Measuring the Impact of the EU Health Emergency Response Authority on the Economic Sectors and the Public Sentiment

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June 7, 2024
2024 Africa Meeting of the Econometric Society
@ ENSEA, Abidjan, Côte d'Ivoire

Outline

Introduction

- Over the past three decades, the world has experienced crisis events that have impacted economic, financial, and social ecosystems, including: Global financial crisis (2008–2009); Covid Pandemic (2020–2022)
- Whatever the origins of the crisis, it is crucial to understand:
  - The nexus between the specific shock event and the triggered effects at different levels - economic, financial, social, and organizational.
  - Envisaging the proper countermeasures to be undertaken in the event of a new (likely) crisis.
- The COVID-19 pandemic revealed vulnerabilities in European health preparedness and crisis response for serious cross-border threats to health.
  - No one was prepared to cope with such a huge shock.
  - Countries were exposed to unexpected risks without mitigation or recovery plans.
  - Resorting to school closures, curfews, lockdowns, and mobility restrictions without a specific and controlled roadmap.

- This work represents a close collaboration between the **European project Periscope** and HaDEA (European Health and Digital Executive Agency).
- HaDEA has a mission to implement actions that strengthen Europe in the domains of health, food safety, digital technologies and networks, industrial capacities, and space.
- HaDEA provides high-quality and service-oriented support to enable European society to become healthier, more resilient, and fair, and for European industry to become more competitive.
- In early 2021, HaDEA decided to establish an authority called HERA (Health Emergency Preparedness and Response Authority) to prevent, detect, and rapidly respond to health emergencies.
- Before launching HERA, HaDEA asked Periscope project coordinators to run a quantitative impact assessment of the different levels of interventions and policies the agency could have put in place.
- The final aim of such analysis is the evaluation of the different levels of interventions that could be subsumed by the newborn agency to establish the ideal authority perimeter and the more efficient action plan.

- The main goal of the analysis is twofold:
  1. to dynamically quantify the impact of the waves/phases of the Covid-19 pandemic on some economic sectors;
  2. to quantify the impact of a list of relevant events referred to as actions undertaken at the EU level, which could be considered a proxy of the agency's role.
- We statistically estimate the structure of interconnectedness among companies, considering both market reactions and public sentiment in a robust manner.
- The structure of interconnectedness considered in this study is based on a Bayesian Graphical SVAR model, which ensures statistically sound estimation of the significant links among the entities, taking into account both contemporaneous and temporal dynamics.

Methodology

- Let R_t denote the returns of the stock market indices of n institutions, and S_t denote the sentiment of the institutions
- Let $Y_t = (R_t, S_t)$ be a $N \times 1$, $N = 2n$, whose dynamic evolution can be described by a SVAR(p) process:

$$Y_t = \sum_{s=1}^{p} B_s \ Y_{t-s} + U_t \tag{1}$$

$$U_t = B_0 \ U_t + \varepsilon_t \tag{2}$$

- The expressions in (1) and (2) can be written in a more compact form as

$$Y_t = B_+ X_t \ + \ (I - B_0)^{-1} \varepsilon_t \tag{3}$$

where $B_+ = (B_1, \ldots, B_p)$ is $N \times Np$, and $X_t = (Y'_{t-1}, \ldots, Y'_{t-p})'$ is $Np \times 1$ vector of stacked lagged observation of Y_t.

- We introduce sparsity in the coefficient matrix $B = (B_0, B_1, \ldots, B_p)$ to reflect the conditional independence structure in the form of a network.
- This sparsity is captured using an element-wise Hadamard product $B = (\Phi \circ G)$, where Φ contains the coefficients and G indicates the presence of edges in the network:

$$B_{ij,s} = \Phi_{ij,s} G_{ij,s} \tag{4}$$

- Thus, the slope coefficients and shock dependence matrices of (1) and (2) can be specified through network graphs by assigning to each $B_{ij,s}$ a corresponding latent indicator in $G_{ij,s} \in \{0, 1\}$, such that for $i, j = 1, \ldots, N$, and $s = 0, 1, \ldots, p$:

