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The impact of first and second wave of the COVID-19 pandemic in society: comparative analysis to support control measures to cope with negative effects of future infectious diseases

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ABSTRACT

The goal of this study is a comparative analysis of the first and second wave of the Coronavirus disease 2019 (COVID-19) to assess the impact on health of people for designing effective policy responses to constrain negative effects of future pandemic waves of COVID-19 and similar infectious diseases in society. The research here focuses on a case study of Italy, one of the first countries to experience a rapid increase in numbers of COVID-19 related infected individuals and deaths. Statistical analyses, based on daily data from February 2020 to February 2021, suggest that the first wave of COVID-19 pandemic in Italy had a high negative impact on health of people over February–May 2020 period; after that, negative effects declined from June 2020 onwards. Second wave of COVID-19 pandemic from August 2020 to February 2021 had a growing incidence of confirmed cases also associated with variants of coronavirus, whereas admissions to Intensive Care Units and total deaths had lower levels compared to first wave of COVID-19. Lessons learned of this comparative analysis between first and second wave of the COVID-19 pandemic in Italy can be generalized in similar geo-economic areas to support effective policy responses of crisis management to constrain the negative impact on health of people of recurring waves of COVID-19 pandemic and similar infectious diseases in future.

1. Introduction

The novel severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) that causes the Coronavirus Disease 2019 (COVID-19), generating high numbers of COVID-19 related infected individuals and deaths in society, is still circulating in 2021 with new variants, such that the state of emergency remains in manifold countries worldwide (Coccia, 2020; CDC, 2021; Zhang et al., 2020). In this context, the main goal of this study is to analyze the first and second wave of the COVID-19 pandemic to compare the effects on health of people in terms of confirmed cases, fatality rates, hospitalization and admission at Intensive Care Units. This study explains the impact of different waves of COVID-19 pandemic in society to design effective policy responses for constraining the negative effects on health of people and economic system of on-going evolution of the COVID-19 and similar epidemics in future.

Bontempi (2020) argues that from September 2020, Europe had to cope with the appearance of a second wave of COVID-19 and Italy compared to other large European countries (e.g., France, Germany, UK, and Spain) seems to show a lower impact on health of people, likely due to containment measures applied to constrain COVID-19 pandemic over March-May 2020 (cf., Atalan, 2020; Prem et al., 2020). Glass (2020) analyses four large European countries and the USA and shows that policy responses based on limited containment measures can generate an impact of the second wave of COVID-19 pandemic on health of people higher than first one: "The results indicate that relaxations took effect in terms of increasing numbers of cases with dates ranging from early June in some countries to mid-July in other countries. For the European countries, results suggest relaxations ranging from 31% to 57% are underway and if current trends continue unchecked could lead to significant second waves that last longer than the corresponding earlier waves. In the case of the US, where the number of cases has already peaked for a second time, an extended version of the model suggests that the level of transmission may now be similar to that after the first peak". Cacciapaglia et al. (2020) analyze COVID-19 pandemic across different European countries for simulating the transmission dynamics of this novel infectious disease. Results suggest that the timing of the peak of second wave can change considering different non-pharmaceutical measures of containment and mitigation; moreover: "sensitivity of the second peak prognosis on the value of the infection rates gives a clear indication that social distancing measures and responsible individual behavior can have

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a strong effect if implemented early on" (Cacciapaglia et al., 2020). Instead, Renardy et al. (2020) apply a model based on discrete and stochastic network in a case study of Washtenaw County in Michigan (USA) to forecast the second wave of the COVID-19 pandemic. Results show that a delay of reopening does not reduce the total impact of the second peak of confirmed cases, but only delays it. Simulations of this study reveal that a reduction of casual contacts between people can both delay and reduce the peak of the second wave of COVID-19 pandemic. Engelbrecht and Scholes (2021) argue that COVID-19 has a seasonal dependence and if herd immunity is not established because vaccinations have a delayed diffusion for high demand of countries that generates problems of production, new pandemic waves may have a larger amplitude than the first one, in particular if containment and mitigation measures are relaxed. Gatto et al. (2020) show, using computer experiments, that restriction to mobility can reduce transmission dynamics of the COVID-19 pandemic by about 45%. Other studies reveal that specific places have a high risk to be COVID-19 outbreaks, acting as *superspreaders* (Chang et al., 2020, original emphasis). Especially, model by Chang et al. (2020), using cell phone data, predicts that a small minority of points of interest (called POIs, such as restaurants, gyms, cafeterias, religious establishments, etc.) account for a large majority of infections; as a consequence, restricting maximum occupancy and empowering social distancing within POIs are more effective policies than a general reduction of mobility or full lockdown (Chang et al., 2020; Chaudhry et al., 2020; Coccia, 2021). In general, timely containment and mitigation measures (e.g., school closing, cancellation of public/private events, restrictions on mass gatherings in public and private places, restriction on internal mobility and international travels, etc.) can reduce the accelerated diffusion of COVID-19 pandemic in society (Petherick et al., 2020). Chu et al. (2020) also point out that mitigation measures based on social distancing and the use of facemasks seem to be effective approaches to reduce the transmission of novel coronavirus. Instead, van Weert (2020) states that in the presence of a shortage of personal protective equipment, social distancing is a vital control measure to reduce the transmission dynamics of the COVID-19 pandemic (cf., Islam et al., 2020).

