COVID, We Are in This Fight Together

David Wei, Imane Farhat, Pak Shing Ho, Shahbaz Mogal

Executive summary

COVID-19 has brought to the world as much division and mistrust as physical suffering and deaths. Countries have adopted the mindset to help themselves, while alienating working with countries claimed to be “epicenters” or those with policies different to their own. Within the same country itself, sections of the society have divided themselves into subgroups obeying rules that benefit them, while turning a blind eye to other rules at the expense of other subgroups of society. This study shows that moving away from COVID-19 will take a more **concerted effort from all countries and all subgroups within countries**, and this will be beneficial to all groups involved.

More specifically, we first explore **the effects countries have on each other**. The success of fighting COVID-19 in a specific country involves coordinating policies with neighboring countries. Moreover, we explore the effects different age groups within the same country have on each other, and **how reducing the impact on a specific age group will require other age groups adhering to policies that apply to them as well**. The following results support our conclusions:

- Countries that are **geographically close** to each other experience similar COVID-19 severity to COVID-19 waves in terms of correlation and lead-lag synchronicity (Fig. A).
- Responses of **different age groups** within a country are also closely related to each other.
- In most cases there are **time lags** in response between two sections, the time lags are very informative information on preventing the spread of the disease (Fig. B).
- The implication of our work includes:
    - Policy-makers should **take the relationship of different sections into account**. For example, how reopening its border affects the neighboring countries or how reopening schools affects the health well-being of the elders.
    - Countries should **work together when implementing a policy** in order to achieve the best effects.

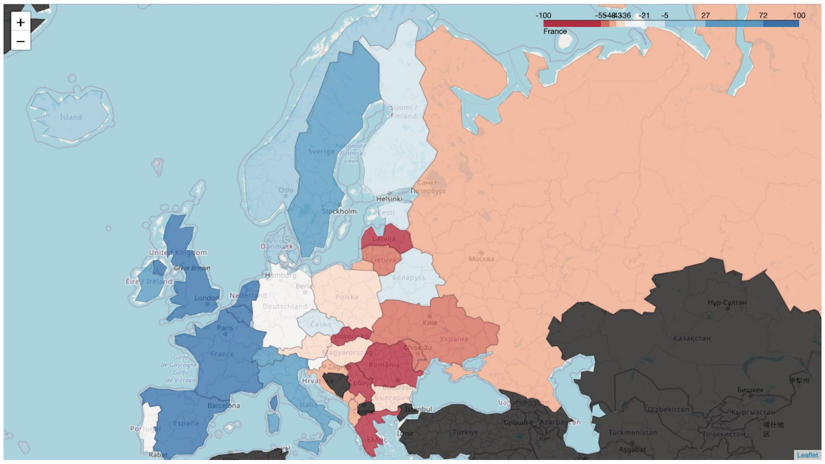


Figure A: **Correlation with France** in terms of new deaths per day. Neighboring countries of France show positive correlation (blue), distant countries in Eastern Europe show negative correlation (red) with France

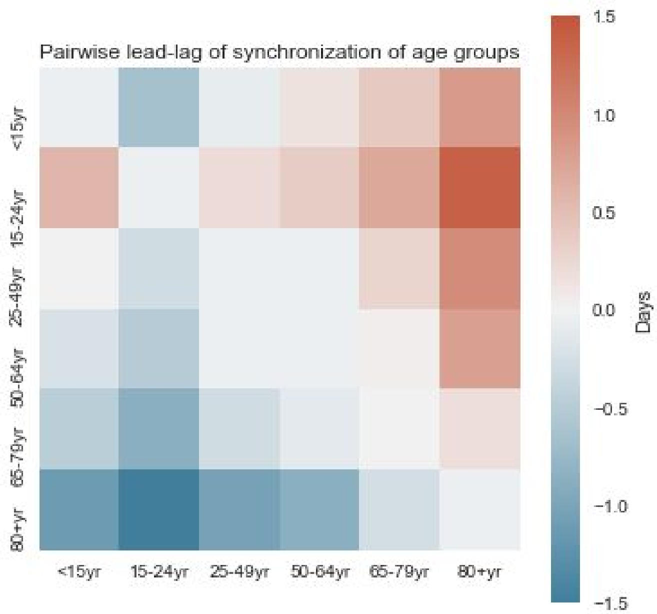


Figure B: Lead-lag of synchronization between weekly new cases of age groups. Roughly speaking, younger groups lead older groups by a week or so.

1. Introduction

Coronavirus disease 2019 (COVID-19) is a contagious respiratory disease. It was first discovered in Wuhan, China in December 2019 and quickly spread across the whole world in the next few months (Page et al., 2021). About 20% of patients experienced severe to critical conditions (Centers for Disease Control and Prevention, CDC, 2020). According to WHO (World Health Organization), COVID-19 has caused 116 million cases and 2.59 million deaths worldwide as of March 2021.

One of the biggest challenges in containing the spread of COVID-19 is from the division and mistrust of the public on government regulations and scientific guidance. For instance, A CDC survey shows that young adults are less likely to wear masks and take other measures against COVID-19, possibly because they are “less likely to suffer the severe illness from COVID-19” (Hutchins et al., 2020). For another example, former President Donald Trump argued for premature school reopening because “not that many of you (students) are going to die”. Such misinformed and misleading opinions have greatly facilitated the spread and damages of COVID-19 in many states and countries. A recent example would be that the Texan governor Greg Abbott is “reopening businesses at 100% capacity” despite the suggestions from health officials and the latest weekly average of 200 deaths per day in Texas.

The purpose of this study is threefold. First, we want to know how closely different sections of a society are connected together and influence each other in response to COVID-19. If all the sections show strong connection to one another, it is necessary for the entire society to put away the self-preservation instinct and join forces in fighting COVID-19. Second, we are also interested in the short term prediction of the outbreak of COVID-19. If we can statistically identify the speed and nature of the spread from one group to another, policy-makers can accordingly make responses in time. Lastly, it is also necessary to quantify the effectiveness of a policy in order to avoid unnecessary negative impact to people’s daily lives and the economy.

Our work shows strong connections between the responses of different sections of the society, namely, the connection between neighboring countries and the connection between different age groups of a nation. We also identify and quantify the transmission processes of COVID-19 with composite analyses and cross-correlation analysis. The results show the propagation of the COVID-19 cases from younger age groups to senior age groups on the time scale of a week, and from one country to another on the time scale from a week to two months, depending on the geographical distance. Lastly, we propose and validate a measure which quantifies the average effect of a policy. The rest of the report is arranged as follows. Section 2 introduces the data and methodology of this study. Section 3 analyzes and discusses the results. Finally, section 4 summarizes the conclusions and discusses their implications.

2. Data and Methods

The datasets used in this study are provided by the organizers. It was compiled from three sources, "Our World in Data", the "European Centre for Disease Prevention and Control" (ECDC) and the "Covid Tracking Project". Since our study focuses on the relationship in responses between different sections of a society, we mainly use the ECDC data to study the interaction between countries and the age-group data from ECDC to study the interaction between age groups.

Three main mathematical models are used in this study. First, we use composite analyses to quantify the average effect of a policy. Specifically, for a certain policy such as closing daycare centers, we collect all related statistics of such instances as well as their history ranging from five weeks before the implementation of the policy and five weeks after that. Then we make pointwise averages of the collection of these time series to obtain the composite mean, which is assumed to have averaged out the effects of all confounding variables.

Second, to quantify the effect of a policy, we devise a measure that calculates the second derivative of new COVID-19 case, which writes

$$\frac{new\_cases(-5\ weeks) + new\_cases(+5\ weeks) - 2 \times new\_cases(now)}{(10\ weeks)^2}.$$

We examine all 60 policies with this measure and find 6 policies that are effective statistically.

Lastly, we also build a simple pipeline to investigate the contemporaneous correlation and lead-lag synchronicity of COVID-19 severity between age groups and between European countries[1]. The contemporaneous correlation is measured as Spearman's rank correlation of two series between countries after removing the corresponding average trend across all age groups/European countries. Without removing the cross-section time trend nor using a ranked correlation, the correlation could yield a result dominated by the large values from the two peaks and possible outliers. To put it in mathematical terms,

- Variable at day t: x_{it}.
- Removing aggregate average time trend (cross-section de-mean): $y_{it} = x_{it} - \sum_i x_{it}$. In other words, we would like to distill the country-specific component by removing the Europe-specific component from the original series.
- Spearman's rank correlation: $r_{ij} = 1 - 6\sum_t \frac{rank(y_{it}) - rank(y_{jt})}{n(n^2-1)}$

The lead-lag synchronicity is measured as the number of leads or lags yielding the highest Pearson's correlation of two series between countries. Specifically,

- $offset\ days = argmax_\tau r_{ij\tau}$, *where* $r_{ij\tau} = \frac{cov(x_{it}, x_{jt-\tau})}{std(x_{it}) * std(x_{jt-\tau})}$, *for* $\tau \in [-60,\ 60]$.

3. Analyses and Results

3.1. Variations on a global scale: Geographical Correlation of COVID-19 Impact

We study the correlation between the impact a country has on the countries that surround it. Our results match our hypothesis that countries close-by each other have a positive correlation in terms of COVID-19's effect on the countries, while countries far away have insignificant/negative correlation. As explained in our method section, we have distilled the country-specific component by removing the Europe-specific component from the original series, so that the correlation would not yield a result dominated by the large values from the two wave peaks and possible outliers. This possibly explains why distant countries are negatively correlated.

[1] Contemporaneous correlation and lead-lag synchronicity results of different series can be generated from our codes submitted.

