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How to measure the environmental and health risk of exposure to future epidemics in cities?

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Abstract. This paper suggests a metrics that measures the environmental risk of exposure of cities to future waves of COVID-19 and epidemics of similar vital agents. The proposed index combines environmental, socioeconomic and health risk factors of cities to assess their vulnerability to the diffusion of infectious diseases. The statistical evidence here seems in general to support the predictive results of the index in assessing the risk of exposure of cities to the spread of infectious diseases. The metrics here can be important to help policymakers in decision making to constrain new waves of the COVID-19 and/or diffusion of new infectious diseases similar to COVID-19 with appropriate control measures on environment and socioeconomic system.
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JEL. Q12, Q13, Q15, Q18.

1. Introduction

Severely epidemics of infectious diseases, such as COVID-19, are a major problem for public health over time and space. The spatial and temporal variability of the spread of COVID-19 and other infectious diseases within and between countries is not random process but this novel coronavirus (SARS-CoV-2) generates higher numbers of COVID-19 related infected individuals and deaths in specific geo-environmental regions. In fact, the diffusion of COVID-19 has high mortality rate in Italy (14.35%), Spain (11.33%), UK (13.97%), Belgium (16.22%), France (15.24%), whereas in other countries seem to have lower rates of fatality (Center for System Science and Engineering at Johns Hopkins 2020). Therefore, deaths of COVID-19 are due to many socioeconomic and environmental causes that interact with this novel coronavirus and not just to SARS-CoV-2. It is extremely important, that nations acknowledge the reality that this novel coronavirus spreads so rapidly and generates numerous deaths in cities with specific geo-environmental factors given by little wind and frequently high levels of air pollution — exceeding safe levels of particulate matter (Coccia, 2020).

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The monitoring of transmission dynamics of COVID-19 is mainly based on basic reproduction number, R_0, that is the expected number of infected individuals directly generated by one infected person in a population with all susceptible people to infection (Chintalapudi *et al.*, 2020, p. 327). However, this indicator monitors real-time transmission dynamics for detecting the spread of pandemic and/or epidemics and, as far as possible, apply measures to control and contain high numbers of COVID-19 related infected individuals and deaths (Yuan *et al.*, 2020). The pandemic of COVID-19 and future pandemics challenge global societies that are susceptible to new infectious diseases and in this global environment it is more and more important to have new indicators that can help policymakers to prevent future epidemics and, if they arrive, to constrain effects on public health and economy. In this global context, contemporary environmental studies have to cope with these new problems that emerge and have to be solved in society, rapidly. In particular, one of the new problems is: how can measure the environmental risk of exposure to infectious diseases, similar to the COVID-19, of cities and/or regions?

In this paper, index *c* (as contagions) is proposed as new method that quantifies the environmental risk of exposure of cities, regions and other geo-economic areas in the presence of new epidemics and/or pandemics. The proposed index *c* is a measure, *ex ante*, of potential risk of diffusion of infectious diseases within and between cities that generates negative effects on public health and economy. The *prediction* of this study is that a high risk of exposure of cities/regions to infectious diseases is given by an index *c* close to 1 (maximum value): a zone with environmental, health and demographic weaknesses having a high risk of exposure to severe infectious disease outbreaks that would result in high numbers of infected individuals and deaths compared to a location with a low magnitude of the index *c* (close to zero, the minimum). The statistical evidence here seems in general to support the predictive results of the index *c* as particularly simple but superior indicator in detecting the global correlation between *potential* risk of high exposure of cities/regions to infectious diseases and *actual* high numbers of COVID-19 related infected individuals and deaths. Overall, then, the proposed index *c* here is a new method that can be applied as a preventive strategy to help policymakers to prevent whenever possible epidemics and, in case they arrive, to constraint effects of new infectious disease outbreaks in society with appropriate control measures of environmental and sustainable sciences.

2. Novel method to measure environmental exposure of cities infectious diseases

The principal factors determining the diffusion of infectious diseases, such as COVID-19, in regions are:

- *Environmental pollution (Factor 1)*. Studies reveals that areas with frequently high levels of air pollution — exceeding safe levels of ozone or particulate matter — had higher numbers of COVID-19 related infected individuals and deaths (Coccia, 2020, 2020c). Moreover, high concentration of nitrogen dioxide and particulate air pollutant emissions induce serious damages to the immune system of people that is weak to cope with infectious diseases (Glencross *et al.*, 2020).

