A population dynamics model on the social damage by negative information spread

有害な情報拡散による社会的被害に関する個体群動態モデル

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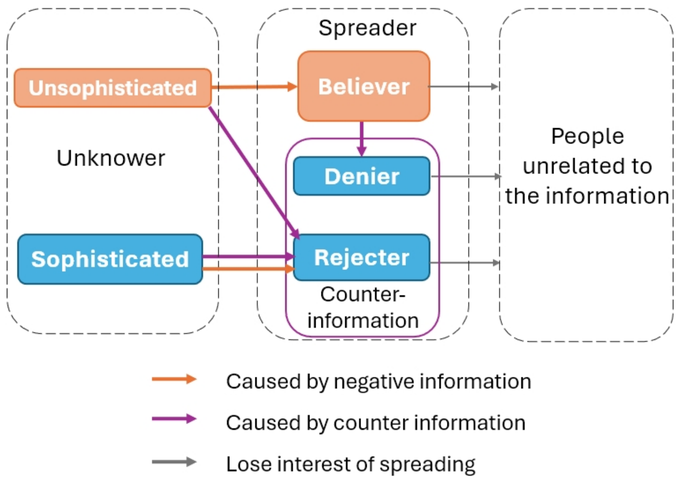
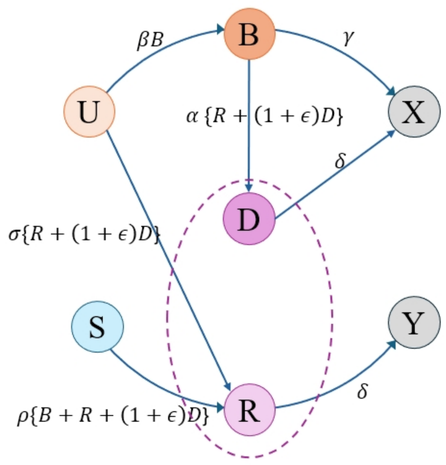
Many rumors and fake news spread and fade out with an autonomous purging by some counter information given by people themselves. In this work, a population dynamic model on the reaction of a spreading negative information and its counter-information is considered. This work focuses on the role of the people who release the counter-information to purge the negative one from the community.

Assumption



- The total population size is constant.
- When a piece of negative information enters the community, an individual has three possible states: unknower, spreader, and those who are not interest in the information.
- Based on the ability to identify the fakeness of the negative information, the unknowers are classified into “unsophisticated” and “sophisticated”.
- The counter information is generated by those who reject to believe the negative information, and then spreaded among the community.

Mathematical model



$$\frac{dU}{dt} = -\beta BU - \sigma\{R + (1+\epsilon)D\}U; \qquad \frac{dS}{dt} = -\rho\{B + R + (1+\epsilon)D\}S;$$
$$\frac{dB}{dt} = \beta BU - \alpha\{R + (1+\epsilon)D\}B - \gamma B;$$
$$\frac{dR}{dt} = \rho\{B + R + (1+\epsilon)D\}S + \sigma\{R + (1+\epsilon)D\}U - \delta R;$$
$$\frac{dD}{dt} = \alpha\{R + (1+\epsilon)D\}B - \delta D;$$
$$\frac{dX}{dt} = \gamma B + \delta D; \qquad \frac{dY}{dt} = \delta R,$$

with initial condition

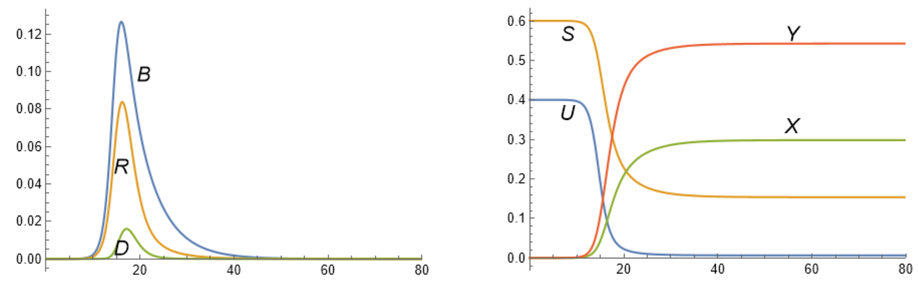
$$U(0) > 0;\ S(0) > 0;\ B(0) > 0;\ R(0) \geq 0;\ D(0) = 0;\ X(0) = 0;\ Y(0) = 0,$$