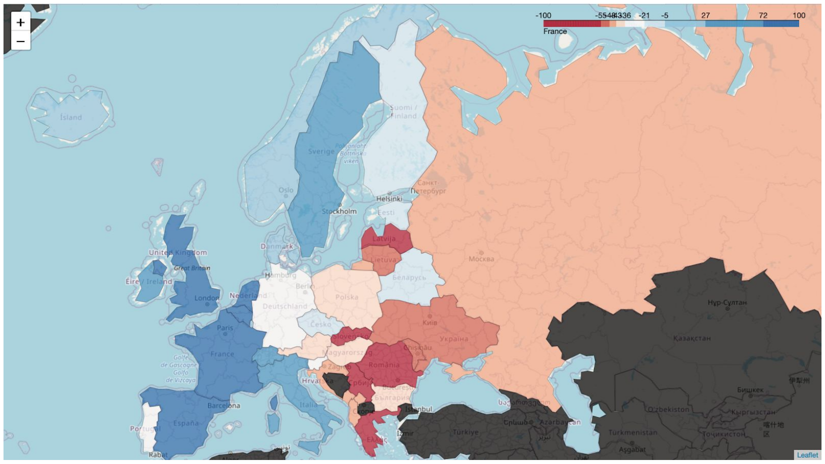


Figure above: **Correlation with France** in terms of new deaths per day. Neighboring countries of France show positive correlation (blue), distant countries in Eastern Europe show negative correlation (red) with France

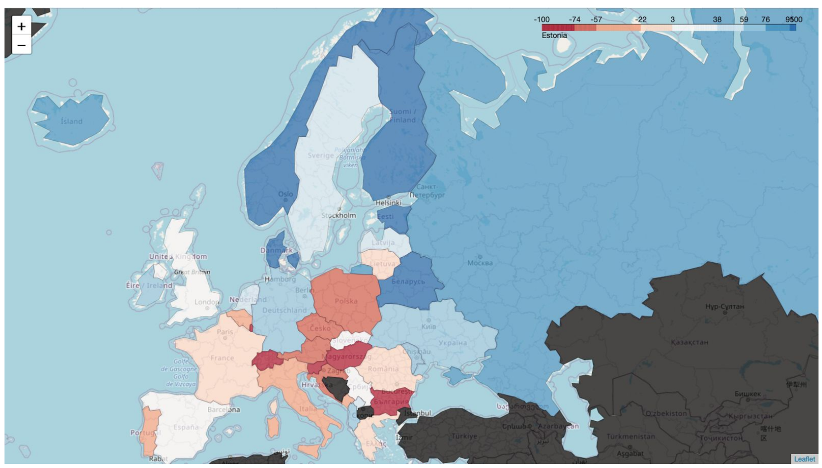
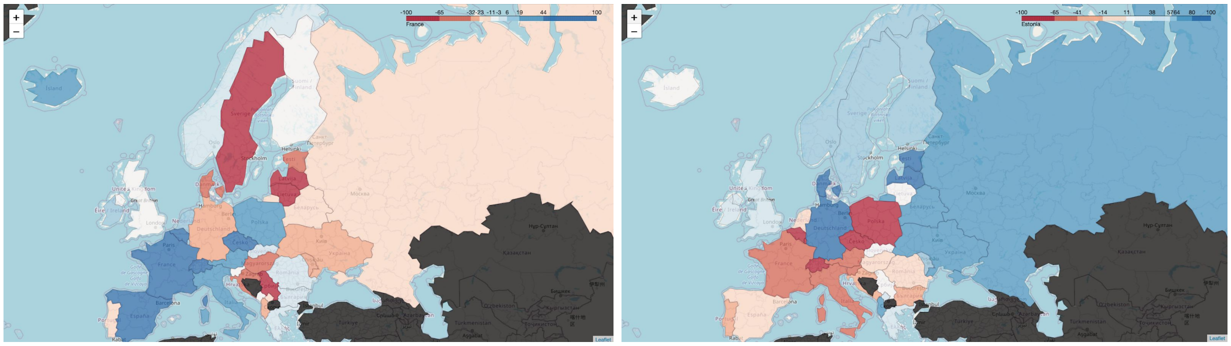


Figure above: **Correlation with Estonia** in terms of new deaths per day. Neighboring countries of Estonia show positive correlation (blue), distant countries in Western Europe show negative correlation (red) with Estonia

We computed the pairwise correlation of the new deaths per day due to COVID-19 between countries across Europe. Two examples are presented above. We find that neighboring countries have synchronized COVID-19 impacts, despite varying policies and cultures. There are a few outliers, the most significant being Germany outperforming its neighbors. This is not surprising in that Germany did a much better job containing COVID-19.

We also find synchronization of COVID-19 death rates between clusters of countries as business-friendly blocks within Europe (Western Europe/Scandinavia/Eastern Europe) and those within travelling distance of each other. This supports our hypothesis that in order to control the impact of COVID-19, countries also need to cooperate with their neighboring countries and coordinate their policies with each other.



Figures above: **Correlations with France (left) and Estonia (right)** in terms of the spread of new cases per day show synchronization between the corresponding neighboring countries.

We see that the spread of new COVID-19 cases per 100k between countries is also synchronized between neighbors. Estonia, for example, shows positive (blue) correlations with its neighbors (Latvia, Russia, Scandinavia) and negative (red) correlations with distant countries (France, Italy, Austria). This further supports our argument that simply focusing on a country's own policy is not doing enough to fight COVID-19. Countries should actively work with their neighbors in containing COVID-19 case spread, which directly leads to deaths, as examined before. Synchronization of the effect of COVID-19 also creates an opportunity for countries to learn from their neighbors' mistakes and improve their future policies.

3.2. Variations on a global scale: Prepare Early, Brace for the Impact

We have shown that neighboring countries exhibit a significant correlation between COVID-19 waves. To further our study into how countries can use this information to dampen the impact of COVID-19, we investigate how COVID-19 spreads across neighboring countries. Our most important finding in this was that there is a time lag between countries getting hit by COVID-19, and this time lag is related to the geographical distance.

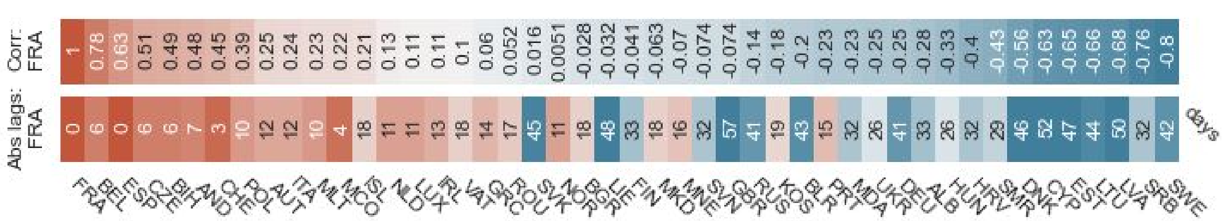


Figure above: **Correlation** and **Lead-Lag Synchronization** of Countries with France – Positive Correlation and Lower Absolute Lead-Lag Days for Neighboring Countries, Negative Correlation and Higher Absolute Lead-Lag Days for Distant Countries

As shown in the figure above, countries neighboring France (Belgium, Spain) have both more positive correlation to France, and higher degree of synchronization (0-7 days). Countries distant to France (Serbia, Sweden) have negative correlation and lower degree of synchronization (30-50 days). This is an important result as it indicates that COVID-19 slowly yet certainly traverses countries at the expected time, despite variation in policies and strategies. Fighting COVID-19 is not effective through the power of just one country for its own population without any time-sensitive coordination[2] across countries.

The relationship between the geographical distances and the synchronization of COVID-19 impact implies that countries can anticipate and prepare for the waves of COVID-19 approaching from their neighboring countries. Having an estimate of the timing of the COVID-19 propagation not only provides valuable preparation time but also provides insights on the international coordinations.

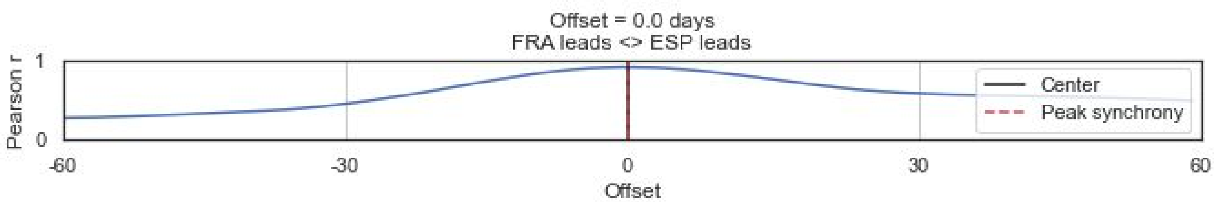


Figure above: New cases per million highly correlated and synchronized between Spain & France

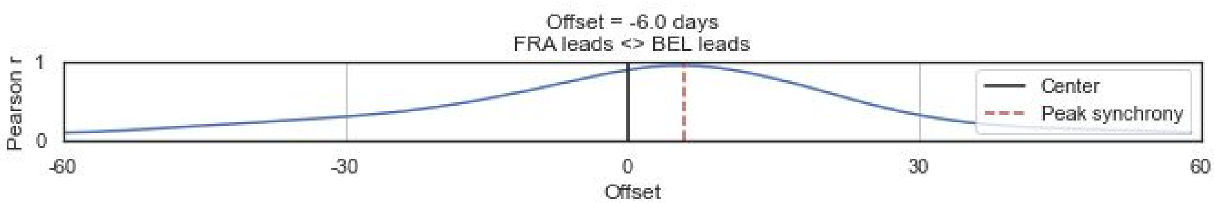


Figure above: Belgium leads France by 6 days in new cases per million

[2] In theory, an extreme example of perfect coordination would be quarantine at home for anybody on the planet for a period of time starting at the same time.

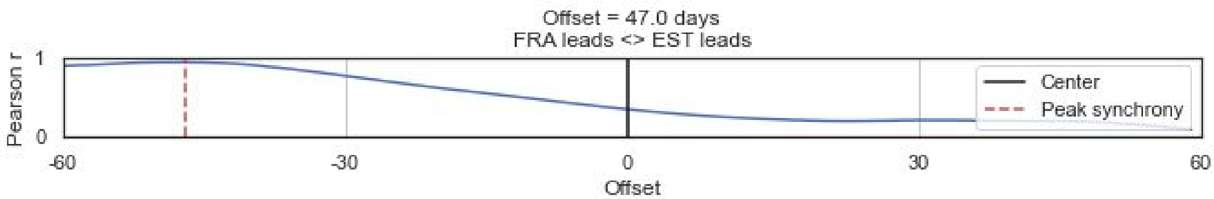


Figure above: France leads Estonia by more than a month in new cases per million

The figures above provide a more intuitive demonstration of the lead-lag of synchronization between countries. France and Spain, which border each other, are almost perfectly synchronized in their numbers of new COVID-19 cases. France lags Belgium by 6 days. Note that this is not due to a global simultaneous outbreak, as Estonia lags France by 47 days. Instead, this is likely due to the virus propagation via travel across neighboring borders. Preparing early for this expected propagation, bracing for the impact by building up hospital capabilities and implementing effective policies in advance would help reduce deaths, and slow down the propagation of the virus.

