Syntropic Criterion for Removing Restrictions During the COVID-19 Pandemic

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Abstract: A new – syntropic – criterion obtained using the synergetic theory of information has been proposed for determining the start date for the cancellation of restrictive measures in the COVID-19 pandemic. Under this criterion, the restrictions should be lifted when the average number of new cases per day during a week becomes disproportionately smaller than at the peak of the pandemic. The article gives the derivation of this criterion, and its practical use is shown by the example of a number of EU countries. In this case, a comparison is made of the dates set by the syntropic criterion with the actual dates of the beginning of the lifting of restrictions.

Keywords: COVID-19, removing restrictions, syntropy, proportionality, number of diseases.

1 Introduction

The key issue in returning to normalcy in the process of easing the COVID-19 pandemic is determining when to start lifting restrictive measures. This question is not currently unambiguously answered and is being addressed differently in different countries based on expert analysis of the medical, social, and economic situation. In this case, as a rule [1-3], special attention is paid to the indicator of the spread of the disease R_t (t is the date of the indicator determination), which indicates that when $R_t > 1$, there is an increase in the number of diseases, and when $R_t < 1$, the number of diseases decreases. A stable $R_t < 1$ value over a number of days is a prerequisite for starting the lifting of restrictions, but this condition does not say anything about exactly when (on what day) this can be started. Therefore, a different criterion is required for a more informed determination of the specific day after which the lifting of restrictions may begin.

In the present article, it is proposed to use the syntropic criterion obtained with the help of the synergetic theory of information to determine the specific time of starting the cancellation of restrictions [4-6]. The essence of this criterion is that it identifies the day, on which the average number of daily cases of illness during the week becomes disproportionately less than at the peak of the pandemic. Accordingly, after this day, one can start cancelling the restrictions. In the following presentation, the necessary information from the synergetic theory of information is first given, and the derivation of the syntropic criterion is given, and then its practical use is shown by the example of a number of EU countries. In this case, the dates obtained using this criterion are compared with the actual start dates for the removal of restrictions.

2 Syntropy of reflection and the condition of proportionality of finite sets

One of the new directions in the study of quantitative aspects of the phenomenon of information is currently the synergetic theory of information. This theory is based on the derivation of the syntropy formula I_{AB}, that is, the amount of information that two intersecting finite sets A and B reflect (reproduce) about each other as a single whole:

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$$I_{AB} = \frac{|K|^2}{|A| \cdot |B|} \cdot \log_2 |K|, \tag{1}$$

where $|A|, |B|, |K|$ is the number of elements in the set $A, B, K = A \cap B$.

In the case when $B \subset A$, the syntropy formula (1) takes the form:

$$B \subset A \Rightarrow I_{AB} = \frac{|B|}{|A|} \cdot \log_2 |B|. \tag{2}$$

The syntropy I_{AB} for each of the sets A and B has the same meaning. At the same time, the number of elements in the composition of these sets is generally different ($|A| \neq |B|$), which determines the asymmetry As of the completeness of their reflection through each other. Thus, the completeness of reflection of each set is characterized by the size of the relative syntropy equal to the relation of syntropy I_{AB} to the attribute information of set, which, in turn, is equal to the binary logarithm of the number of its elements. That is, denoting the relative syntropy of the set A by the symbol $I^*_{A \to B}$, and of the set B by the symbol $I^*_{B \to A}$, for the case $B \subset A$ according to (2), one can obtain:

$$I^*_{A \to B} = \frac{|B|}{|A|} \cdot \frac{\log_2 |B|}{\log_2 |A|}, \tag{3}$$

$$I^*_{B \to A} = \frac{|B|}{|A|}. \tag{4}$$

Accordingly, the asymmetry of the completeness of the reflection of sets is equal to the difference between the relative syntropies (3) and (4):

$$\begin{aligned} As &= I^*_{B \to A} - I^*_{A \to B} \\ &= \frac{|B|}{|A|}\left(1 - \frac{\log_2 |B|}{\log_2 |A|}\right). \end{aligned} \tag{5}$$

Figure 1 shows a graph of the dependence of asymmetry (5) on $|B|$ at $A >> 1$, which shows that in the process of a sequential increase in the values $|B|$ from 1 to $|A|$, the asymmetry As first increases from zero to a maximum value $As^{\max}$ at $|B| = |B|^*$, after which it decreases and at $|B| = |A|$, again becomes equal to zero.

