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Effects of government policies and the Nowruz holidays on confirmed COVID-19 cases in Iran: An intervention time series analysis

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Cover Letter

We confirm that the enclosed article entitled:

Effects of government policies and the Nowruz holidays on confirmed COVID-19 cases in Iran: An intervention time series analysis

has not previously been published, is not currently being considered or submitted else where for publication, and, if accepted for publication in the above Journal, will not be published elsewhere.

Highlights

- Interrupted time series analysis was used to know the impacts of government policies and the Nowruz holidays on the new cases of COVID-19 in Iran.
- Social distancing measures is helping to meet the new cases of COVID-19 reduction target.
- Closing of schools and universities had no significant impacts on the pandemic.
- Findings shows that the Nowruz holidays increased the number of coronavirus patients in Iran.

Effects of government policies and the Nowruz holidays on confirmed COVID-19 cases in Iran: An intervention time series analysis

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Abstract

Background: Public health policies, with varying degrees of restriction, have been imposed around the world to prevent the spread of coronavirus disease 2019 (COVID-19). In this study, we aimed to evaluate the effects of the implementation of government policies and the Nowruz holidays on the containment of the COVID-19 epidemic in Iran using an intervention time series analysis.

Methods: Daily data on COVID-19 cases registered between 19th February 2020 and 28th April 2020 were collected from the World Health Organization (WHO) website. Using an intervention time series modeling, the impact of two government policies, that is, closing of schools and universities and the implementation of social distancing measures, on the number of confirmed cases was evaluated. Furthermore, the effect of the Nowruz holidays as a non-intervention factor for the spread of COVID-19 was analyzed.

Results: Our analysis showed that the closing of universities and schools had no impact on the number of confirmed COVID-19 cases. The Nowruz holidays were followed by a significant increase in new cases, while the implementation of social distancing measures was followed by a significant decrease in such cases (both $p<0.001$).

Conclusion: The Nowruz holidays and the implementation of social distancing measures in Iran were related to a significant increase and decrease in COVID-19 cases, respectively.

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1. Introduction

As a global pandemic, COVID-19 has led to 403,080 deaths (1, 2) and 7,028,020 confirmed cases as of 7th June 2020. The first confirmed COVID-19 cases in Iran were reported in Qom on 19th February 2020. Shortly after this, COVID-19 cases were reported in other Iranian cities, and Iran is still heavily impacted by this pandemic as of 8th June 2020 with 175,927 confirmed cases (1).

COVID-19 can lead to severe acute respiratory distress syndrome (ARDS), anemia, secondary infection, acute cardiac injury, fever, fatigue, and dry cough (3, 4). Due to these serious symptoms, countries have implemented COVID-19-related policies to limit the spread of the disease and prevent the exhaustion of national health systems (5). However, the impact of government policies on the number of COVID-19 cases has not been established so far, and questions remain about the impact of such measures on case numbers. Besides, the effect of national holidays in countries affected by COVID-19 has not been well researched. In our analysis, we employed a time series analysis to analyze the trend of new COVID-19 cases in Iran and to relate government policies and the Nowruz holidays to case numbers. Time series analysis has been used to model trends in the prevalence and incidence of COVID-19 cases registered in the Johns Hopkins epidemiological database (https://coronavirus.jhu.edu/) (6).

Similarly, Soudeep et al. proposed a time series model to analyze the trend pattern of COVID-19 incidence (7), and Petropoulos et al. provided statistical forecasts for the confirmed cases of COVID-19 using robust time series models (8). In Iran, Moftakhar and Seif predicted the number of newly infected patients using the ARIMA model on 20th March 2020, anticipating 3,574 cases by 20th April (9). Jamshidi et al. applied a time series model to predict the spread of COVID-19 in Iran. According to their prediction, the expected cumulative number of confirmed cases in Iran reaches 71,000 by 15th April 2020 (10).

Time series analyses can also detect change points and assess the influence of interventions. Change points are abrupt changes that represent transitions occurring in time series data (11). Interventional analysis is useful when the exact effect of interventions is of interest. In other words, the analysis aims to predict a time series by applying an intervention (12). Siedner et al. utilized intervention time series analysis to investigate whether the implementation of social distancing measures was associated with a reduction in the mean daily growth rate of COVID-19 cases in US states (13).

