To vaccinate or not to vaccinate? A coevolutionary dilemma

Kanchan Mopari   Paolo De Los Rios   Alex Arenas

Alessio Cardillo   Jesús Gómez-Gardeñes

The dilemma

Vaccination is an effective way to prevent the spread of a disease. Despite compelling evidence, we are witnessing the re-emergence of anti-vaccination movements in most of the economically developed countries.

Getting vaccinated can be seen as an act of cooperation since it implies to pay a costs to provide benefits for the whole population. Free-riders, instead, do not pay the cost and assume the risk of getting exposed.

If all the members of the population except one vaccinate, the free-rider benefits of herd immunization effects and places himself in a position of advantage. Such scenario gives rise to a social dilemma that can be studied within the framework of evolutionary game theory.
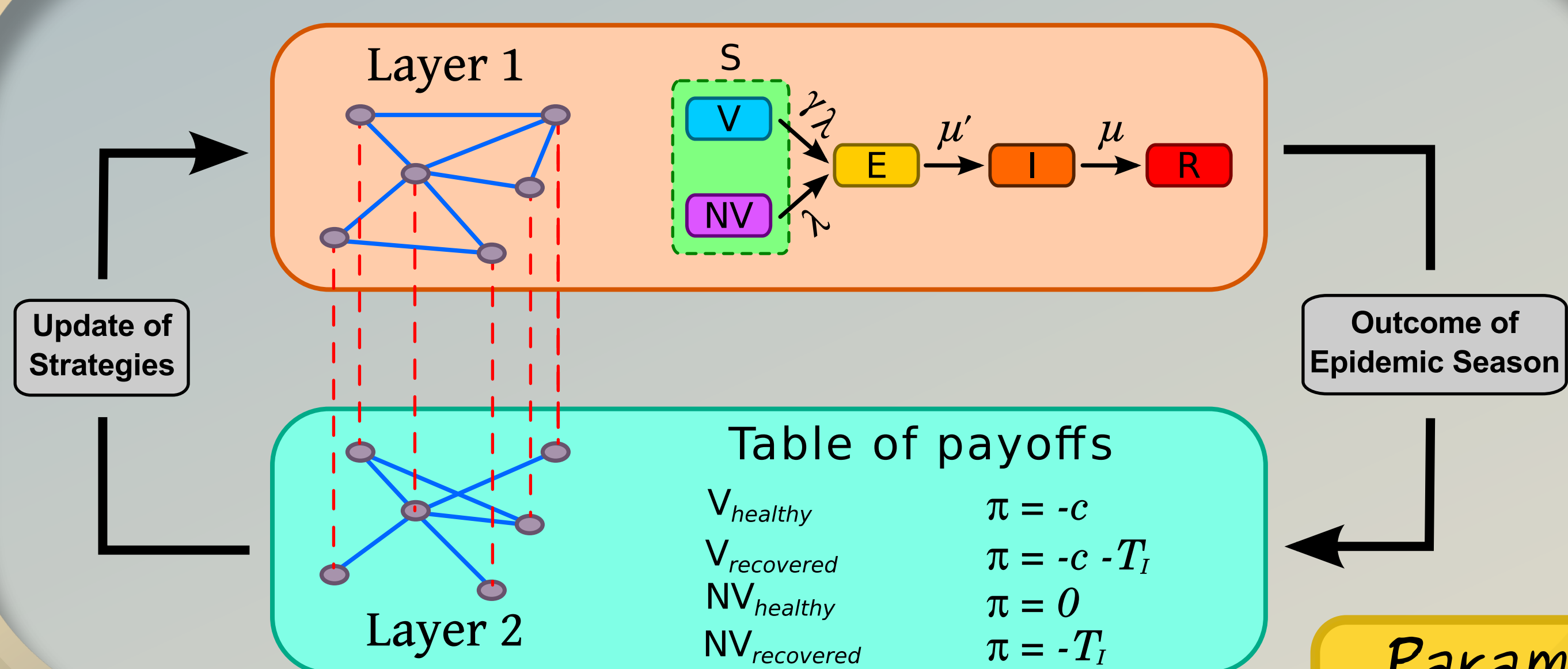
Previous results