However, these studies just mentioned are mainly based on models that generate simulations with computer experiments to predict eventual real effects of the pandemic waves of COVID-19 in different urban contexts. *What is hardly known in these research topics* is to explain whether the evolution of the second wave of the COVID-19 has generated an impact on health of people higher or lower than first pandemic wave, using empirical data of the COVID-19 pandemic. Bontempi et al. (2020) argue that similar issues related to COVID-19 diffusion need interdisciplinary and multidimensional perspectives of analysis to clarify vital relationships among factors. The study here proposes an empirical analysis based on daily data in Italy from February 2020 to February 2021 to explain the evolutionary dynamics of the second wave of COVID-19 compared to first one in order to design effective strategies of crisis management directed to cope with recurring waves of COVID-19 pandemic and future epidemics of new viral agents.

2. Materials and methods

2.1. Research setting

The paper here focuses on a case study of Italy that was the first large European country to experience a rapid increase in COVID-19 related confirmed cases and deaths in 2020. Italy is located at 43° North latitude and 12° East longitude and has dry summers and mild winters (Mediterranean or dry summer climate). In particular, this study analyzes the evolution of the first and second wave of COVID-19 pandemic in Italy from February 2020 to February 2021. The end of the first wave of COVID-19 is detected here considering the minimum number of confirmed cases from February 2020 onwards, which is July 31, 2020; after this date, confirmed cases begin to increase in Italy and this study considers the starting point of the second wave of COVID-19 pandemic in Italy (i.e., August 1, 2020) that from March 2021 generated a third wave by new variants of the SARS-CoV-2. In short, in Italy:

- ❑ *First wave of COVID-19* is about from 24th February to July 31, 2020, $N = 159$ days
- ❑ *Second wave of COVID-19* is from August 1, 2020 to February 22, 2021, $N = 206$ days

In the period of first wave of COVID-19 pandemic in Italy, the containment measures of national lockdown and quarantine, –started on March 8, 2020 and ended on May 18, 2020–, were directed to mitigate transmission dynamics of the novel coronavirus (Governo Italiano, 2020; Coccia, 2021). Italy is a country located in the North hemisphere of the globe and the summer season starts on 20–21 June and ends on 23 September, for a period of 92 days of average warmer temperatures. This period plays a critical role for current analysis because some scholars suggest that hot weather can reduce the viral infectivity of COVID-19: "high temperatures damage the virus lipid layer decreasing its stability and infection potential and may even cause virus inactivation, therefore lowering the transmission rate" (Rosario Denes et al., 2020, p. 4).

In the period of second wave of COVID-19, Italian government on 3 November, 2020 applied a differentiation of containment measures among regions (cf., Ministero della Salute, 2021; Prevenzione e risposta a COVID-19, 2020; Chaudhry et al., 2020). In particular, regions are categorized in three risk clusters (yellow, orange and red) through regions' risk coefficients (based on a set of 21 risk indicators, including the level of Reproduction Number index, of positive tests, of hospital capacity saturation, of ICUs admissions, etc.) assessed weekly by the Italian Ministry of Health with the support of Regional Prevention Departments and of a committee of experts; in brief, this strategy of containment categorizes:

- Yellow regions with moderate risk of diffusion
- Orange regions with medium-high risk of diffusion
- Red regions with high risk of diffusion

2.2. Data and sources

Period under study is from 24 February to February 2021, and the source of data is the Ministero della Salute (2021) in Italy. The monitoring of COVID-19 cases in Italy is carried out through:

- the flow of aggregate data sent by regions with the support of the Civil Protection Department and the Italian Higher Institute of Health (ISS= Istituto Superiore di Sanità) provides timely information on the total number of positive tests, deaths, hospitalizations and admissions to intensive care units in every province of Italy.
- the flow of individual data sent from regions to the ISS also includes demographic data, comorbidities and clinical status of patients for more accurate epidemiological analyses (Ministero della Salute, 2021).

In short, data of the COVID-19 pandemic under study here are:

- daily confirmed cases
- daily deaths
- daily admissions to Intensive Care Units (ICUs)
- daily hospitalized people (patients with different COVID-19 symptoms and patients in ICUs)
- daily swabs

2.3. Measures

Zuin et al. (2021) maintain that daily absolute numbers of new infected people provide a snap-shot of epidemiological situation in geographic regions but can provide misleading information for making

predictions about the evolution of the novel coronavirus in society. These scholars argue that daily data reports have an intrinsic delay, since they are the outcome of contagions or restrictive measures that have occurred or been adopted up to 14 days before. Similarly, the daily number of admissions to ICUs should be cautiously interpreted since some patients have deteriorated after symptoms onset and were not immediately admitted to ICUs, so a delay also in the trend of these admissions should be considered. In this methodological context, evolution of the first and second wave of COVID-19 pandemic in Italy is measured by:

