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The relation between length of lockdown, numbers of infected people and deaths of Covid-19, and economic growth of countries: Lessons learned to cope with future pandemics similar to Covid-19 and to constrain the deterioration of economic system

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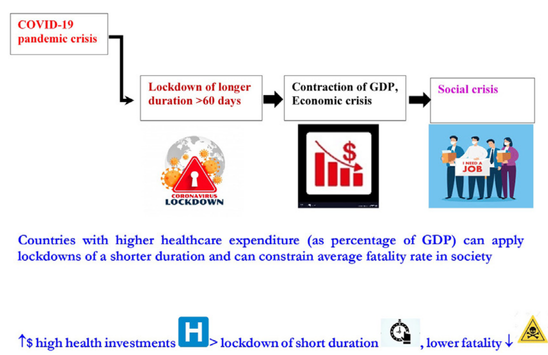
HIGHLIGHTS

- A longer period of lockdown has a negative impact on economic growth.
- A longer period of lockdown does *not* reduce significantly fatality rate.
- Countries with a weak healthcare sector apply lockdown of longer duration
- High healthcare expenditures (as % of GDP) reduce COVID-19 fatality rates.
- An efficient strategy for future pandemics is to increase healthcare investments.

GRAPHICAL ABSTRACT



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ABSTRACT

How is the relation between duration of lockdown and numbers of infected people and deaths of Coronavirus disease 2019 (COVID-19), and growth level of Gross Domestic Product (GDP) in countries? Results here suggest that, during the first wave of COVID-19 pandemic, countries with a shorter period of lockdown (about 15 days: Austria, Portugal and Sweden) have average confirmed cases divided by population higher than countries with a longer period of lockdown (about 60 days, i.e., 2 months: France, Italy and Spain); moreover, countries with a shorter period of lockdown have average fatality rate (5.45%) lower than countries with a longer length of lockdown (12.70%), whereas average variation of fatality rate from March to August 2020 (first pandemic wave of COVID-19) suggests a higher reduction in countries with a longer period of lockdown than countries with a shorter duration (−1.9% vs. −0.72%). Independent Samples Test reveals that average fatality rate of countries with a shorter period of lockdown was significantly lower than countries with a longer period of lockdown (5.4% vs. 12.7%, p-value<.05). The Mann-Whitney Test confirms that average fatality rate of countries with a shorter period of lockdown is significantly lower than countries having a longer period of lockdown ($U = 0$, *p*-value = .005). In addition, results show that lockdowns of longer duration have generated negative effects on GDP growth: average contraction of GDP (index 2010 = 100) from second quarter 2019 to second quarter of 2020 in countries applying a longer period of lockdown (i.e., about two months) is about −21%, whereas it is −13% in countries applying a shorter period of lockdown of about 15 days (significant difference with Independent Samples Test: $t_4 = -2.274$, *p*-value < .085). This finding shows a systematic deterioration of economic system because of containment policies based on a longer duration of lockdown in society. Another novel finding here reveals that countries with higher investments in healthcare (as percentage of GDP) have alleviated fatality rate of COVID-19 and simultaneously have applied a shorter period of lockdown, reducing negative effects on economic system in terms of contraction of economic growth. Overall, then, using lessons learned of the first

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wave of COVID-19 pandemic crisis, this study must conclude that a strategy to reduce the negative impact of future epidemics similar to COVID-19 has to be based on a reinforcement of healthcare sector to have efficient health organizations to cope with pandemics of new viral agents by minimizing fatality rates; finally, high investments in health sector create the social conditions to apply lockdowns of short run with lower negative effects on socioeconomic systems.

1. The problem

Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) is the strain of novel coronavirus that causes the Coronavirus Disease 2019 (COVID-19). The World Health Organization (WHO) states, on 11 March 2020, that COVID-19 is characterized as a pandemic. COVID-19 is predominantly a respiratory illness that can affect other organs, generating a wide range of symptoms from mild respiratory disorders to severe pneumonia and death (Coccia, 2020a, 2021a). In the presence of COVID-19 pandemic crisis, and in general of epidemics of novel viruses without appropriate treatments based on effective antiviral drugs and/or new vaccines, governments can cope with health emergencies with containment measures based on restriction policies, such as stay-at-home, business closures, full lockdown in society, etc. (Ardito et al., 2021; Atalan, 2020; Coccia, 2020b; Liu et al., 2021; Mahato et al., 2020; Tobías, 2020).

In this context, the main goal of this study is to explain how the duration of lockdown, applied to constraint COVID-19 pandemic, can affect rates of infected people and deaths, and growth of Gross Domestic Product (in short, GDP) of nations. This study focuses on data of the first wave of COVID-19 pandemic (from March to August 2020) in six European countries that have applied lockdowns of different duration to analyze effects in society directed to design effective public responses for constraining future pandemic waves of the COVID-19 and similar infectious diseases within and between countries, and at the same time for alleviating negative effects on economic system.