3.3. Variations within a Country: COVID-19 Impact on Sub-groups Requires Policies from a Holistic Perspective

Next, we investigate how countries not only need to coordinate on a global scale, but also domestically. To analyze the domestic transmission of COVID-19, we divide the population of a country into subgroups based on their age. We pick age as our choice of study because most countries choose age as the main aspect to design age-differentiating policies. Examples include lifting bans on daycare when new cases in children are low. Our results show that age-differentiating policies have a broader impact through transmission between sub-groups and should be evaluated from a holistic perspective.

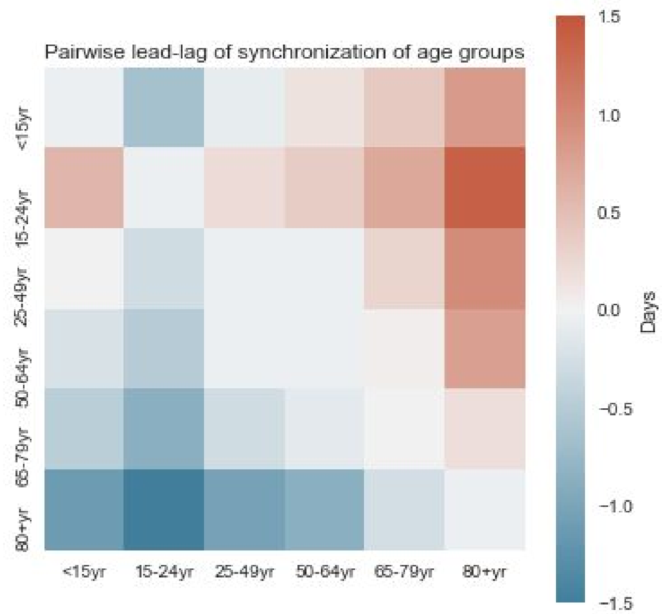


Figure above: Lead-lag of synchronization between weekly new cases of age groups. Roughly speaking, younger groups lead older groups by a week or so.

The figure above shows the pairwise lead-lag of synchronization between weekly new cases of age groups. In general, the upper right corner has positive values and the lower left corner has negative values, which indicates that younger groups tend to lead older groups by a week or so. The bigger the age difference between two groups, the longer is the lag. This consistent pattern of the lead-lag of synchronization likely implies an underlying causal relationship between the age groups -- an asymmetric transmission of COVID-19 cases from younger to older generations.

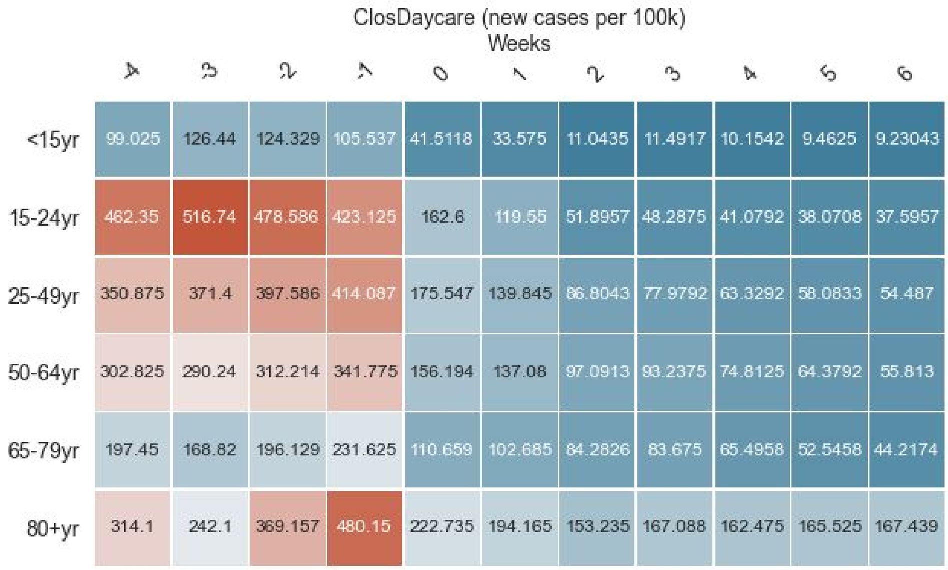


Figure above: Composite mean of new cases per 100k across age groups when closing daycare centers at week 0. There is a uniform drop of new cases in week 0.

To further validate the broader impact of a policy, we perform the composite analysis on age-differentiating policies. The figure above shows a 10-week time series of new cases per 100k averaged across all instances of closing daycare centers in Europe. Even though closing daycare centers is only targeting younger age groups, the figure shows a uniform drop in new cases across all age groups at around week 0. This is likely due to the prevention of the one-way transmission from younger to older generations. Even an age-specific policy could effectively influence all sub-groups. Therefore, a policy-maker should avoid isolating the impact of a policy and evaluate a policy from a holistic perspective.

3.4. Quantifying the effect of a policy

In this section, we propose a measure to estimate the effect of a policy on the time scale of two and a half months, and validate all 60 policies with data. The measure is a classic three-point finite difference scheme of the second derivative of the new cases as follows,

$$\frac{new\_cases(-5\ weeks) + new\_cases(+5\ weeks) - 2 \times new\_cases(now)}{(10\ weeks)^2}.$$

The physical meaning of this measure is the increase of increase in new cases. If the new cases increase linearly with time, the measure gives 0. If the new cases increase slower and slower with time, the measure would be negative. We apply this measure to all 60 policies from the dataset stored in “2_ecdc/country_response_measures”, and find 6 statistically effective policies, namely, “ClosDaycare”, “EntertainmentVenues”, “ClosSec”, “ClosHigh”, “BanOnAllEvents” and “GymsSportsCentres”. An example for “EntertainmentVenues” is shown below.

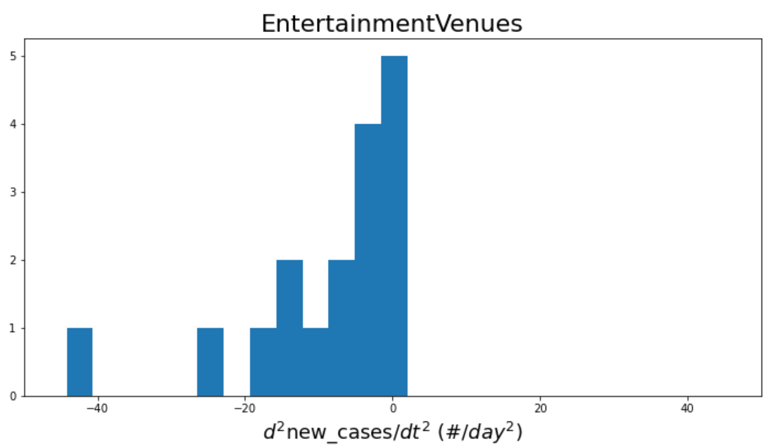


Figure above: histogram of the effect of shutting down entertainment venues. All cases show a negative second derivative (decrease in increase) of the new cases over the course of 10 weeks.

The figure above shows the histogram of the effect of shutting down all entertainment venues. There are a total of 16 cases of such policy and all of them decrease the increase of new cases per 100k. The result suggests an effective and consistent impact of shutting down all entertainment venues, and proves the reliability of measuring the effect of a policy with the finite-difference second derivatives.

4. Conclusions and Discussions

We have studied the interactions between the impact of COVID-19 on different sections, namely, countries and age groups. With the datasets provided by the organizer, and a mathematical framework involving composite analyses and cross correlation, we identified the propagation of COVID-19 waves from one country to another, and from younger to older generations. We found that the transmission between age groups within a country takes about a week, while the transmission from one country to another takes from one week to two months, depending on the geographical distance. The further two age groups are apart, the longer the geographical distance, the longer it takes for the propagation of COVID-19 waves. The result suggests that an effective policy needs to take a holistic perspective for both consideration of coordination between countries and between domestic sub-groups. In addition, we proposed to use a second-order derivative of the finite difference scheme to quantify the effect of a policy. We validated this measure with the data and identified 6 effective policies.

The conclusions suggest that nobody is alone in the battle with COVID-19 --- we are all in this fight together! The safeness of a section is highly dependent on the other sections. As a result, the society needs to put away the pure self-preservation instinct and join forces in the fight. The enemies of our public enemy (virus) are indeed our friends! The policy-makers should not make isolated decisions based on a specific fraction of the society. The conclusions have many implications to the nowadays world. For example, reopening schools is not necessarily a good idea during the pandemic, considering the likelihood of the transmission from children to elders. Banning exports of medical supplies to neighboring countries risks suffering backfires in the long term.

