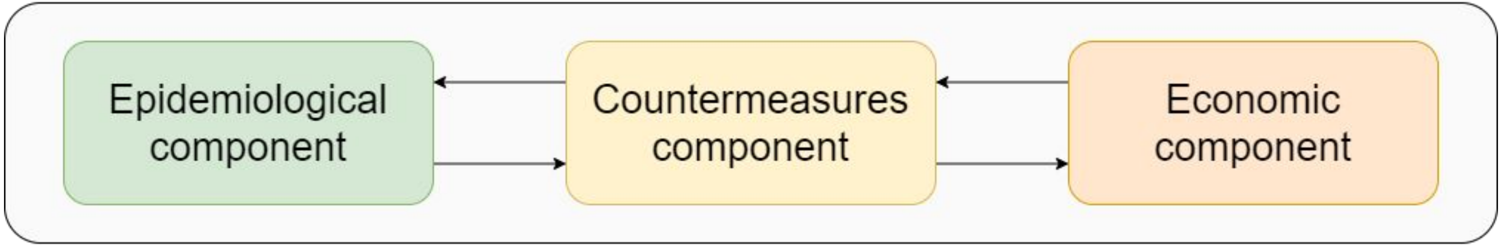
Measuring COVID-19 economic and epidemiological countermeasures impact

Massimo Mengarda - Matteo Bortolon

Simulation - Architecture

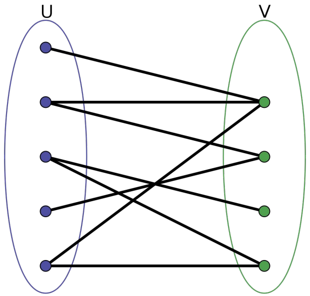


Epidemiological component - Environment

CBGs

Population between 600 and 3000 people

Bipartite graph



POIs

Epidemiological component - Data

Core POI

Weekly Patterns

SAFEGRAPH

Home Summary

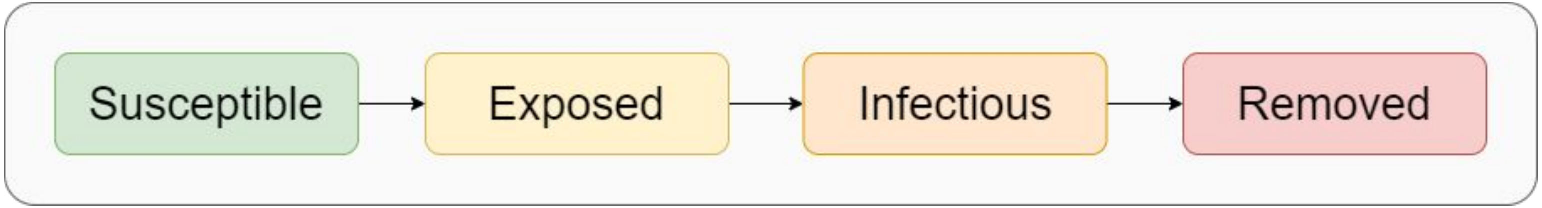
American Community Survey - 2016

(US Census Bureau)