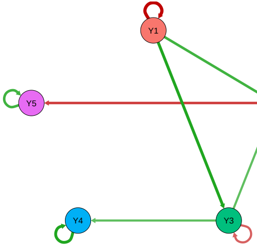
$$B_{ij,s} = \begin{cases} 0 & \text{if} \quad G_{ij,s} = 0 \quad \Longrightarrow \quad Y_{j,t-s} \nrightarrow Y_{i,t} \\ \Phi_{ij,s} \in \mathbb{R} & \text{if} \quad G_{ij,s} = 1 \quad \Longrightarrow \quad Y_{j,t-s} \rightarrow Y_{i,t} \end{cases} \tag{5}$$

- Consider the VAR(1) process:

$$Y_t = B_1 Y_{t-1} + \varepsilon_t$$

- Example:

$$\begin{bmatrix} Y_{1,t} \\ Y_{2,t} \\ Y_{3,t} \\ Y_{4,t} \\ Y_{5,t} \end{bmatrix} = \begin{pmatrix} -0.8 & 0 & 0 & 0 & 0 \\ 0.6 & 0 & 0.5 & 0 & 0 \\ 0.7 & 0 & -0.5 & 0 & 0 \\ 0 & 0 & 0.5 & 0.7 & 0 \\ 0 & -0.6 & 0 & 0 & 0.6 \end{pmatrix} \begin{bmatrix} Y_{1,t-1} \\ Y_{2,t-1} \\ Y_{3,t-1} \\ Y_{4,t-1} \\ Y_{5,t-1} \end{bmatrix}$$



- $\Phi_{ij,s}$ are modeled conditionally on the indicator variables $G_{ij,s}$

$$[\Phi_{ij,s}|G_{ij,s}=1] \sim \mathcal{N}(0,\eta), \quad G_{ij,s} \sim \mathcal{B}er(\pi_{ij,s})$$

  where η is the variance of the normal distribution, and $\pi_{ij,s}$ is the prior probability that $G_{ij,s}=1$. Typically, $\pi_{ij,s}=0.5$ is chosen for noninformative priors.

- We assume Σ_u^{-1} is Wishart distributed:

$$\Sigma_u{}^{-1} \sim \mathcal{W}(\delta_u, \Lambda_{u,0})$$

  where δ_u is the degrees of freedom, and $\Lambda_{u,0}$ is scale matrix. We assume $\delta_u = n+2$, and $\Lambda_{u,0} = \delta_u I_n$.

- Σ_ε is a diagonal matrix. We assume $\Sigma_\varepsilon{}^{-1}$, follows a G-Wishart:

$$\Sigma_\varepsilon{}^{-1} \sim \mathcal{W}_{G\varepsilon}(\delta_\varepsilon, \Lambda_{\varepsilon,0})$$

  where δ_ε is degrees of freedom, and $\Lambda_{\varepsilon,0}$ is the scale matrix. We assume $\delta_\varepsilon = n+2$, and $\Lambda_{\varepsilon,0} = \delta_\varepsilon I_n$.

- Under the Bayesian framework, the conditional probability $P(Y_{i,t}|X_{\pi,t})$ is

$$P(Y_{i,t}|X_{\pi,t}) = \frac{\pi^{-\frac{1}{2}N}\ \nu_0^{\frac{1}{2}\nu_0}}{\nu_n^{\frac{1}{2}\nu_n}} \frac{\Gamma\left(\frac{\nu_0+N-n_f}{2}\right)}{\Gamma\left(\frac{\nu_0-n_f}{2}\right)} \left(\frac{|X'_{\pi,t}X_{\pi,t} + \nu_0 I_{n_\pi}|}{|X'_{f,t}X_{f,t} + \nu_0 I_{n_f}|}\right)^{\frac{1}{2}\nu_n}$$

- Given the data, the lag p, we apply a collapsed Gibbs sampler:
  - Sample $[\ G_{1:p}\ |\ X = (Y, Z)\ ]$ - lagged network
  - Sample $[\ G_0\ |\ X = (Y, Z),\ G_{1:p}\ ]$ - contemporaneous