- *Daily confirmed cases standardized* = ratio of confirmed cases (t)/swab tests (t-2). The lag of 2 days from swab test to the result of positivity to the novel coronavirus (confirmed case) is based on an average period of activity in laboratories to deliver results of the COVID-19 swab test that is roughly 1–2 days from the date of specimen pickup (LabCorp, 2020).
- *Daily admissions to ICUs standardized* = ratio of admissions to ICUs (t)/confirmed cases at (t-5). The lag of 5 days from initial symptoms, positivity to swab test to the hospitalization and recovery in ICUs of patients is based on an average period from diagnosis to hospitalization as explained by specific studies (Faes et al., 2020).
- *Daily hospitalized people standardized* = ratio of hospitalized people (patients with different COVID-19 symptoms and patients in ICUs) at t/confirmed cases at (t-3). In this case, the lag is 3 days to consider mainly hospitalized people with symptoms that represent the principal component of this measure.
- *Daily fatality rate* = ratio of deaths at (t)/confirmed cases at (t-14). The lag of 14 days from initial symptoms to deaths is based on empirical evidence of some studies (Zhang et al., 2020).

2.4. Data analysis procedure

Firstly, data are analyzed with descriptive statistics, comparing arithmetic mean of variables, which are measured as just mentioned, between first and second wave of the COVID-19 pandemic in Italy.

Secondly, each variable is represented in graphs comparing trends of the 1st and 2nd wave of COVID-19 pandemic, inserting the variable under study on *y*-axis (e.g., fatality rates) and on *x*-axis the temporal unit given by a progressive series, in which the number 1 indicates the starting day of the pandemic wave (i.e., 24th February for 1st wave and 1st August for 2nd wave), the number two is the second day of COVID-19 pandemic wave, and so on.

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:

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

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. Moreover, variables are also compared within 1st and 2nd wave to show the overall evolutionary dynamics and impact of COVID-19 pandemic in society over time (cf., Coccia and Benati, 2018).

Thirdly, the study explores relationships between variables with correlation analysis and test of association. This study also 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. The specification of linear relationship is given by a semi-log model using the time series y^*_t:

$$log\ y^*_t = \alpha + \beta\ t + u \qquad [1]$$

y^*_t = variables of the impact of COVID-19 pandemic in society: e.g., Daily fatality rates, Daily admissions to ICUs, Daily confirmed cases, using MM7 of time series
t = time given by a progressive series representing days of the first and second wave of COVID-19 pandemic
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

3.1. Impact of the COVID-19 pandemic on health of people comparing 1st and 2nd wave in Italy

First wave of COVID-19 pandemic shows, from February 2020 onwards, an average fatality rate (using MM7) of about 15%, whereas second wave of COVID-19 has an average fatality rate (also with MM7) of about 2.5%. Comparative analysis of the average admissions to Intensive Care Units (ICUs) shows an 68% in the first wave and about 14% in the second one. Hospitalized people are 839% in the first wave and about 156% in the second one. Instead, ratio of confirmed cases and swab tests is about 7.2% in the first pandemic wave of COVID-19 and roughly 7.1% in the second one (Table 1). Figs. 1 - 3 show the trend of variables confirming, *ictu oculi,* that the negative impact of the first wave of COVID-19 pandemic on health of people in Italy has been stronger than second one.

Fig. 1 of confirmed cases reveals a growing trend for second pandemic wave during autumn 2020-winter season 2020–2021, but the dynamics decreased from January 2021, whereas the first one had a declining trend from May 2020 also because of lockdown and quarantine public interventions (Coccia, 2021) and the progression of COVID-19 pandemic towards summer season, when the novel coronavirus has a natural reduction of transmission dynamics that is likely due to hot and dry temperatures and low levels of air pollution (cf., Coccia, 2020, 2020a, 2020d, 2021a, 2021b; Rosario Denes et al., 2020).

Fig. 2 shows trends of admissions to ICUs: the second wave has an intensity lower than first pandemic wave of COVID-19; in addition, dynamics of the second wave of COVID-19 presents stationarity over time. Instead, Fig. 3 shows trends of fatality rates: second pandemic wave has a low intensity over time and also a dynamics of stationarity, suggesting a low impact of COVID-19 on health of people in Italy and similar geo-economic areas (cf., Coccia, 2020c, 2020d; Coccia, 2021a, 2021b).

Table 2 shows bivariate correlation of variables under study in the first wave of COVID-19 pandemic in Italy: fatality rates have a high positive association with admissions to ICUs ($r = 0.69$, p-value $<.01$) and confirmed cases ($r = 0.74$, p-value $<.01$), whereas correlation between admissions to ICUs and hospitalization of people is $r = 0.60$ (p-value $<.01$), and confirmed cases is $r = 0.58$ (p-value $<.01$). Table 2 seems to show that during the first wave of COVID-19, many infected individuals died as well as a lot of patients in ICUs, likely because of low knowledge of the pathological features of this novel infectious disease in patients, low number of ICUs in hospitals to treat ill patients, lack of appropriate therapies, drugs and vaccines (Gattinoni et al., 2020; Sterpetti, 2020).