2. Theoretical framework

What is already known on these topics is based on different studies. Nicoll and Coulombier (2009, p. 3ff) argue that containment measures have the goal to stop as many transmissions of infectious diseases as possible. In particular, governments can constrain/prevent chains of transmission and outbreaks through different restriction policies based on quarantine of people, social distancing, business closures, full lockdown, etc. or a combination of these measures (Atalan, 2020; Petherick et al., 2020). The crux of the study here is rooted in the concept of *lockdown* as policy response of countries to cope with diffusion of pandemics in society and some brief backgrounds are useful to understand and clarify it. The dictionary of Merriam-Webster (2021) defines lockdown as: "a temporary condition imposed by governmental authorities (as during the outbreak of an epidemic disease) in which people are required to stay in their homes and refrain from or limit activities outside the home involving public contact (such as dining out or attending large gatherings)". This containment measure, in the presence of pandemics or epidemics, has a variable duration and a variety of restrictions, such as: school and workplace closing, cancellation of public/private events, closure of museums, banned mass gatherings in public and private places, stay at home requirements, reduction of internal mobility and international travel, maintain social distancing, etc. (Nicoll and Coulombier, 2009; Petherick et al., 2020). Atalan (2020) argues that countries can start the public policy of lockdown when there is an acceleration of daily confirmed cases beyond a critical threshold and can stop it when there is a strong reduction of Intensive Care Unit (ICU) admissions. Tobías (2020, p. 2) states that: "Lockdown, including restricted social contact and keeping open only those businesses essential to the country's supply chains, has had a beneficial effect". Flaxman et al. (2020) show that lockdowns seem to have effectively reduced transmission of the COVID-19. Verma et al. (2020) argue that to reduce the spread of COVID-19, lockdown policy must be timely implemented and enforced, representing a step toward social distancing to decrease the impact of this pandemic in society. Tarrataca et al. (2021) suggest that the spread of COVID-19 generates consequential waves of decreasing amplitude and this dynamics persists even if the lockdown release is a gradual process. Lockdown generates different effects on manifold factors in society, such as on rate of mortality and of infection, Intensive Care Unit (ICU) admission, level of air pollution, growth of Gross Domestic Product (i.e., wealth) of countries, etc. (Chakraborty and Maity, 2020; Coccia, 2020a, 2020b, 2020c, 2021a, 2021b). Islam et al. (2020) argue that early application of lockdown can reduce the incidence of COVID-19 cases. In this context, the model by Balmford et al. (2020) reveals that countries with an immediate application of lockdown reduced deaths compared to countries that delayed the application of this strong containment measure. Chaudhry et al. (2020) show, analyzing fifty countries having high numbers of confirmed cases of COVID-19, that 40 countries applied a full lockdown, 5 a partial one and 5 curfew only with different effects. In addition, this study suggests that a decreased country vulnerability to biological threats was significantly associated with the increase of patient recovery rates (Chaudhry et al., 2020). Gatto et al. (2020) maintain that restriction to mobility and to human interactions can reduce transmission dynamics of the COVID-19 by about 45%. Instead, Tobías (2020) shows that after the first lockdown in Spain and Italy, the slopes of daily confirmed cases, of deaths and of Intensive Care Unit (ICU) admissions have been flattened, but the evolution of COVID-19 pandemic has not changed underlying dynamics that continued to increase. Instead, the second lockdown, based on stronger containment measures for mobility, seems to have reduced basic trend of growth. Glass (2020, p.11) analyzes four large countries in Europe and the USA: "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". Renardy et al. (2020) apply a model based on discrete and stochastic networks in a case study of Washtenaw County in Michigan (USA); results show that a delay of reopening does not reduce total impact of the second peak of confirmed cases, but only delays it. Simulations of this model reveal that a reduction of casual contacts between people can both delay and reduce the peak of the second wave of COVID-19 pandemic (Renardy et al., 2020). New studies show that specific places have a high risk to be COVID-19 outbreaks (e.g., restaurants, cafeterias, gyms, stadium, discotheques, etc.), generating a lot of infections (Chang et al., 2020); as a consequence, the restriction of maximum occupancy in these specific places is more effective than uniformly reducing mobility of people (Chang et al., 2020). Moreover, in the presence of pandemics, the possibilities that a mandatory lockdown will or will not be required at a later stage of health crises can depend on three aspects (Karnon, 2020): 1) number of COVID-19 confirmed cases; 2) effects on the economy; 3) effects of quarantine on well-being of population. In particular, Karnon (2020, p. 330) argues that: "a longer but less intense period of social distancing is highly likely to reduce the economic and isolation effects of the crisis". Finally, Sabat et al. (2020) confirm that the COVID-19 pandemic acts as a social stressor, causing health and economic anxieties even in households that were not directly affected by the novel coronavirus.

However, in this vast literature, *what is hardly known* is how the duration of full lockdown to cope with COVID-19 pandemic has affected numbers of COVID-19 infected people and deaths, and growth of the Gross Domestic Product of nations. The investigation of this problem here is part of a large research project that analyzes factors determining the transmission dynamics of the COVID-19 pandemic and public policies to constrain the impact of pandemic crisis in society. Results of the study here can explain, whenever possible, the effects in society of different durations of full lockdown, focusing on first wave of COVID-19 pandemic crisis in 2020, to design effective strategies to cope with future waves of COVID-19 and similar epidemics of infectious diseases, and constrain the deterioration of driving forces of economic growth.

3. Materials and methods

This study has the primary objective to explain how, in the presence of COVID-19 pandemic, the duration of full lockdown has affected the health of population and the dynamics of socioeconomic systems. The study is based on a specific analysis of six countries in Europe because they have a comparable institutional and socioeconomic background based on a similar geographical area. Countries under study here are: Austria, France, Italy, Portugal, Spain and Sweden. In particular, these six European countries are homogenous units of investigation to support a case study research that captures the effects in society of lockdowns having a different length to cope with COVID-19 pandemic crisis. This case study research based on six countries may be conceptualized as a basis for a possible generalization of results to explain effects of lockdowns of different duration to design better public policies to cope with health and socioeconomic threats of future infectious diseases in society (cf., Gomm et al., 2000 for different approaches of case study research; Eisenhardt, 1989, Eisenhardt and Graebner, 2007 for supporting theoretical contributions from case study research).

