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Comparative analysis of the effects of COVID-19 in 2020 and 2021: Case study of Italy

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Abstract. This study develops a comparative analysis of the effects of Coronavirus disease 2019 (COVID-19) between April-June 2020 (without vaccinations) and April-June 2021 (with vaccinations) in Italy. The findings reveal that the dynamics of COVID-19 is declining because of its seasonality that reduce the effects in summer season. Hence, this study provides critical lessons that could be of benefit to countries for crisis management of pandemic diseases, showing how seasonality can reduce the diffusion of airborne disease of novel viral agents in summer.

Keywords. Pandemic diseases; Coronavirus, vaccines, Vaccination campaigns; Health systems; Climate; Seasonality.
JEL. Q10; O31; O33; Q01; Q16; Q18.

1. Introduction

The novel Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) is the causative viral agent of the Coronavirus disease 2019 (COVID-19), an infectious disease that appeared in late 2019 (Anand *et al.*, 2021; Coccia, 2020, 2021, 2 021b, 2022). COVID-19 is still circulating in 2021 with mutations of the novel coronavirus that generate a constant pandemic threat in manifold countries with higher numbers of COVID-19 related infected individuals and deaths (Bontempi & Coccia, 2021; Bontempi *et al.*, 2021; Johns Hopkins Center for System Science and Engineering, 2021).

The alarming levels of spread and severity of COVID-19 worldwide has supported the development of vaccines in 2020 based on messenger RNA vaccines, known as mRNA vaccines for high levels of protection by preventing COVID-19 among people that are vaccinated (Coccia, 2021a, 2021c, 2022b, 2022c, 2022d). New mRNA vaccines for COVID-19 are based on accumulated knowledge that the infective process itself is effective in raising an immune response and genetic engineering can be utilized to construct virus-like particles from the capsid and envelope proteins of viruses (Smoot, 2020). These mRNA vaccines eliminate a lot of phases in manufacturing process for the development of new drugs because rather than having viral proteins injected, the human body uses the instructions to manufacture viral proteins itself. In short, mRNA vaccines are produced and manufactured by chemical rather than biological synthesis, as a consequence the process of development is much faster than conventional vaccines to be redesigned, scaled up and mass-produced (Komaroff, 2020). Manifold public agencies for protecting and promoting public health through the control and supervision in the United

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Kingdom, the USA, Canada, Europe and other countries confirm that mRNA vaccines for COVID-19 can be effective and safely tolerated in population (Abbasi, 2020; Cylus *et al.*, 2021; Heaton, 2020; Jeyanathan *et al.*, 2020; Komaroff, 2020).

Because of the rapid spread of COVID-19 worldwide, understanding whether and how the effects of COVID-19 in society change in the presence of vaccinations is a crucial aspect to eradicate infectious diseases in the population (Aldila *et al.*, 2021). Vaccination has the potential to keep low basic reproduction number, to relax nonpharmaceutical measures and to support the recovery of socioeconomic activities (cf., Anser *et al.*, 2020; Prieto Curiel *et al.*, 2021). Akamatsu *et al.* (2021) argue that to cope with infectious disease severity that increases considerably, governments have to implement an efficient campaign of vaccination to substantially reduce infections and mortality in society and also avoid the collapse of the healthcare system. Aldila *et al.* (2021) maintain that higher levels of vaccination rate can eradicate COVID-19 from the population. The final goal of a plan of vaccination is achieving herd immunity to protect vulnerable individuals (Anderson *et al.*, 2020; de Vlas and Coffeng, 2021; Randolph & Barreiro, 2020; Redwan, 2021). Herd immunity indicates that only a share of a population needs to be immune and as a consequence no longer susceptible (by overcoming natural infection or through vaccination) to a viral agent for epidemic control and to stop generating large outbreaks (Fontanet & Cauchemez, 2020; Rosen *et al.*, 2021).