Table 3 shows results for second wave of COVID-19 pandemic in Italy: correlation coefficient has a lower positive association between fatality rates and confirmed cases ($r = 0.25$, p-value $<.01$), and hospitalization of people ($r = 0.26$, p-value $<.01$) and admissions to ICUs ($r = 0.35$, p-value $<.01$). The reduction of intensity during the second wave of COVID-19 pandemic can be due to knowledge accumulated about the characteristics of novel coronavirus during the first pandemic wave that has improved learning processes in the treatment of patients and management of healthcare facilities in the presence of recurring COVID-19

Table 1
Descriptive statistics of variables measuring the impact on health of people during the waves of COVID-19 pandemic in Italy (from February 2020 to February 2021).

	Fatality rates		Admissions to ICUs		Hospitalized people		Confirmed cases	
	1 Wave	2 Wave	1 Wave	2 Wave	1 Wave	2 Wave	1 Wave	2 Wave
Mean	0.1505	0.0250	0.6804	0.1408	8.3870	1.5572	0.0716	0.0712
Std. Error of Mean	0.0129	0.0010	0.0205	0.0024	0.3330	0.0299	0.0081	0.0036

Notes: data under study are MM7 of time series. Fatality rates = ratio of deaths at (t)/confirmed cases at (t-14); Admissions to ICUs = ratio of admissions to ICUs (t)/ confirmed cases at (t-5), Hospitalized people = patients with different symptoms and patients in ICUs at (t)/confirmed cases at (t-3); Confirmed cases = ratio of confirmed cases (t)/swab tests (t-2).

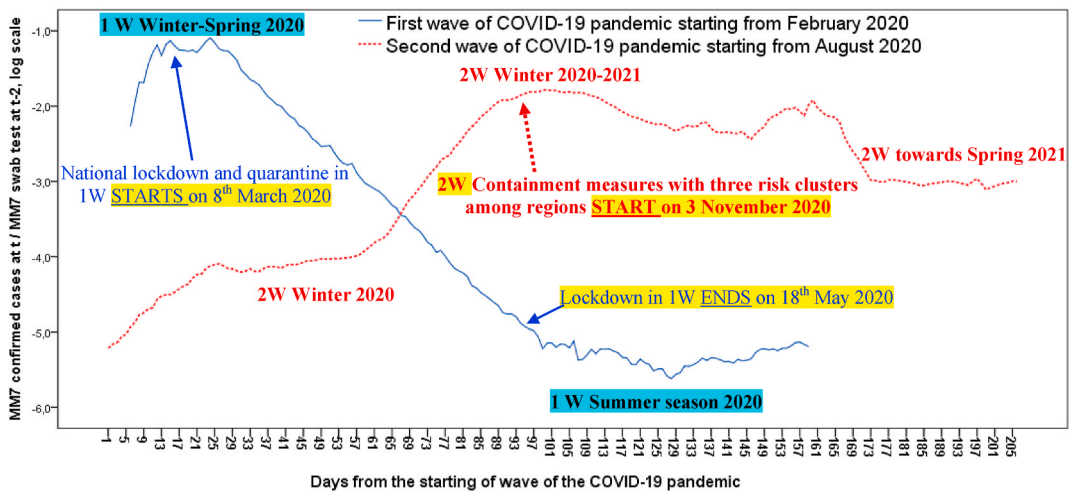

Fig. 1. Trend of confirmed cases of the first and second wave (W) of COVID-19 pandemic in Italy. Data are MM7 of time series in log scale. *Notes*: Measures to control the spread of the COVID-19 within the community are being pursued to safeguard societies and economies, until vaccines and therapies become available and widespread distributed. For first wave was applied a full lockdown in Italy, whereas for second wave of COVID-19 pandemic was applied a policy based on three risk clusters: yellow regions – moderate risk, orange regions – medium-high risk and red regions - high risk (COVID-19 Health system response monitor, 2021). (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