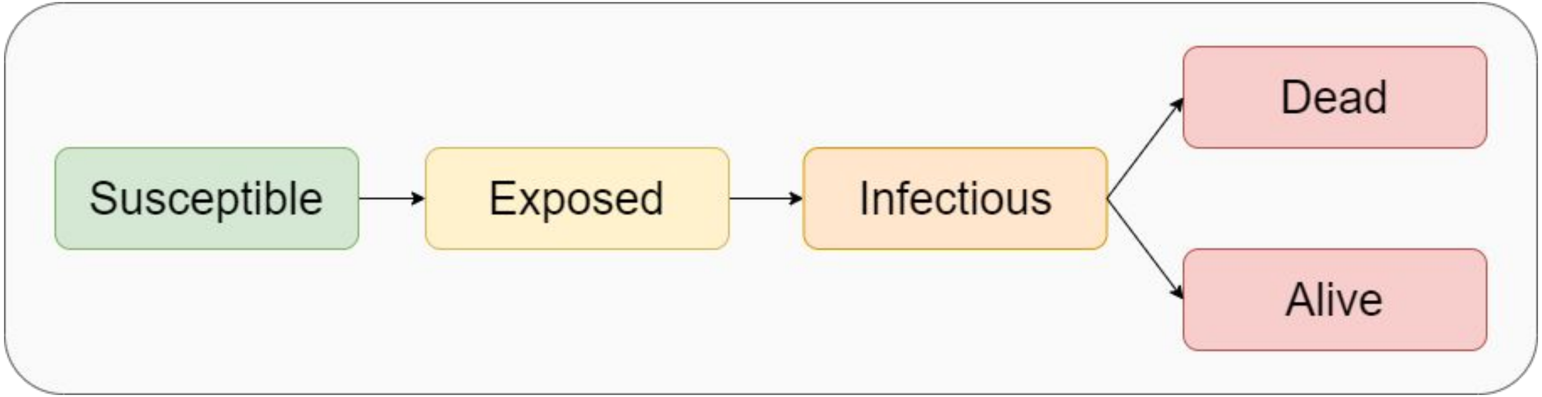
Social Distancing

POI Area

Epidemiological component - Model



Epidemiological component - Model



Epidemiological component - Model

$$N_{c_i} = S_{c_i}^{(t)} + E_{c_i}^{(t)} + I_{c_i}^{(t)} + R_{c_i}^{(t)}$$

$$\Delta S_{c_i}^{(t)} = -N_{S_{c_i} \to E_{c_i}}^{(t)}$$

$$\Delta E_{c_i}^{(t)} = N_{S_{c_i} \to E_{c_i}}^{(t)} - N_{E_{c_i} \to I_{c_i}}^{(t)}$$

$$\Delta I_{c_i}^{(t)} = N_{E_{c_i} \to I_{c_i}}^{(t)} - N_{I_{c_i} \to R_{c_i}}^{(t)}$$

$$\Delta R_{c_i}^{(t)} = N_{I_{c_i} \to R_{c_i}}^{(t)}$$

Epidemiological component - Initialization

$$S_{c_i}^{(0)} = N_{c_i} - E_{c_i}^{(0)}$$
$$E_{c_i}^{(0)} = Binom(N_{c_i}, p_0)$$
$$I_{c_i}^{(0)} = 0$$
$$R_{c_i}^{(0)} = 0$$

Serina Chang et al. “Mobility network models of COVID-19 explain inequities and inform reopening”. In: Nature 589 (2020), pp. 82–87. DOI: 10.1038/s41586-020-2923-3.

Epidemiological component - Simulation

$$N^{(t)}_{S_{c_i} \to E_{c_i}} = Binom(w^{(t)}_{ij} \cdot \frac{S^{(t)}_{c_i}}{N_{c_i}}, \lambda^{(t)}_{p_j}) + Binom(S^{(t)}_{c_i}, \lambda^{(t)}_{c_i})$$

$$N^{(t)}_{E_{c_i} \to I_{c_i}} = Binom(E^{(t)}_{c_i}, \frac{1}{\delta_E})$$

$$N^{(t)}_{I_{c_i} \to R_{c_i}} = Binom(I^{(t)}_{c_i}, \frac{1}{\delta_I})$$

$$\lambda^{(t)}_{p_j} = \psi d{p_j}^2 \cdot \frac{I^{(t)}_{p_j}}{a_{p_j}}$$

$$\lambda^{(t)}_{c_i} = \beta_{base} \frac{I^{(t)}_{c_i}}{N_{c_i}}$$

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Epidemiological component - Grid Search