- Given $(G_0, G_{1:p})$, estimate $(B_0, B_{1:p}, \Sigma_u, \Sigma_\varepsilon)$
  - Let $z_\pi = \{j : G_{y_i,j|1:p} = 1\}$, $\hat{B}_{y_i,\pi_i|1:p} = (Z'_{\pi_i} Z_{\pi_i} + \eta I_{|z_\pi|})^{-1} Z'_{\pi_i} Y_i$
  - Estimate $\hat{U}_{y_i} = Y_i - Z_{\pi_i} \hat{B}'_{y_i,\pi_i|1:p}$
  - Let $y_\psi = \{j' :\ G_{y_i,j'|0} = 1\}$ and $U_{\psi_i} = U_{y_\psi}$
  - Estimate $\hat{B}_{y_i,\psi_i|0} = (\hat{U}'_{\psi_i} \hat{U}_{\psi_i} + \eta I_{|\psi_i|})^{-1} \hat{U}'_{\psi_i} \hat{U}_{y_i}$
  - Estimate $\hat{\Sigma}_u = E(\hat{U}'\hat{U})$ and $\hat{\Sigma}_\varepsilon = (I_n - \hat{B}_0)\hat{\Sigma}_u(I_n - \hat{B}_0)'$

- Once B_+ and Σ_u are estimated, the Spillover Index can computed through the H-step GFEVD as:

$$d_{ij}^H = \frac{\tilde{d}_{ij}^H}{\sum_{j=1}^N \tilde{d}_{ij}^H}, \qquad \text{where} \qquad \tilde{d}_{ij}^H = \frac{\sigma_{jj}^{-1} \sum_{h=0}^{H-1} (\mathfrak{e}_i' \theta_h \Sigma_u \mathfrak{e}_j)^2}{\sum_{h=0}^{H-1} (\mathfrak{e}_i' \theta_h \Sigma_u \theta_h' \mathfrak{e}_j)} \tag{6}$$

  where $\theta_i = B_1 \theta_{i-1} + B_2 \theta_{i-2} + \ldots + B_p \theta_{i-p}$, $\theta_0 = I_N$ and $\theta_i = 0$ for $i < 0$, d_{ij}^H measures the proportion of the H-step ahead forecast error variance of the i^{th} element of Y_t accounted for by the innovations in the j^{th} element of Y_t, $\mathfrak{e}_i$ is a selection vector with i^{th} element unity and 0 elsewhere.

- The nice property of the H-step GFEVD matrix is that it can be naturally interpreted as a weighted, directed network, where the edges represent the quota of forecast error variance explained by each node.

- We define the index of SPILLOVER TO and SPILLOVER FROM as

$$\mathcal{F}_{i \leftarrow \bullet} = \sum_{j=1, j \neq i}^{N} d_{ij}^H, \qquad \mathcal{T}_{\bullet \leftarrow i} = \sum_{i=1, i \neq j}^{N} d_{ij}^H \tag{7}$$

Empirical Application

- We consider daily data of 89 top companies from EuroStoxx 600 (October 2018 - April 2021)
- The variables of interest are financial equity prices (Yahoo Finance) and Sentiment Indices produced by (Brain Company)
- The Brain Company specializes in developing proprietary sentiment indicator (BSI) based on natural language processing approaches to collect and classify company news from a series of providers. They provide daily sentiment indicator for the largest listed worldwide companies.
- Such an indicator represents a score that ranges between -1 and +1 and is based on financial news and blogs written in English.
- Each news is pre-analyzed to assign the corresponding company through the use of a dictionary of company names; then the news is categorized using syntactic rules or machine learning classifiers.
- The data are collected using data mining and filtering techniques to assess the pertinence of news to a specific company.

Data Description - 2

- We grouped the 89 top companies into Five macro-sectors: Financial, Consumer, Health, Technological, Others
- Financial: Banking, Financial Services, and Insurance;
- Consumer: Consumer Defensive and Consumption;
- Health: Health sector;
- Technological: Technological sector;
- Other sectors: Chemical, Industrial, Oil-Gas, Telecommunication, and Utility-Energy.

- We decided to take advantage of scenario analysis by using some relevant events that occurred during the first one and and half year of the pandemic as proxies of the supranational institution in charge of addressing countermeasures organization.
- We identify the following 4 phases (plus the pre-Covid period):
  1. **Pre-Covid** : period until February 2020;
  2. **First wave** : from March – May 2020;
  3. **Phase 1** : from June – September 2020;
     this window is not called "wave" since it was a period with a particularly low incidence of the pandemic;
  4. **Second wave** : from October – December 2020;
  5. **Third wave** : from January – April 2021.
- The waves are important as reference points for evaluating the role of a possible agency as in our simulation study.