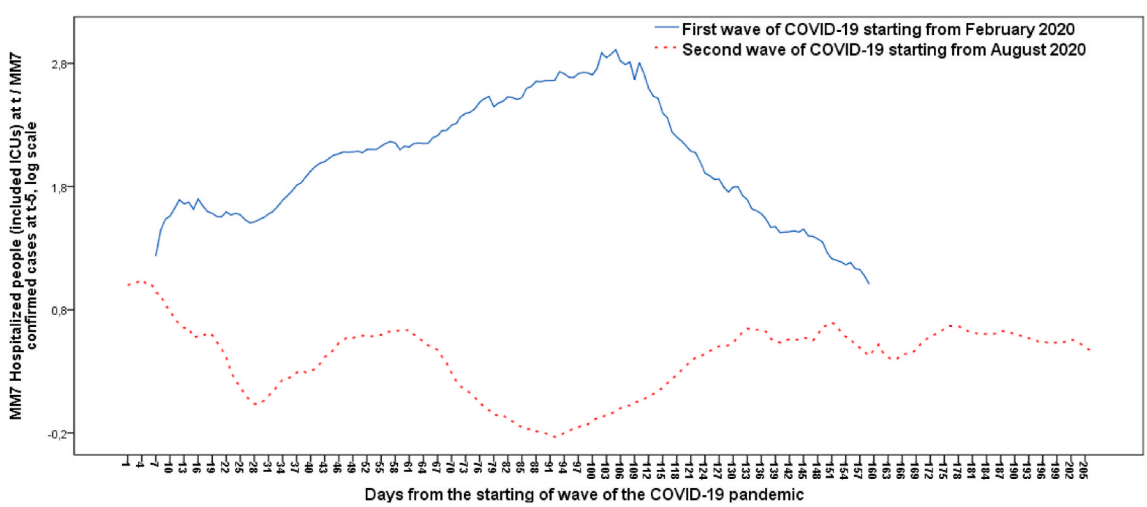

Fig. 2. Trend of hospitalized people (included ICUs) of the first and second wave (W) of COVID-19 in Italy.

pandemic waves (cf., Ardito et al., 2021).

Table 4 shows the estimation of parameters of loglinear models between dependent variables (based on MM7 of time series) and time as explanatory variable (see, Appendix for interpretation of the coefficients of regression here). The coefficient of regression in model of fatality rates (as dependent variable) indicates that in the first wave of COVID-19 pandemic, an increase of 1 day, it reduces the expected fatality rates by approximately 1.3% (*p-value* = .001), whereas for second wave of the COVID-19, an increase of 1 day, it increases the expected fatality rates by approximately a mere 0.3% (*p-value* = .001). The coefficient R^2 in the first wave indicates that about 64% of the variation of fatality rates can be attributed (linearly) to time, whereas for second pandemic wave the coefficient of determination is rather low (14%). The coefficient of regression in model of admissions to ICUs (as dependent variable) indicates that an increase of 1 day in the first wave, it reduces the expected admissions to ICUs by 0.9% (*p-value* = .001), whereas for second wave of the COVID-19, an increase of 1 day, it increases the expected admissions to ICUs by a mere 0.2% (*p-value* = .001). Finally, the coefficient of

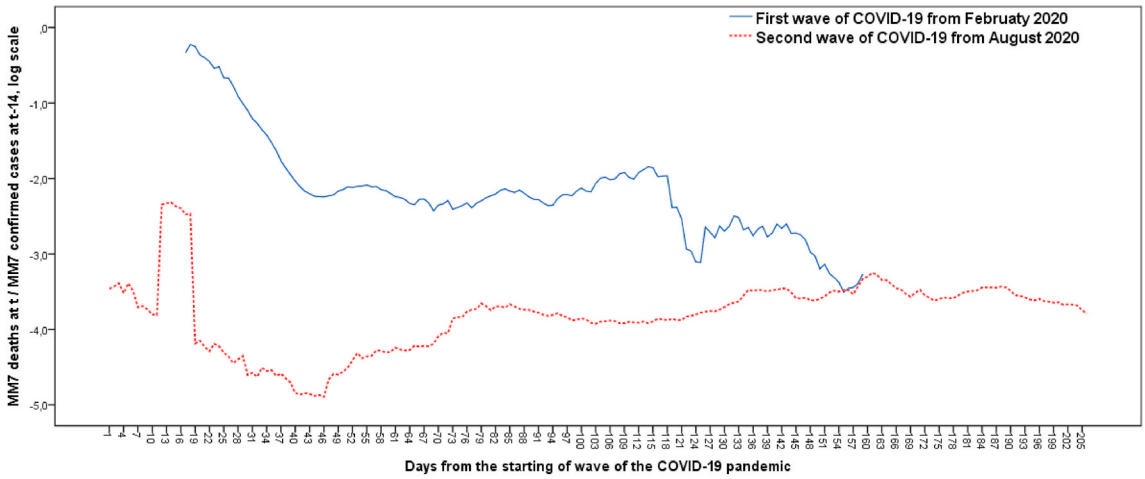

Fig. 3. Trend of fatality rates of the first and second wave of COVID-19 in Italy.

Table 2
Bivariate correlation of variables in the First Wave of COVID-19 pandemic in Italy.

	Fatality rates	Admissions to ICUs	Hospitalization of people	Confirmed cases
Fatality rates	1			
Admissions to ICUs	0.687**	1		
Hospitalization of people	0.096	0.596**	1	
Confirmed cases	0.744**	0.580**	−0.254**	1

Notes: Values in *log* scale of MM7 of time series.
** Correlation is significant at the 0.01 level.
Fatality rates = ratio of deaths at (t)/confirmed cases at (t-14).
Admissions to ICUs = ratio of admissions to ICUs (t)/confirmed cases at (t-5).
Hospitalized people = patients with different symptoms and patients in ICUs at (t)/confirmed cases at (t-3).
Confirmed cases = ratio of confirmed cases (t)/swab tests (t-2).

Table 3
Bivariate correlation of variables in the Second Wave of COVID-19 pandemic in Italy.