5. Appendix

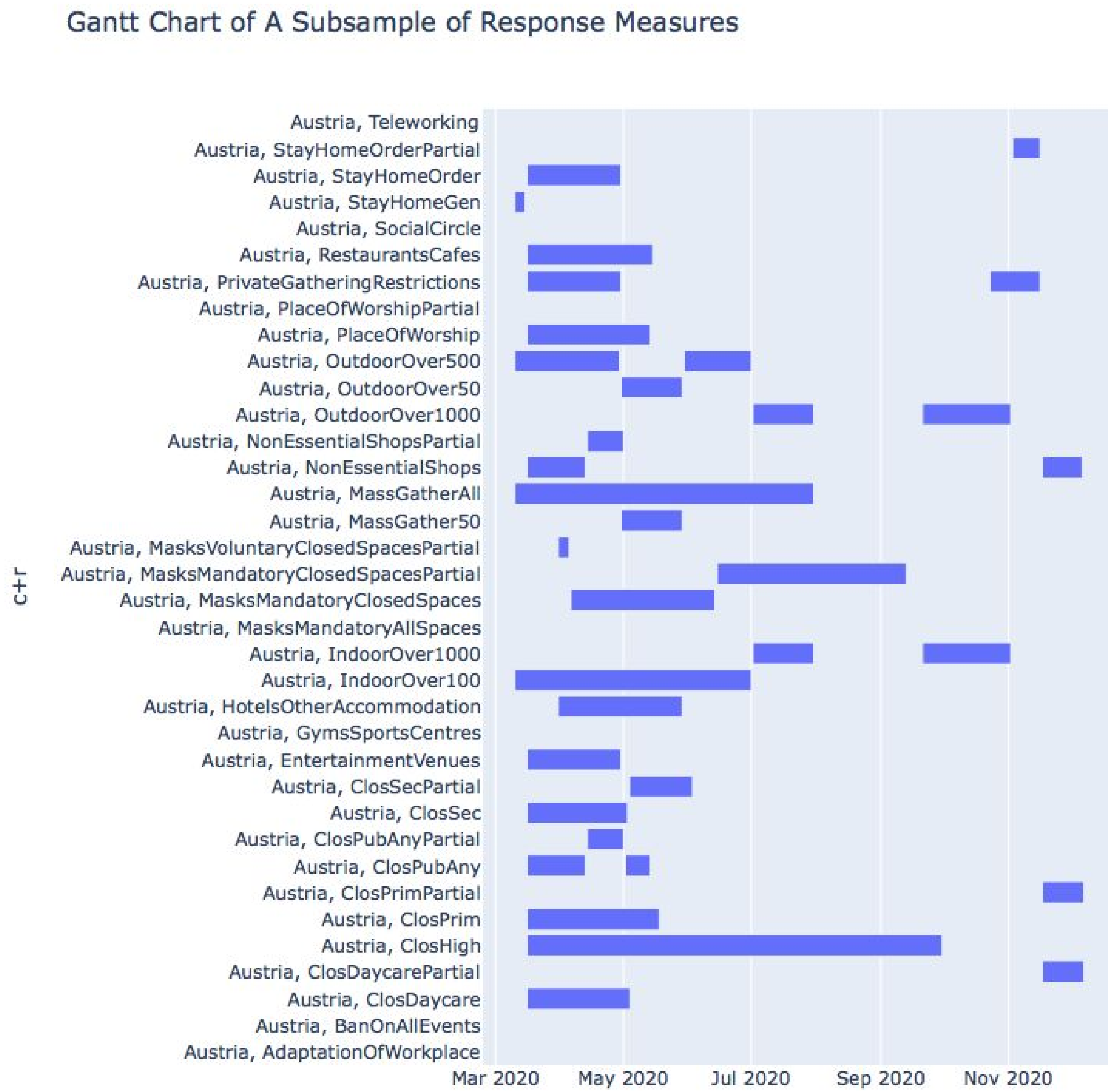


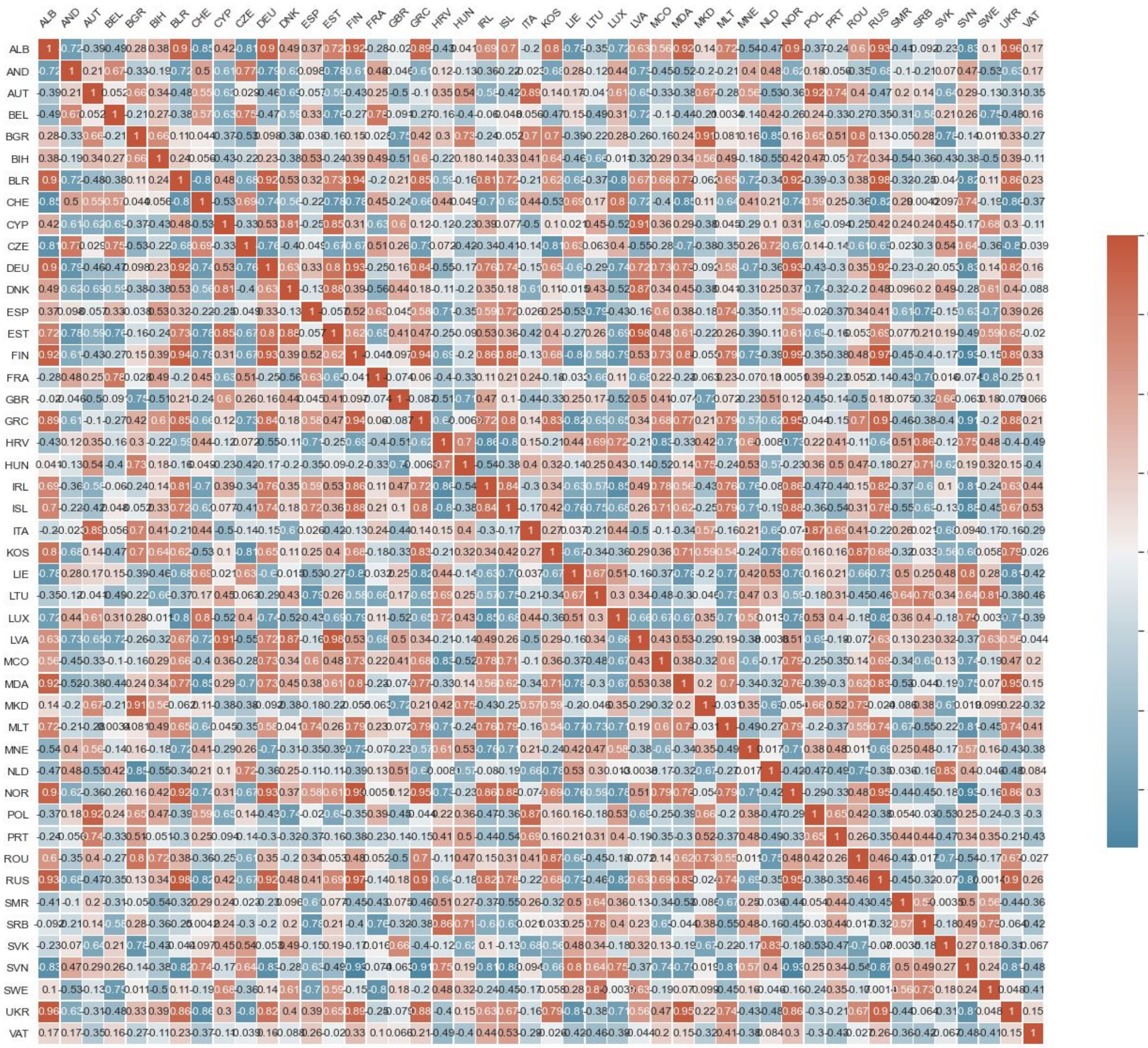
Figure above: Gantt chart of a subsample of the European response measures.

Corr: FRA		Abs lags: FRA	AUT		AUT	EST		EST	POL		POL	CZE		CZE	HUN		HUN
1	FRA	0	1	AUT	0	1	EST	0	1	POL	0	1	CZE	0	1	HUN	0
0.78	BEL	6	0.92	POL	2	0.98	LVA	0	0.92	AUT	2	0.77	AND	5	0.75	MKD	3
0.63	ESP	0	0.89	ITA	1	0.88	DNK	2	0.87	ITA	1	0.75	BEL	2	0.73	BGR	4
0.51	CZE	6	0.74	PRT	3	0.85	CYP	23	0.66	MKD	5	0.72	NLD	4	0.71	SRB	10
0.49	BIH	6	0.67	MKD	3	0.8	DEU	17	0.65	BGR	5	0.69	CHE	8	0.7	HRV	3
0.48	AND	7	0.66	BGR	3	0.73	BLR	0	0.65	PRT	5	0.64	SVN	8	0.54	AUT	8
0.45	CHE	3	0.61	LUX	3	0.72	ALB	17	0.59	CHE	5	0.63	LIE	6	0.53	MNE	2
0.39	POL	10	0.56	MNE	4	0.69	RUS	19	0.53	LUX	2	0.54	SVK	0	0.5	PRT	5
0.25	AUT	12	0.55	CHE	8	0.65	UKR	29	0.47	BIH	3	0.51	FRA	6	0.47	ROU	4
0.24	ITA	12	0.54	HUN	8	0.62	FIN	17	0.42	ROU	3	0.4	LUX	14	0.43	LUX	4
0.23	MLT	10	0.4	ROU	2	0.61	MDA	20	0.39	FRA	10	0.26	MNE	19	0.4	ITA	8
0.22	MCO	4	0.35	HRV	15	0.61	NOR	31	0.38	MNE	6	0.26	GBR	3	0.36	POL	10
0.21	ISL	18	0.34	BIH	6	0.59	SWE	11	0.36	HUN	10	0.14	POL	16	0.32	KOS	1
0.13	NLD	11	0.29	SVN	7	0.53	IRL	59	0.25	SVN	4	0.072	HRV	34	0.32	SWE	15
0.11	LUX	11	0.25	FRA	12	0.48	MCO	45	0.24	BEL	15	0.063	LTU	48	0.27	SMR	15
0.11	IRL	13	0.21	AND	22	0.47	GRC	31	0.22	HRV	17	0.029	AUT	17	0.25	LTU	18
0.1	VAT	18	0.2	SMR	16	0.41	GBR	43	0.18	AND	20	-0.023	SMR	37	0.19	SVN	8
0.06	GRC	14	0.17	LIE	12	0.4	KOS	23	0.16	LIE	11	-0.039	VAT	12	0.18	BIH	9
0.052	ROU	17	0.14	SRB	19	0.36	ISL	60	0.16	KOS	11	-0.049	ESP	5	0.15	UKR	3
0.016	SVK	45	0.14	KOS	6	0.26	MLT	45	0.14	CZE	16	-0.14	PRT	19	0.14	MDA	7
0.0051	NOR	11	0.052	BEL	17	0.26	LTU	8	0.054	SMR	19	-0.14	ITA	17	0.049	CHE	12
-0.028	BGR	18	0.029	CZE	17	0.21	SRB	14	-0.02	ESP	11	-0.22	BIH	13	0.041	ALB	8
-0.032	LIE	48	-0.041	LTU	30	0.19	SVK	47	-0.03	SRB	21	-0.28	MCO	7	-0.0063	GRC	5
-0.041	FIN	33	-0.057	ESP	12	0.077	SMR	11	-0.044	GRC	4	-0.3	SRB	36	-0.09	EST	23
-0.063	MKD	18	-0.1	GRC	2	0.053	ROU	34	-0.18	LTU	31	-0.33	CYP	54	-0.13	AND	29
-0.07	MNE	16	-0.13	SWE	26	-0.02	VAT	60	-0.2	MLT	8	-0.34	IRL	6	-0.14	LIE	18
-0.074	SVN	32	-0.28	MLT	10	-0.057	ESP	50	-0.24	SWE	24	-0.35	MLT	8	-0.14	LVA	23
-0.074	GBR	57	-0.31	UKR	12	-0.09	HUN	23	-0.25	MCO	6	-0.36	SWE	43	-0.16	BLR	21
-0.14	RUS	41	-0.33	MCO	7	-0.11	NLD	54	-0.29	NOR	3	-0.38	MKD	21	-0.17	DEU	10
-0.18	KOS	19	-0.35	VAT	29	-0.16	BGR	29	-0.3	UKR	13	-0.4	DNK	52	-0.18	RUS	16
-0.2	BLR	43	-0.36	NOR	1	-0.16	PRT	32	-0.3	VAT	26	-0.41	ISL	13	-0.2	DNK	37
-0.23	PRT	15	-0.38	MDA	18	-0.22	MKD	30	-0.35	FIN	21	-0.42	HUN	26	-0.2	FIN	10
-0.23	MDA	32	-0.39	ALB	17	-0.24	BIH	38	-0.36	ISL	28	-0.53	BGR	20	-0.23	NOR	8
-0.25	UKR	26	-0.42	ISL	31	-0.25	HRV	21	-0.37	ALB	19	-0.55	LVA	52	-0.23	CYP	32
-0.25	DEU	41	-0.43	FIN	19	-0.27	LIE	37	-0.38	RUS	25	-0.61	ROU	19	-0.24	MLT	16
-0.28	ALB	33	-0.46	DEU	14	-0.39	MNE	33	-0.39	BLR	31	-0.67	NOR	16	-0.33	FRA	25
-0.33	HUN	26	-0.47	RUS	25	-0.42	ITA	32	-0.39	MDA	20	-0.67	RUS	41	-0.35	ESP	26
-0.4	HRV	32	-0.48	BLR	30	-0.49	SVN	33	-0.43	DEU	11	-0.67	EST	52	-0.38	ISL	40
-0.43	SMR	29	-0.5	GBR	16	-0.59	AUT	34	-0.45	GBR	15	-0.67	FIN	37	-0.4	VAT	47
-0.56	DNK	46	-0.53	NLD	22	-0.65	FRA	47	-0.47	NLD	20	-0.68	BLR	46	-0.4	BEL	31
-0.63	CYP	52	-0.58	IRL	25	-0.65	POL	35	-0.47	IRL	23	-0.7	MDA	35	-0.42	CZE	26
-0.65	EST	47	-0.59	EST	34	-0.67	CZE	52	-0.53	SVK	16	-0.73	GRC	19	-0.52	MCO	23
-0.66	LTU	44	-0.62	CYP	35	-0.69	LUX	30	-0.65	CYP	38	-0.76	DEU	43	-0.54	IRL	36
-0.68	LVA	50	-0.64	SVK	18	-0.76	BEL	53	-0.65	EST	35	-0.8	UKR	29	-0.57	NLD	29
-0.76	SRB	32	-0.65	LVA	34	-0.78	CHE	40	-0.69	LVA	36	-0.81	ALB	35	-0.62	SVK	26
-0.8	SWE	42	-0.69	DNK	35	-0.78	AND	55	-0.74	DNK	37	-0.81	KOS	24	-0.71	GBR	21