☐ *Atmospheric environment, given by stability/instability of atmosphere measured with wind speed (Factor 2).* A higher wind speed, creating atmospheric instability, seems to reduce the number of infected individuals because it fosters the dispersion of air pollution that can act as carrier of the SARS-CoV-2 in the air, whereas stable atmosphere with low wind speed prevents the dispersion of air pollutants that remain stagnant in the air with content of bacteria and viruses, such as SARS-CoV-2, generating a higher diffusion of COVID-19 and other infectious diseases (Coccia, 2020a)

☐ *Demographic aspects, given by density of population per km^2(Factor 3),* is a main factor determining human-to human transmission of infectious diseases (Kucharski et al., 2020)

☐ *Respiratory disorders of people, given by mortality rate for trachea, bronchi and lung cancer (Factor 4)*. Lung cancer (LC) is a: "cancer that forms in tissues of the lung, usually in the cells lining air passages". Lung cancer is one of the main diseases in several countries and a leading cause of cancer death – both sexes –worldwide (National Cancer Institute, 2020). Amoatey et al. (2020) show that air pollution could increase respiratory diseases, such as chronic obstructive pulmonary diseases and lung cancer, because air pollution is genotoxic and contributes to the development of tumor via inducing sustained inflammation.

Step 1.

Let Factors *i* (*i*=1, 2, 3, 4), just mentioned, observed per *j* units (e.g., cities, regions, countries, etc.) with *j*=1, …, *n*

Step 2.

For each Factor *i* (*i*=1, 2, 3, 4) is calculated the percentile 25th, 50th, 75th and subsequently the *j*-th units of the population are grouped in four sets according to their value for each Factor *i*:

- Set 1. If factor *i* of j-th unit has a value lower than 25th percentile
- Set 2. If factor *i* of j-th unit has a value between 25th – 50th percentile
- Set 3. If factor *i* of j-th unit has a value between 50th – 75th percentile
- Set 4. If factor *i* of j-th unit has a value greater than 75th percentile

Step 3.

To each *j*-th unit (e.g., cities, regions, etc.) is assigned a score from a minimum of 0 to a maximum of 3, according to location in set 1, 2, 3, and 4 indicated in step 2 as follows:

Set of *j*-th unit for Factor *i*	Score (p_k)
1	0 (*low* intensity of Factor *i*)
2	1
3	2
4	3 (*high* intensity of Factor *i*)

Step 4.

If *j*-th unit has the max score of 3 (three) for the four Factors *i* (*i*=1, 2, 3, 4), the total is 12; if *j*-th unit has the min score of 0 (zero) for all four factors, then total value is, of course, 0 (zero). In the middle there is a range of scores for *j*-th unis (*j*=1 ,…, *n*) from 1 to 11.

Definition of the index c (ontagions) of environmental exposure to the risk of infectious diseases

Let F*i* (*i*=1, 2, 3, 4) the four Factors that measure the environmental exposure to infectious diseases of *j*-th units (*j*=1, 2, …, *n*), e.g., a city, a region, a nation.

Let p_k the score of *j*-th unit per each Factor F*i* with values from 0 (min), 1, 2, to 3 (Max)

Let the max score of *j*-th unit for four Factors F*i* equal to 12, given by (3 ×4) = 12

The index *c* that quantifies the environmental risk of exposure to infectious diseases of *j*-th units is defined as follows:

$$Index\ c_j = \frac{[F1(p_k)+F2(p_k)+F2(p_k)+F4(p_k)]_j}{12} = \frac{[\sum_{i=1}^{4}\sum_{k=0}^{3} Fi(p_k)\ ]_j}{12} \quad (unit\ j = 1, \dots, n) \qquad (1)$$

Properties of the index *c*

- *Range of variation.* Index *c* has a range of variability in the set of real numbers: Index $c \in [0, 1]$
- *Minimum*. The min value of the index *c* is 0 (zero) and indicates a very low risk of exposure to infectious diseases
- *Maximum*. The max value of the index *c* is 1 (one) and indicates a very high risk of exposure to infectious diseases of individuals
- *Transitive property*. If $F_i(p_k)_j \leq F_i(p_k)_{j+1} \Rightarrow$ index $c_j \leq$ index c_{j+1} for *i*=1,2,3,4 and *k*=0,1,2,3
- *Symmetry property*. If $F_i(p_k)_j = F_i(p_k)_{j+1} \Rightarrow$ index $c_j =$ index c_{j+1} for *i*=1,2,3,4 and *k*=0,1,2,3

