTO, D., GIOVANNETTI, M., CICCOZZI, A., SPOTO, S., ANGELETTI, S. & CICCOZZI, M. (2020). The 2019-new coronavirus epidemic: evidence for virus evolution. *Journal of Medical Virology, 92:* 455-459.

BOISSAY, F. & RUNGCHAROENKITKUL, P. (2020). *Macroeconomic effects of Covid-19: an early review.* Bank for International Settlements: BIS Bulletins.

BOUDRIOUA, M.S. & BOUDRIOUA, A. (2020). Predicting the covid-19 epidemic in Algeria using the SIR model. https://www.medrxiv.org/content/10.1101/2020.04.25.20079467v6

BUCZAK, A.L., BAUGHER, B., LINDA, J., MONIZ, L.J., BAGLEY, T., BABIN, S.M. & GUVEN, E. (2018). Ensemble method for dengue prediction. *PLoS ONE, 13*(1).

CALVETTI, D., HOOVER, A.P., ROSE, J. & SOMERSALO, E. (2020). Metapopulational network models for understanding, predicting, and managing the coronavirus disease covid-19**.** arXiv preprint arXiv:2005.06137

CAPITANELLI, A. (2020). Modeling the spread of diseases. https://towardsdatascience.com/ modeling-the-spread-of-diseases-821fc728990f

CARVALHO, A. & GONCALVES, S. (2016). An Algebraic solution for the Kermack-McKendrick model. https://arxiv.org/pdf/1609 .09313.pdf

CHEN, Y. (2020). COVID-19 Pandemic Imperils Weather Forecast. *Geophysical Research Letters, 47*(15): 1-7.

CHINAZZI, M., DAVIS, J.T., AJELLI, M., GIOANNINI, C., LITVINOVA, M., MERLER, S. & PIONTTI, A.P. (2020). The effect of travel restrictions on the spread of the 2019 novel coronavirus (2019-nCoV) outbreak. https://doi.org/10.1101/2020.02.09.20021261

COOPER, I., MONDAL, A. & Antonopoulos, C.G. (2020). A SIR model assumption for the spread of COVID-19 in different communities. *Chaos, Solitons & Fractals, 139*(110057).

COSTA, G. S., COTA, W. & FERREIRA, S.C. (2020). Metapopulation modeling of COVID-19 advancing into the countryside: An analysis of mitigation strategies for Brazil. https://www.medrxiv.org/content/10.1101/2020.05.06.20093492v2

DEHESH, T., MARDANI-FARD, M. H.A. & DEHESH, P. (2020). Forecasting of covid-19 confirmed cases in different countries with ARIMA models. https://www.medrxiv.org/ content/medrxiv/early/2020/03/18/2020.03.13.20035345.full.pdf

DHANWANT, J.N., & RAMANATHAN, V. (2020). Forecasting covid 19 growth in India using Susceptible-Infected-Recovered (SIR) model. arXiv:2004.00696>

KARTAL, M. (2020). Dünya Ekonomisindeki Güncel Gelişmelere Koronavirüsün (COVİD-19) Olası Ekonomik Etkileri. Erhan Kılınç ve Emel Gelmez (Editör), *Yönetsel ve Ekonomik Açıdan İşletme Biliminde Güncel Yaklaşımlar* içinde (223-231). Konya: Eğitim Yayınevi.

KERMACK W. O. & MCKENDRICK, A. G. (1927). A contribution to the mathematical theory of epidemics. http://www.math.utah.edu/~bkohler/Journalclub/kermack1927.pdf

KHALIL, K. M. & ABDELAZIZ, M. (2010). *An agent-based modeling for pandemic influenza in Egypt. Informatics and Systems (INFOS)*, The 7th International Conference on Project.

LONGINI I.M., HALLORAN M.E., NIZAM A. & YANG Y. (2020). Containing pandemic influenza with antiviral agents. *American Journal of Epidemiology, 159:* 623-633

MALISZEWSKA, M., MATTOO, A. & VAN DER M. D. (2020). *The Potential Impact of COVID-19 on GDP and Trade: A Preliminary Assessment.* The World Bank Publishing: Policy Research Working Paper 9211.

MU, K., ROSSI, L., SUN, K., VIBOUD, C., XIONG, X., YU, H., HALLORAN, M.E., LONGINI, M. & VESPIGNANI, A. (2020). The effect of travel restrictions on the spread of the 2019 novel coronavirus (covid-19) outbreak. https://science.sciencemag.org/ content/sci/368/6489/395.full.pdf

RHODES, T., LANCASTER, K. & LEES, S. (2020). Modelling the pandemic: attuning models to their contexts. *BMJ Global Health*, *5:* 1-8.

TODA, A. A. (2020). Susceptible-Infected-Recovered (SIR) dynamics of covid-19 and economic impact. arXiv:2003.11221

VIBOUD, C. & SIMONSEN, L. (2012). Global mortality of 2009 pandemic influenza A H1N1. *The Lancet Infectious Diseases, 12*(9), 651–653.

YIN, Y. (2020). A Statistical Estimation of Coronavirus (COVID-19) Infection Population in Wuhan. http://dx.doi.org/10.2139/ssrn.3573499