3.1. Data

The study here considers data of confirmed cases, fatality rates and Gross Domestic Product (GDP) levels in countries under study here that have applied full lockdowns of different duration in the period from 15 April to 30 August 2020, a time interval indicating the first wave of COVID-19 pandemic. These data provide important information to analyze the effects in society of lockdowns of different length to cope with effects of COVID-19 pandemic crisis. Data of COVID-19 infected people and deaths are from Johns Hopkins Center for System Science and Engineering (2020); economic data are from Eurostat (2020c); healthcare expenditures are also from Eurostat (2020a); finally, indicator of the structure of population is from Eurostat (2020b) too.

3.2. Research setting and measures

The study, as said, is a specific analysis of six countries in Europe having a homogenous socioeconomic background given by European area.

Countries are: Austria, France, Italy, Portugal, Spain and Sweden.

Period under study is from March to August 2020, a time lapse indicating the first wave of the COVID-19 pandemic.

The measures are:

- *Number of COVID-19 infected individuals* is measured with confirmed cases of COVID-19 divided by population of countries under study (%)
- *Number of COVID-19 deaths* is measured with fatality rate of COVID-19 given by deaths divided by total infected individuals of countries (%)
- *Economic growth of countries* is measured with level of Gross Domestic Product (GDP) based on chain linked volumes, using index 2010 = 100. The accounting period is the calendar quarter (Q) based on 2019-Q2, 2020-Q1 and 2020-Q2 (Q1 = January, February, March; Q2 = April, May, June). Quarterly national accounts are vital data for economic analysis to assess the dynamics of business cycles supporting long-run economic growth of countries.
- *Total healthcare expenditure* quantifies the economic resources dedicated to health functions. Healthcare expenditure concerns healthcare goods and services that are consumed by resident units. Unit of measure of healthcare expenditure is given by annual Euro per inhabitant, Purchasing power standard-PPS-per inhabitant, and healthcare expenditure as percentage of Gross Domestic Product-GDP in 2018.
- *Structure of population* is measured with median age of population in 2019. Median age divides a population into two numerically equal groups: half the people are younger than median age and half are older.

3.3. Data analysis procedure

The six countries under study are categorized in two groups, countries with a shorter period of lockdown and countries with a longer period of lockdown:

☐ *Countries with a shorter period of lockdown* are (about 15 average days of full lockdown):
- Austria from March/16/2020 to April/13/2020, 29 days
- Portugal from March/19/2020 to April/2/2020, 15 days
- Sweden did not apply any lockdown

☐ *Countries with a longer period of lockdown* are (roughly 61 average days of full lockdown; i.e. two months):
- France from March/17/2020 to May/11/2020, 56 days
- Italy from March/09/2020 to May/18/2020, 71 days
- Spain from March/14/2020 to May/09/2020, 57 days.

Firstly, data are analyzed with descriptive statistics, applying a comparative approach between countries with a longer and a shorter period of lockdown, considering arithmetic mean and standard deviation of confirmed cases (standardized with population) and fatality rates (i.e., average values from April to August 2020 between countries), of indexes of the quarterly national accounts of GDP level in 2019 and 2020, of healthcare expenditures in 2018 and median age of population in 2019. In addition, the effects of different duration of lockdown on COVID-19 infected people and deaths are also investigated with average variation of confirmed cases standardized with population and average variation of fatality rates from 15 April 2020 to 30 August 2020, a period indicating the first wave of the COVID-19 pandemic crisis in Europe. The descriptive statistics are also applied categorizing countries having high/low investments in healthcare (% of GDP), using as cut-off point the arithmetic mean of this variable among countries under study to detect the effects of different duration of lockdown in countries considering their level of investments in healthcare sector.

Secondly, the difference of arithmetic mean between countries with a shorter and a longer period of lockdown (group 1 and 2) is analyzed by Independent Samples *t*-Test, comparing the means of these two independent groups, just mentioned, to determine whether there is statistical evidence that associated population means are also significantly different. The null hypothesis (H_0) and alternative hypothesis (H_1) of the Independent Samples *t*-Test are:

H0. $\mu_1 = \mu_2$, the two population means are equal in countries with a shorter and a longer period of lockdown.

H1. $\mu_1 \neq \mu_2$, the two population means are *not equal* in countries with a shorter and a longer period of lockdown.

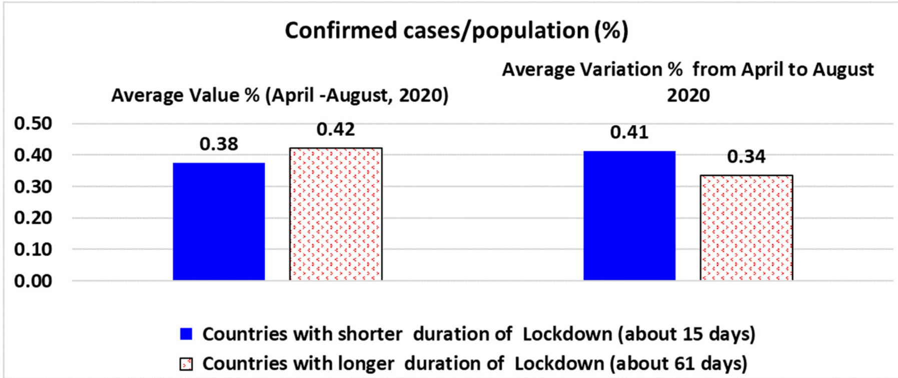

Fig. 1. Average values and average variation of confirmed cases/population (%) over April–August 2020 period in countries with a shorter length of lockdown of about 15 days and countries with a longer length of lockdown of roughly 61 days.

Considering the small sample of the study here, the nonparametric Mann-Whitney *U* Test is also applied to confirm whether there is a difference in dependent variable for independent groups under study. In particular, this *U* test compares whether the distribution of the dependent variable (i.e., confirmed cases standardized with population or fatality rate) is the same for two groups under study and therefore from the same population.