where

$$U(0) + B(0) = (1-p)N; \qquad S(0) + R(0) = pN.$$

- U, S: population sizes of “unsophisticated” and “sophisticated” people, who are susceptible to the information.
- B, R, D: population size of “believer”, “rejecter” and “denier” respectively, who participate in the spread of information.
- X, Y: population size of those who lost interest in the information.
- $N = U + S + B + R + D + X + Y$: the total population size.
- p: the proportion of the sophisticated people in the community.
- β: coefficient of unsophisticated people become “believer”.
- σ: coefficient of unsophisticated people become “rejecter”.
- ρ: coefficient of sophisticated people become “rejecter”.
- α: coefficient of transition from “believer” to “denier”.
- γ: coefficients of a negative information spreader lose interest in spreading.
- δ: coefficients of a counter information spreader lose interest in spreading.
- ϵ: the extra persuade power of information released by “denier” than “rejecter”.

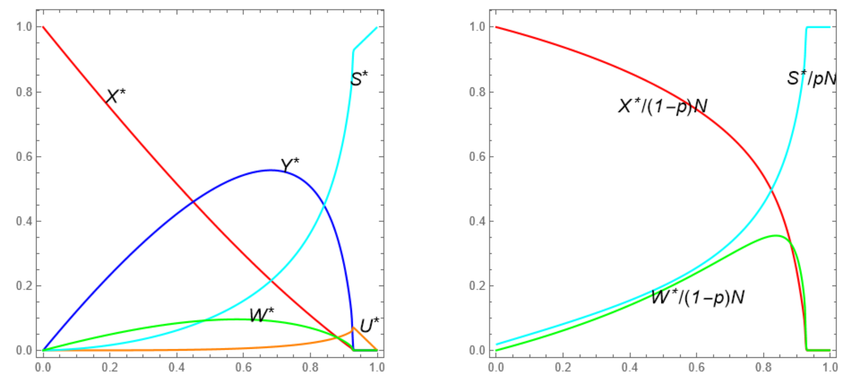
Temporal variation



$p = 0.6$; $\beta = 3.0$; $\sigma = 1.5$; $\alpha = 1.5$; $\rho = 0.8$; $\gamma = 0.2$; $\delta = 1.0$; $\epsilon = 0.0$; $U(0) = (1-p)N - B(0)$; $S(0) = p$; $B(0) = 1.0 \times 10^{-7}$; $R(0) = D(0) = X(0) = Y(0) = 0$; $N = 1.0$.

$$(U, S, B, R, D, X, Y) \to (U^*, S^*, 0, 0, 0, X^*, Y^*) \text{ as } t \to \infty.$$