However, other climatological, environmental, demographic, and geographical factors of the total environment can influence the spread of COVID-19 (Bashir *et al.*, 2020; Rosario *et al.*, 2020; Sahin, 2020; Sarmadi *et al.*, 2020). Zhong *et al.* (2018) argue that static meteorological conditions may explain the increase of bacterial communities in the presence of air pollution. Coccia (2020) reveals that, among Italian provincial capitals, the number of infected people was higher in cities having high air pollution, cities located in hinterland zones (i.e. away from the coast), cities having a low average intensity of wind speed and cities with a lower temperature (cf., Coccia 2020, 2021a, 2021b). Rosario *et al.* (2020) also reveal that high wind speed improves the circulation of air and also increases the exposure of the novel coronavirus to the solar radiation effects, a factor having a negative correlation in the diffusion of COVID-19.

In this context, a key problem in current COVID-19 pandemic crisis is to assess the effects of COVID-19 related infected individuals and deaths, hospitalizations of people and admissions to Intensive Care Units with and without vaccinations. The study here confronts this problem here by developing a comparative analysis between the period April-May-June 2020 (without vaccinations) and April-May-June 2021 (with vaccinations) in Italy, which was the first European country to experience a rapid increase in confirmed cases and deaths of COVID-19 in 2020 and in 2021 is one of the countries with a widespread plan of vaccinations. The study here can provide critical results to clarify the dynamics of COVID-19pandemic, effects of vaccinations in society and behavior of the novel Coronavirus in environment. Lessons learned from this study could be of benefit to countries to design strategies of health, environmental and social policy to cope with and/or to prevent pandemics similar to COVID-19. This study is part of a large body of research directed to explain drivers of transmission dynamics of COVID-19 and design effective policy responses of crisis management for pandemic threats (Coccia, 2021a, 2021d, 2022b).

2. Materials and methods

The goal of this study is a comparative analysis of the effects of COVID-19 between April-May-June 2020 (without vaccination plan) and April-May-June 2021 (with vaccination plan) in Italy to assess differences and effects of the dynamics of this novel infectious disease in society (Coccia, 2018, 2018c, 2019a).

Research question

How is the behavior of the COVID-19 in environment with or without vaccinations?

Are the effects of COVID-19 between April-May-June 2021 (with vaccination plan) lower than April-May-June 2020 without vaccination plan in Italy?

Research setting

The research setting is a case study of Italy, the first European country to experience a rapid increase of COVID-19 related infected individuals and deaths 2020 in which this novel coronavirus is still circulating in 2021 continuing to generate a higher number of infected individuals and deaths (Coccia, 2020, 2021a). Moreover, Italy, on 20 June 2021 is one of the countries with widespread vaccinations having 76.11 doses of vaccines administered per 100 inhabitants, with a share of people fully vaccinates equal to 26% and share of people only partially vaccinated against COVID-19 also equal to 26 % (Our World in Data, 2021; Lab24, 2021).

Period, sample and source

The period under study is from 1st April to 15th June 2020 that is compared to the same period in 2021 in Italy, using daily data based on N=76 days in 2020 and N=76 days in 2021 for a total of N=152 cases for different variables. Source of epidemiological data under study is The Ministry of Health in Italy (Ministero della Salute, 2020).

Measures

The measures for statistical analyses are:

- *Number of daily COVID-19 infected individuals* is measured with confirmed cases of COVID-19 in population per day.
- *Number of daily COVID-19 swab tests* to verify the positivity to the novel coronavirus (confirmed case) by analyzing specimen of people (LabCorp, 2020).
- *Daily hospitalized people* are the hospitalized people (patients with different COVID-19 symptoms and patients in ICUs).
- *Daily admission to Intensive Care Units (ICUs)* is the number of recovery in ICUs of patients.
- *Number of daily COVID-19 deaths* is measured with total deaths per day in society
- *Daily Fatality rate* = ratio of deaths at (t) /confirmed cases at (t-14). The lag of about 14 days from initial symptoms to deaths is based on empirical evidence of some studies (Zhang *et al.*, 2020).