Thirdly, the study represents the trends, from April to August 2020, of infected individuals and fatality rates in:

- ☐ Countries with a shorter period of lockdown of about 15 days
- ☐ Countries with a longer period of lockdown of roughly 61 days.

The study analyzes these trends with a simple regression model based on a linear relationship:

$$y_t = \alpha + \beta\, t + u \tag{1}$$

- y = number of infected individuals or deaths standardized
- t = time from April to August 2020
- u = error term.

Ordinary Least Squares (OLS) method is applied for estimating the unknown parameters of linear model Eq. (1). Statistical analyses are performed with the Statistics Software SPSS® version 26.

4. Results

4.1. Impact of COVID-19 and of full lockdowns with different duration on infected people and deaths

Fig. 1 and Table 1 reveal that countries with a shorter duration of lockdown have a lower average value of confirmed cases/population (%) but a higher average variation of confirmed cases/population (%) than countries with a longer period of lockdown form April to August 2020 (period indicating the first wave of the COVID-19 pandemic).

Fig. 2 and Table 1 reveal that countries with a shorter duration of lockdown have a lower average level of fatality rates (%) and an average reduction of fatality rate lower than countries with a longer period of lockdown over April–August 2020 (−0.72% vs. −1.90%).

The difference of arithmetic mean of values, of the variation of confirmed cases standardized with population, and of the variation of fatality rates between countries with a shorter and a longer duration of lockdown is analyzed with Independent Samples *t*-Test. In this statistical analysis, the *p*-value of Levene's test is not significant, and we have to consider the output of "Equal variances assumed". Results show that there is a significant difference in average fatality rates ($t_4 = -3.343$, p-value $< .05$) between countries with a longer and a shorter duration of lockdown. In particular, the average fatality rate of countries with a shorter period of lockdown was −7.3 percent points lower than countries with a longer period of lockdown. Other differences are not significant (Table 2).

Nonparametric Mann-Whitney *U* Test confirms previous results. In particular, Tables 3 and 4 show that average fatality rate in countries with a shorter period of lockdown is significantly lower than countries having a longer period of lockdown ($U = 0$, p-value $= .005$). Other differences are also here not significant.

Finally, Table 5 of estimated relationships does not provide significant results because of small sample under study. Fig. 3 provides trends of confirmed cases and of fatality rates that approximately do not suggest a difference in the evolution of COVID-19 pandemic in countries with a longer or a shorter duration of national lockdown. In this context, Meo et al. (2020, p. 1) show that: "15 days after the lockdown there was a trend toward a decline, but no significant decline in the mean prevalence and mean mortality rate due to the COVID-19 pandemic compared to 15 days before, and 15 days during the lockdown in 27 countries. The mean growth factor for number of cases was 1.18 and for mortality rate was 1.16". The visual representation of Fig. 3 suggests that the average reduction of fatality rates over time in groups under

Table 1
Descriptive statistics between countries with a shorter and a longer period of national lockdown, period April–August 2020.

Period April–August 2020	Countries with a shorter period of lockdown, about 15 days (Austria, Portugal, Sweden)		Countries with a longer period of lockdown, roughly 61 days (France, Italy and Spain)	
	Arithmetic mean	Std. deviation	Arithmetic mean	Std. deviation
⊗ Days of lockdown	14.670	14.503	61.330	8.386
⊗ Cases/population	0.004	0.002	0.004	0.001
⊗ Fatality rate	0.055	0.032	0.127	0.020
⊗ Variation cases/population	0.004	0.003	0.003	0.002
⊗ Variation fatality rate	−0.007	0.012	−0.019	0.020
⊗ Healthcare expenditure (Euro per inhabitant)	€3806.443	€1692.595	€2937.467	€899.985
⊗ Median age of population (years)	43.033	2.371	44.167	2.454

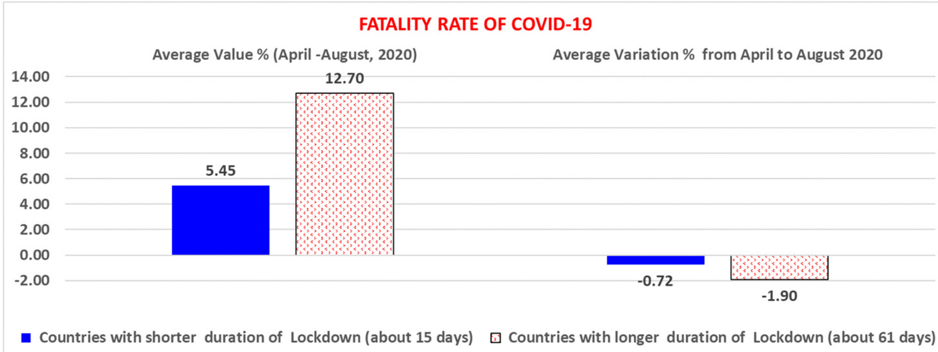

Fig. 2. Average value and average reduction of fatality rate (%) over April–August 2020 in countries with a shorter period of lockdown of about 15 days and countries with a longer period of lockdown of roughly 61 days.

study here seems to be likely associated with approaching of favorable climate conditions of summer season in 2020; in fact, many studies show that hot and dry climate can reduce the diffusion of the COVID-19 in environment (cf., studies by Coccia, 2020a; Rosario Denes et al., 2020).

4.2. Impact of COVID-19 and of full lockdown with different length on economic system

Fig. 4 and Table 6 show *ictu oculi* that countries applying a longer period of lockdown, they have had a higher reduction of the level of GDP, comparing the index 2010 = 100 of the second quarter 2020 to the indicator in the same period of 2019, and comparing the index of GDP of the second quarter 2020 to the first quarter (Q) of 2020.