β_{base}

Transmission constant for CBGs

10 values in the range
0.0012 - 0.024

Ψ

Transmission constant for POIs

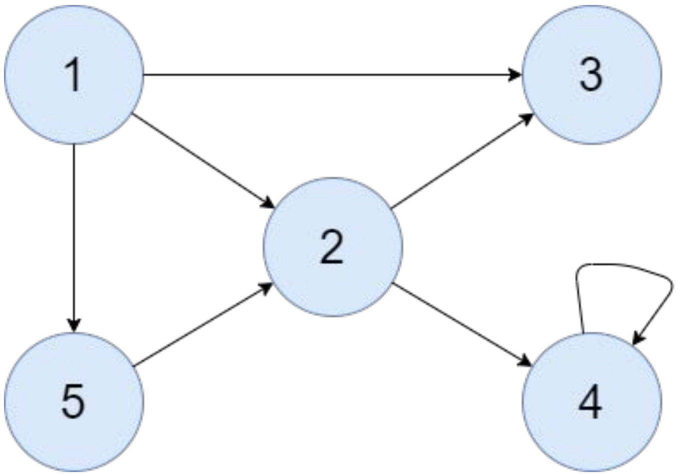
9 values in the range
0.001 - 50

p_0

Probability of being infected at time t_0

These 10 values
$1{\cdot}10^{-2}$ $5{\cdot}10^{-3}$ $2{\cdot}10^{-3}$ $1{\cdot}10^{-3}$ $5{\cdot}10^{-4}$,
$2{\cdot}10^{-4}$ $1{\cdot}10^{-4}$ $5{\cdot}10^{-5}$ $2{\cdot}10^{-5}$ $1{\cdot}10^{-5}$

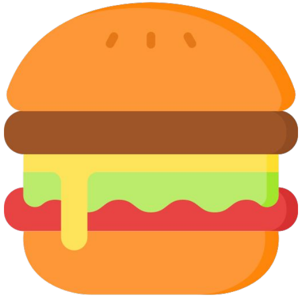
Economic component - Input Output Theory



Economic Activities	1	2	3	...	Z	Final Demand	Exports
1							
2							
3							
...							
Z							
Imports							

Leontief Wassily. Input-output economics. New York: Oxford University Press, 1986. ISBN: 978-0195035278.

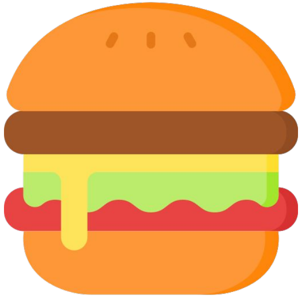
Countermeasure component



Closure of
food activities

Closure of
cinemas and
theaters

Closure of
religious
organizations



Closure of
food activities
after 18

Implementation

python™

PyTorch

AMD 3900X - 64 GB - Nvidia RTX 3090 (using the sparse matrix capabilities)