Data analysis procedure

Firstly, the study calculates the daily contagiousness coefficient of COVID-19 in the period under study of 2020 and 2021, given by:

$$\text{Contagiousness coefficient of COVID} - 19 \text{ at } t \text{ (CCV)} = \frac{Confirmed\,cases\,at\,t}{swab\,tests\,at\,t}$$

In order to eliminate from original time series y_t weekly seasonal variation, it is applied the method of moving averages (MM) considering the sub-period of length r =7 days (a week), using the following formula for MM7:

$$y'_t = \frac{y_{t-3} + y_{t-2} + y_{t-1} + y_t \ + y_{t+1} + y_{t+2} + y_{t+3}}{r = 7\ days}$$

The new time series adjusted with averaging process is given by $y^*_t = \sum_t^s y'_t$ that tends to eliminate period to period weakly fluctuations and produces a much smoother series than original observations.

Data of daily hospitalization of people and admissions to ICUs are standardized as follows:

$$\text{Daily hospitalization of people standardized} = \frac{\text{daily hospitalization of people (t)}}{MM7\ \text{Contagiousness coefficient of COVID} - 19\ (\text{t} - 5)}$$

$$\text{Daily admission ICUs standardized} = \frac{\text{daily admission ICUs (t)}}{MM7\ \text{Contagiousness coefficient of COVID} - 19\ (\text{t} - 5)}$$

The lag of about 5 days used to standardize these variables is based on an average period from diagnosis (initial symptoms and positivity to swab test) to the hospitalization and recovery in ICUs of patients as explained by specific studies (Faes *et al.*, 2020).

The sample of N=152 *cases* is divided in two sub-samples having similar temporal, health and societal conditions for a structural comparative analysis:

- group 1: data from 1st April to 15th June 2020, N=76
- group 2: data from 1st April to 15th June 2021, N=76

Secondly, Data are analyzed with descriptive statistics given by arithmetic mean (M) and Std. error of mean for a comparative analysis between two groups just mentioned.

Thirdly, follow-up investigation is the Independent Samples *t*-Test that compares the means of two independent groups in order to determine whether there is statistical evidence that the associated population means are significantly different. The assumption of homogeneity of variance in the Independent Samples *t* Test -- i.e., both groups have the same variance -- is verified with Levene's Test based on following statistical hypotheses:

H_0: σ_1^2 - σ_2^2 = 0 (population variances of group 1 and 2 are equal)
H_1: σ_1^2 - $\sigma_2^2 \neq 0$ (population variances of group 1 and 2 are not equal)

The rejection of the null hypothesis in Levene's Test suggests that variances of the two groups are not equal: i.e., the assumption of homogeneity of variances is violated. If Levene's test indicates that the variances are equal between the two groups (i.e., p-value large), equal variances are assumed. If Levene's test indicates that the variances are not equal between the two groups (i.e., p-value small), the assumption is that equal variances are not assumed.

After that, null hypothesis (H'_0) and alternative hypothesis (H'_1) of the Independent Samples *t*-Test are:

H'_0: $\mu_1 = \mu_2$, the two population means are equal in 2020 and 2021
H'_1: $\mu_1 \neq \mu_2$, the two population means are not equal in 2020 and 2021

Finally, trends of variables under study are visualized and analyzed for a comparative analysis of the impact of COVID-10 in Italy between 2020 (without vaccinations) and 2021 (with vaccinations). In particular, this study extends the statistical analysis with a regression model based on a linear relationship in which variables measuring the impact of the COVID-19 on health of people are a linear function of time in 2020 and 2021 period. The specification of linear relationship is given by a model using the time series y^*_t in 2020 and 2021:

$$\log y^*_t = \alpha + \beta\, t + u \qquad (1)$$

y^*_t = measures of the impact of COVID-19 pandemic in society using MM7 of time series

t = time given by 2020 and 2021 period

u = error term

Ordinary Least Squares (OLS) method is applied for estimating the unknown parameters of linear model [1].

Statistical analyses are performed with the Statistics Software SPSS® version 26.

3. Results

Table 1 shows that confirmed cases in 2020 is about 4%, whereas in 2021 is 3.4%. Number of hospitalizations and ICUs of people, and deaths in 2020 has a slightly higher level, whereas fatality rate is lower in 2021 compared to 2021 likely because of a higher number of swab tests in 2021 that have detected more confirmed cases that increase the denominator of the ratio of fatality reducing the total value.