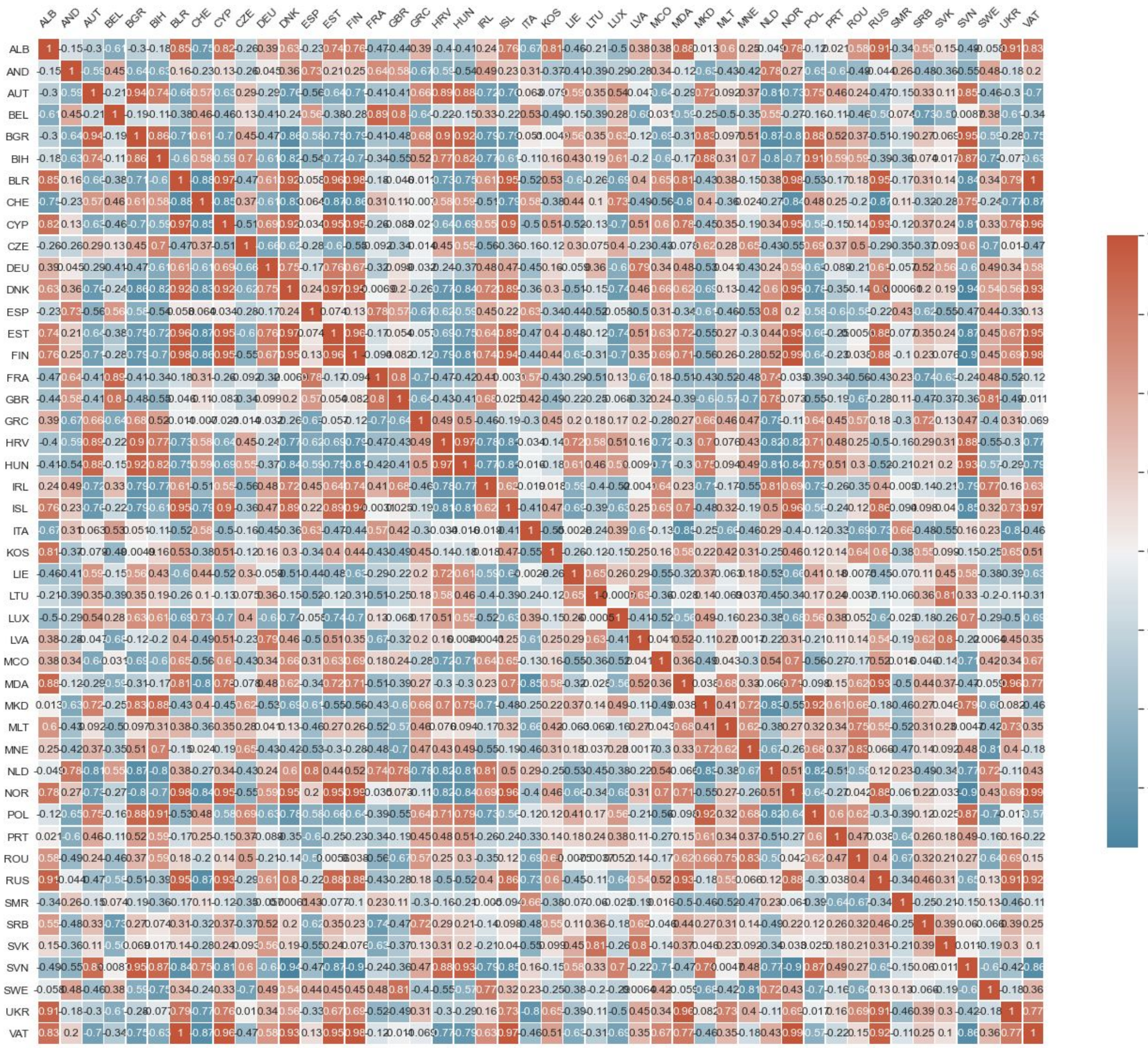
New cases per million highly correlated and synchronized with neighboring countries