In Iran, the government implemented health policies for COVID-19 and applied social distancing rules to limit the transmission of COVID-19. Amid the pandemic, Iran celebrated the Nowruz holiday (the New Year in Iran, two weeks), a time when people visit elderly relatives. This elderly population represents the

most at-risk population for severe disease and death if infected with SARS-CoV-2 (14). It was expected that the outbreak of COVID-19 would encourage people to stay at home. Despite all warnings, Iranians started their Nowruz travels inside the country, leading to a high incidence of COVID-19 disease in the Northern provinces (15). Heidari and Sayfouri, in their study questioned whether Persian Nowruz aggravated the COVID-19 crisis in Iran (16).

Evidence suggests that multiple factors influence the number of COVID-19 cases in Iran. We conducted an intervention time series analysis to analyze the daily new confirmed cases of COVID-19 and evaluate the effects of government policies and the Nowruz holidays on the number of new COVID-19 cases in Iran.

2. Materials and Methods

The collected dataset included the new confirmed cases of COVID-19 occurred in Iran from 19th February to 2nd May 2020. The dataset was obtained from the daily reports of the Iranian Ministry of Health and Medical Education (https://behdasht.gov.ir/), which is identical to the COVID-19 data published on the WHO website (https://www.who.int/emergencies/diseases/novel-coronavirus-2019/situation-reports/), which aggregates case data from national authorities.

2.1 Interventions

In Iran, different health policies have been implemented to control the spread of COVID-19 (5, 17). The primary interventions enacted in Iran were the closing of kindergartens, schools, and universities, emphasis on the importance of handwashing, staying at home, and self-quarantining, banning large gatherings, eliminating nonessential traffic, and closure of recreational areas. Entry of traffic into the cities was restricted to their residents. In addition to schools and universities, parks, gardens, and other public places were closed. All ceremonies, whether official or not, were banned. The new social distancing measures were launched on 27th March 2020, and the police enforced new measures. People were requested to return to their homes as many Iranians had traveled to other provinces during the Nowruz holidays. Also, all new travels outside of the cities were banned, and car seizure and 5,000,000 IRR fines ($35) were imposed for travel ban offenders (17). Figure 1 indicates these data points.

On 17th April, Iran decreased social distancing measures, and the Smart Social Distancing plan was implemented. This plan was in line with social distancing and provided conditions for the society to gradually return to normal (16). After 2nd May, Iran reached the disease management phase, expanded its active case finding program, implemented contact tracing, and tested those in close contact with COVID-19 patients.

2.2 Statistical analysis

Autoregressive integrated moving average (ARIMA) is a powerful tool for forecasting a time series model (18), and seasonal auto-regressive integrated moving average (SARIMA) model is used when a seasonal component is involved (19). The effect of the intervention, a one-off event affecting the new confirmed cases variable, was analyzed by using intervention time series analysis. Introduced by Box and Tiao, intervention time series analysis is an approach for handling the effectiveness of interventions in a dynamic regression framework (20). Although it is assumed that an intervention can only happen at a specific time, its effects can spread over time. In this study, three types of interventions, including step, delayed (linear trend), and decayed (exponential trend) response, were considered for evaluating the impact of the Nowruz holiday and government policies (Figure 2).

Figure 3 shows the time series of new confirmed COVID-19 cases in Iran from 19th February 2020 to 2nd May 2020. We considered two government policies as two interventions. The first policy was the closing of schools and universities (CSU), which was implemented on 1st March 2020. On 27th March 2020, a new legislation came into force requiring the social distancing measures (SDM) to be implemented.