Table 7 shows, considering the output of "Equal variances assumed", a significant reduction in average GDP level from second quarter in 2019 to second quarter in 2020 between countries with a longer and a shorter period of lockdown ($t_4 = -2.274$, p-value $< .085$). In particular, the average reduction of GDP level (based on index 2010 = 100) in European countries applying a longer period of lockdown was about 7 points less compared to countries applying a shorter period of lockdown. The factors determining the systematic deterioration of economic system are likely due to negative impact of COVID-19 pandemic in society and also restriction policies on economic and social activities that have worsened structural indicators of economy mainly in countries with longer periods of national lockdown (i.e., >61 days).

5. Discussion on what this study adds

The study is based on a specific comparative analysis of six countries in Europe because have a comparable institutional and socioeconomic background given by European area. In particular, this study analyzes how policy responses to cope with COVID-19 pandemic, based on a longer or a shorter duration of full lockdown, have affected COVID-19 infected people and deaths, and a main indicator of economic growth of nations (i.e., the GDP level). Previous studies suggest that measures of containment can constraint the human-to-human transmission of infectious diseases in different ways (Atalan, 2020; Prem et al., 2020;

Table 2
Independent Samples Test for the impact of lockdown on rate of COVID-19 infected people and fatality.

		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
Days of lockdown	--Equal variances assumed	0.445	0.541	−4.825	4	0.008	−46.667	9.672
	--Equal variances not assumed			−4.825	3.203	0.015	−46.667	9.672
Cases/population	--Equal variances assumed	0.047	0.84	−0.382	4	0.722	0.000	0.001
	--Equal variances not assumed			−0.382	3.83	0.723	0.000	0.001
Fatality rate	--Equal variances assumed	1.51	0.286	−3.343	4	0.029	−0.073	0.022
	--Equal variances not assumed			−3.343	3.386	0.037	−0.073	0.022
Variation cases/population from April to August 2020	--Equal variances assumed	0.132	0.735	0.376	4	0.726	0.001	0.002
	--Equal variances not assumed			0.376	3.704	0.727	0.001	0.002
Variation fatality rate from April to August 2020	--Equal variances assumed	0.393	0.565	0.878	4	0.429	0.012	0.013
	--Equal variances not assumed			0.878	3.273	0.440	0.012	0.013

Table 3
Mann-Whitney Test. Rank for the impact of lockdown on rate of COVID-19 infected people and fatality.

Period from April to August 2020	Countries with a shorter period of lockdown, about 15 days (Austria, Portugal, Sweden)		Countries with a longer period of lockdown, roughly 61 days (France, Italy and Spain)	
	Mean rank	Sum of ranks	Mean rank	Sum of ranks
⊗ Days of lockdown	2	6	5	15
⊗ Cases/population	3	9	4	12
⊗ Fatality rates	2	6	5	15
⊗ Variation cases/population	3.67	11	3.33	10
⊗ Variation fatality rate	3.67	11	3.33	10

Table 4
Mann-Whitney Test for the impact of lockdown on rate of COVID-19 infected people and fatality.

	Test statistics[a]				
	Days of lockdown	Cases/population	Fatality rates	Variation of cases/population from April to August 2020	Variation of fatality rate from April to August 2020
- Mann-Whitney U	0	3	0	4	4
- Wilcoxon W	6	9	6	10	10
- Z	−1.964	−0.655	−1.964	−0.218	−0.218
- Asymp. sig. (2-tailed)	0.05	0.513	0.05	0.827	0.827
- Exact sig. [2 ∗ (1-tailed Sig.)]	0.100[b]	0.700[b]	0.100[b]	1.000[b]	1.000[b]

[a] Grouping variable: groups.
[b] Not corrected for ties.

Table 5
Estimated relationships based on linear model of regression.

	Confirmed cases in countries having lockdown of shorter duration (about 15 days)	Confirmed cases in countries having lockdown of longer duration (about 61 days)	Fatality rates in countries having lockdown of shorter duration (about 15 days)	Fatality rates in countries having lockdown of longer duration (about 61 days)
- Constant α (st. err.)	−5.34*** (0.18)	−2.97*** (0.18)	26.00* (8.88)	21.95 (14.06)
- Coefficient β (st. err.)	3.87E−10[a] (0.00)	2.156E−10[a] (0.00)	−1.88E−9[a] (0.00)	−1.58E−9[a] (0.00)
- Stand. coefficient beta	0.995	0.896	−72	−0.48
- R^2 (st. err. of estimate)	0.99 (0.00)	0.77 (0.00)	0.52 (0.007)	0.23 (0.012)
F-test	869.52***	34.42***	8.54*	2.41

Note: explanatory variable is time.
[a] Not indicated.
*** Significance: p-value<.001.
* Significance: p-value<.05.

Tobías, 2020). However, to our knowledge, none investigations have performed a comparative analysis of the effects of a longer or a shorter period of national lockdown on rates of COVID-19 infected people and deaths, and on dynamics of economic growth of countries. *What this study adds to current studies* on the COVID-19 global pandemic crisis is that a longer period of national lockdown to constraint the diffusion of COVID-19 does not seem to be associated with a significant reduction of infected cases on population and of fatality rates in society, whereas