Grid Search ~7 days

Single simulation on SSD ~7 minutes

Single simulation on HDD ~1 hour

Area and Period

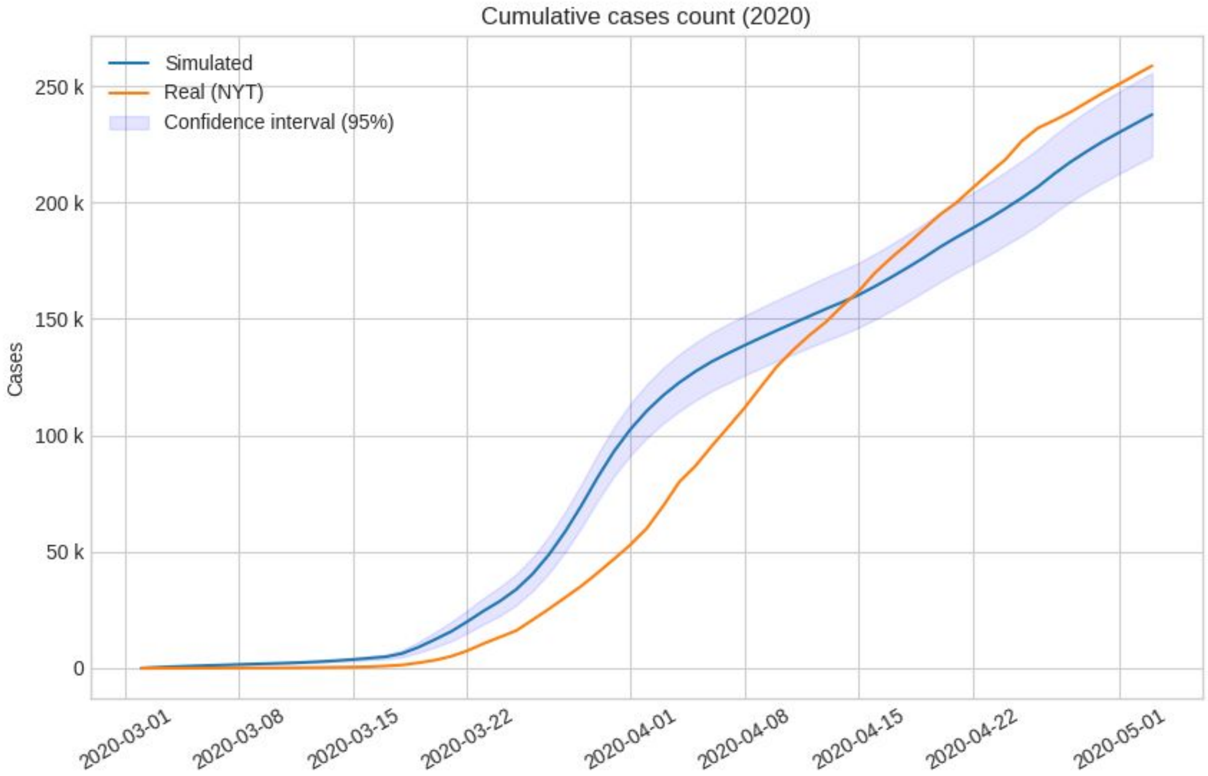
Grid search & cases evaluation

02/03/2020 03/05/2020

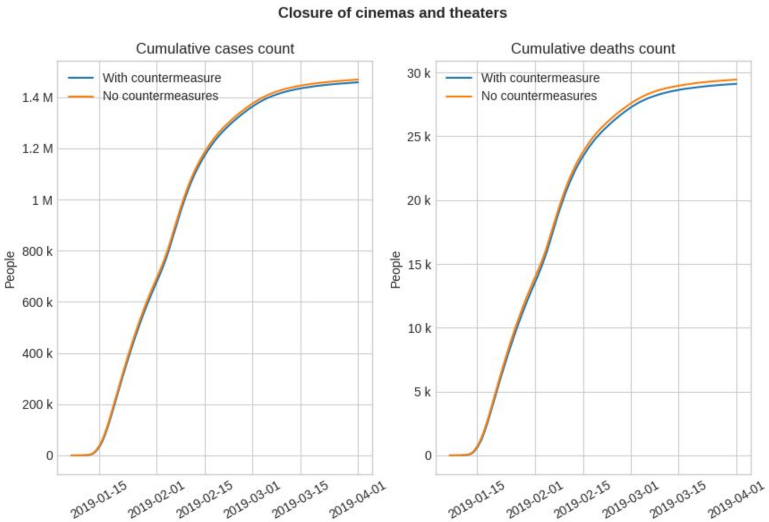