Table 1. *Descriptive statistics*

	April-May-June 2020		April-May-June 2021	
Description of variables	M	Std. Error Mean	M	Std. Error Mean
Confirmed cases standardized	0.04	0.00	0.034	0.002
Hospitalizations standardized	1270.45	191.07	854.010	84.281
ICUs standardized	135.01	22.95	101.460	9.612
Deaths	289.51	24.19	239.080	15.515
Fatality rates	0.11	0.00	0.018	0.000

Note: M= arithmetic mean, *N*=76 days in 2020 and 76 in 2021

Table 2 shows the Independent Samples *t* Test, as follow-up inspection, to assess the significance of the difference of arithmetic mean between groups of 2020 and 2021 under study. The *p*-value of Levene's test is significant, and we have to reject the null hypothesis of Levene's test and conclude that the variance in the groups under study is significantly different (i.e., equal variances are not assumed).

Table 2. *Independent Samples Test*

		Levene's Test for equality of variances		*t*-test for equality of Means				
		F	Sig.	*t*	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference
Confirmed cases 2020 vs. 2021	•Equal variances assumed	28.9	0.001	0.64	150.00	0.53	0.00	0.00
	•Equal variances not assumed			0.64	108.97	0.53	0.00	0.00
Hospitalizations 2020 vs. 2021	•Equal variances assumed	32.139	0.001	1.99	150.00	0.05	416.43	208.83
	•Equal variances not assumed			1.99	103.12	0.05	416.43	208.83
ICUs 2020 vs. 2021	•Equal variances assumed	27.08	0.001	1.35	150.00	0.18	33.55	24.88
	•Equal variances not assumed			1.35	100.52	0.18	33.55	24.88
Deaths 2020 vs. 2021	•Equal variances assumed	21.297	0.001	1.94	150.00	0.06	55.65	28.76
	•Equal variances not assumed			1.94	127.90	0.06	55.65	28.76
Fatality rates 2020 vs. 2021	•Equal variances assumed	74.863	0.001	48.80	150.00	0.001	0.09	0.00
	•Equal variances not assumed			48.80	78.70	0.001	0.09	0.00

Table 2 also shows t-test for Equality of Means that provides the results for the actual Independent Samples t Test. Results are convergent, except fatality rates. In particular, since p -value≥0.5, higher than fixed significance level $\alpha = 0.01$, we can accept the null hypothesis, and conclude that the mean of confirmed cases, hospitalizations of peoples, ICUs, and deaths in 2020 and 2021 is significantly equal: there is not a significant difference in mean between 2020 and 2021. Instead, for fatality rates, since p -value<0.001 is less than chosen significance level $\alpha = 0.01$, we can reject the null hypothesis, and conclude that the mean in 2021 and 2021 is significantly different, likely for reasons mentioned for table 1.

Table 3. *Estimated relationships based on linear model of regression*

	Confirmed cases standardized		Hospitalizations standardized		ICUs standardized	
	2020	2021	2020	2021	2020	2021
Constant α	0.095***	0.065***	3776.09***	2089.60***	420.90***	243.34***
Coefficient β	−0.002***	−0.001***	−65.08***	−32.09***	−7.43***	−3.69***
Stand. Coeff. β	−0.90	−0.99	−0.86	−0.97	−0.82	−0.97
R^2	0.81	0.97	0.74	0.93	0.67	0.94
F-test	316.99***	2557.12***	215.57***	989.43***	151.34***	1229.56***
	Deaths		Fatality rates			
	2020	2021	2020	2021		
Constant α	654.86***	466.71***	0.11***	0.02***		
Coefficient β	−9.26***	−6.05***	0.000021	−0.00008***		
Stand. Coeff. β	−0.97	−0.99	−.80	.53		
R^2	0.94	0.97	0.01	0.48		
F-test	1143.21***	2525.92***	0.067	68.25***		

Notes: Explanatory variable: Case sequence (*time)*
Dependent variables: Hospitalizations standardized, Confirmed cases standardized, ICUs standardized, Deaths, Fatality rates
Significance: ****p*-value<0.001, **p*-value<0.5

Table 3 and figures 1-4 confirm, *ictu oculi*, previous results. In particular, simple regression analysis in table 3 shows, in average, a higher reduction in 2020 than year 2021 of the coefficients of regression of variables under study

(p-value= .001, except fatality rate that in 2021 is not significant). The R^2 of regression models indicates that more than 47% and until to 97% of the variation in variables of the COVID-19 can be attributed (linearly) to time. *F*-test is significant with p-value <.001, except fatality rate in 2021.