The *j*-th units are classified in increasing order using the index *c*, from 1st to*n-th Rank*, according to the value of index *c* ranges from 1 to 0. In particular, a higher rank close to the 1 indicates a high risk of exposure to infectious diseases, a low rank close to *n* (*last position*) suggests a low risk of exposure to infectious diseases.

Step 5.

The magnitude of index *c* of *j-th* unit is the basis for a scale of measurement of the risk of exposure to infectious diseases, based on socioeconomic and environmental factors (table 1), as follows.

Table 1. *Scale of measurement of geo-environmental risk of exposure to infectious diseases*

Grade	Index *c*	Level of risk of exposure to infectious diseases
1	<.25	*Low*
2	0.25-.50	Moderate
3	.51-.75	High
4	>.75	Very High

The evaluation of the effectiveness and robustness of predictive capacity of index *c* is performed with the Spearman rank-order correlation coefficient r_s : a nonparametric measure of the strength and direction of association that exists between two variables measured on an ordinal scale. This study uses the ranking of *j*-th units based on index *c*, and ranking of the same *j*-th units based on number of confirmed cases of COVID-19. If this Spearman rank-order correlation coefficient r_s provides a strong positive correlation, statistically significant, then it can be a robust and predictive method to assess the risk of exposure of cities, regions and other geoeconomic zones to infectious diseases. The effectiveness of index *c* is also evaluated with the bivariate Pearson correlation with correlation coefficient, *r*, which measures the strength and direction of linear relationships between pairs of continuous variables given by index *c* of *j-th* units under study and number of infected individuals in specific days of COVID-19 outbreak. The null hypothesis (H_0) and alternative hypothesis (H_1) of the significance test for correlation is performed. These coefficients of correlation (r_s and *r*) have a value in the range [−1, 1]. The sign of these correlation coefficients indicates the direction of the relationship, while the magnitude of the correlation indicates the strength of the relationship and in particular a positive magnitude indicates a positive relationship. The strength of these coefficients can be assessed by these general guidelines:

$.1 < | r_s$ or $r | < .3$ indicates a weak correlation

$.3 < | r_s$ or $r | < .5$ indicates a moderate correlation

Finally, $| r_s$ or $r | > .5$ reveals a strong correlation

3. Application of the research technique: Case study in Italy

- *Sample*. Fifty-five (*N*=55) cities that are provincial capitals in Italy, one of the countries with the highest number of world-wide deaths of COVID-19.
- *Factor 1. Air pollution (particulate matter emissions).* Total days exceeding the limits set for PM_{10} or for ozone in 2018 per Italian provincial capitals. Days of high levels of air pollution — exceeding safe levels of ozone or particulate matter —are a main factor that affects environment and public health (Coccia, 2020b).
- *Factor 2. Atmospheric stability / turbulence.* Average wind speed in km/h on February-March 2020 during the COVID-19 outbreak in Italy. Sources are based on meteorological stations in Italian provinces (Coccia, 2020b).

- *Factor 3. Demographic aspects, given by density of population per km²*. Data of the density of population in 2019 are from the Italian National Institute of Statistics (Coccia, 2020b).
- *Factor 4. Mortality rate of trachea, bronchi and lung cancer*. Rate of mortality per 10,000 people for trachea, bronchi and lung cancer in 2017 (Coccia, 2020b).
- *Factor to control index c is diffusion of COVID-19 across cities.* Number of confirmed cases on March-April, 2020 across cities under study (Coccia, 2020b).

Table 2 shows the percentile of these factors in the sample under study.