Both disease spreading and emergece of cooperation are promoted by networks

Overall behaviour
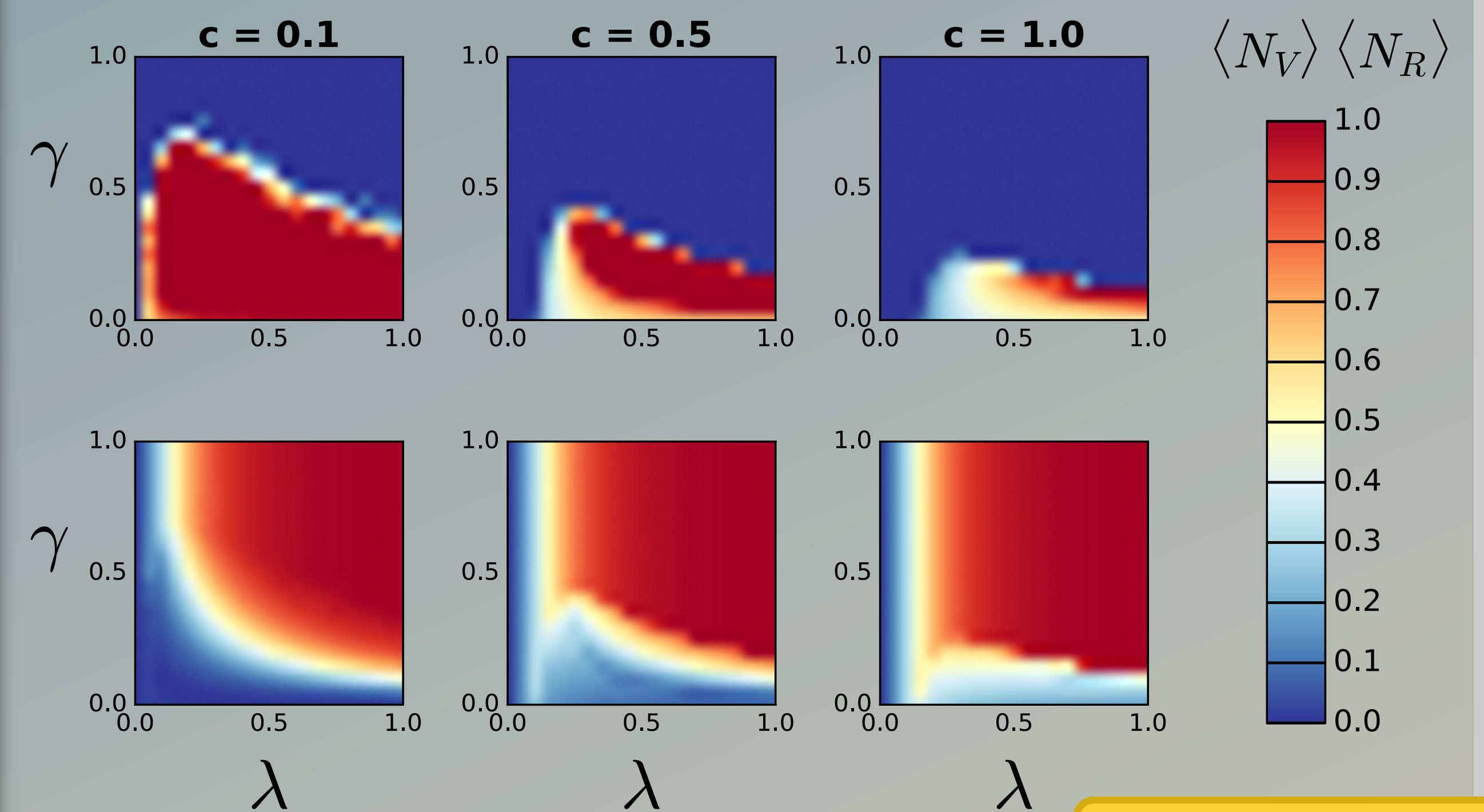
$\langle N_V \rangle \longrightarrow$ Average frac. of vaccined

$\langle N_R \rangle \longrightarrow$ Average frac. of recovered

The Model

Layer 1   S
V
NV

$\gamma\lambda$ → E $\xrightarrow{\mu'}$ I $\xrightarrow{\mu}$ R
λ

Update of Strategies

Outcome of Epidemic Season

Table of payoffs

$V_{healthy}$	$\pi = -c$
$V_{recovered}$	$\pi = -c - T_I$
$NV_{healthy}$	$\pi = 0$
$NV_{recovered}$	$\pi = -T_I$

Layer 2

Networks

ER = Erdős-Rényi

SF = Scale-free

RGG = Random Geometric Graph

Parameters

$\lambda \longrightarrow$ Probability of infection

$\gamma \longrightarrow$ Quality of vaccine (0 = good; 1 = bad)