For time series modeling, it is assumed that the intervention occurs at a time point, say 'τ', where a dummy variable can be considered 0 before the intervention and 1 after the intervention (21). This is called a step intervention. Figure 3 shows the effect of the CSU and SDM on the series in x using these dummy variables with τ_1 and τ_2 corresponding to 1st March 2020 and 27th March 2020, respectively. The model is then,

$$Y_t = \beta_0 + \beta_1 CSU_t + \beta_2 Nowruz\ holidays + \beta_3 SDM_t + e_t,$$

, where Y_t represents the outcome variable over time point t, which is considered the number of confirmed COVID-19 cases. The value of β_0 is the baseline level of the response variable (also the initial value at $t = 0$). β_1 and β_3 represent the effects of the drop in newly confirmed COVID-19 cases because of the CSU and SDM interventions. Also, β_2 represents the effect of the Nowruz holidays in decreasing the number of new confirmed COVID-19 cases. Furthermore, a SARIMA model was used for error term e_t.

Plots of the autocorrelation function (ACF), partial autocorrelation function (PACF), and Ljung–Box test were proposed for determining uncorrelated residuals (22). Furthermore, residual plots were used to assess the zero mean assumption, and the normality of residuals was evaluated using the Kolmogorov-

Smirnov test. All the model developments, computations, and comparisons were performed using the R forecast package, and the statistical significance level was set at *P*-value less than 0.05.

2.3 Ethical statement

The data was provided by the Iranian Ministry of Health and is publicly available online on the WHO website. Therefore, ethical approval was not required.

3. Results

After detecting the first COVID-19 case on 19th February 2020 in Iran, the daily number of new confirmed COVID-19 cases rose gradually to 1046 until 19th March. With the beginning of the Nowruz holidays on 20th March, the number of new confirmed cases increased sharply with three days delay and exceeded 3000 at the maximum point on 30th March (Figure 3).

As shown in Table 1, the mean number of new confirmed cases per day before 2nd March 2020 (before any intervention) was 645.47 cases (95% CI, 78.32 to 1212.62; p=0.03) in Iran. A significant linear increment in new confirmed cases, which was about 0 to 1872.20 (95% CI, 1257.603 to 2486.79; p<0.001), followed by the Nowruz holiday was observed. Furthermore, with a three-day delay, a linear increase in COVID-19 case numbers was observed for eight days after the beginning of the Nowruz holiday. As shown in Table 1 and Figure 3, the Nowruz holiday caused a significant increase in the number of COVID-19 new cases. Although the Nowruz holidays began on 20th March 2020, its impact was observed within eight days after 23rd March 2020. Although the Nowruz holiday lasts two weeks, after 31st March 2020, it did not affect the daily number of new cases.

The results showed that the first intervention (CSU) had no significant impact on the new cases of COVID-19 (p=0.45), while the second intervention (SDM) significantly decreased the number of new confirmed cases from 2182.80 cases (95% CI, 1556.56 to 2809.04; p<0.001) to 0 during the intervention time.

The confirmed COVID-19 cases model is as follows:

$$Y_t = 645.47 + 130.0\ CSU_t + 1872.20 Nowruz\ holidays + 2182.80\ SDM_t + e_t$$

, where $e_t \sim SARIMA(1,0,0)(1,0,0)_{14}$ and indicates a seasonality variation in the daily new cases of COVID-19 in Iran. That is to say, there is a recurrent pattern of changes in the number of new cases within the period series. This season was 14 days, which shows that a uniform pattern happens every two weeks. This can be due to the incubation period of the disease, which is a maximum of 14 days.

The effect of social distancing rules was substantial considering the gradual downtrend in the daily number of new cases. As shown in Figure 3, the daily number of cases exponentially decreased after 27th March for 23 days. In detail, this reduction was observed from 27th March to 19th April 2020, when the government removed the social distancing restriction afterwards.

For model diagnostics, the residuals should be white noise. In this connection, there was no pattern in the plot of residuals, and they were randomly scattered around zero. Also, there were no spikes in the autocorrelation function, indicating that there was no remaining autocorrelation regarding the residuals. Furthermore, the Ljung-Box (LB) test was utilized to understand whether any of the groups of autocorrelations of a time series are different from zero. As shown in Table 1, uncorrelated residuals were confirmed at the 5% significance level ($p>0.05$). Moreover, the Kolmogorov-Smirnov test established the normality of residuals.