Corr: FRA		Offset: FRA	AUT		AUT	EST		EST	POL		POL	CZE		CZE	HUN		HUN
1	FRA	0	1	AUT	0	1	EST	0	1	POL	0	1	CZE	0	1	HUN	0
0.89	BEL	3	0.94	BGR	2	0.97	DNK	1	0.92	MKD	2	0.7	BIH	13	0.97	HRV	4
0.8	GBR	6	0.89	HRV	3	0.96	FIN	16	0.91	BIH	0	0.69	POL	18	0.93	SVN	4
0.78	ESP	6	0.88	HUN	1	0.96	BLR	7	0.88	BGR	7	0.65	MNE	10	0.92	BGR	3
0.74	NLD	1	0.85	SVN	7	0.95	NOR	2	0.87	SVN	4	0.62	MKD	18	0.88	AUT	1
0.64	AND	6	0.75	POL	8	0.95	CYP	14	0.79	HUN	10	0.6	SVN	22	0.82	BIH	10
0.57	ITA	6	0.74	BIH	9	0.95	VAT	60	0.75	AUT	8	0.55	HUN	29	0.79	POL	10
0.48	SWE	9	0.72	MKD	8	0.89	ISL	50	0.71	HRV	14	0.5	ROU	15	0.75	MKD	9
0.41	IRL	13	0.66	GRC	0	0.88	RUS	5	0.69	CZE	18	0.45	BGR	24	0.61	LIE	19
0.31	CHE	0	0.59	LIE	8	0.76	DEU	2	0.68	MNE	6	0.45	HRV	32	0.59	CHE	0
0.23	SMR	16	0.57	CHE	3	0.74	ALB	27	0.64	GRC	8	0.4	LUX	17	0.55	CZE	29
0.18	MCO	8	0.54	LUX	6	0.72	MDA	60	0.62	ROU	2	0.37	PRT	18	0.55	LUX	4
0.13	LUX	2	0.46	PRT	4	0.67	UKR	60	0.6	PRT	7	0.37	CHE	18	0.51	PRT	2
-0.0031	ISL	8	0.37	MNE	33	0.64	IRL	18	0.56	LUX	1	0.3	LIE	50	0.5	GRC	3
-0.0069	DNK	5	0.35	LTU	14	0.63	MCO	8	0.48	CHE	3	0.29	AUT	25	0.49	MNE	20
-0.035	NOR	2	0.33	SRB	6	0.51	LVA	34	0.41	LIE	32	0.28	MLT	15	0.46	LTU	30
-0.092	CZE	9	0.29	CZE	25	0.45	SWE	13	0.32	MLT	4	0.13	BEL	5	0.3	ROU	13
-0.094	FIN	16	0.24	ROU	12	0.44	NLD	0	0.17	LTU	40	0.093	SVK	49	0.21	SRB	5
-0.12	VAT	60	0.11	SVK	19	0.4	KOS	23	0.12	KOS	4	0.075	LTU	49	0.2	SVK	16
-0.17	EST	11	0.092	MLT	18	0.35	SRB	3	0.12	SRB	15	0.01	UKR	12	0.094	MLT	5
-0.18	BLR	35	0.063	ITA	4	0.27	MLT	31	0.025	SVK	40	-0.014	GRC	25	0.0094	LVA	26
-0.24	SVN	6	-0.047	LVA	11	0.24	SVK	38	-0.017	UKR	0	-0.078	MDA	33	-0.016	ITA	35
-0.26	CYP	24	-0.079	KOS	9	0.21	AND	60	-0.098	MDA	10	-0.092	FRA	9	-0.15	BEL	16
-0.29	LIE	10	-0.15	SMR	41	0.074	ESP	11	-0.12	ITA	4	-0.12	KOS	23	-0.18	KOS	9
-0.32	DEU	11	-0.21	BEL	11	0.054	GBR	5	-0.12	ALB	5	-0.16	ITA	31	-0.21	SMR	45
-0.34	PRT	5	-0.29	DEU	16	0.0056	ROU	50	-0.16	BEL	10	-0.23	LVA	47	-0.29	UKR	10
-0.34	BIH	60	-0.29	MDA	48	-0.057	GRC	18	-0.21	LVA	33	-0.26	AND	12	-0.3	MDA	2
-0.39	POL	6	-0.3	ALB	4	-0.077	SMR	13	-0.3	RUS	11	-0.26	ALB	24	-0.37	DEU	16
-0.41	BGR	13	-0.3	UKR	27	-0.12	LTU	9	-0.39	FRA	5	-0.28	ESP	2	-0.41	ALB	6
-0.41	AUT	7	-0.41	FRA	7	-0.17	FRA	11	-0.39	SMR	45	-0.29	RUS	30	-0.41	GBR	59
-0.42	HUN	13	-0.41	GBR	5	-0.25	PRT	14	-0.53	BLR	32	-0.34	GBR	60	-0.42	FRA	11
-0.43	KOS	10	-0.46	SWE	16	-0.3	MNE	60	-0.55	GBR	60	-0.35	SMR	48	-0.52	RUS	3
-0.43	RUS	24	-0.47	RUS	3	-0.38	BEL	8	-0.56	MCO	7	-0.36	ISL	1	-0.54	AND	52
-0.43	MKD	7	-0.56	ESP	11	-0.47	ITA	13	-0.56	ISL	18	-0.37	SRB	31	-0.57	SWE	60
-0.47	ALB	60	-0.59	AND	54	-0.48	LIE	2	-0.57	VAT	60	-0.43	MCO	10	-0.59	ESP	19
-0.47	HRV	15	-0.63	CYP	18	-0.55	MKD	35	-0.58	CYP	29	-0.43	NLD	60	-0.69	CYP	35
-0.48	MNE	52	-0.64	MCO	11	-0.6	CZE	48	-0.58	ESP	15	-0.47	BLR	40	-0.71	MCO	17
-0.51	LTU	32	-0.64	EST	12	-0.64	AUT	12	-0.63	DEU	27	-0.47	VAT	60	-0.75	EST	43
-0.51	MDA	59	-0.66	BLR	34	-0.66	POL	33	-0.64	NOR	49	-0.51	CYP	43	-0.75	BLR	36
-0.52	MLT	56	-0.7	VAT	60	-0.69	HRV	21	-0.64	FIN	60	-0.55	NOR	52	-0.77	IRL	60
-0.52	UKR	60	-0.71	FIN	21	-0.72	BIH	41	-0.65	AND	32	-0.55	FIN	55	-0.79	VAT	60
-0.56	ROU	60	-0.72	IRL	16	-0.74	LUX	15	-0.66	EST	33	-0.56	IRL	60	-0.81	ISL	29
-0.63	SVK	11	-0.73	NOR	6	-0.75	BGR	27	-0.7	SWE	60	-0.6	EST	48	-0.81	FIN	60
-0.67	LVA	32	-0.76	DNK	42	-0.75	HUN	43	-0.73	IRL	60	-0.62	DNK	60	-0.81	NLD	54
-0.7	GRC	60	-0.76	ISL	21	-0.87	SVN	30	-0.78	DNK	60	-0.66	DEU	46	-0.84	DNK	54
-0.74	SRB	18	-0.81	NLD	0	-0.87	CHE	12	-0.82	NLD	60	-0.7	SWE	60	-0.84	NOR	51

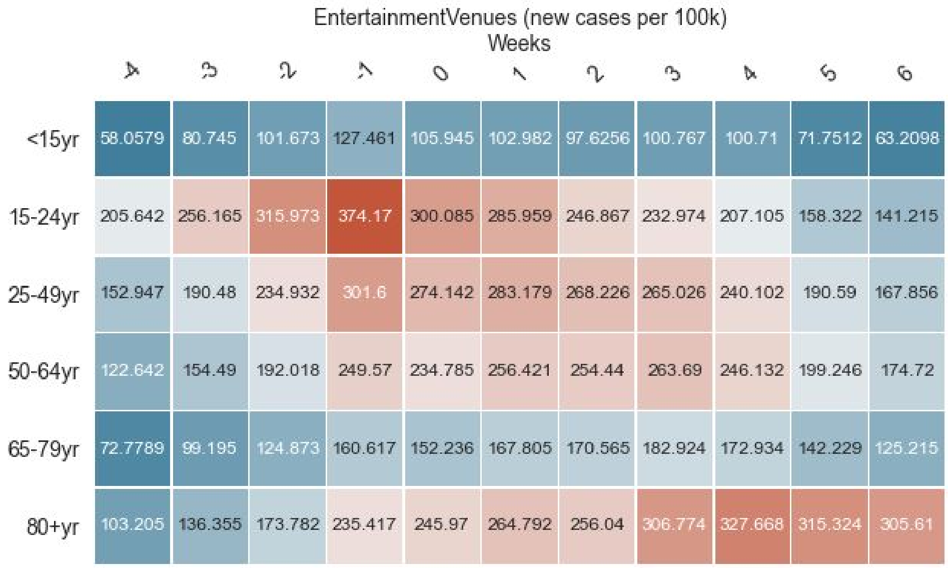
New deaths per million highly correlated and synchronized with neighboring countries



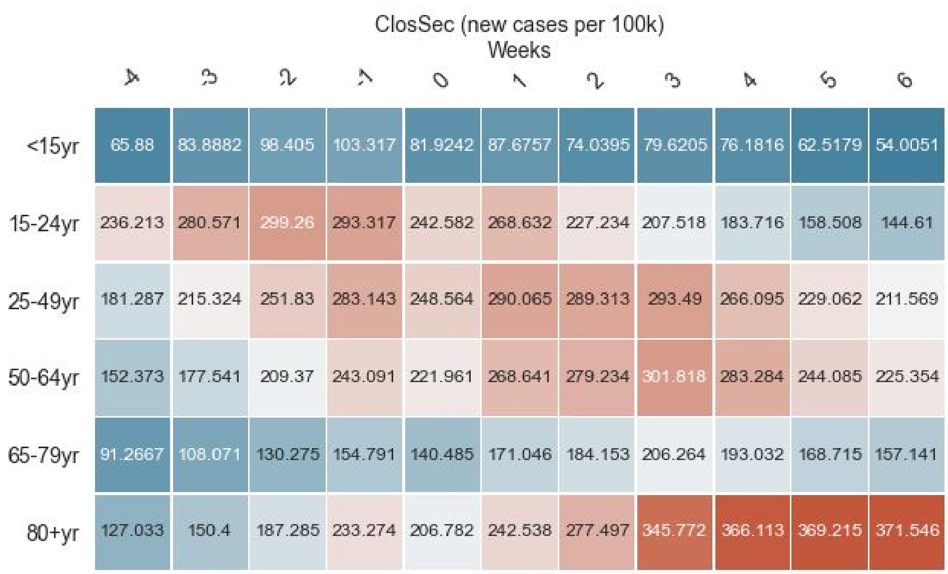
Full correlation matrix for new cases per million in Europe



Full correlation matrix for new deaths per million in Europe

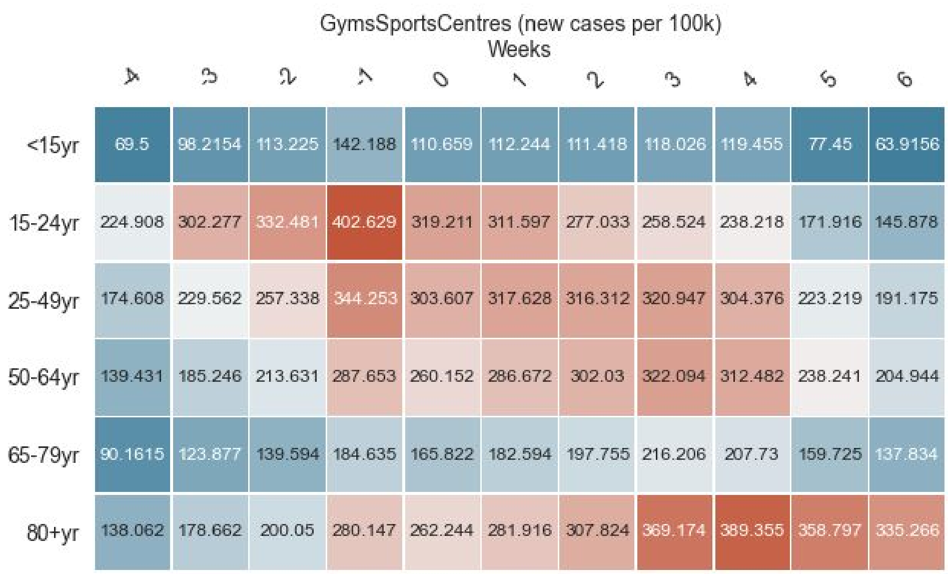


Composite mean of new cases per 100k across age groups when closing entertainment venues at week 0.