- We assume that the first wave (March–May 2020) represents the lowest level of preparedness and response to the Covid-19 pandemic.
- Countries, at that time were facing shortages of personal protective equipment and medical devices (including tests and testing materials).
- Such a situation represents the worst scenario and, in this sense, it can be assumed as a benchmark (Policy option 0: Baseline scenario).
- All the subsequent waves, although severe in terms of the number of cases and deaths, witnessed an increased reaction capacity of the European countries, thanks to the coordinated actions undertaken at the EU level.
- In this sense, we assume that waves 2 and 3 can mimic different levels of agency interventions.

- The events of interest, which we explicitly consider in our analysis are:
  1. 17th June '20 - First action: Establishment of EU vaccines strategy; Policy Option 1: Strengthened coordination for threat assessment and knowledge generation based on joint undertakings;
  2. 14th August '20 - Second action: First APAs (Advance Purchase Agreements) under the vaccines strategy; Policy option 2.1: Operational Authority;
  3. 17th Feb '21 - Third action: Establish Vaccelerate trial network; Policy option 2.2: Operational and Infrastructure Authority;
  4. 16th March '21- Fourth action: Additional purchase agreements of BioNTech-Pfizer and Moderna vaccines. Policy option 3: Full end-to-end Authority & streamlining of EU level initiatives on medical countermeasures for serious cross-border threats to health.
- We introduce these actions by the specific event (through the dummy variable) in influencing the equity and sentiment time series.

- For robustness checks, we considered 3 supplementary events, namely:
  - 28th July '20 - Securing EU access to Veklury (Remdesivir)
  - 21st December '20 - the EU Commission authorizes first safe and effective vaccine against Covid-19,
  - 17th February '21 Launch of the "HERA Incubator".
- To assess the impact of these events on the economic sectors, we control for the number of Covid-19 cases aggregated at the European level.
- We summed up all the daily cases of the European countries and categorized the counts variable according to some standard statistical distribution (first quartile and third quartile).
- Specifically, we define classes as follows:
  - Below 10,893 daily cases as **low impact**;
  - 10,893 – 153,250 daily cases as **medium impact**;
  - Above 153,250 daily cases as **high impact**.

- From a methodological point of view, to quantify the impact of the waves and the events/actions, we split the exercise into two sub-analysis:
  1. Spillover analysis at the sector level (averaging data at the companies level) to quantify the specific impact of each event onto the economic sectors considering both market and public sentiments;
  2. Interconnectedness analysis at the companies level, considering both the waves and the events.
- For Spillover analysis, we considered a temporal window of up to 14 days.
- For the sake of comparison, we report the results of the aggregated Spillover index (in percentages) at the 1st, 7th, and 14th horizon.

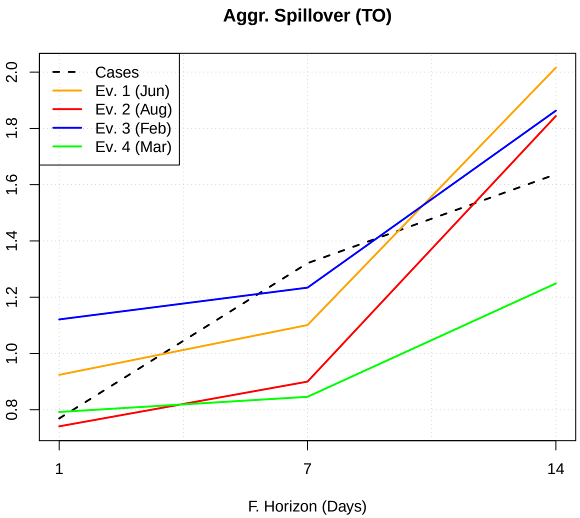


Figure: Aggregated Spillover (TO) evolution according to the events, the daily Covid-19 cases, and the temporal horizon (1, 7, and 14 days)

- There is an ordering in the impact of events: the Vaccelerate trial (in blue) and the First EU Vaccine Strategy (yellow) are the most impacting events;
- The first APAs (red) appears as the least effective event on day 1 but it rapidly converges to the other two important events on day 14;
- The Additional purchase of Pfizer/Moderna (green) is less impacting especially on days 1 and 7;
- The cases variable (dashed black line) seems to rise at an increasing rate with a peak at the 7th horizon, after which the multiplier effect begins to fall. This can be attributed to the rise in the two vaccine-related events.