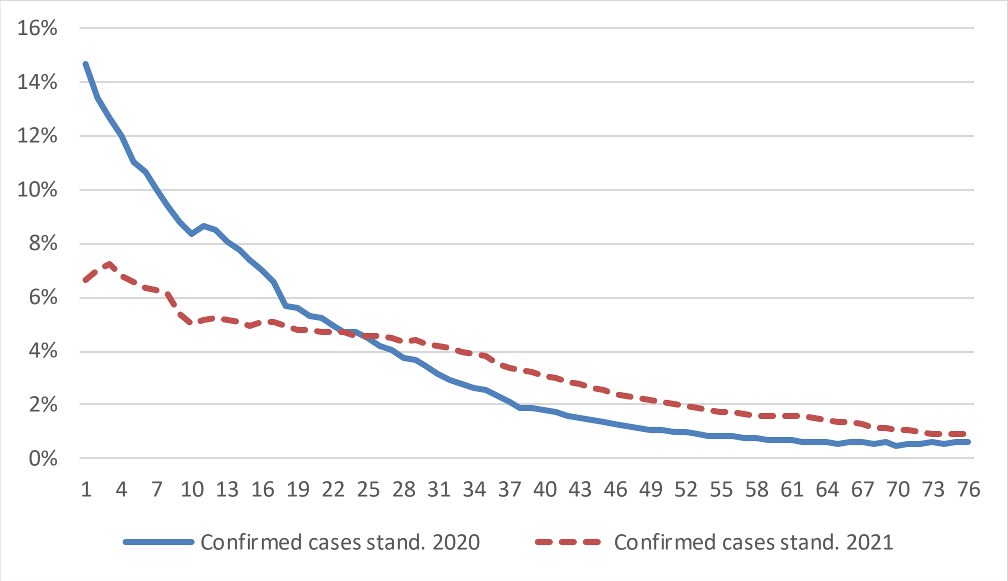

Figure 1. *Trends of confirmed cases from April to June in 2020 and 2021, Italy*

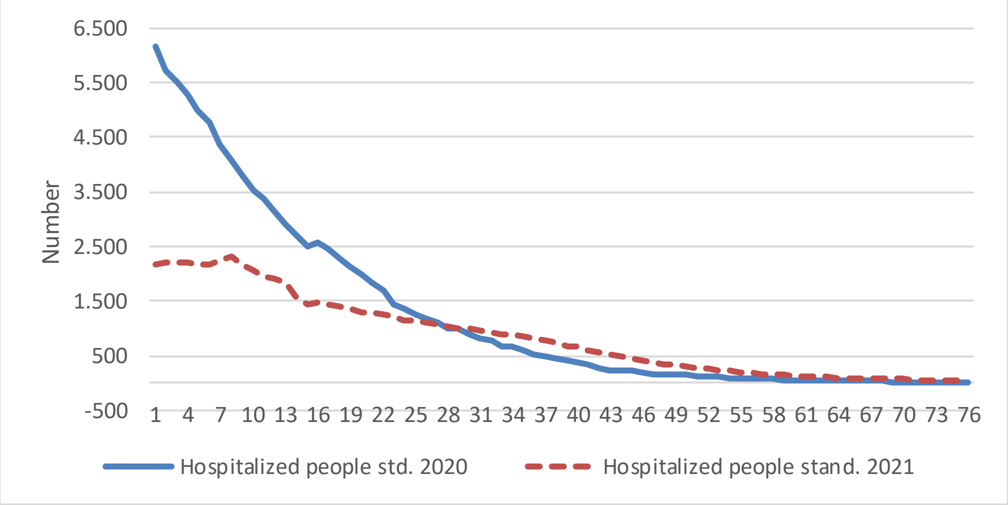

Figure 2. *Trends of hospitalized people from April to June in 2020 and 2021, Italy*