Table 2. *Percentiles of factors in the sample N=55 cities*

Percentiles	Total days exceeding the limits set for PM_{10}, 2018	*p*(k)	Density of population per km², 2019	*p*(k)	Wind Speed* km/h 2020	*p*(k)	Rates of mortality for trachea, bronchi and lung cancer 10 000 people, 2017	*p*(k)	Total score		Index *c*
25th	38	0	470	0	>	0	5.23	0	0	*min*	0
50th	72	1	950	1	10.5	1	5.88	1	4		.33
75th	116	2	1738	2	9.4	2	6.7	2	8		.67
>75th	>116	3	>1738	3	7.85	3	>6.7	3	12	*Max*	1

Notes: * wind speed has inverted percentiles from the 75th to 25th to assign a low score to high percentile (when high wind speed fosters dispersion of air pollution) and high score to low percentile (when low wind speed prevents dispersion of air pollution, cf., Coccia, 2020b).

The application of the formula of index *c*, as described in methods (see [1]), provides the following results in table 3.

Table 3. *Cities, index c, number of infected and ranking (with rank 1=high index c=high risk, 55= low score=low risk)*

Italian Provincial capitals	Index *c*	Ranking Index *c*	Infected people 7 April	Ranking Infected people 7 April	Infected people 27 March	Ranking Infected people 27 March
Agrigento	0.000	53	110	55	58	53
Alessandria	0.500	29	1946	19	1106	22
Aosta	0.333	41	835	32	452	35
Asti	0.583	21	629	38	303	43
Avellino	0.583	16	375	47	182	49
Benevento	0.000	54	111	54	15	55
Bergamo	0.750	6	9868	2	8060	1
Biella	0.583	23	591	40	367	38
Bologna	0.583	20	2656	13	1413	16
Bolzano	0.250	47	1811	20	1003	23
Brescia	0.750	7	9594	3	7305	3
Como	0.417	34	1525	28	816	27
Cremona	0.750	9	4323	5	3496	4
Enna	0.250	48	289	49	155	51
Ferrara	0.583	24	522	42	244	45
Firenze	0.667	11	1805	21	764	28
Forlì	0.333	44	1034	30	580	31
Frosinone	0.583	17	401	46	191	48
Genova	0.667	12	2157	17	817	26
Grosseto	0.333	45	290	48	174	50
Lecco	0.583	18	1731	24	1210	21
Lodi	0.750	8	2321	16	2006	7
Lucca	0.417	38	920	31	481	34
Macerata	0.000	55	664	37	411	37
Mantova	0.417	37	2142	18	1398	17
Milano	0.917	1	11787	1	7469	2
Modena	0.667	10	2758	11	1772	11
Monza	0.833	2	3206	7	1948	8
Napoli	0.500	26	1643	25	734	29
Padova	0.750	5	2965	8	1891	9
Parma	0.417	35	2365	15	1690	14
Pavia	0.833	4	2735	12	1712	12
Piacenza	0.667	13	2953	9	2276	6
Pisa	0.250	51	584	41	350	41
Pistoia	0.417	39	404	45	264	44
Pordenone	0.333	40	480	44	332	42

Table 3. *(Continue). Cities, index c, number of infected and ranking (with rank 1=high index c=high risk, 55= low score=low risk)*

Italian Provincial capitals	Index *c*	Ranking Index *c*	Infected people 7 April	Ranking Infected people 7 April	Infected people 27 March	Ranking Infected people 27 March
Ravenna	0.250	50	738	34	488	32
Reggio Emilia	0.417	36	3215	6	1861	10
Rieti	0.167	52	268	52	43	54
Rimini	0.333	43	1584	26	1264	20
Roma	0.500	28	283	51	1703	13
Rovigo	0.583	19	218	53	122	52
Savona	0.333	46	509	43	223	46
Sondrio	0.500	31	620	39	362	39
Terni	0.583	22	288	50	195	47
Torino	0.833	3	6375	4	3361	5
Trento	0.333	42	2476	14	1391	18
Treviso	0.583	14	1738	22	1310	19
Trieste	0.500	32	733	35	411	36
Udine	0.250	49	813	33	487	33
Varese	0.417	33	1326	29	711	30
Venezia	0.500	27	1543	27	955	25
Vercelli	0.500	30	665	36	358	40
Verona	0.500	25	2856	10	1645	15
Vicenza	0.583	15	1734	23	966	24

Table 3 shows the index *c* that indicates the risk of exposure to COVID-19 (0=min, 1=Max) and the ranking of cities also from the highest risk (rank 1) of exposure to the lowest risk (rank 55) of exposure to infectious diseases. Moreover, table 3 shows number of infected individuals on 27 March and 7 April 2020 and the ranking from 1st to 55th position, indicating the cities from the highest number of infected individuals to the city with the lowest number of infected individuals.

