Wavelet coherence of COVID-19 pandemic variables in Japan

1st Goizalde Badiola Computational intelligence group University of the Basque Country (UPV/EHU) San Sebastian, Spain goizaldebadiola@ehu.eus

Computational intelligence group University of the Basque Country (UPV/EHU) San Sebastian, Spain manuelgrana@ehu.eus

2nd Manuel Graña



Contents of the presentation

- Motivation
- Definitions about wavelet coherence
- Materials
- Results and comments
- Some comparative visuals: Spain versus Japan
- Conclusions

Motivation

- Japan response to the COVID-19 has been in some aspects special
 - Non-pharmaceutical measures less stringent than in Europ
 - Pharmaceutical interventions still going on in 2023
- We were interested in studying the relation among main epidemiological variables
 - Our world in data
 - Synchronization of some variables in specific points of time
- Temporal correlations at multiple time scales
 - Wavelet coherence
 - Phase relations \rightarrow potential causal relations

Motivation

- Focus on mortality results
 - Less prone to bias
 - Cases are extremely dependent on test reliability
 - FDA approved over a thousand brands with no formal validation
 - False positives due to pressure to avoid false negatives



Fig. 1. Joint normalized plot of relevant variables for Japan since the beginning of the pharmaceutical interventions.

Time series normalized to the [0,1] interval to highlight pattern synchronization

Wavelet coherence definitions

Morlett wavelet

$$\psi_0(\eta) = \pi^{-1/4} e^{i\omega_0 \eta} e^{-\frac{1}{2}\eta^2}$$

 ω_0 is frequency,

 η is time,

Time series

$$X = \{x_n, n = 1, \dots, N\}$$

Continuous wavelet transform (CWT)

$$W_{n}^{X}(s) = \sqrt{\frac{\delta t}{s}} \sum_{n'=1}^{N} x_{n'} \psi_{0} \left[(n'-n) \frac{\delta t}{s} \right]. \qquad \left| W_{n}^{X}(s) \right|^{2} \quad \text{Wavelet power}$$

scale s:

Crosswavelet transform (XWT)

10110 11.0

Wavelet coherence (WC)

$$W^{A\,I} = W^A W^{I\,*}$$

$$R_{n}^{2} = \frac{\left|S\left(s^{-1}W_{n}^{XY}\left(s\right)\right)\right|^{2}}{S\left(s^{-1}\left|W_{n}^{X}\left(s\right)\right|^{2}\right) \cdot S\left(s^{-1}\left|W_{n}^{Y}\left(s\right)\right|^{2}\right)}, \quad S \text{ is a smoothing operator}$$

Materials

- Data downloaded from Our World in Data
- Variables: deaths, cases, tests, vaccine doses, stringency index, excess deaths, hospitaized patients, ICU patients
- Cut off date 01/january/2023
 - Most countries stopped mass testing in the summer of 2022
 - Same for other pandemic follow up observations and measures
 - By the end of 2022, considerations were dropped in practice
 - Spring 2023 the WHO declared the end of the emergency, after USA administration dropped all mandates and measures

Results

- We compute the wavelet coherence of various variables versus COVID_19 mortality
- Intensity (red) indicates strength of coherence (correlation)
- Arrows indicate phase between variables
 - Up: first variable precedes second variable
 - Right: variables are synchronized (positive correlation)
 - Down: second variable precedes first variable
 - Left: variables in oposition (negatively correlated)

Cases vs deaths



Long term coherence where cases precede deaths

Short term erratic relations: sometimes in phase, sometimes in opposed phase

Tests vs deaths



Tests always are strongly correlated with deaths, in some scales are preceding deaths

11

Hospital patients vs deaths



12

ICU patients vs deaths



Strong coherence at the beginning and end of the pandemic ICU patients preceding deaths

No short term coherences

Vaccine doses vs deaths



There is coherence between vaccine doses and deaths since the end of 2021 at large scales

Sometimes vaccines precede or are in phase with deaths in short term scales

Stringency index vs deaths



Stringency index is almost uncorrelated with the COVID-19 deaths

Excess deaths (all cause) vs deaths



COVID-19 deaths as a major driver of excess deaths

16

Some comparative visuals: Spain versus Japan

- Spain was one the European countries with the worst pandemic outcomes in 2020
- Japan was little affected by the pandemic in 2020
- Different non-pharmaceutical interventions and care of patients
- Similar vaccination policies in 2021
- Different policies in 2022
- Data from OWID until july 2023 (since March 2023 data source changes)