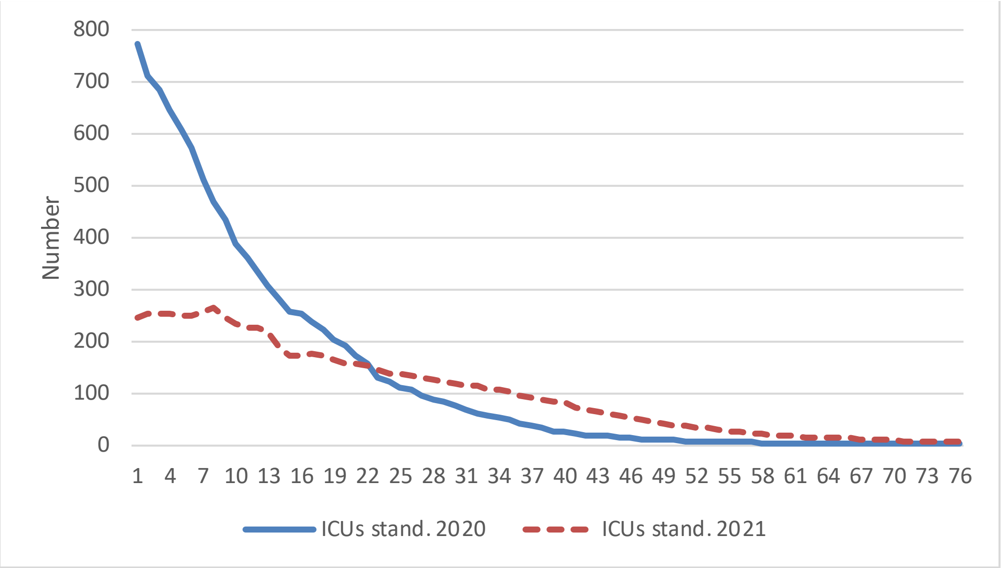

Figure 3. *Trends of ICUs from April to June in 2020 and 2021, Italy*

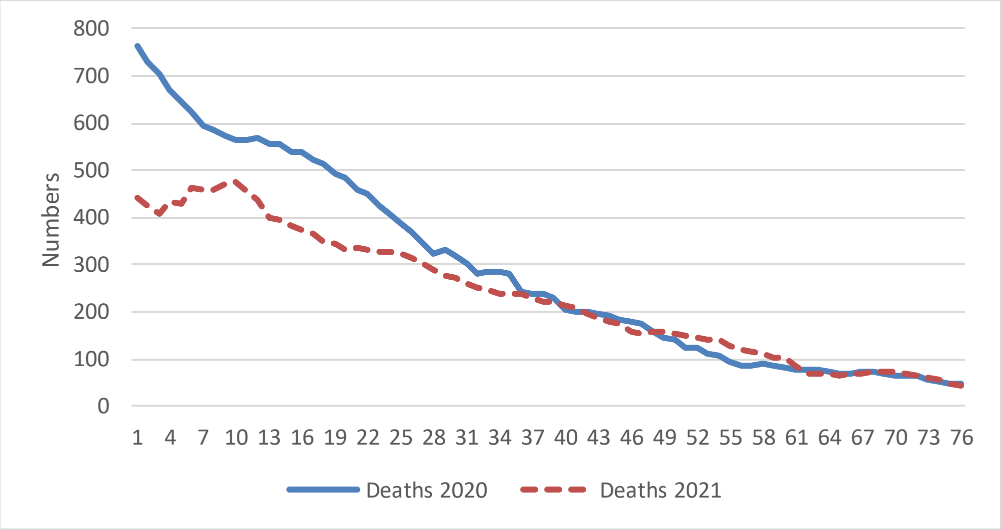

Figure 4. *Trends of deaths from April to June in 2020 and 2021, Italy*

4. Discussion of phenomena expalined

One of the most crucial problems for the management of the COVID-19 pandemic crisis has been the effective implementation of vaccinations to constrain negative effects of pandemics in society. This study does not deal with effectiveness of vaccinations but it is a comparative analysis of the effects of COVID-19 in 2020 (without vaccinations) and 2021 (with vaccinations) in the same socioeconomic system, given by Italy. Results reveal similar dynamics of COVID-19, regardless vaccinations. These findings suggest that other factors are associated with the dynamics of COVID-19, such as seasonality, which reduces the spread of the airborne disease of novel coronavirus over time and space and constrain the negative effects in society in the presence of specific conditions of total environment (atmosphere, biosphere and anthroposphere) in summer season.