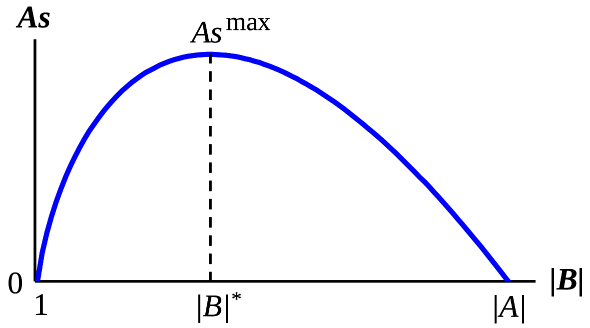

Figure 1. Dependence of the asymmetry *As* on the value $|B|$.

This behavior of the asymmetry of *As* is explained by the fact that at $|B| < |B|^*$, the relative syntropy $I^*_{B\to A}$ increases faster than $I^*_{A\to B}$ and at $|B| > |B|^*$ – vice versa. At the same time, in accordance with equations (3) and (4), the increase in $I^*_{B\to A}$ remains constant all the time, and the increase in the values $I^*_{A\to B}$ is logarithmic in nature. A clear illustration of the indicated change in relative syntropies is **Figure 2**, which shows the graphs of their increments $\Delta I^*_{A\to B}$ and $\Delta I^*_{B\to A}$ with a sequential increase in $|B|$ by one.

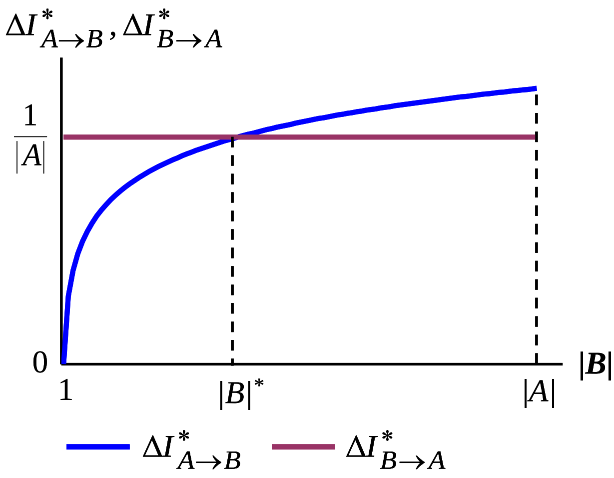

Figure 2. Dependence of increments $\Delta I^*_{A\to B}$ and $\Delta I^*_{B\to A}$ on the value $|B|$.

The noted features of the asymmetry *As* behavior and the nature of the change in the magnitude of relative syntropies $I^*_{A\to B}$ and $I^*_{B\to A}$ are naturally associated with the proportionality of the sets *A* and $B \subset A$, that is, with their correspondence to each other in terms of the number of elements. In this case, the following can be said.

When $|B| = |A|$, the sets *A* and *B* are commensurate with each other to the maximum extent, and when $|B| = 1$ and $A >> 1$, the commensurability of the sets is completely degenerate. That is, in the process of decreasing the number of elements in the set $B \subset A$ from $|B| = |A|$ to $|B| = 1$, the sets *A* and *B* gradually cease to correspond to each other in the number of their elements. Moreover, as long as $|B| \geq |B|^*$, proportionality remains between the sets, and when the inequality $|B| < |B|^*$ begins to hold, proportionality degenerates. Hence, it follows that the condition of the commensurability of two finite sets *A* and $B \subset A$ can be considered the inequality

$$|B|^* \leq |B| \leq |A|. \tag{6}$$

Let us determine the value $|B|^*$, for which equate to zero the result of differentiating the right side of equation (5) by $|B|$:

$$\ln|B| - \ln|A| + 1 = 0. \tag{7}$$

The solution of equation (7) gives that

$$|B|^* = \left\lceil \frac{|A|}{e} \right\rceil, \tag{8}$$

where $e = 2.71828..$ is the base of natural logarithms.

Substituting the value $|B|^*$ from (8) into (6), one can obtain the condition for the proportionality of finite sets in the following form:

$$\left\lceil \frac{|A|}{e} \right\rceil \leq |B| \leq |A|. \tag{9}$$

Inequality (9) was obtained on the basis of an information analysis of the reflection through each other of two intersecting finite sets A and $B \subset A$, but, obviously, this inequality can be adapted to analyze the proportionality of any other finite sets C and D so that $C \cap D = \varnothing$, $|C| \leq |D|$.

3 Syntropic criterion for removing restrictions

The condition of proportionality of finite sets (9) can be used to determine the start time of the abolition of restrictive measures in the COVID-19 pandemic. The object of analysis in this case is the set of new cases of the disease per day, and the methodology for determining the criterion for canceling restrictions is as follows.