- The analysis reveals that all the considered events have some significant impact on the sectors, although with different magnitudes.
- The vaccine-related events are the most important ones, regardless of the horizon, and they overcome the Covid-19 cases effect in many scenarios.
- The Vaccelerate trial network (Policy option 2.2) has the highest impact, although partially overcome at the longest horizon by the event EU vaccines strategy (Policy Option 1).
- First APAs under the vaccine strategy, although starting with a particularly low impact on day 1, rapidly reach the highest levels of influence on day 14.
- The last event (additional purchase agreements) being a long-term action has a low impact on day 1 but it increases rapidly at the longest horizon.

F. Horizon	EU vax strategy		First APAs		Vaccelerate trial		Add. Purchase	
1 day	CONS(S)	0.30	CONS(S)	0.35	TECH(E)	0.26	CONS(E)	0.42
	HLT(E)	0.25	HLT(S)	0.27	CONS(S)	0.25	TECH(E)	0.19
	FIN(S)	0.17	TECH(E)	0.21	FIN(E)	0.18	HLT(E)	0.15
7 days	CONS(S)	0.25	CONS(S)	0.29	TECH(E)	0.26	CONS(E)	0.41
	CONS(E)	0.19	HLT(S)	0.22	CONS(S)	0.25	TECH(E)	0.18
	HLT(E)	0.18	TECH(E)	0.21	FIN(E)	0.18	HLT(E)	0.14
14 days	CONS(E)	0.22	TECH(E)	0.23	TECH(E)	0.26	CONS(E)	0.32
	TECH(E)	0.19	CONS(E)	0.19	CONS(S)	0.25	TECH(E)	0.23
	HLT(E)	0.16	FIN(E)	0.17	FIN(E)	0.18	FIN(E)	0.19

Table: Spillover impact of each event on considered sectors. The top 3 sectors are listed. In parenthesis, E stands for equity data and S for sentiment data.

- First of all, we can notice that both equities and sentiments are affected by the events.
- The consumer sector is ranked first (either the equity or the sentiment component) about all the events but second on the Vaccelerate trial.
- The technological sector is first in that category, even though we should stress that the relative numbers are close to each other (0.26 and 0.25).
- The health sector is particularly relevant in Event 1 (EU vaccine strategy), Event 2 (first APAs), and Event 4 (Additional Purchase) while Event 3 and Event 4 (respectively Vaccelerate trial and Additional Purchase) have more impact on the financial and technological sectors.
- The last action (Additional Purchase - Policy Option 3) shows the highest spillover effect on the consumer sector.

  This is a relevant result that highlights the importance of the undertaken action in a phase of the pandemic where European countries were ready to begin a massive vaccination campaign but were experiencing a severe shortage in the supply of doses.

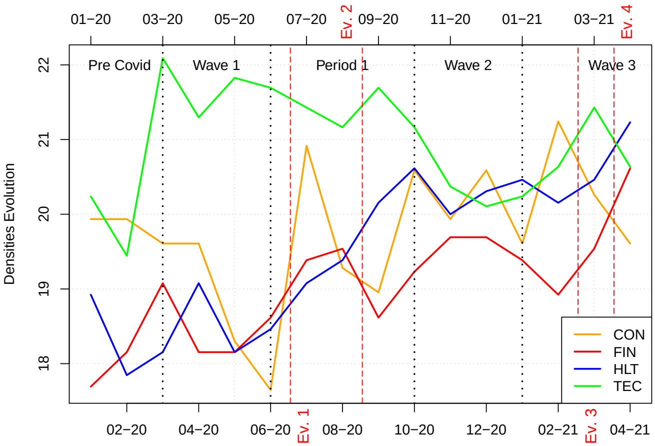


Figure: Temporal evolution of network density according to sectors, periods, and events. Ev.1 = Establishment of EU vaccines strategy, Ev.2 = First APAs under the vaccines strategy, Ev.3 = Establishment of the Vaccelerate trial network, Ev.4 = Additional purchase agreements of BioNTech-Pfizer and Moderna vaccines.