4. Discussion

COVID-19 is an infectious disease spread through direct contact between individuals (23). Outbreak control measures implemented to diminish the contacts within the population can reduce the height of the peak and the final size of the epidemic. In Iran, different policies and strategies have been implemented based on the experience and recommendations of China and the WHO to control the outbreak of COVID-19 (5, 17). The new social distancing measures were implemented in Iran Provinces to reduce the risk of expansion of the epidemic. The most important part of the social distancing rules was travel restrictions and car seizure and 5,000,000 IRR ($ 35) fines implemented on 27th March 2020. Our findings indicated that the implementation of the social distancing rules in Iran has been effective in controlling the spread of the outbreak, and the COVID-19 new cases significantly decreased after adopting those measures. Our results regarding the impact of social distancing policies on the COVID-19 case number support earlier findings on the effectiveness of such measures **(13, 24, 25).**

In general, we found that the national Nowruz holidays and the new social distancing measures influenced the number of newly confirmed COVID-19 cases in Iran. However, the closing of kindergartens, schools, and universities was not followed by a reduction in new cases.

There are some potential reasons for the ineffectiveness of government policies on the number of new cases. In Iran, like some other countries, the outbreak coincided with a significant national holiday. We found a negative relationship between the Nowruz holidays and number of cases which might have dwindled the effectiveness of disease control measures. The general population were requested to stay at home and self-quarantine during the Nowruz holidays and refrain from visiting their families. Therefore, the degree of the outbreak was expected to be manageable. This somewhat contradictory result may be

due to the fact that millions of Iranians travelled around the country. With the beginning of the Nowruz holidays, the police reported heavy traffic toward northern cities, and traveling has exacerbated the spread of the outbreak. This finding corroborates the results of Heidari and Sayfouri, who suggested that Nowruz aggravated the COVID-19 crisis in Iran (16).

It is worth noting that designing and implementing rules is essential, but the timing of implementation of such measures is critical as well. Previous studies have also indicated that earlier implementation of measures can be more productive. A recent study has shown that every one day delay in the implementation of social distancing measures leads to 2.41 days delay in containment (15). The impact of delays may be particularly significant for communities that are prone to rapid disease transmission. For example, during the Nowruz holidays in Iran, people visit relatives and many others use the two-week break to travel to spectacular areas across the country. Therefore, earlier implementation of restriction rules and prevention of travels would have potentially made it easier to control the spread of the outbreak.

There are several limitations to the analysis conducted in this study. First, we only analyzed the data related to 19th February to 2nd May 2020, as the Iranian Ministry of Health only began its active case finding program during this period. Second, it is important to note that although time points for interventions can be clearly identified, the enforcement of the studied measures was not instantaneous as policies were gradually implemented.

Notwithstanding these limitations, the study suggests that in general, government policies can have a significant influence on COVID-19 case numbers and can be used to control similar outbreaks. Our results also underscore the critical influence of national holidays on the spread of COVID-19 in Iran. Our findings should be considered for planning and implementing future measures.

5. Conclusion

This study evaluated the effects of two government policies and the Nowruz holidays on the number of new COVID-19 cases in Iran using intervention time series analysis. The results indicated that the Nowruz holidays significantly increased case numbers. We also found that the implementation of social distancing measures as a non-pharmaceutical intervention in Iran has had a significant influence on the number of COVID-19 cases and could effectively control the spread of the disease in Iran.

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Credit authorship contribution statement

Ali Hadianfar: Data curation, Writing - original draft, Visualization. **Razieh Yousefi**: Investigation, Writing - review & editing. **Milad Delavary Foroutaghe**: Formal analysis, Software, Writing. **Vahid Fakoor**: Conceptualization, Methodology, Supervision. **Mohammad Taghi Shakeri**: Investigation, Writing - review & editing.

Conflict of Interest Disclosures

The authors declare no conflict of interest.

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Table 1. The effects of the government policies and Nowruz holidays on the daily confirmed new COVID-19 cases, SARIMA models.