Spain (green) vs Japan (red) pandemic outcomes

COVID-19 Data Explorer Explore global data on COVID-19. Download this dataset	METRIC INTERVAL Confirmed cases 7-day rolling average Relative to Population Color by test positivity	COVID-19 cases
${\bf Q}$ Type to add a country or reg	Daily new confirmed COVID-10 cases per million people	
Sort by Country name V	7-day rolling average. Due to limited testing, the number of confirmed cases is lower than the true number of infections.	
🗹 Japan	🖽 Table 🚯 Map 🗠 Chart	
Spain	Π	
🗆 Afghanistan	2 500	
🗆 Africa	Spa	ain: omicron wave in january 2022
🗆 Albania		an: delayed big wave autumn 2022
□ Algeria		an. delayed big wave additin 2022
American Samoa	Л	
Andorra	1,500	
🗆 Angola		
🗆 Anguilla	1,000	
Antigua and Barbuda		
Argentina		
🗆 Armenia		
🗆 Aruba	0 Japan 10 2020 Aug 8 2020 Feb 24 2021 Sep 12 2021 Mar 31 2022 Oct 17 2022 Jul 11 2023 Spain	
🗆 Asia	▶ Play time-lapse Jan 10, 2020	
🗆 Australia	Data source: WHO COVID-19 Dashboard – Learn more about this data	
🗆 Austria	CC BY	
× Clear selection	Related: Since 8 March, we rely on data from the WHO for confirmed cases and deaths [2]	18

Spain (green) vs Japan (red) pandemic outcomes

COVID-19 Data Explorer	METRIC	INTERVAL				COVID-19 confirmed deaths	
Explore global data on COVID-19. Download this dataset	Confirmed deaths	7-day rolling average V	Relative to Population	Color by test positivity	itivity		
${\bf Q}_{}$ Type to add a country or reg	Daily new confirme	ed COVID-19 deaths p	per million people		Our World in Data		
Sort by Country name V	7-day rolling average. Due to vary may not accurately represent the	ing protocols and challenges in the att true number of deaths caused by COV	tribution of the cause of death, the nun /ID-19.	nber of confirmed deaths	s		
🗹 Japan	🖽 Table 🛛 🕄 Map 🗠 Cł	nart			Settings		
✓ Spain	Π						
🗌 Afghanistan	16					Spain: hig first wave	
Africa							
🗌 Albania	14				U U	lapan: worst results in 2022	
□ Algeria	12						
American Samoa	10	Į					
Andorra	10						
🗆 Angola	8	_ 1					
🗌 Anguilla	6						
Antigua and Barbuda			ſl				
Argentina							
🗆 Armenia							
🗆 Aruba			22 Mar 31 2022 Oct 1	7 2022 WI 11	Japan 2023 Spain		
🗆 Asia	 Play time-lapse Jan 10, 202 	20			Jun 16. 2024		
🗆 Australia	Data source: WHO COVID-19 Dash	board - Learn more about this data		-			
🗆 Austria	CC BY						
× Clear selection			Related: Since 8 March, we rely on data fro	m the WHO for confirmed ca	ases and deaths		

Spain (green) vs Japan (red) interventions

COVID-19 Data Explorer Explore global data on COVID-19. Download this dataset	METRIC INTERVAL Stringency index Daily Relative to Population Color by test positivity Stringency index
Q Type to add a country or reg	COVID-19: Stringency Index Our World in Data
Sort by Country name V	The stringency index is a composite measure based on nine response indicators including school closures, workplace closures, and travel bans, rescaled to a value from 0 to 100 (100 = strictest).
✓ Japan	🖽 Table 🗠 Chart
🗹 Spain	
□ Afghanistan	Spain: extreme stringency in 2020
Africa	Japan: sustained (low) stringency
🗆 Albania	
□ Algeria	
American Samoa	
Andorra	
🗆 Angola	Japan - Non-vaccinated
🗆 Anguilla	Japan - Weighted average of vaccinated and non-vaccinated and
Antigua and Barbuda	20
□ Argentina	
C Armenia	Spain - Vaccinated Spain - Vaccinated Spain - Weighted average of vaccinated and
🗆 Aruba	0 Jan 5, 2020 Aug 8, 2020 Feb 24, 2021 Sep 12, 2021 Mar 31, 2022 Dec 31, 2022
🗆 Asia	▶ Play time-lapse Jan 5, 2020
🗆 Australia	Data source: Hale, T., Angrist, N., Goldszmidt, R. et al. A global panel database of pandemic policies (Oxford COVID-19 Government Response Tracker). Nat Hum Behav 5, 529–538 (2021). https://doi.org/10.1038/s41562-021-01079-8 – Learn more about this data
🗌 Austria	CC BY
× Clear selection	Related: What is the COVID-19 Stringency Index? [2]