	Fatality rates	Admissions to ICUs	Hospitalization of people	Confirmed cases
Fatality rates	1			
Admissions to ICUs	0.354**	1		
Hospitalization of people	0.258**	0.832**	1	
Confirmed cases	0.253**	−0.033	−0.487**	1

Notes: Values in *log* scale of MM7 of time series.
** Correlation is significant at the 0.01 level.
Fatality rates = ratio of deaths at (t)/confirmed cases at (t-14).
Admissions to ICUs = ratio of admissions to ICUs (t)/confirmed cases at (t-5).
Hospitalized people = patients with different symptoms and patients in ICUs at (t)/confirmed cases at (t-3).
Confirmed cases = ratio of confirmed cases (t)/swab tests (t-2).

regression in model of confirmed cases indicates that an increase of 1 day in the first wave, it reduces the expected confirmed cases by approximately 3.34% (*p-value* = .001), whereas for second wave of the COVID-19, an increase of 1 day, it increases the expected confirmed cases by a mere 1.01% (*p-value* = .001). Standardized coefficients beta of regression are negative during the first wave and positive during the second wave.

General observation is that the first wave of the COVID-19 pandemic, after national containment policies and the evolution of COVID-19 towards summer season, has a tendency to reduce fatality rates, admissions to ICUs and confirmed cases, whereas second wave of COVID-19 had a very low growth of variables understudy likely for the evolution of this pandemic towards the autumn 2020-winter season 2020/2021 when climate conditions and also higher levels of air pollution can create an habitat that fosters the diffusion of COVID-19 in society (cf., Coccia, 2020). The study by Contou et al. (2021) also performs a comparison of patients between first and second wave of COVID-19 and shows within second wave a lower proportion of patients requiring invasive mechanical ventilation and a lower rate of thrombotic events. Moreover, the delay between ICU admissions and tracheal intubation was longer during the second wave, whereas ICU mortality and duration of ICU stay did not differ between the two waves of COVID-19.

3.2. *Analysis of the health effects of COVID-19 pandemic within the first and second wave in Italy*

In order to analyze the impact of the COVID-19 pandemic over time in society, variables under study are also represented simultaneously in the same graph from starting period of the COVID-19 pandemic wave. Fig. 4 shows that the first wave of COVID-19 pandemic from February 2020 had declining evolutionary trends of confirmed cases, admissions to ICUs and fatality rates also due to the progression of this infectious disease towards summer season 2020.

Fig. 5 shows trends for second wave of COVID-19 from August 2020 onwards: in general, trends had a stationarity over time, except for confirmed cases that had a (moderate) growth. These results suggest that in general the first wave had a stronger impact on health of people, reduced with the approaching of summer season 2020 and national containment policies. Instead, the second wave of COVID-19 pandemic had a lower negative effect on heath of people compared to the first wave of COVID-19 pandemic; the dynamics of second wave evolved with stationarity over time. In order to reduce the impact of the COVID-19 pandemic, Italian government applied different policy responses in the first and second wave that have generated different effects on health of people and economic system (Coccia, 2021).

4. Policy implications and conclusions

The study here sought to understand mainly the different impact on health of people of the first and second wave of COVID-19 pandemic, analyzing Italy as case study, which is a country characterized by dry summers and wet winters similar to other countries in the geo-economic area of the North Hemisphere of the Globe.

The results of comparative analysis are:

Table 4
Estimated relationships based on linear model of regression in Italian case study.

	1 Wave Fatality rates	2 Wave Fatality rates	1 Wave Admissions to ICUs	2 Wave Admissions to ICUs	1 Wave Confirmed cases	2 Wave Confirmed cases
Constant α	−1.025***	−4.12***	.260***	−2.24***	−1.02***	−4.09***
Coefficient β	−.013***	.003***	−.009***	.002***	−.034***	.010***
Stand. Coeff. Beta	−.799	.38	−.80	.53	−.95	.65
R^2 (St. Err. of Estimate)	.64 (.41)	.14 (.44)	.65 (.29)	.29 (.22)	.89 (.52)	.43 (.73)
F-test	249.69***	33.80***	270.29***	81.18***	1278.02***	151.82***

Notes:
Explanatory variable: *time units*.
Dependent variables: *log* scale of MM7 of time series.
Fatality rates = ratio of deaths at (t)/confirmed cases at (t-14).
Admissions to ICUs = ratio of admissions to ICUs (t)/confirmed cases at (t-5).
Confirmed cases = ratio of confirmed cases (t)/swab tests (t-2).
Significance: ***p-value<.001.