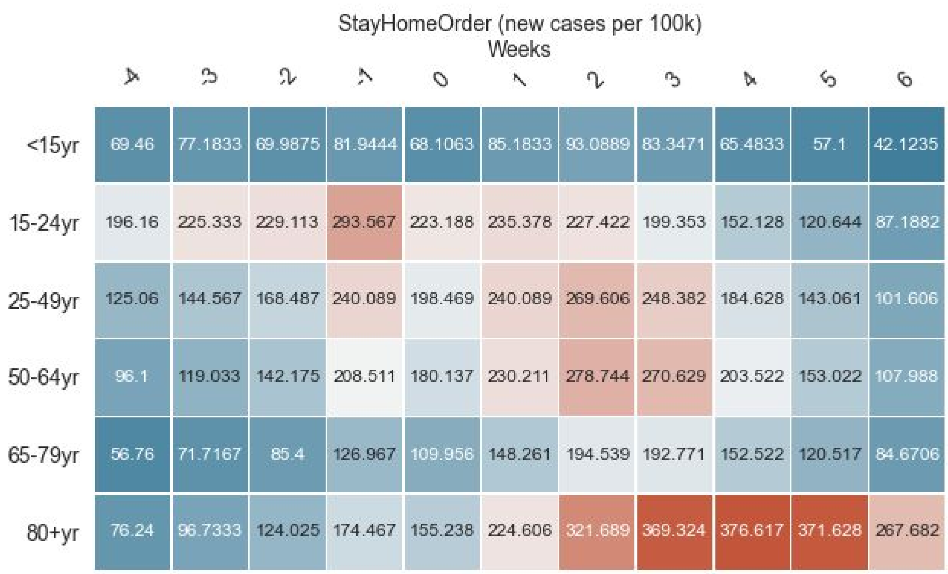
Composite mean of new cases per 100k across age groups when closing secondary schools at week 0.

<u>Composite mean of new cases per 100k across age groups when closing higher educational institutions at week 0.</u>

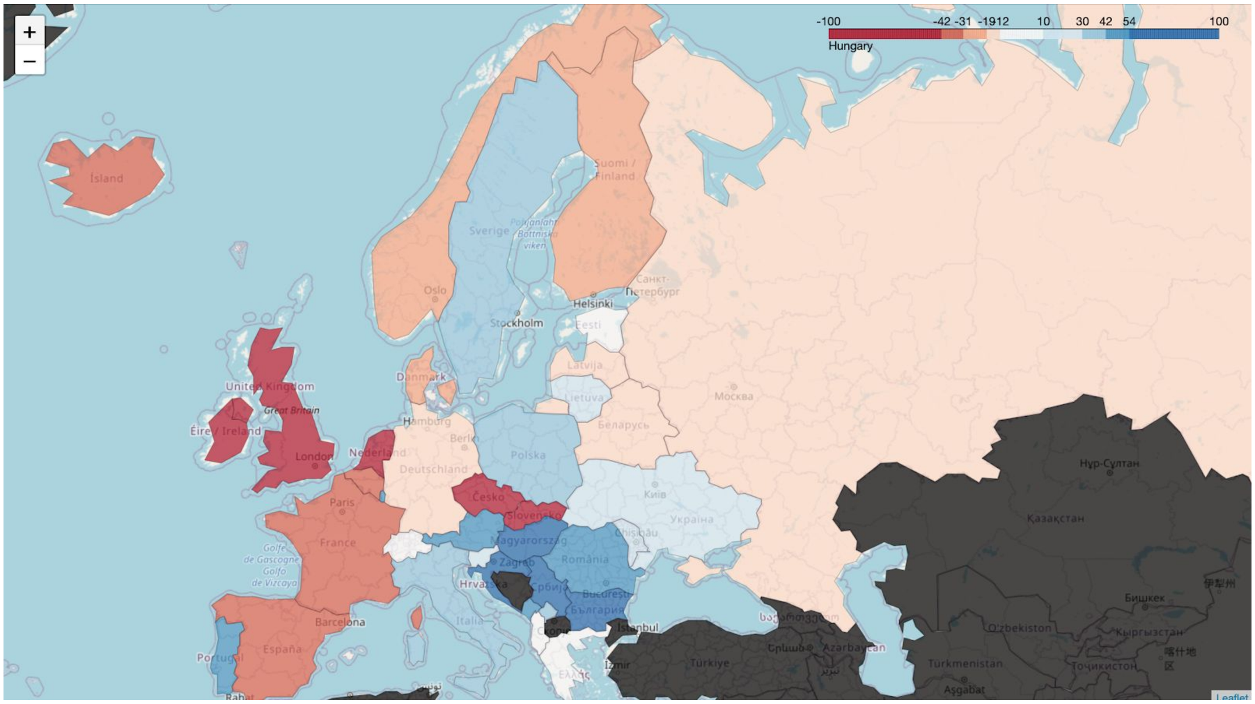


<u>Composite mean of new cases per 100k across age groups when closing gyms sports centers at week 0.</u>

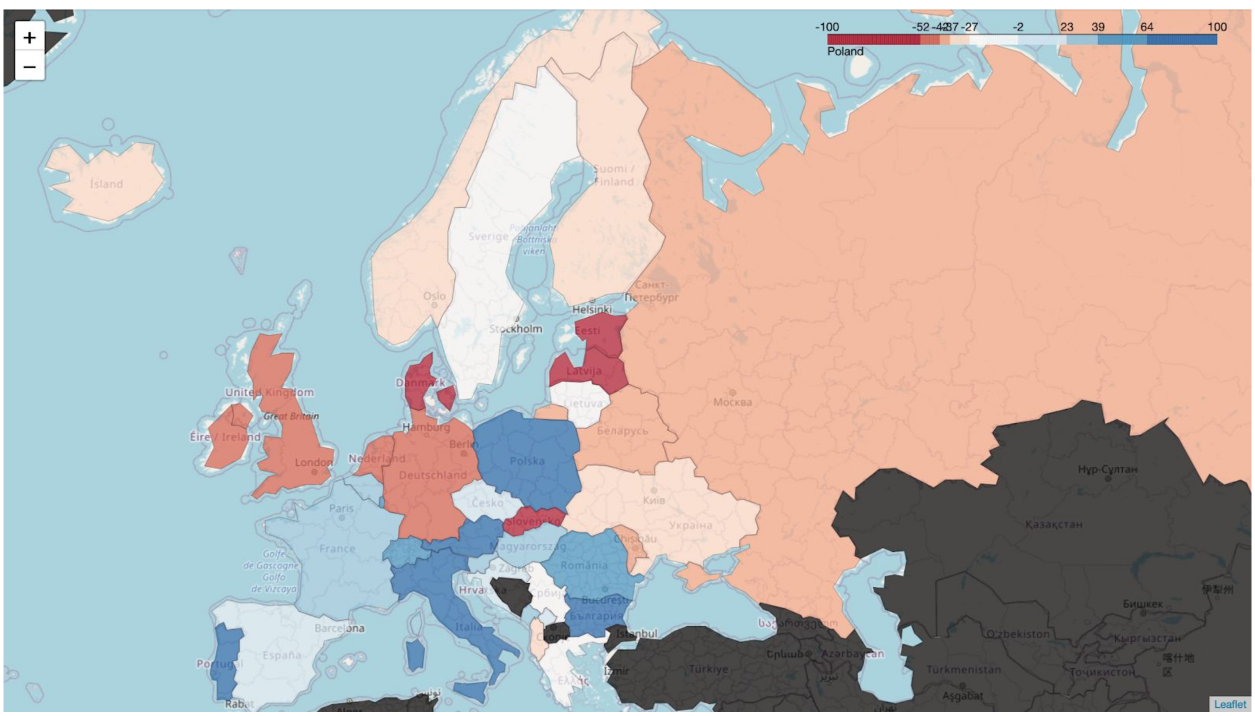
<u>Composite mean of new cases per 100k across age groups when banning gathering over 50 people at week 0.</u>



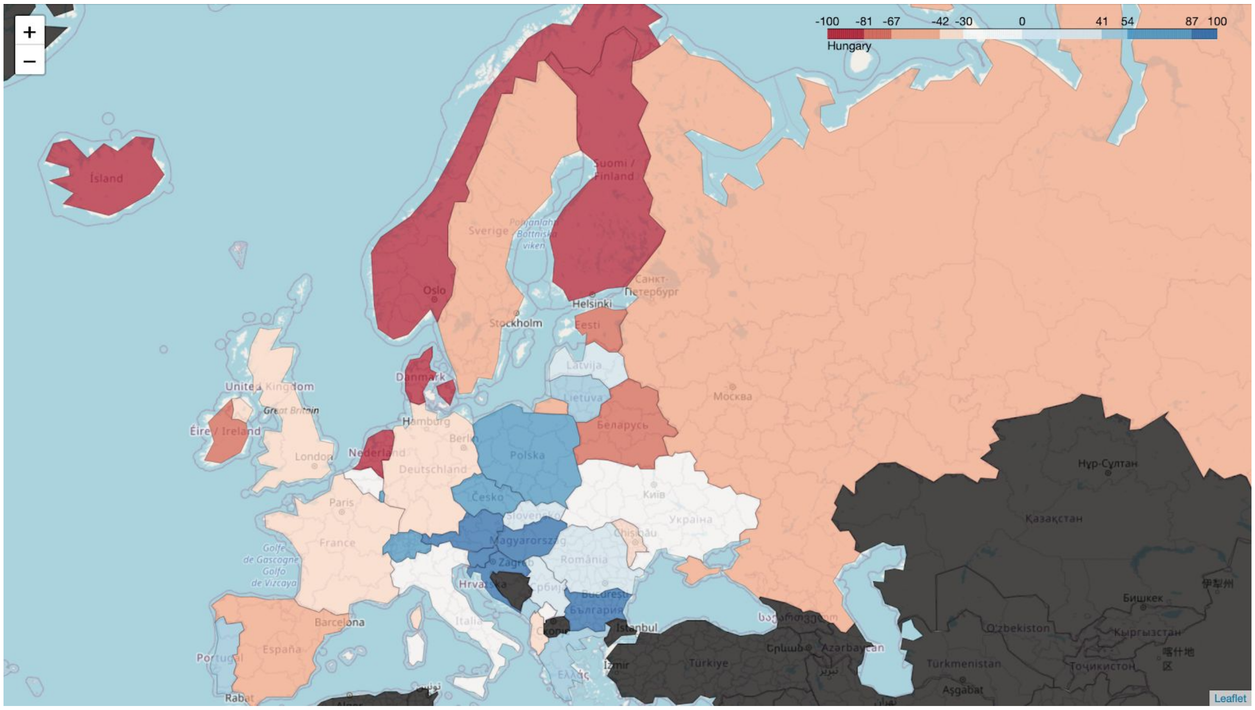
<u>Composite mean of new cases per 100k across age groups when ordering staying at home at week 0.</u>