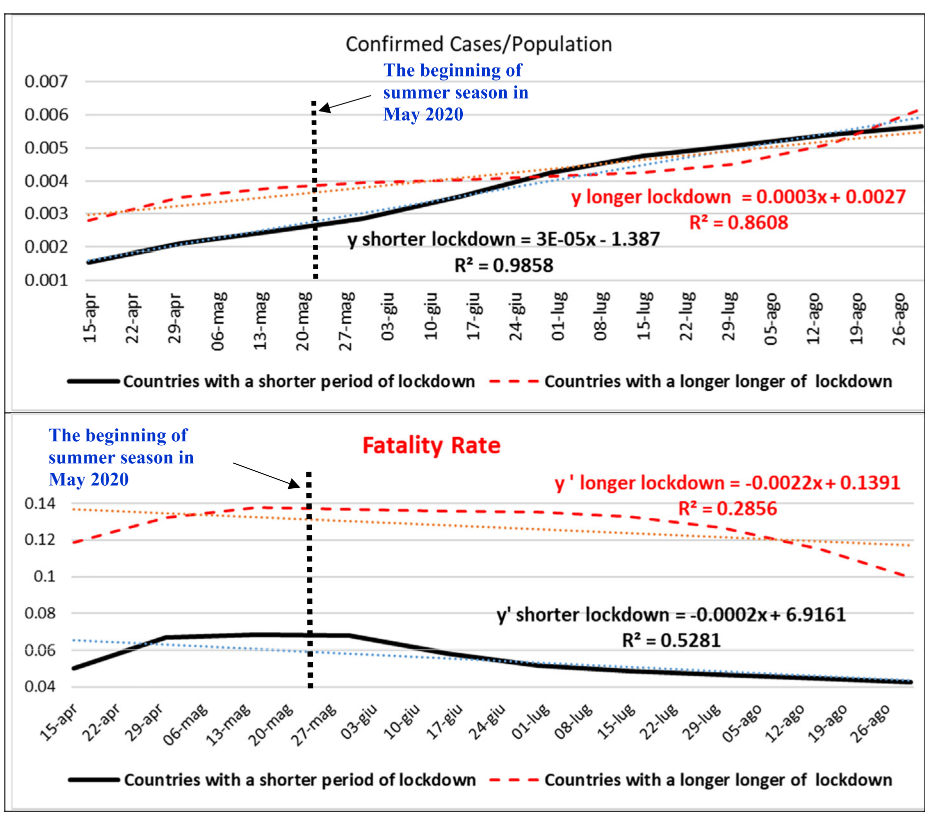

Fig. 3. Trends of confirmed cases/population and of fatality rates over April–August 2020 period in countries with a shorter period of lockdown of about 15 days and with a longer period of lockdown of roughly 61 days.

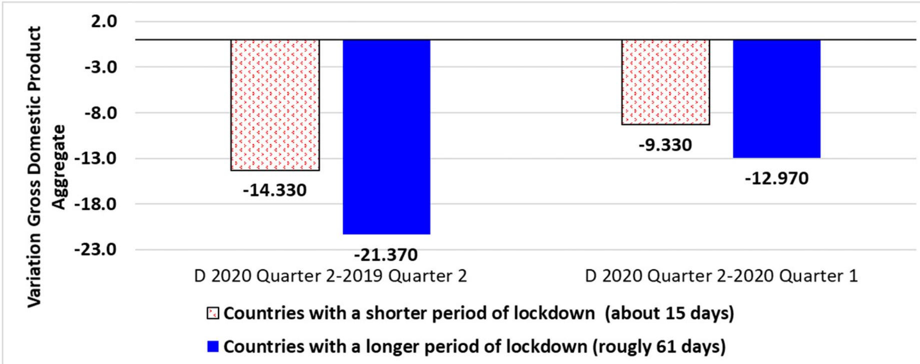

Fig. 4. Average variation of GDP (index 2010 = 100) from 2nd Quarter 2019 to 2nd Quarter of 2020 and from 1st Quarter 2020 to 2nd Quarter of 2020 between countries with a longer and a shorter period of lockdown. Note: Q1 = January, February, March; Q2 = April, May, June; GDP = Gross Domestic Product.

results here suggest that countries applying a longer duration of lockdown (>61 days) generate a significant contraction of GDP growth with subsequent socioeconomic issues. To put it differently, in the presence of vast pandemics, the policy responses of lockdown with longer duration at nation level seem to have a low effect in terms of significant reduction of COVID-19 infected cases and mortality rates, but a longer duration of national lockdown can slow down the dynamics of economic systems with consequential socioeconomic issues. These results can be schematically summarized in the Fig. 5.

Results suggest that countries with a longer duration of national lockdown have a higher fatality rate of COVID-19 and the causes can be explained with a lower average level of healthcare expenditure and an older structure of population (i.e., demographic structure has a higher median age in years) as indicated in Table 8. Hence, many countries with lower investments in healthcare sector and older population were almost obliged to apply a longer duration of national lockdown aimed at delaying and reducing the height of epidemic peak, affording healthcare system more time to expand and respond to this emergency and, as a result, reducing the expected negative impact of COVID-19 pandemic in society. However, this public policy of crisis management has a side effect given by a deterioration of structural indicators of economic system, generating a severe contraction of GDP growth with consequential socioeconomic issues, such as higher unemployment, high general government debt-to-GDP ratio, etc. (cf. also, Coccia, 2017). The contraction of economic growth can also trigger future reductions of investments in strategic sectors, such as health and research sector, which increase the vulnerability of these nations to future pandemics similar to COVID-19 and other environmental threats (cf., Coccia, 2020a). In particular, Table 8 reveals vital findings: countries with higher investments in healthcare (as percentage of GDP) have applied lockdowns of a shorter duration, reducing the deterioration of economic system in terms of contraction of economic growth, and simultaneously, they have also a lower fatality rate of COVID-19 (because of a consistent healthcare structure), though a higher incidence of confirmed cases in population.

In general, the policy response of lockdown has in theory the main goal, as containment measure, to reduce the impact of infectious diseases in society, but results here suggest that in the presence of vast pandemics, such as COVID-19, a longer duration of full lockdown has *contradictory* and not significant effects on reduction of fatality rates, but *sure* negative effects on economic systems compared to a shorter length of full lockdown. Instead, higher investments in healthcare sector play a vital role to cope with unforeseen pandemics, alleviating mortality in society.