Spain (green) vs Japan (red) interventions



Spain (green) vs. Japan (red) interventions

COVID-19 Data Explorer Explore global data on COVID-19. Download this dataset	METRIC INTERVAL Vaccine doses Cumulative Vaccine doses Cumulative Vaccine doses Cumulative	
Q Type to add a country or reg	COVID-19 vaccine doses administered per 100 people All doses, including boosters, are counted individually.	
🗹 Japan	I Table 🕜 Map 🗠 Chart	
Spain	300 Japan	
Afghanistan		
Africa	250	
🗆 Albania	Snain	
Algeria	200	Cumulative vaccine
American Samoa		
Andorra	150	doses
🗋 Angola		
Anguilla	100	
Antigua and Barbuda		
Argentina		
Armenia	50	
🗆 Aruba		
🗆 Asia	0 Jan 4, 2021 Sep 12, 2021 Mar 31, 2022 Oct 17, 2022 May 24, 2023	
Australia	▶ Play time-lapse Jan 4, 2021 ● May 24, 2023	
Austria Clear selection	Data source: Official data collated by Our World in Data – Learn more about this data CC BY Share CC BY	

Our goal at Our World in Data is to make data and research accessible so that we can achieve progress against the world's largest problems.

Spain (below) vs. Japan (above) excess deaths outcomes

COVID-19 Data Explorer	METRIC INTERVAL
Explore global data on COVID-19. Download this dataset	Excess mortality (estimates) V Cumulative V Relative to Population Color by test positivity
${\bf Q}_{\mbox{\ }}$ Type to add a country or reg	Estimated cumulative excess deaths per 100,000 people during COVID-19
Sort by Country name V	For countries that have not reported all-cause mortality data for a given week, an estimate is shown, with uncertainty interval. If reported data is available, that value only is shown. On the map, only the central estimate is shown.
✓ Japan	🖽 Table 🚯 Map 🗠 Chart 🗘 Settings
🗹 Spain	Central estimate Lower bound, 95% uncertainty interval Upper bound COVID-19 deaths (per 100,000)
🗌 Afghanistan	Japan
Africa	350
🗆 Albania	250
□ Algeria	150
American Samoa	100 50
□ Andorra	0 Jan 6, 2020 Aug 8, 2020 Feb 24, 2021 Sep 12, 2021 Mar 31, 2022 Oct 17, 2022 May 5, 2023 Nov 21, 2023 Jun 16, 2024
🗆 Angola	Spain
🗆 Anguilla	350
Antigua and Barbuda	250
Argentina	200
Armenia	
🗌 Aruba	
🗆 Asia	Jan 6, 2020 Aug 8, 2020 Feb 24, 2021 Sep 12, 2021 Mar 31, 2022 Oct 17, 2022 May 5, 2023 Nov 21, 2023 Jun 16, 2024
Australia	P Flay time-tapse Jan 6, 2020 Jun 16, 2024
Austria Clear selection	Note: For some countries, all-cause deaths and COVID-19 Dashboard – Learn more about this data Learn more about the other to when it was reported. This difference could produce an artificial lag between the two time series.

Estimates of excess deahts (all-cause vs. COVID-19)

Conclusions

- Major differences in pandemic outcome (deaths) may be due to cultural/healthcare system differences
 - In Spain's first wave was dealt with forbidding antibiotics, repurposed drugs, and treating old people with end-of-life treatments
 - Different administrative routines for COVID-19 death coding may have an influence on the outcomes
- In Japan, the non-pharmaceutical interventions seem to have little impact on the time evolution of COVID-19 deaths
- In Japan continued vaccination waves appear to have little impact in reducing the tail of the pandemic
- However, excess deaths appear to grow independently of COVID in 2023 and onwards