Economic loss & countermeasures effect

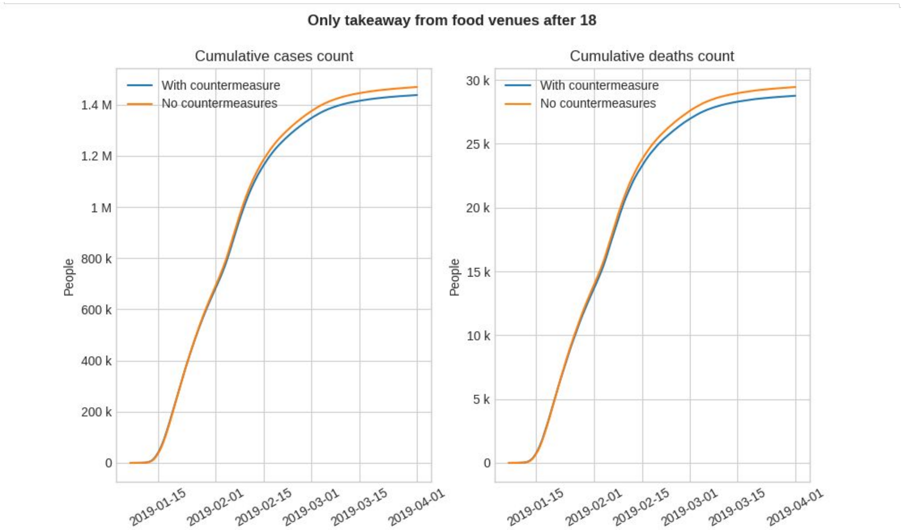
01/07/2019 31/03/2019

Results - Cumulative real / simulated cases

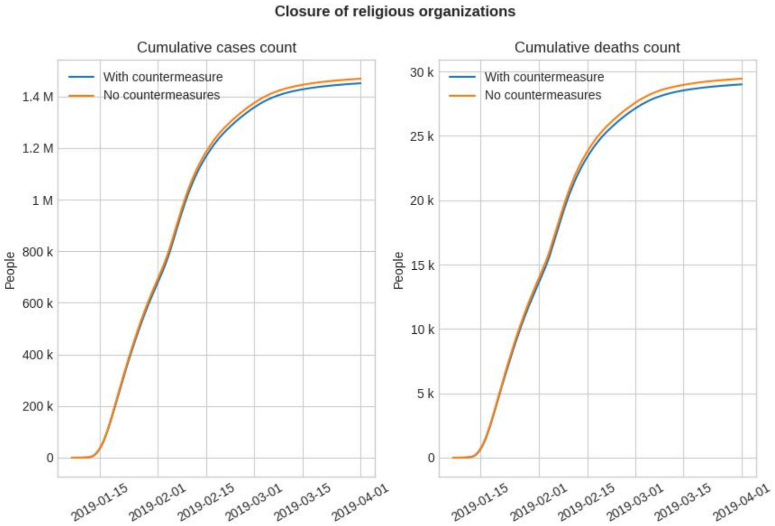


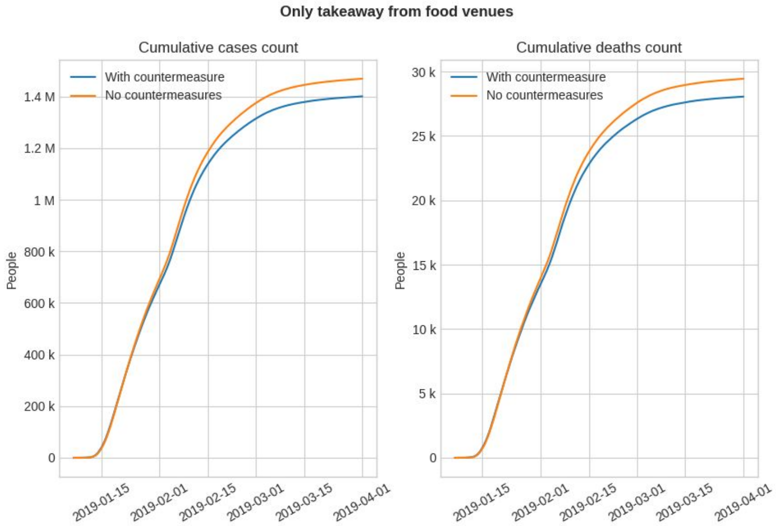
Results - Countermeasure effects (1)