To test the predictive capacity of index *c*, the coefficient of correlation of Spearman's Rho (r_s) is calculated between the ranking of cities based on index *c* (from high to low value of the risk of exposure to COVID-19) and ranking of cities (from the highest to lowest position) based on number of confirmed cases of COVID-19 at 27 March 2020 and 7 April 2020, during COVID-19 outbreak in Italy. Results are in table 4 and show a strong positive correlation of r_s: more than .60 (*p*-value 0.001).

Table 4. *Coefficient of correlation of Spearman's Rho (N=55 cities)*

	Ranking of infected individual 7 April 2020	Ranking of infected individual 27 March 2020	Ranking Risk Index *c*
Ranking of infected individual 7 April 2020	1		
Ranking of infected individual 27 March 2020	.929**	1	
Ranking Risk Index c	.602**	.607**	1

Notes: ** Correlation is significant at the 0.01 level (2-tailed).

In addition, to confirm this result the coefficient of correlation by Pearson *r* is calculated between index *c* of cities and number of infected individuals on 27 March and 7 April, 2020. Results confirm that *r* has a high magnitude, suggesting that index *c* effectively *predicts* the risk of infectious diseases over time and space (Table 5)

Table 5. *Coefficient of correlation of Pearson (N=55 cities)*

	Infected individuals 7 April 2020	Infected individuals 27 March 2020	Risk Index *c*
Infected individuals7 April 2020	1		
Infected individuals 27 March 2020	.975**	1	
Risk Index *c*	.593**	.567**	1

Notes: ** Correlation is significant at the 0.01 level (2-tailed).

Table 6 shows the average index *c* of the sample into the scale of measurement of the risk of exposure to infectious diseases. In the last column, average number of infected individuals on 7th April 2020 for Italian case study shows the robustness of proposed index *c* that confirms how a value higher than .75 (or close to 1, max of the index *c*) suggests a very high risk of infectious disease (confirmed with the high number of confirmed cases of COVID-19), whereas a value less than .25 indicates that the risk of exposure to infectious disease is rather low.

Table 6. *Scale of measurement of environmental risk of exposure to infectious disease of COVID-19 and application on Italian case study*

Grade	Index *c*	Average index *c* for Italian case study	*Potential* Level of risk of Infectious Diseases	*Actual* Average number of infected individuals for Italian case study on 7th April 2020
1	<.25	*.15*	*Low*	*598.67*
2	0.25-.50	.42	Moderate	1336.09
3	.51-.75	.64	High	2481.35
4	>.75	**.85**	**Very High**	**6025.65**

4. Discussion and conclusive observations

The index *c* provides a synthetic value, based on socioeconomic and environmental factors, that can help policymakers to know the preventive risk of exposure of cities and/or regions to infectious diseases similar to COVID-19 to apply appropriate *ex-ante* measures to prevent the emergence of future epidemics and, when epidemics arrive to constrain new infectious disease outbreaks (Coccia, 2020d). Policymakers, to reduce the risk of vulnerability to future epidemics and pandemic with accelerated diffusion of infectious disease, can act on some factors determining the structure of index *c* given by:

1) sources of air pollution;
2) atmospheric environment on urban ventilation;
3) density of population;

4) causes of lung and bronchi cancer.