First, each day for the entire time of the pandemic is matched with the average number of new diseases per day for a week

$$\overline{N}_t = \frac{N_t + N_{t-1} + \ldots + N_{t-6}}{7} \tag{10}$$

and the maximum value of $\overline{N}_t^{\max}$ is determined. After that, in accordance with the proportionality condition (9), the boundary value of the average number of diseases $\overline{N}^*$ is calculated, below which the number of diseases $\overline{N}_t$ is disproportionately less than $\overline{N}_t^{\max}$:

$$\overline{N}^* = \frac{\overline{N}_t^{\max}}{e} \approx 0.37\overline{N}_t^{\max}. \tag{11}$$

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As a criterion (S_t) for making a decision to remove restrictions, the relation

$$S_t = \frac{\overline{N}_t}{\overline{N}^*} \tag{12}$$

is taken. Moreover, if the inequality $S_t \geq 1$ is satisfied, then it is concluded that it is too early to remove the restrictions, and if there is an inequality $S_t < 1$, then a decision is made to start cancelling the restrictions. In the event that, after the restrictions are lifted, the second wave of the pandemic sets in and the inequality $S_t \geq 1$ starts to be satisfied again, then restrictions are introduced again.

The criterion S_t is obtained using the condition of the proportionality of finite sets (9), which, in turn, is the result of a joint analysis of the relative syntropies (3) and (4). Therefore, in order to distinguish the criterion S_t from other mathematical characteristics of the pandemic, it is reasonable to name it *the syntropic criterion for removing restrictions*. Let us now test this criterion using the example of the EU countries that are most affected by COVID-19, and compare the results with the actual dates when restrictions were lifted in these countries.

4 Analysis of the dates of the cancellation of restrictions in the EU countries

The lifting of restrictions in the EU countries with the highest number of people who died from COVID-19 (Italy, Spain, UK, France, Germany, and Belgium) began in late April – early May 2020. The actual dates of the beginning of this cancellation [7] are given in the **Table 1**, which also gives the values $\overline{N}_t^{\max}$ and $\overline{N}^*$, determined on the basis of daily statistics of the number of diseases [8], and shows the dates of lifting the restrictions established by the syntropic criterion S_t.

Table 1. The start date of lifting restrictions in the EU countries most affected by the COVID-19 pandemic and values $\overline{N}_t^{\max}$, $\overline{N}^*$.

Parameters	Countries					
	Belgium	**France**	**Italy**	**Germany**	**Spain**	**UK**
$\overline{N}_t^{\max}$	1,407	4,482	5,643	5,595	7,902	5,519
$\overline{N}^*$	518	1,649	2,076	2,059	2,907	2,031
The beginning of the lifting of restrictions by the syntropic criterion	May 2	April 24	May 2	April 26	April 24	June 3
The actual beginning of the lifting of restrictions	May 4	May 11	May 4	April 20	May 4	May 13

Analysis of the **Table 1** allows making the following observations. The discrepancy between the actual start dates for the cancellation of restrictions with the dates determined by the syntropic criterion (syntropic dates) varies from 2 days for Italy and Belgium to 21 days for the UK. The average value of this discrepancy across all countries is 9 days. At the same time, in Italy, Spain, Belgium, and France, the actual cancellation of restrictions began later than the syntropic date (as it should be), and in Germany and Great Britain, they began to cancel the restrictions earlier. A clear illustration of what has been said is **Figure 3**, which shows the dynamics of change in the values $\overline{N}_t$ for all countries, and markers indicate those values that correspond to the actual and syntropic dates of the beginning of the lifting of restrictions.