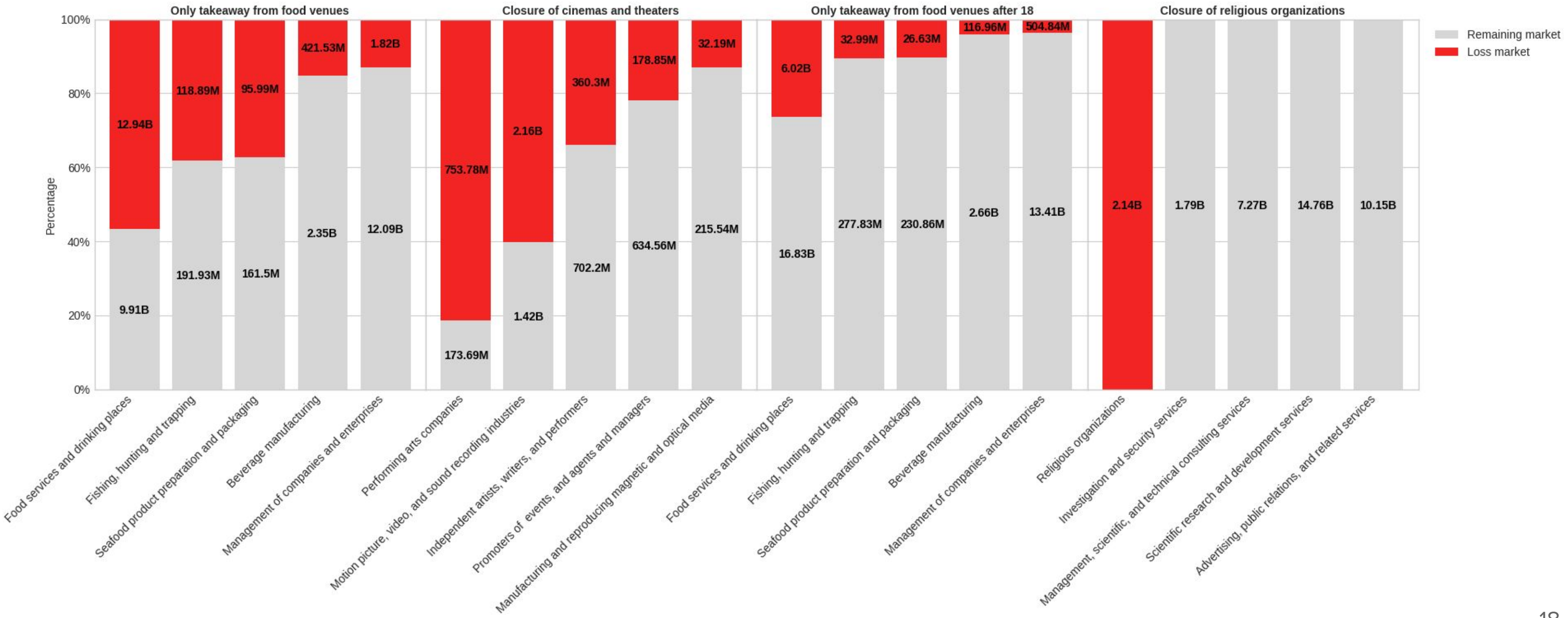


Results - Countermeasure effects (2)