In short, acting on these four factors, reducing their intensity of index *c* over time and space, it can reduce the future risk of exposure to infectious diseases. First of all, it is important to reduce levels of air pollution in polluted cities, fostering sustainable mobility as engine of socioeconomic change to improve public respiratory health. It is basic to encourage local, urban and commuter public transport with electric vehicles and creating vast Low Emission Zones within cities. About the atmospheric environment, it can be important the improvement of urban ventilation and the exchange of air between areas within and above the urban canopy for the atmospheric dispersion of pollutant concentration in cities, enhancing air quality in cities. Gu *et al.* (2020) argue that urban ventilation is a function of a manifold urban characteristics, e.g., frontal and plan area density, and the aspect ratio of urban morphology. In fact, polluted cities with atmospheric stability and lack of a wind driven natural ventilation for pollutant dispersion have to apply sustainable policy to reduce main sources of air pollution and, at the same time, improve urban ventilation to foster the dispersion of particulate compounds emissions considering morphological characteristics of the openness of surrounding areas, the coverage and heights of buildings, etc. that are factors affecting the surface roughness of cities and dispersion of air pollution (Coccia, 2020b). Luo *et al.* (2020) argue that in China the daily mean $PM_{2.5}$ concentration reduction from 2016 to 2018 by about 14.50% has generated positive heath impact and economic benefit, avoiding premature mortalities for cardiovascular diseases, respiratory diseases, and lung cancer. Amoatey *et al.* (2020) suggest that adoption of stringent air pollution regulations and sustainable city planning, such as the increase in urban green infrastructures and improvement of road transportation can reduce $PM_{2.5}$ levels in urban environment, safeguarding public health from air pollution. Hence, sustainable policies that reduce air pollution and particulate compounds emissions generate significant environmental, public health, social and economic benefits, as well as it can reduce the risk of exposure to future epidemics similar to COVID-19. This index *c* suggests that the prevention of future infectious diseases is not only a problem limited to nonpharmaceutical interventions to reduce human-to-human transmission of viral agents but is a larger and complex problem including socioeconomic, demographic and environmental factors. In particular, this index *c* suggests that in order to constraint future infectious diseases and epidemics similar to COVID-19 that affect public health and economies, regions and nations have to apply a sustainable policy directed to reduce sources of air pollution and improve urban ventilation. In addition, Italy and other advanced countries should introduce organizational, product and process innovations to cope with future viral threats also using artificial intelligence, new Information and communication technologies for diagnostics, treatments and monitoring effective interactions between infectious and susceptible individuals, and finally of course to develop effective vaccines and new antivirals that can counteract future global public health threats in the presence of new epidemics similar to COVID-19[1]. Hence, science and technology, for years to come, can provide new tools and approaches to support nations to cope with new infectious diseases, also redefining the way governments interact with their citizens (for the role of science & technology to cope with problems in society, see Coccia, 2004, 2005, 2005a, 2005b, 2006, 2009, 2016, 2016a, 2016b, 2016c, 2017, 2017a, 2017b, 2017c, 2018, 2018a, 2019, 2019a, 2020e, 2020f, 2020g, 2020i; Coccia and Wang, 2015, 2016, Coccia and Watts, 2020).

Overall, then, the statistical evidence here seems in general to support the predictive results of the index *c* as particularly simple but superior approach in detecting the global correlation between *potential* risk of high exposure of cities/regions to infectious diseases and *actual* high numbers of COVID-19 related infected individuals and deaths. The proposed index *c* here seems to be a new method that can be applied as an *ex-ante* strategy to help policymakers to prevent new infectious disease outbreaks similar to COVID-19 and, if epidemics arrive in geoeconomic areas to prepare appropriate control measures to constraint that the accelerated transmission dynamics of viral infectivity are not triggered. To conclude, study therefore encourages further investigations for developing comprehensive indexes also based on environmental and sustainable factors, and not only related to medicine, such as reproduction number, that can help *ex-ante* policymakers to cope with future epidemics for designing appropriate long-run strategies to alleviate or eliminate the negative impact on public health, economy and society.

Declaration of competing interest

The author declares that he is the sole author of this manuscript and he has no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper. This study has none funders.

[1] For studies about the interaction between science, technology and innovation, their sources, evolution, diffusion and impact on socioeconomic systems, see: Cavallo et al., 2014; Coccia, 1999, 2001, 2004, 2005, 2005a, b, c, 2006, 2007, 2008, 2009, 2009a,b,c; 2010, 2010a,b; 2012, 2012a,b; 2013; 2014, 2014a, b, c, d; 2015, 2015a, b; 2016, 2016a; 2017, 2017a, b, c, d, e, f, g, 2018, 2018a, b, c, d, e, f, g, h, i; 2019, 2019a, b, c, d, e, f, g, h, i, l, m; Coccia, 2020a, b, c, d, e, f, g, h, i, l, m, n, o, p, q; Coccia and Bellitto, 2018, Coccia and Cadario, 2018; Coccia et al., 2015; Coccia and Finardi, 2012, 2013; Coccia et al., 2012; Coccia and Rolfo, 2008, 2009, 2010, 2013, Coccia and Wang, 2015, 2016; Coccia and Watts, 2020.

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