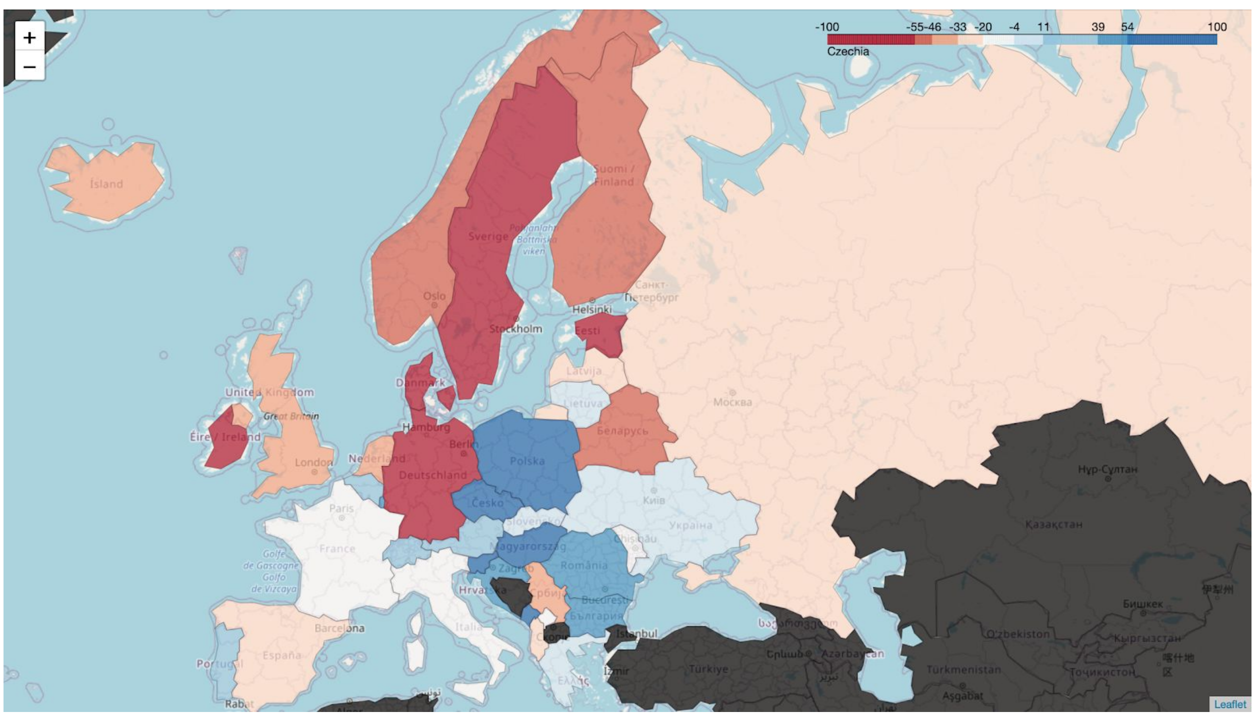
Correlation with Hungary in terms of new cases per day.



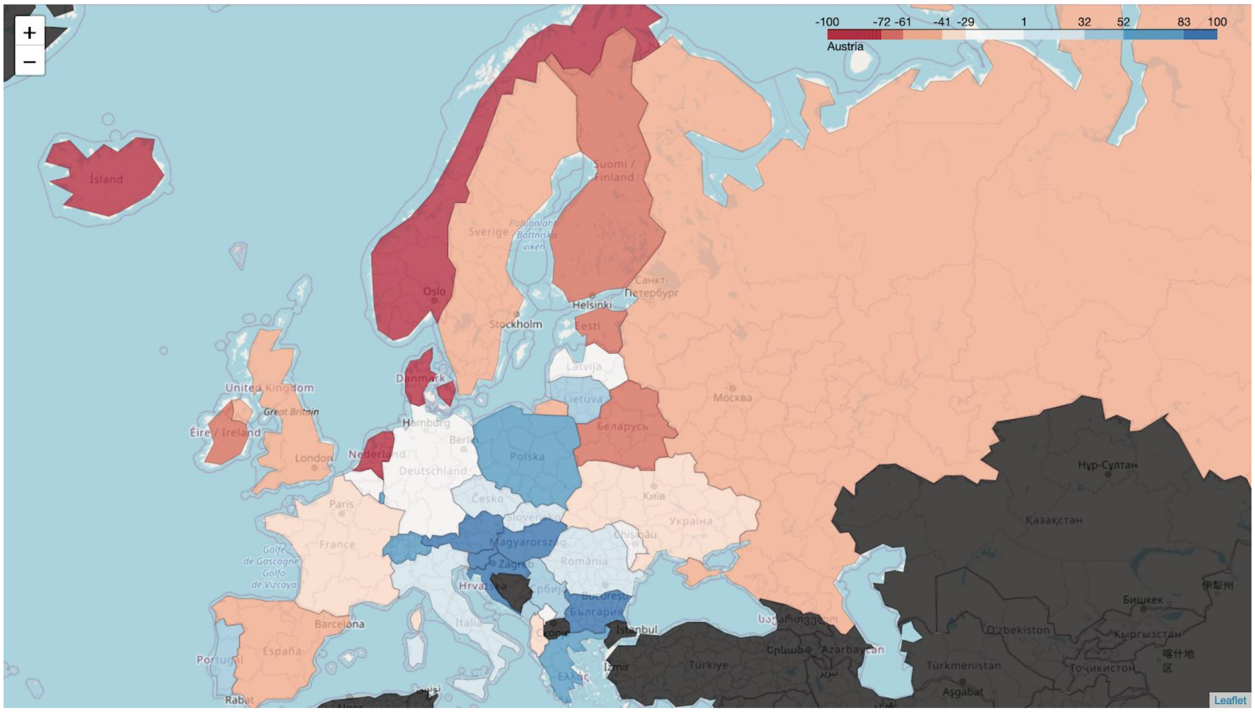
Correlation with Poland in terms of new cases per day.



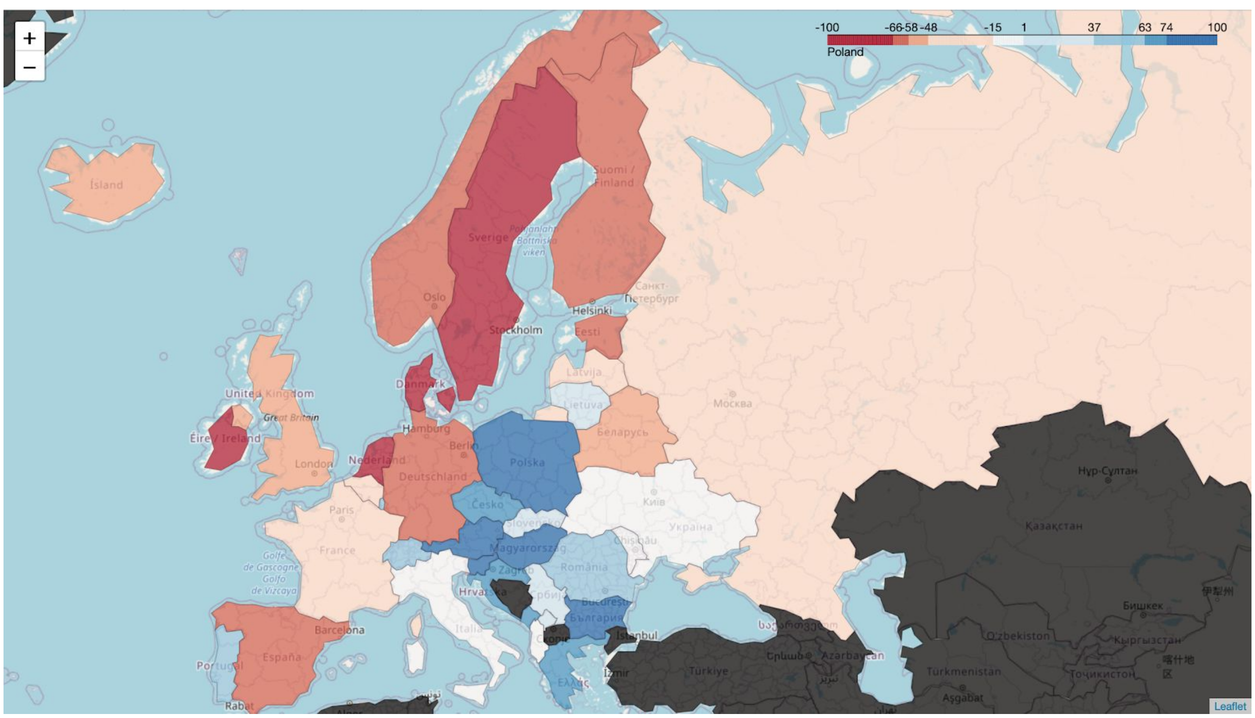
Correlation with Hungary in terms of new deaths per day.



Correlation with Czechia in terms of new deaths per day.



<u>Correlation with Austria</u> <u>in terms of new deaths per day.</u>



<u>Correlation with Poland</u> <u>in terms of new deaths per day.</u>

References

1. Page, Jeremy; Hinshaw, Drew; McKay, Betsy (26 February 2021). "*In Hunt for Covid-19 Origin, Patient Zero Points to Second Wuhan Market - The man with the first confirmed infection of the new coronavirus told the WHO team that his parents had shopped there*". The Wall Street Journal.
2. "*Interim Clinical Guidance for Management of Patients with Confirmed Coronavirus Disease (COVID-19)*". U.S. Centers for Disease Control and Prevention (CDC). 6 April 2020. Archived from the original on 2 March 2020.
3. Hutchins HJ, Wolff B, Leeb R, et al. *COVID-19 Mitigation Behaviors by Age Group* — United States, April–June 2020. MMWR Morb Mortal Wkly Rep 2020;69:1584–1590. DOI: http://dx.doi.org/10.15585/mmwr.mm6943e4external icon