Overall, then, lockdown as policy response to cope with COVID-19 pandemic crisis can generate different effects over time and space. The study here has explained the vital role of duration of full lockdown on COVID-19 infected people and deaths, and on economic growth of six representative countries in Europe having a comparable institutional and socioeconomic background.

Table 6
Group statistics for GDP level.

	Countries with a shorter period of lockdown, about 15 days (Austria, Portugal, Sweden)		Countries with a longer period of lockdown, roughly 61 days (France, Italy and Spain)	
	Arithmetic mean	Std. deviation	Arithmetic mean	Std. deviation
⊕ GDP2019Q2	114.83	9.00	108.67	6.39
⊕ GDP2020Q1	109.83	9.31	100.27	6.90
⊕ GDP2020Q2	100.50	13.52	87.30	4.19
− Δ GDP (2020Q2 − 2019Q2)	−14.33	4.59	−21.37	2.76
− Δ GDP (2020Q2 − 2020Q1)	−9.33	4.37	−12.97	2.83

Note: GDP = Gross Domestic Product (index 2010 = 100); Q = Quarter of the Gross Domestic Product; Q1 = January, February, March; Q2 = April, May, June.

Table 7
Independent Samples *t*-Test for the impact of lockdown on economy of countries.

		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
Δ (variation) GDP (2020Q2 − 2019Q2)	- Equal variances assumed	1.503	0.287	2.274	4	0.085	7.033	3.093
	- Equal variances not assumed			2.274	3.276	0.1	7.033	3.093

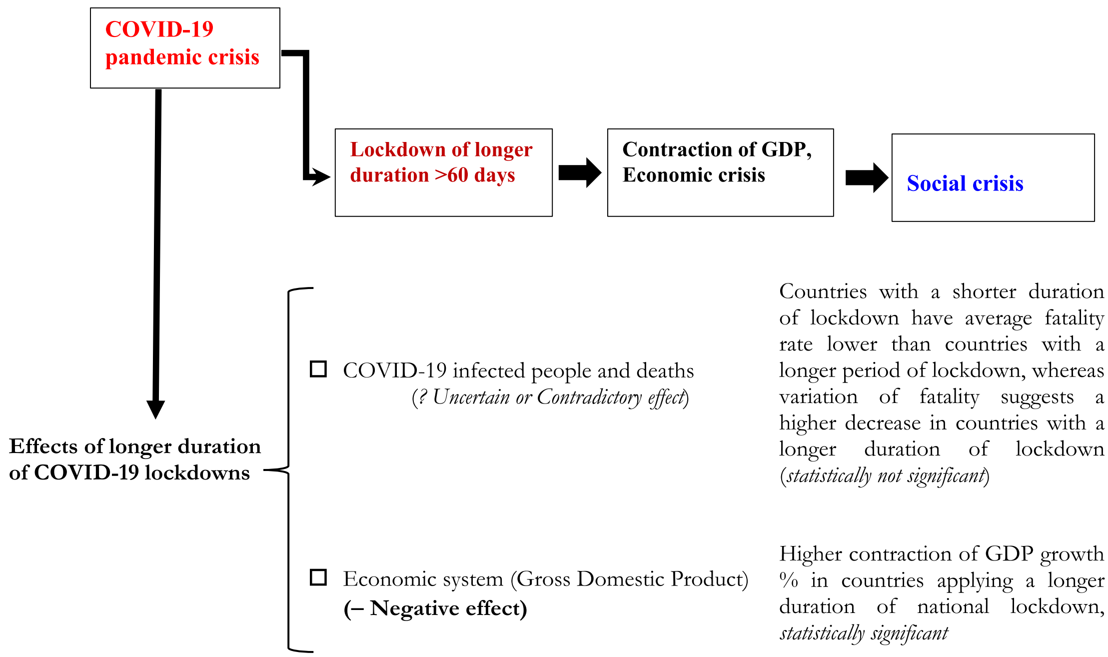

Fig. 5. Impact of a longer duration of lockdown on COVID-19 infected people and deaths, and Gross Domestic Product level (wealth of nations).

In short, the results of this analysis are that:

- *a longer duration of full lockdown generates uncertain effects on reduction of COVID-19 infected people and deaths*
  - countries with a shorter duration of lockdown (about 15 days) are associated with lower average levels of confirmed cases/population (%) but they have a higher average variation of confirmed cases/population (%) than countries with a longer duration of lockdown
  - countries with a shorter period of lockdown are associated with an average level of fatality rates (%) lower than countries with a longer duration of lockdown, likely because of their high investments in health sector.

- *a longer length of national lockdown generates negative effects on economic system*
  - countries applying a longer duration of lockdown have had a contraction of GDP growth higher than countries with a shorter duration of lockdown (comparing the index of GDP of the second quarter 2020 to the indicator in the same period in 2019 and comparing GDP of the second quarter 2020 to the first quarter of 2020).

To put it differently, the statistical analyses here seem in general to reveal that a longer duration of *full lockdown at national level* has contradictory and not univocal effects on reduction of COVID-19 infected people and deaths (i.e., it seems of not generating any significant reduction of confirmed cases and fatality rates), whereas a longer period of lockdown can damage mechanisms of socioeconomic systems. Hence, to reiterate, results suggest that extensive and longer containment policies based on full lockdowns in the presence of widespread infectious diseases, such as COVID-19, can deteriorate economic system with uncertain benefits on health of people in terms of significant reduction of mortality in society. Current lockdown policies to reduce the diffusion of COVID-19 can bring the world economy to a halt, and Roy et al. (2021) suggest dynamic lockdown measures that incorporate the healthcare resource budget of people in a zone, restricting the COVID-19 hospitalizations within its healthcare resource budget. In this manner, regions can regulate own lockdown level and also manage the overheads associated with time-varying dynamic lockdown policies. Farsalinos et al. (2021) also argue that full lockdowns can have unintended adverse socioeconomic and health effects, and long-lasting lockdowns cannot provide a solution in pandemic containment but they can generate likely a vicious cycle of consecutive lockdowns with in-between breaks. These scholars suggest that community and home care can be better viable strategies that could mitigate negative effects of COVID-19 pandemic, associated with social distancing measures and facemask wearing (instead of full and longer lockdowns). Salvatore et al. (2020) point out that lockdown has been partly effective

Table 8
Descriptive statistics of factors associated with COVID-19 pandemic crisis between countries with higher and lower healthcare investments as % of GDP.