Output	Estimate	SE	P–value	95%CI	Ljung–Box	Kolmogorov–Smirnov
Intercept	645.47	289.36	0.03	(78.32 , 1212.62)		
Effect(CSU[a])	130.0	172.87	0.45	(-208.82, 468.83)		
Nowruz holidays	1872.20	313.57	<0.001	(1257.603 , 2486.79)		
Effect(SDM[b])	2182.80	319.51	<0.001	(1556.56 , 2809.04)		
Noise	(1,0,0)(1,0,0)				0.18	0.96

[a] Closing schools and universities, 1 March 2020

[b] New social distancing rules 27 March 2020

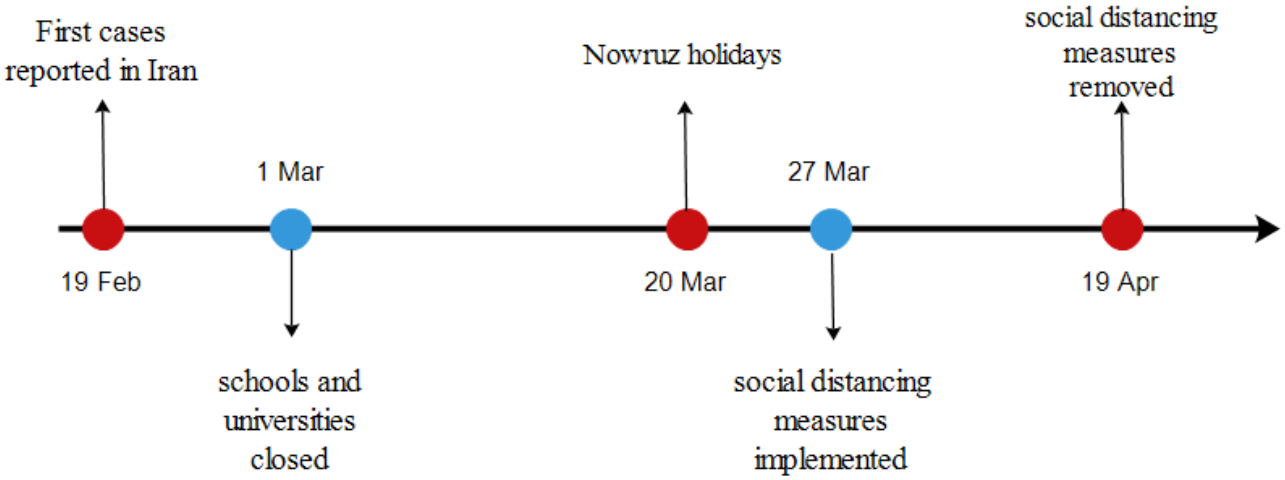

Figure 2. Timeline of COVID-19 related events in Iran, from 19. of February to 19. of April 2020. Red dots present events in the COVID-19 outbreak, blue dots present control measures.