In general, meteorological factors (e.g., temperature and humidity) play a well-established role in the seasonal transmission of respiratory viruses and influenza in temperate climates. Scholars analyze the sensitivity of COVID-19 to meteorological factors to explain how changes in the weather and seasonality may constrain COVID-19 transmission (Kerr *et al.,* 2021). In fact, studies report that the transmission of COVID-19 can be influenced by the variation of environmental factors associated with seasonality. Scholars suggest that the effects of seasonality on the influenza epidemic are associated with seasonal fluctuations connected with latitude in the North and South Hemisphere (Ianevski *et al.,* 2019; Shaman *et al.,* 2020). Recent studies point out the strong seasonal factor of COVID-19 because of environmental elements (Audi *et al.,* 2020; Moriyama *et al.,* 2020). The explanation of the role of seasonality in the spread of the COVID-19 pandemic is more and more important to design and implement appropriate public health interventions and plans of vaccination over time. The study by Liu *et al.* (2021, p.1ff) shows that the cold season in the Southern Hemisphere countries caused a 59.71 ±8.72% increase of the total infections, whereas the warm season in the Northern Hemisphere countries contributed to a 46.38 ± 29.10% reduction. These results suggest that COVID-19 seasonality is more pronounced at higher latitudes, in the presence of larger seasonal amplitudes of environmental indicators are observed. Other studies have focused on temperature or humidity effects that might slow down transmission of the novel coronavirus (Karapiperis *et al.,* 2021; Rosario *et al.,* 2020). Byun *et al.* (2021) show that that manifold studies suggest an inverse relation between temperature and humidity and global transmission of SARS-CoV-2. In fact, COVID-19 tends to be temperature-sensitive and, as a consequence driven by a seasonal viral agent (cf., Engelbrecht & Scholes, 2021). The empirical evidence of these scholars seems to suggest that the novel coronavirus pandemic has just completed a full seasonal cycle, showing a negative correlation of the rate of diffusion with humidity and temperature: i.e. the SARS-CoV2 transmissibility tends to naturally decrease in summer seasons regardless vaccinations. Karapiperis *et al.* (2021) demonstrated that UV radiation is strongly associated with incidence rates, rather than mobility, suggesting that UV radiation is a seasonality indicator for COVID-19, irrespective of the initial conditions of the epidemic (cf., Kumar *et al.,* 2021). Many infectious diseases, such as endemic human coronaviruses, can be a seasonally recurrent infectious disease that varies over time and space (Kronfeld-Schor *et al.,* 2021).

Dbouk & Drikakis (2020) argue that epidemiologic models do not consider for the effects of climate conditions on the transmission dynamics of viruses, but a vital relationship between weather seasonality, airborne virus transmission, and pandemic disease exists over time. These scholars, applying fluid dynamics simulations, show that weather seasonality can induce two outbreaks of the COVID-19 pandemic worldwide. These two pandemic outbreaks per year are inevitable because are directly associated with weather seasonality based on temperature, relative humidity, and wind speed. Many studies, analyzing the role of climate and seasonality of pandemic diseases, have proposed an extension of the family of epidemiologic models with the introduction of seasonality transmission of SARS-CoV-2 (Batabyal, 2021).

5. Concluding observations and limitations

Currently, we know very little about relationships between novel coronavirus infections and environmental factors that can reduce virus spread, because of solar exposure and other climatological factors (Coccia, 2020, 2021a, 2021b; Rosario *et al.,* 2020). Since the initial outbreaks worldwide, scholars analyze the seasonal dynamics of COVID-19 because results can be basic to better planning and preparedness to cope with the novel coronavirus disease (Byun *et al.,* 2021). This study reveals,–with a comparative analysis between the period April-May-June 2020 (without vaccinations) and April-May-June 2021 (with vaccinations) in Italy–, that the mean of confirmed cases, hospitalizations of people, admissions to ICUs and deaths in 2020 and 2021 is significantly equal, corroborating the seasonal behavior in the total environment of the COVID-19, which decreases regardless vaccinations. This result is basic for policy implications of crisis management. These findings can support the implementation of best practices of public health, based on seasons in the Northern and Southern Hemispheres, in which the COVID-19 and similar infectious disease pandemics unfold over time (cf., Coccia, 2021d). In fact, Danon *et al.* (2021) show that seasonal changes in transmission rate can affect the timing and size of the COVID-19 pandemic, shifting the peak into winter, with important implications for planning the healthcare capacity and also vaccinations.