	HIGH investments in healthcare as % GDP		LOW investments in healthcare as % GDP	
	Mean	St. dev.	Mean	St. dev.
⊕ Healthcare as percent of GDP 2018	10.83	0.47	9.04	0.39
⊕ Healthcare per inhabitants in Euros, PPS 2018	€3862.947	€142.7616	€2398.337	€150.7042
⊕ Days of lockdown in 2020	28.33	28.01	47.67	29.14
⊕ Difference between GDP2020Q2 and 2019Q2	−15.63	6.27	−20.07	3.43
⊕ Difference between GDP2020Q1 and 2020Q2	−10.13	5.28	−12.17	2.45
⊕ Median age population 2019, years	41.90	1.45	45.30	1.35
⊕ Percent fatality rate COVID-19, December 2020	2.03	0.63	2.60	0.98
⊕ Percent cases/population, December 2020	3.36	0.32	3.33	0.35

Note: countries with *high* investments in healthcare (% of GDP) > 9.93% (arithmetic mean of countries under study); countries with *low* investments in healthcare (% of GDP) ≤ 9.93% (arithmetic mean of countries under study); purchasing power standard (PPS) per inhabitant; GDP = Gross Domestic Product.

in slowing the spread of COVID-19 pandemic in India because of large state-level variations. Caulkins et al. (2020) show that two different containment measures can be optimal strategies: 1) an eradication strategy, where a long lockdown significantly reduces not only the bad health effects of the epidemic but also economic activity of countries; 2) curve flattening strategy characterized by a relatively short lockdown period to reduce epidemic peak of infections, supporting intensive care capacity constraint without damaging economic activity. These different strategies of lockdown can produce similar effects to alleviate number of people urgently need healthcare when hospitals are already filled to capacity (Caulkins et al., 2020). Bendavid et al. (2021) also argue that small benefits with mandatory policies of stay-at-home and business closures cannot be excluded, but results do not support significant benefits on case growth of more restrictive nonpharmaceutical interventions. Similar reductions in case growth may be achievable also with less-restrictive containment measures (Bendavid et al., 2021).

Therefore, the complex problem of epidemic threats has to be solved with interdisciplinary approaches (Coccia, 2019, 2020e,f), considering both health and economic aspects, and applying whenever possible, containment policies on specific places having a high risk to be COVID-19 outbreaks, rather than general lockdowns of longer duration (Coccia, 2020d). In fact, new studies reveal that a minority of places (such as restaurants, cafeterias, gyms, etc.) can generate a large number of infections; as result, selected containment measures in these places and facemask wearing may be more effective policies than national lockdown and uniform reduction of mobility of people (Coccia, 2020d; Chang et al., 2020; Renardy et al., 2020). Janssen and van der Voort (2020) show positive effects in some countries that have applied the "smart lockdown" based on suggested and not mandated mitigation measures, focusing on responsibility of individuals. In short, general lockdown of longer duration can be substituted with selected policies at local and regional level having agility and speed of responses in specific places at high risk of infections to cope with social threats of new waves of COVID-19 and/or similar epidemics/pandemics (Chang et al., 2020; Janssen and van der Voort, 2020; Renardy et al., 2020). Finally, Evans and Bahrami (2020) pinpoint that super-flexibility can be an appropriate approach to cope with COVID-19 pandemic in which decision making is oriented to versatility, agility, and resilience.

6. Conclusions

The most important finding of this study is that countries with a prior high investment in healthcare (as percentage of GDP), they have the social and health structures for alleviating fatality rate of the COVID-19 (and/or other infectious diseases), and simultaneously can apply a full lockdown of a shorter duration, reducing the deterioration of economic system in terms of contraction of economic growth, though the risk of a higher incidence of confirmed cases in population. This evidence, of course, is based on relations of association between variables under study rather than relations of dependence, because of manifold confounding factors that influence relationships under study (Sabat et al., 2020, p. 917). In fact, the number of confirmed cases and of fatality rates is affected by different factors, apart from the length of lockdown; this study has investigated some critical variables and there is need for much more detailed research considering other factors associated with reduction of the spread of novel infectious diseases. The positive side of this study is that analyzes countries located in the same geo-economic European area, having a uniform socioeconomic, cultural and institutional background, which is appropriate for comparative analyses to assess the effects of containment measures to cope with COVID-19 pandemic crisis in society. The negative side of the study here is a specific analysis of six countries in Europe and results are, of course, tentative. Future studies have to enlarge the sample with other countries, maintaining a comparable framework for performing much more detailed research to support the generalization of these critical findings here.

Overall, then, this study, based on results analyzed here, must conclude that an effective strategy to reduce the negative impact of future epidemics/pandemics similar to COVID-19 has to be based on preventive high investments in healthcare sector to create an prearranged efficient organization directed to cope with pandemics of new viral agents, able to minimize fatality rates, rather than apply general lockdowns of longer duration that generate *ambiguous* results on health of people (in terms of significant reduction of fatality rate) but induce sure *negative* effects on structural indicators of economic systems with consequential socioeconomic issues.

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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