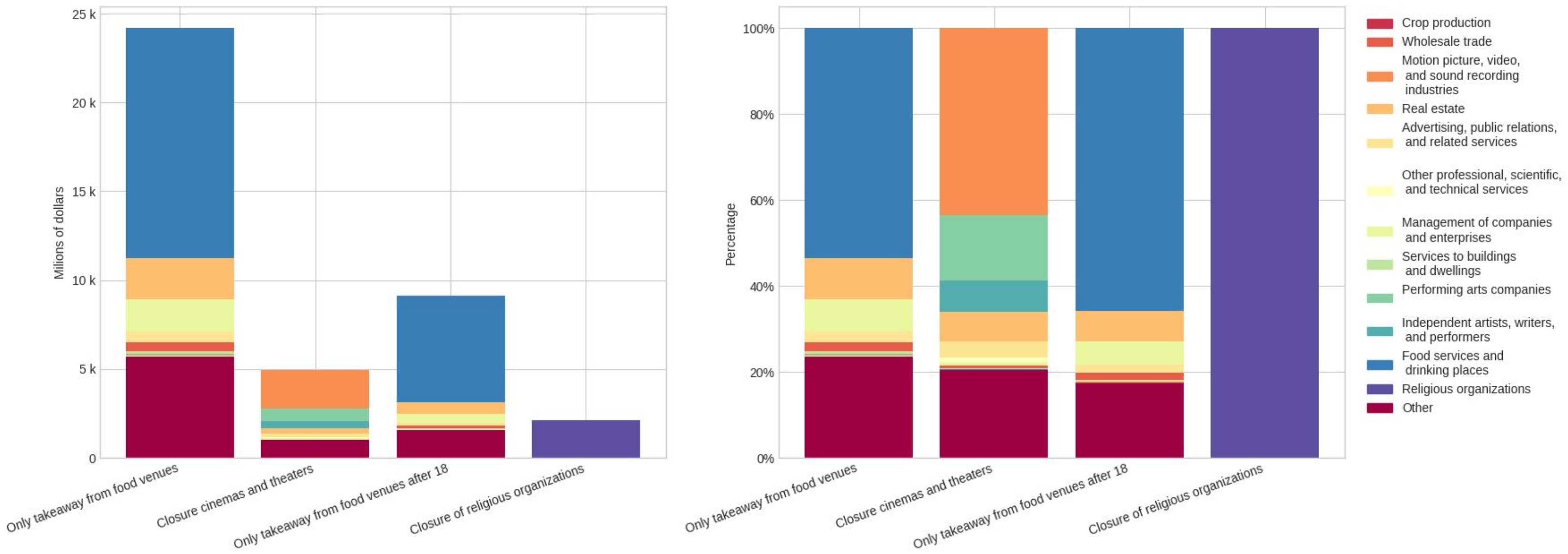




Results - Countermeasure economic impact (sector viewpoint)



Results - Countermeasure economic effects (economy viewpoint)



Results - Conclusion

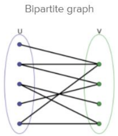
Counter-measure	Economic losses (in B$)	People saved	Cases avoided	Ratio (in M$ x people saved)
Closure of cinemas and theaters	4.95	336	10365	14.7
Closure of religious organizations	2.14	443	17393	4.8
Only takeaway from food venues	24.19	1389	66837	17.4
Only takeaway from food venues after 18	9.14	682	30629	13.4

Conclusion

- New simulation paradigm, combines AI-like workloads (characterized by the use of large quantities of data) with the classic simulation world
- Fills the gap between agent-oriented simulation and high-level statistical techniques
- Can be improved by correlating the disease spreading mechanisms with people social behaviour inside different POI categories.
- From the economic viewpoint, the main problem is the unavailability of data with finer granularity

Discussion

Epidemiological component - Environment

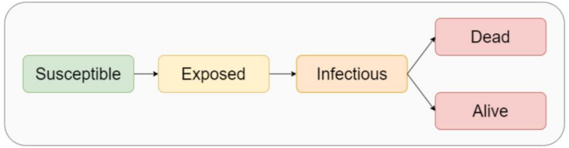


CBGs

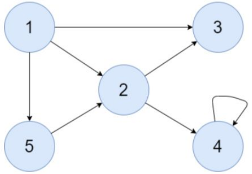
Population between 600 and 3000 people

POIs

Epidemiological component - Model



Economic component - Input Output Theory



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Countermeasure component

Closure of food activities

Closure of cinemas and theaters

Closure of religious organizations

Closure of food activities after 18