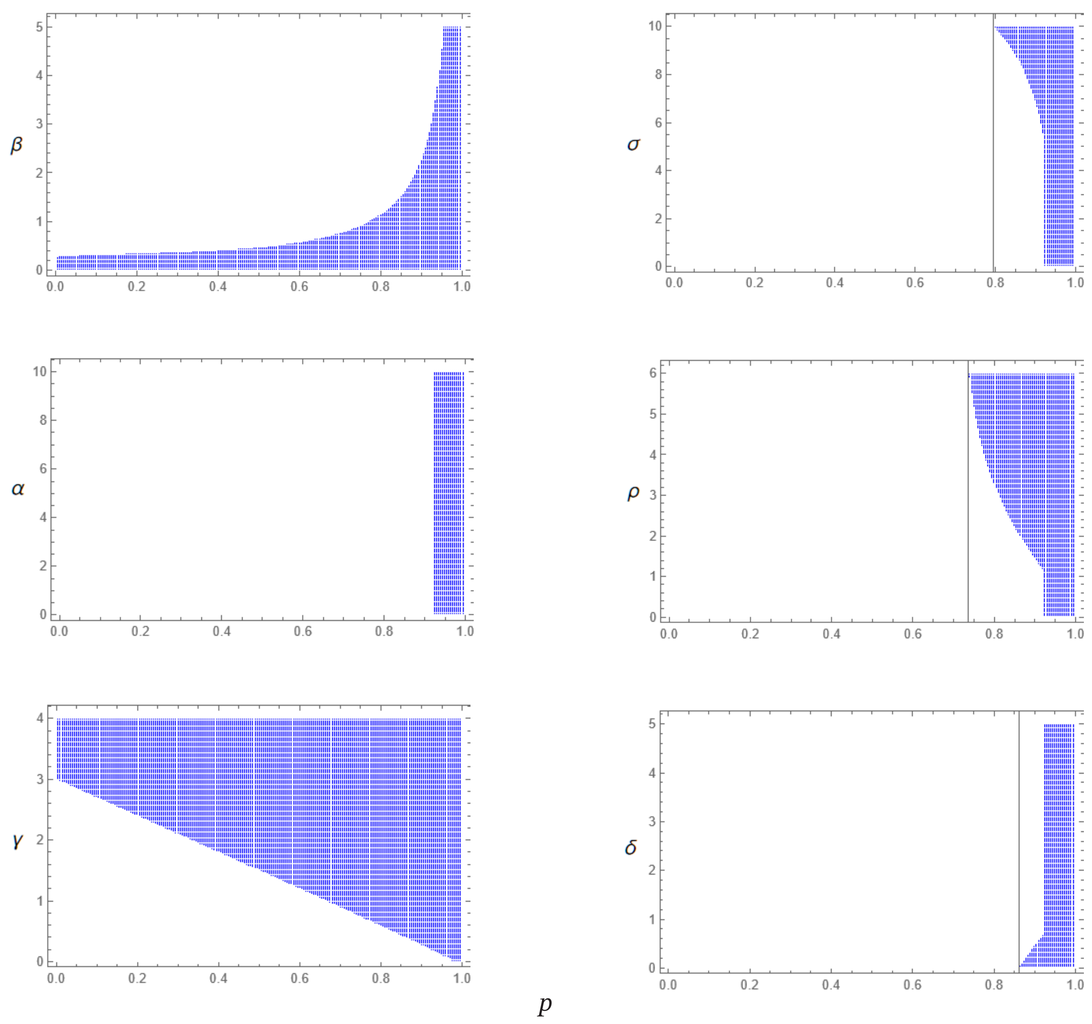
Final state



$\beta = 3.0$; $\sigma = 1.5$; $\alpha = 1.5$; $\rho = 0.8$; $\gamma = 0.2$; $\delta = 1.0$; $\epsilon = 0.0$; $U(0) = (1-p)N - B(0)$; $S(0) = p$; $B(0) = 1.0 \times 10^{-8}$; $R(0) = D(0) = X(0) = Y(0) = 0$; $N = 1.0$.

$W^* := (1-p)N - U^* - X^*$ is the population size of unsophisticated people who received the counter information before believing in the negative information.

Parameter dependence of the social damage



$\beta = 3.0$; $\sigma = 1.5$; $\alpha = 1.5$; $\rho = 0.8$; $\gamma = 0.2$; $\delta = 1.0$; $\epsilon = 0.0$; $U(0) = (1-p)N - B(0)$; $S(0) = p$; $B(0) = 1.0 \times 10^{-8}$; $R(0) = D(0) = X(0) = Y(0) = 0$; $N = 1.0$.

The filled area is the numerically estimated parameter region that makes X^* sufficiently small.

Remarks

- We have found the existence of a critical value p_c for the proportion of sophisticated people in the community p. If $p > p_c$, people can successfully suppress the social damage by the negative information to be minimized.
- We are going to investigate the criticality with the social structure to consider the condition that makes the social damage by a negative information minimal.