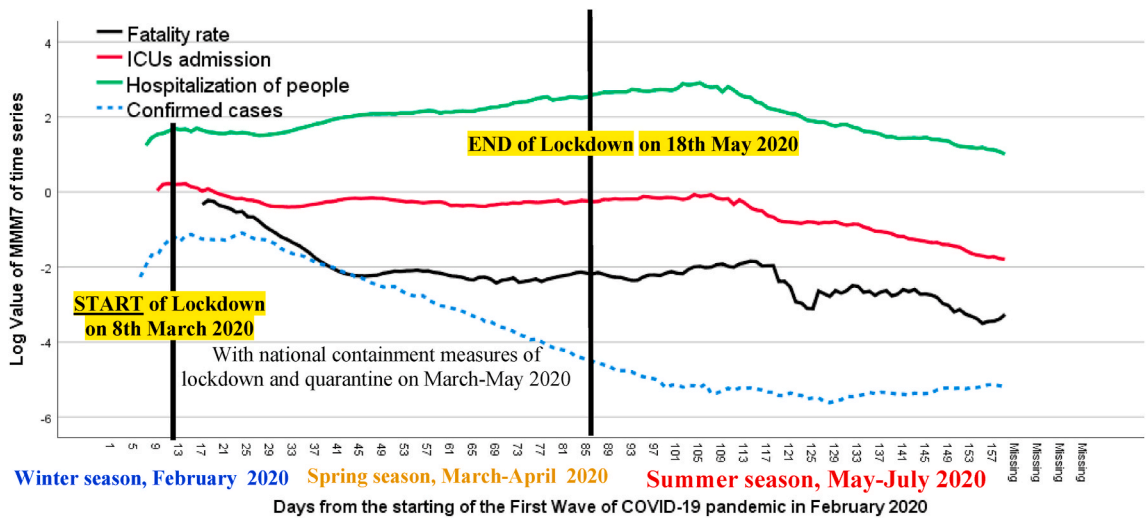

Fig. 4. Effects of the first wave of COVID-19 pandemic on health of people in Italy from February to July 2020.

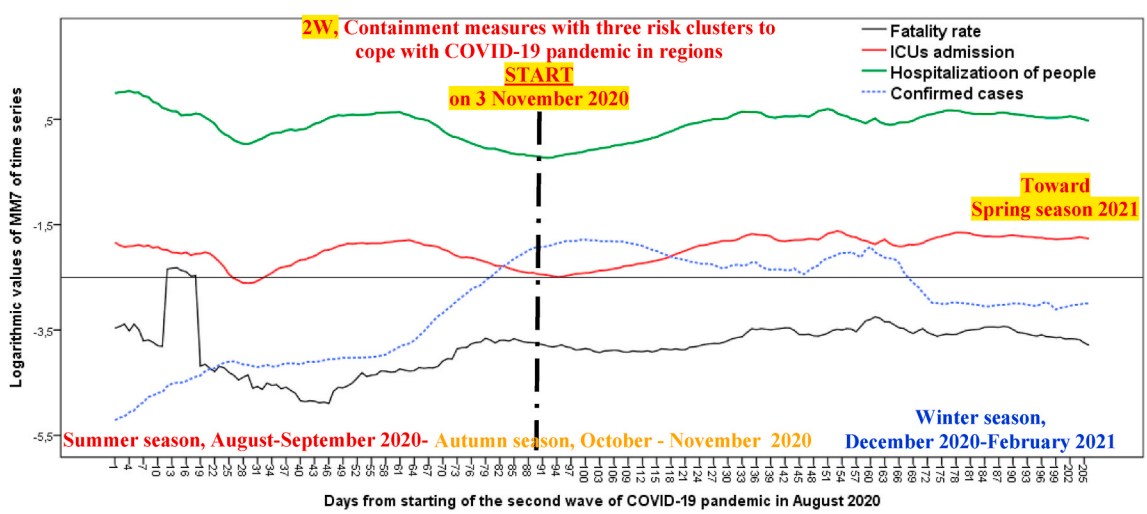

Fig. 5. Effects of the second wave of COVID-19 pandemic on health of people in Italy from August 2020 to February 2021.

Table 5
Effects of the first and second wave of COVID-19 pandemic on health of people in Italy.

Contexts	First wave of COVID-19	Second wave of COVID-19
Health of people	**High Impact**	**Low Impact**
Fatality rate	High, 15%	Low, 2.5%
Admissions to ICUs	High, 68%	Low, 14%
Confirmed cases	Moderate, 7.2%	Moderate, 7.1%
Strategy to reduce negative effects of COVID-19 pandemic in society	Containment policies based on national lockdown and quarantine (Coccia, 2021)	Public policy based on three risk clusters: yellow regions – moderate risk, orange regions – medium-high risk and red regions - high risk (COVID-19 Health system response monitor, 2021) associated with selected restrictions in points of interest (cf., Chang et al., 2020).

- First wave of COVID-19 pandemic showed an average fatality rate of 15%, whereas second wave of COVID-19 had an average fatality rate of about 2.5%.
- Average admissions to Intensive Care Units (ICUs) was an 68% in the first wave and about 14% in the second one, whereas hospitalization of people was 838% in the first wave and about 156% in the second one.
- Average confirmed cases were rather similar in the first and second waves of COVID-19.
- Average confirmed cases increased in second pandemic wave occurring in the period of autumn 2020-winter 2020/2021, whereas the first one had a declining trend also because of national containment policies and the progression of COVID-19 pandemic towards summer season 2020.
- Analysis of relationships between variables shows a high impact on health of people of the first wave of COVID-19 pandemic that reduced intensity over time, whereas second wave of COVID-19 pandemic had a dynamics characterized by stationarity with a lower negative impact in society.