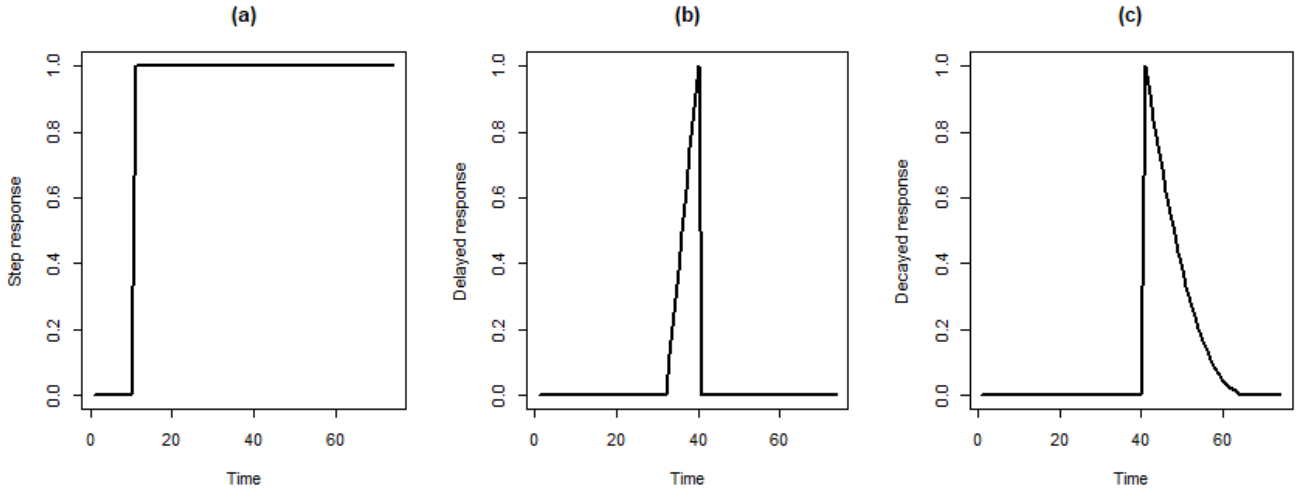

Figure 1. Three type of interventions used in dynamic regression, step response (a), delayed response (b) and decayed response (c)

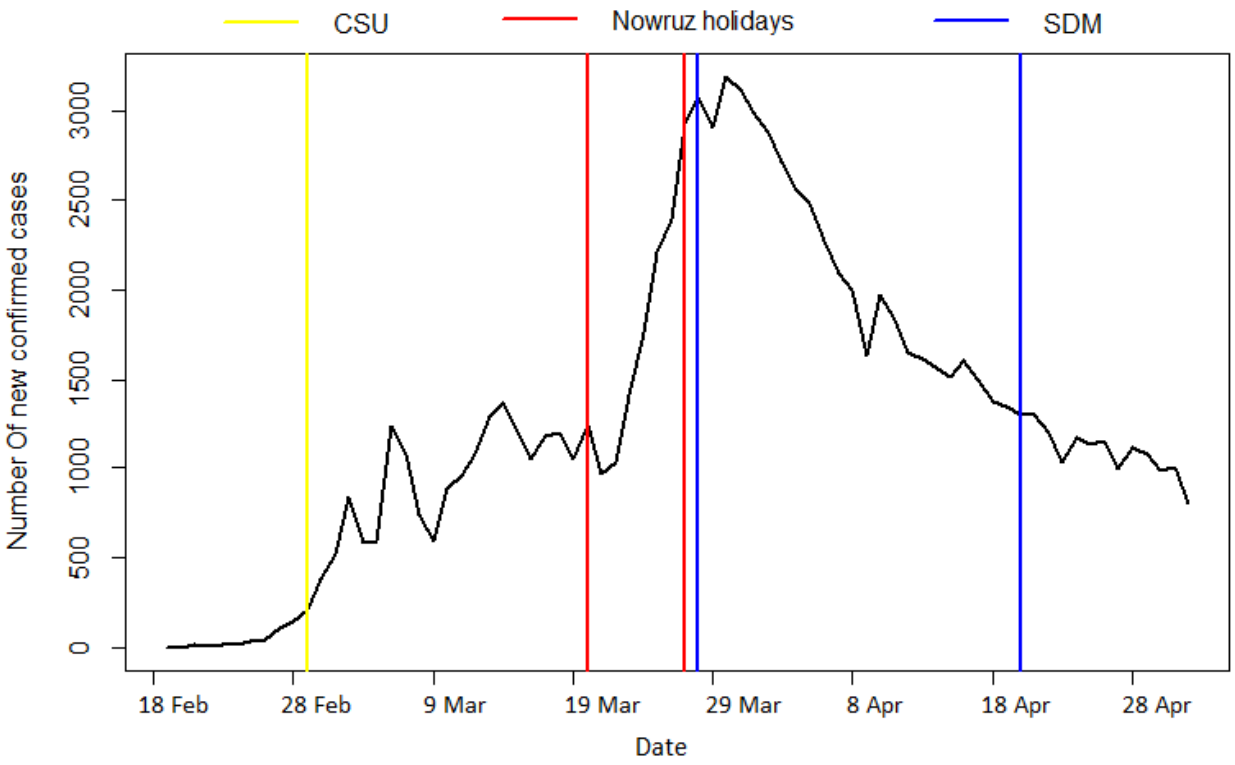

Figure 3. The times series of new confirmed COVID-19 cases in Iran from February 19, 2020 to May 2, 2020. Yellow, Blue and Red vertical lines indicate time of implementation of Closing schools and universities, Nowruz holidays and implementation of new social distancing rules respectively.

Conflict of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.