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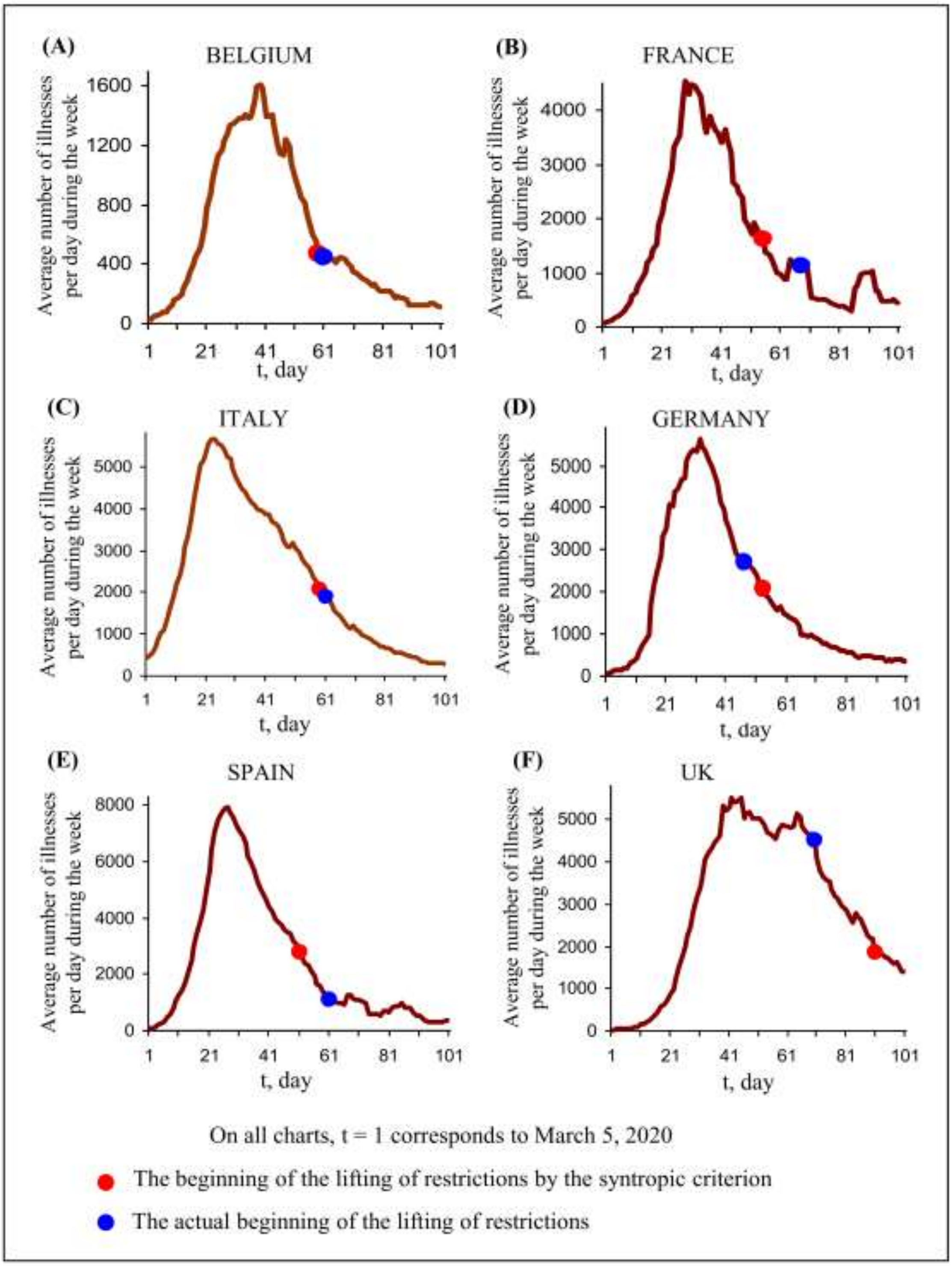

Figure 3. Dynamics of the average number of diseases per day during the week in the EU countries most affected by the COVID-19 pandemic: **(A)** Belgium; **(B)** France; **(C)** Italy; **(D)** Germany; **(E)** Spain; **(F)** UK.

It should also be noted that the actual beginning of the lifting of restrictions in the UK, which occurred on May 13, drew sharp criticism [7] as premature, which is consistent with a large advance of this day relative to the syntropic date (June 3). If for this reason, the UK is excluded from the calculations, the average discrepancy between actual and syntropic dates for all other countries will be 6.7 days. Such a small discrepancy in the dates of the start of the cancellation of restrictions on COVID-19 may indicate that decision-makers on the cancellation of restrictions intuitively feel the limit of the daily number of new cases of the disease below which this number becomes

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disproportionately lower than at the peak of the pandemic. Accordingly, in order to make decisions on the lifting of restrictions on COVID-19 more reasonable and objective, it is advisable to take into account the values of the syntropic criterion in the process of making these decisions (12).

5 Conclusion

Based on the synergetic theory of information, the article developed a syntropic criterion for starting the lifting of restrictions during the COVID-19 pandemic, according to which restrictions should be lifted when the average number of new diseases per day during the week becomes disproportionately less than at the peak of the pandemic. Testing this criterion by the example of a number of EU countries showed that the dates of lifting the restrictions determined with its help were in fairly good agreement with the actual dates that were previously established empirically. This allows recommending the syntropic criterion for widespread use when making decisions on the lifting of restrictive measures established to block the pandemic.

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