- The technological sector is the most connected until the second wave.
- The first event (EU vac strategy) had an impact on the consumer sector which dropped significantly after a sharp increase.
- The second event (first APAs) instead shows a diversified effect: the technological sector reported a delayed reaction with a decrease in density while all the other sectors kept increasing.
- The last two actions implemented during the third wave seem to be relevant for the technology sector which recorded a decline in density again while the other sectors maintained their patterns.
- It is worth noticing the density evolution of the health sector. That is, there is a clear and consistent increasing trend in their network density. At the end of the third wave, we see that the health sector is the most connected one; this is a reasonable reaction to the huge solicitation experienced from the beginning of the pandemic either for medicament or for vaccine research.

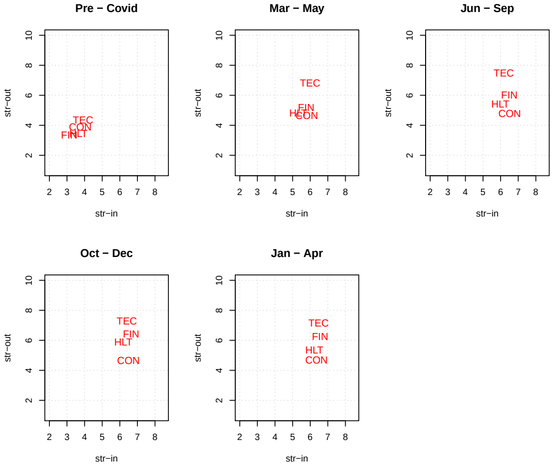


Figure: Relationship between strength in and strength out along the five periods at the sectors level.

- We notice that in the pre-Covid period, the sectors are very close to each other, meaning that they have similar patterns.
- Then, a rather stable level of the strength-in index (around 6 and 7) corresponds to a ranking for the strength-out index: the technological sector is the most influencing one while the consumer is the most influenced.
- We can then conclude that the pandemic had a huge impact on the organization of the economic sectors and their relative roles.
- The crisis induced a ranking in the sectors led by the tech industries which experienced a boost in development due to the hype in all the online and technological activities.

- We report the RMSE ratio of the basic model (with no events) and all the other models, one for each possible combination of events.

Combination	RMSE ratio	Combination	RMSE ratio
No events	1	Second and Third	0.959
First event	0.978	Second and Fourth	0.959
Second event	0.977	First-Second-Third	0.942
Third event	0.977	First-Second-Fourth	0.942
Fourth event	0.977	First-Third-Fourth	0.943
First and Second	0.959	Second-Third-Fourth	0.943
First and Third	0.959	All	**0.917**
First and Fourth	0.959		

Table: RMSE ratio between each specification and the basic model without events.

- The lower the ratio, the greater the predictive accuracy of the model considered.
- What emerges is that the configuration with the full specification (i.e. all the events contemporaneously), reaches the lowest error rate, suggesting that such configuration produces the best fit to the observed data.
- Such a result confirms the need for an ensemble of actions to be undertaken at the EU level, that is to say, a full policy scenario (Policy 3).
- Just one action or even a combination of two, is not enough to describe the variability and patterns of the 89 companies during the pandemic.

Conclusion

- We present an extensive quantitative analysis requested by the EU within the activities of the European project Periscope.
- From a methodological point of view, we evaluated the interconnectedness risk by leveraging market prices and sentiment data.
- Using spillover (TO) index, we were able to assess the effects induced by some specific and relevant actions undertaken at the EU level, after controlling for the number of Covid cases, such as

  The establishment of the EU vaccines strategy, first APAs under the vaccines strategy, establishment of the Vaccelerate trial network and additional purchase agreements of BioNTech-Pfizer and Moderna vaccines.
- The results are relevant from the policymakers' perspective. In particular, the Vaccelerate trial and the first EU Vaccine Strategy are the most impacting events. On the contrary, the first APA appears the least effective event in the short term (day 1) but rapidly converges with the other two important events on day 14.

Thank you !

for your attention

Q&A?

Research supported by

The European Union's Horizon 2020 research and innovation program "PERISCOPE: Pan European Response to the ImpactS of COvid-19 and future Pandemics and Epidemics", under the Grant Agreement No. 101016233, H2020-SC1- PHE-CORONAVIRUS-2020-2-RTD.