More specifically, results of the impact of first and second wave of COVID-19 pandemic on health of people can be schematically summarized in Table 5.

What this paper adds to current studies on the COVID-19 global pandemic crisis is that an accurate comparison of the first and second wave of COVID-19 pandemic reveals that the first one generated a stronger impact on health of people in Italy (as well as in other countries having similar geo-economic characteristics). The results here suggest that the impact of COVID-19 on health of people depends on manifold environmental, climate, social and economic factors and policy responses of governments (Coccia, 2020, 2021; Sabat et al., 2020). In this context, countries in the presence of on-going COVID-19 pandemic, driven by variants of the novel coronavirus that are rapidly emerging, have showed an uncertain governance and an unrealistic optimism that consequential waves of this pandemic cannot hit them (cf., Weinstein, 1987). Although the severe impact on health of people of the first wave of COVID-19 pandemic, many countries have shown still a low capability of efficient national planning and of timely application of best practices of crisis management. In particular, many countries apply ambiguous, delayed and uncertain policy responses in the presence of recurring waves of COVID-19 pandemic crisis. In general, it seems that manifold countries do not absorb completely lessons learned of the negative effects of COVID-19 pandemic crisis for supporting effective and timely critical decisions to cope with consequential pandemic waves on health of people (cf., Coccia, 2020b; 2021c). The results here suggest that policy responses of containment need to be revised and focused mainly on selected restrictions in specific places having a high risk to be COVID-19 outbreaks to constrain negative health effects and negative economic impact in society (Coccia, 2021). In fact, Chang et al. (2020) reveal that a minority of points of interest can generate a large number of infections and suggest that selected containment measures are more effective policy responses than full lockdown to cope with accelerated transmission dynamics of COVID-19. Xu and Cao (2021) maintain that crisis management of the COVID-19 pandemic needs: "active surveillance, massive polymerase chain reaction (PCR) testing, stringent lockdown and isolation, as well as other measures can certainly contain the epidemic but the total cost may be high". Dawood and Dawood (2020), analyzing Iraq, argue that the quarantine has been a factor for containing the virus in the early stages, but it did not generate expected result during second pandemic wave of COVID-19 also because of the lack of commitment of citizens to the comprehensive implementation of the ban and shortcomings rules of social spacing. Kuehn (2021) observes that Africa succeeded against COVID-19's first wave, but subsequent waves, driven by new variants of the coronavirus can create problematic situations for health of people.

Overall, then, the investigation and explanation of the effects of pandemic waves on health of people are important, very important topics in order to design effective policy responses, apply new technologies and support R&D and healthcare investments directed to minimize the negative impact in society of recurring COVID-19 outbreaks and of other epidemics similar to the COVID-19 (cf., Ardito et al., 2021; Coccia, 2020a, 2020b, 2021, 2021b, 2017, 2018, 2019, 2020; Coccia and Watts, 2020).

To conclude, the positive side of this study is the analysis of a large European country, Italy, that was the first country in Western world to experience a rapid increase in numbers of COVID-19 related infected individuals and deaths; subsequently, many countries have had similar negative effects of COVID-19 pandemic crisis on health of people. The results for Italian case study here may be generalized, *mutatis mutandis*, for countries having similar socioeconomic system. However, there are several challenges to such studies because pandemic evolution is due to manifold factors associated with novel coronavirus, and sources of data can only capture certain aspects of the on-going outbreak dynamics. Results here are based on a case study research and future investigations have to reinforce suggested findings by enlarging the sample with other European countries to maintain a comparable framework for statistical analyses. Hence, these conclusions are of course tentative because in the presence of recurring waves of the COVID-19 pandemic with new variants of the coronavirus, various socioeconomic and environmental factors play a critical role to explain evolutionary dynamics over time and space (Coccia, 2020a). There is need for much more detailed research on how COVID-19 pandemic and similar epidemics evolve in different economic, social, environmental, climate and institutional contexts and especially in a specific period of time (e.g., autumn, winter, spring or summer) of a given geographical area.

Declaration of competing interest

The author, Mario Coccia, declares that he has no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix. Interpreting coefficients of regression in loglinear models

Note that in loglinear model, $exp(\beta) = 1 + \beta$, hence $\beta = \exp(\beta) - 1$.

As a consequence, coefficients of regression in Table 4 of the text indicate the values in Table 1A, calculated as just mentioned.

Table 1A
Calculation of coefficients of regression in loglinear models described in Table 4.

Estimated coefficient of regression	1 Wave Fatality rates	2 Wave Fatality rates	1 Wave Admissions to ICUs	2 Wave Admissions to ICUs	1 Wave Confirmed cases	2 Wave Confirmed cases
b	−0.01	0.00	−0.01	0.00	−0.03	0.01
exp(b)	0.99	1.00	0.99	1.00	0.97	1.01
exp(b)-1	−0.01	0.00	−0.01	0.00	−0.03	0.01
%	*−1.29*	*0.30*	*−0.90*	*0.20*	*−3.34*	*1.01*

Credit author statement

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