What this study adds to current studies on the COVID-19 pandemic crisis is that the behavior of the novel coronavirus in the environment seems to be seasonal, regardless plans of vaccinations. This finding is critical to clarify transmission dynamics and support appropriate interventions of health policy to cope with virus spread and contain outbreaks of future infectious diseases. The understanding of the role of for seasonality is also a vital factor to mitigate socioeconomic issues. Policymakers and the public will need a deeper understanding of this factor associated with the COVID-19 and if a seasonality pattern for COVID-19 is confirmed, it can guide better health and social policies to cope with future infectious diseases similar to COVID-19. Kronfeld-Schor *et al.* (2021) argue that additional investigation should be directed to explain relationships between host immune seasonality warrants evaluation, weather and human behavior that may contribute to clarify dynamics of COVID-19 in terms of seasonality. A big challenge will be to predicting seasonality of infectious diseases directed to alleviate and/or prevent seasonal infectious diseases in complex, changing human-earth system. In particular, knowledge of other viral respiratory diseases suggests that the transmission of SARS-CoV-2 could be associated with seasonally varying environmental factors (e.g., temperature and humidity). Smit *et al.* (2021) argue that different studies suggest that climatic factors would reduce the viral transmission rate in places entering the boreal summer and the COVID-19 peak would coincide with the peak of the influenza season, increasing the burden on health systems. However, seasonality alone can be a main factor in transmission dynamics of COVID-19 but cannot be a sufficient element to curb the novel coronavirus transmission that requires multidisciplinary and timely intervention policies of short and long run, a scaled up health care capacity in the winter seasons, rather than summer period. In this perspective, the study here can provide main lessons learned from a comparative analysis that supports seasonal factors when formulating intervention strategies to cope with and/or prevent future pandemic diseases.

Overall, then, this statistical analysis here suggests that the reduction of the dynamics of COVID- seems to be associated with seasonality of the novel coronavirus that reduce the effects in the presence of favorable conditions of total environment in summer that constrain the spread of the airborne disease in society. These conclusions are, of course, tentative. A main concern is that there can be differences among countries according to their geographical position, climatological factors and also level of air pollution. Moreover, there can be a bias for detecting and reporting all COVID-19 data among different regions of the same nation. Finally, structure of population and characteristics of patients (e.g., ethnicity, age, sex, and comorbidities) may vary between regions affecting results. Although the study here provides main findings to better explain the behavior of COVID-19 in total environment to design policy responses to cope with pandemic threat, other confounding factors that influence variables under study here (e.g., institutional aspects, culture, medical technologies, investments in hospital sector, in prevention, in medical personnel, etc.)[1] need to be considered for more comprehensive analysis.

To conclude, the evidence here suggests a strong seasonally effect of COVID-19, that if it confirmed, will be more evident in subsequent months. The positive side of this study is that proposes findings that are *prima facie* (i.e., accepted as correct until proved otherwise) to explain transmission dynamics of COVID-19 over time for appropriate policy responses of crisis management at country level. However, results have to be reinforced with much more follow-up investigations concerning relations between negative effects of pandemic in society, health system, climate factors to support effective policy responses to cope with pandemic diseases within and between countries.

Declaration of competing interest. The author declares that he has no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper. No funding was received for this study.

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[1] For the role of technology, science and socioeconomic factors see: Ardito et al., 2021; Coccia, 2003, 2014, 2016, 2017, 2017a, 2017b, 2018a, 2018b, 2018d, 2019, 2019b; Coccia and Bellitto, 2018, 2018a; Coccia et al., 2015; Coccia and Finardi, 2013; Coccia and Rolfo, 2000; Coccia and Wang, 2016; Pagliaro and Coccia, 2021.

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