$c \longrightarrow$ Cost of vaccine

$Z \longrightarrow$ Fraction of Zealots

Role of topology

c = 0.50   c = 1.00

- ER-single
- SF-single
- SF-SF-MP
- SF-SF-MN
- GSF-ERGG

Zealotry

● Z=0% ■ Z=5% ▲ Z=10% ▼ Z=25% ◆ Z=50%
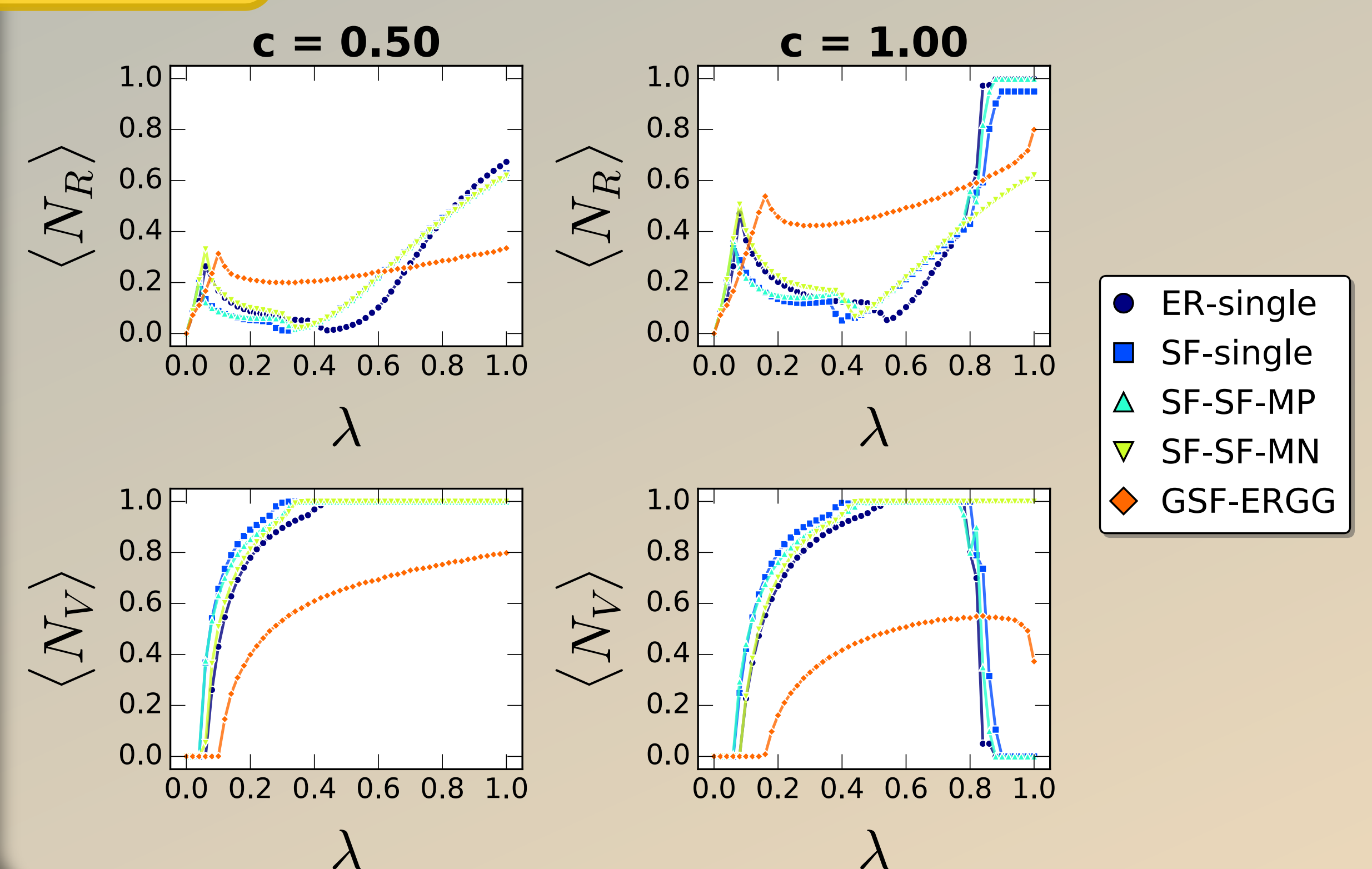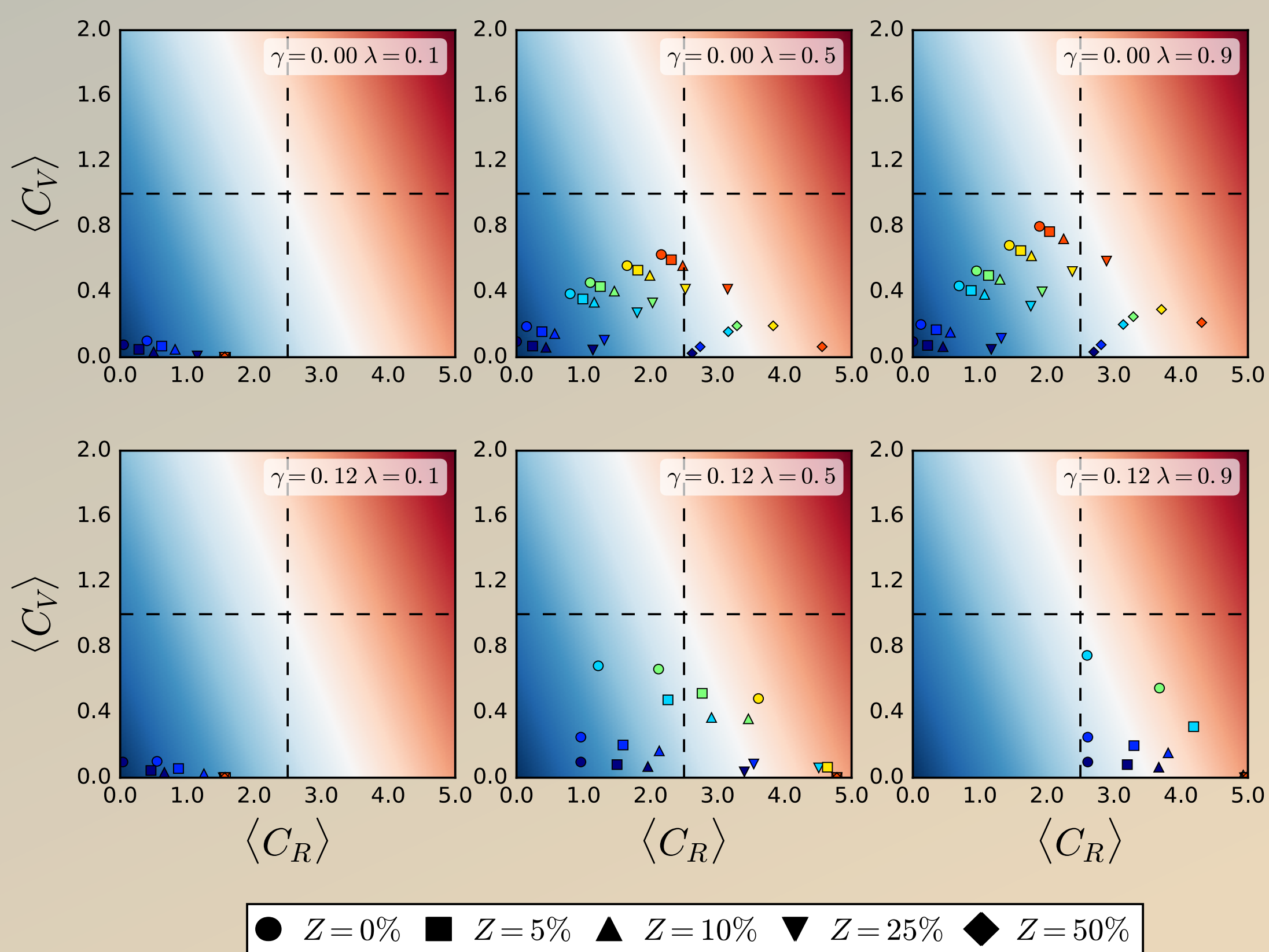
$\langle C_V \rangle \longrightarrow$ Average total cost of vaccine

$\langle C_R \rangle \longrightarrow$ Average total cost of recovering

Conclusions

The coevolution of vaccination behavior and spreading of disease displays features that are not typical of neither of the two processes taken separately.

The values of cost c, quality of vaccine γ and probability of infection λ (as well as topology of interactions) shape the region where cooperation could be observed.

The presence of a certain amount of zealot individuals, Z, drives the system towards the sub-optimal performance regime.

References

Cardillo, A., Reyes-Suárez, C., Naranjo, F., & Gómez-Gardeñes, J. (2013). Evolutionary vaccination dilemma in complex networks. Physical Review E, 88, 32803.

Mopari K., Cardillo A., De Los Rios P., Gòmez-Gardeñes J., & Arenas A. Evolutionary vaccination dilemma on multiplex networks. In preparation

Wang, Z., Andrews, M. A., Wu, Z.-X., Wang, L., & Bauch, C. T. (2015). Coupled disease-behavior dynamics on complex networks: A review. Physics of Life Reviews, 15, 1–29.

Berkley, S. (2015). Make vaccine coverage a key UN health indicator. Nature, 526, 165–165.

alessio.cardillo@epfl.ch

http://bifi.es/~cardillo/

ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE