Life History Theory of the Behavioural Immune System - A Theoretical Perspective

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Highlights

- This study proposes a theoretical model of the Behavioural Immune System (BIS) as an optimal life-history strategy to maximize an individual's reproductive fitness.
- Diseases not only harm an individual's survival and reproductive success but also carry the risk of disease transmission to relatives, particularly offspring.
- We employ the finite-horizon stochastic dynamic programming method by taking the reproductive capacity and the number of current offspring as state variables.
- The results suggest that a lower reproduction rate drives a higher activation of the behavioural immune reaction under certain condition.

Objectives

- We derive the optimal behavioral immune response (i.e., contact level) that maximizes the total number of offspring at the end of the reproductive period and analyze its qualitative patterns.

The Model

$$\max_{\{x_t\}_{t=0}^{T-1}} \mathbb{E}\left[\sum_{t=0}^{T-1} B_t(x_t) + \alpha \cdot F_T(c_T)\right]$$

s.t. $x_t \in [0, \overline{x}]$, $s_t \in [0, \overline{s}]$,

$$s_{t+1} = f(x_t, s_t, \omega_i)$$

$$c_{t+1} = q(x_t, s_{t+1}, c_t, \omega_i)$$

where

s_0 (Initial Reproductive Capacity) given

$$B_t(x_t) = \begin{cases} B(x_t) & \text{if } s_t > 0 \\ 0 & \text{otherwise} \end{cases}$$

$$F_T(c_T) = \begin{cases} c_T & \text{if } c_T > 0 \\ 0 & \text{otherwise} \end{cases}$$

$$s_{t+1} = f(x_t, s_t, \omega_i) = \begin{cases} s_t & \text{if } \omega_1 \\ s_t - \frac{\mathbb{C}^s}{s_t+1} & \text{if } \omega_2 \\ 0 \cdot s_t & \text{if } \omega_3 \end{cases}$$

$$c_{t+1} = q(x_t, s_{t+1}, c_t, \omega_i) = \begin{cases} g(x_t, c_t, \omega_i) + \lambda \cdot s_{t+1} & \text{if } s_{t+1} > 0 \\ g(x_t, c_t, \omega_i) & \text{otherwise} \end{cases}$$

$$g(x_t, c_t, \omega_i) = \begin{cases} c_t & \text{if } \omega_1 \\ c_t - \frac{\mathbb{C}^c}{c_t+1} & \text{if } \omega_2 \\ 0 \cdot c_t & \text{if } \omega_3 \end{cases}$$

Probability of each state:

$$\mathbb{P}(\omega_i \mid x_t) = \begin{cases} 1 - \mathbb{P}(x_t) & \text{if } \omega_1 \\ (1-\kappa) \cdot \mathbb{P}(x_t) & \text{if } \omega_2 \\ \kappa \cdot \mathbb{P}(x_t) & \text{if } \omega_3 \end{cases}$$

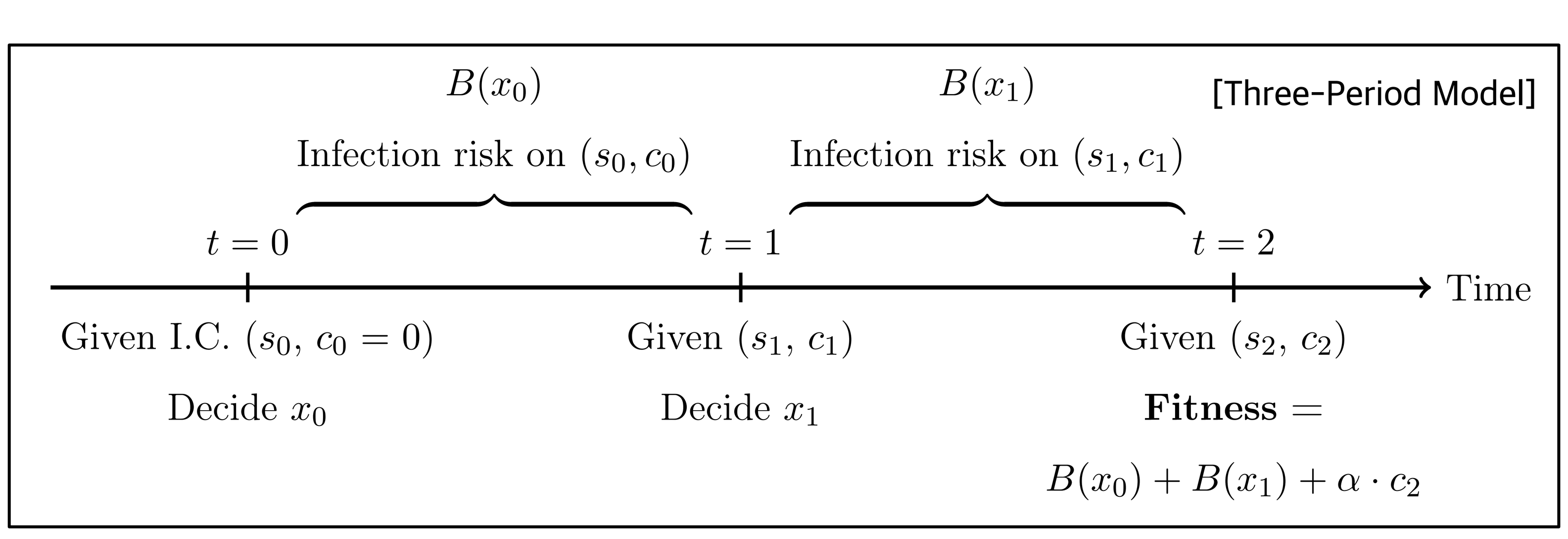
$$\mathbb{P}(x_t) = 1 - (1-\beta)^{\mathbb{I} \cdot x_t}$$

State definitions:

ω_1 : (No infection)

ω_2 : (Sublethal infection)

ω_3 : (Fatal infection)



References

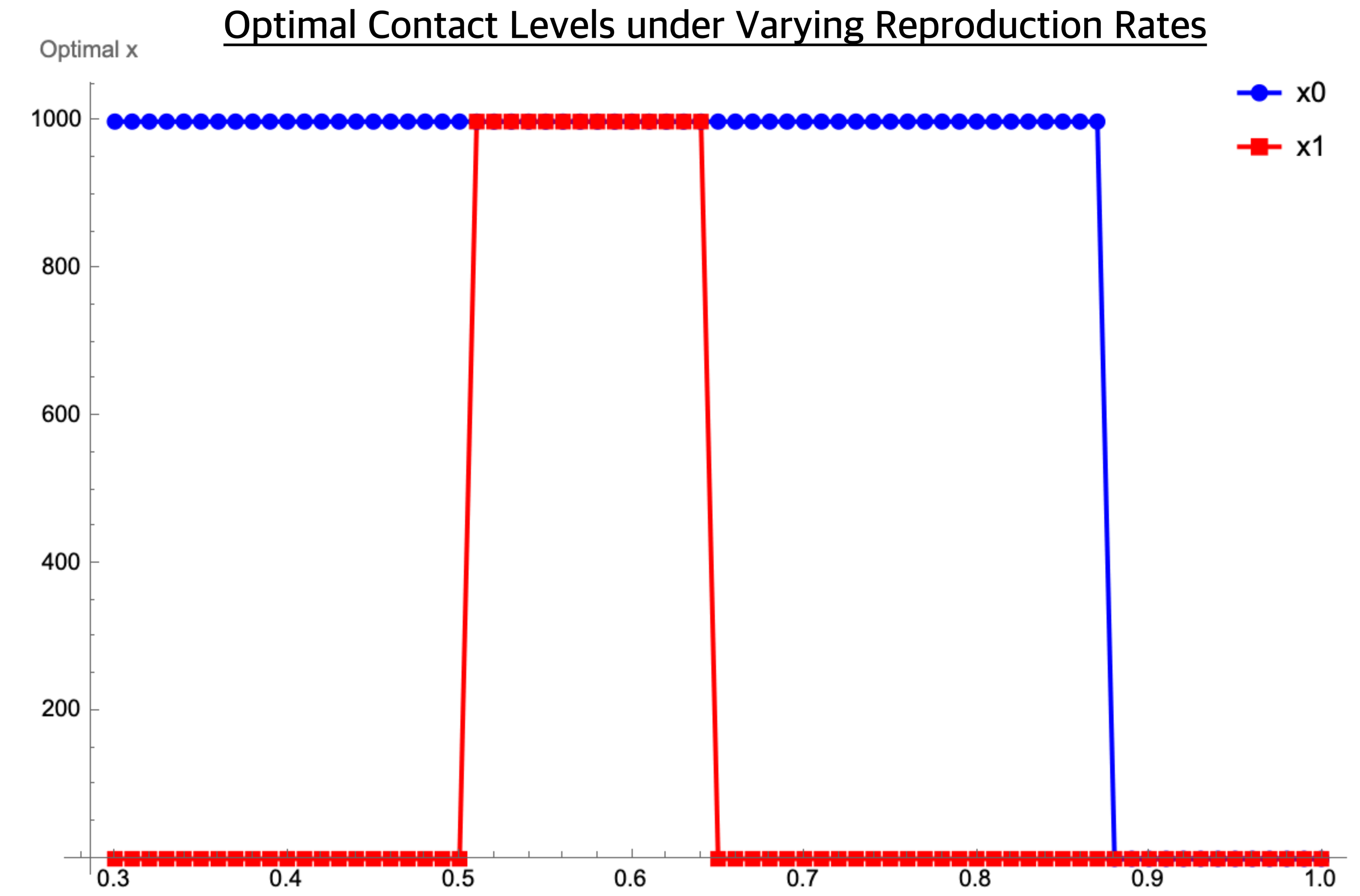
- Schaller, M. (2016). The behavioral immune system. In D. M. Buss (Ed.), The handbook of evolutionary psychology (pp. 206-224). John Wiley & Sons.
- Goodman, D. (1982). Optimal life histories, optimal notation, and the value of reproductive value. The American Naturalist, 119(6), 803-823.

Results

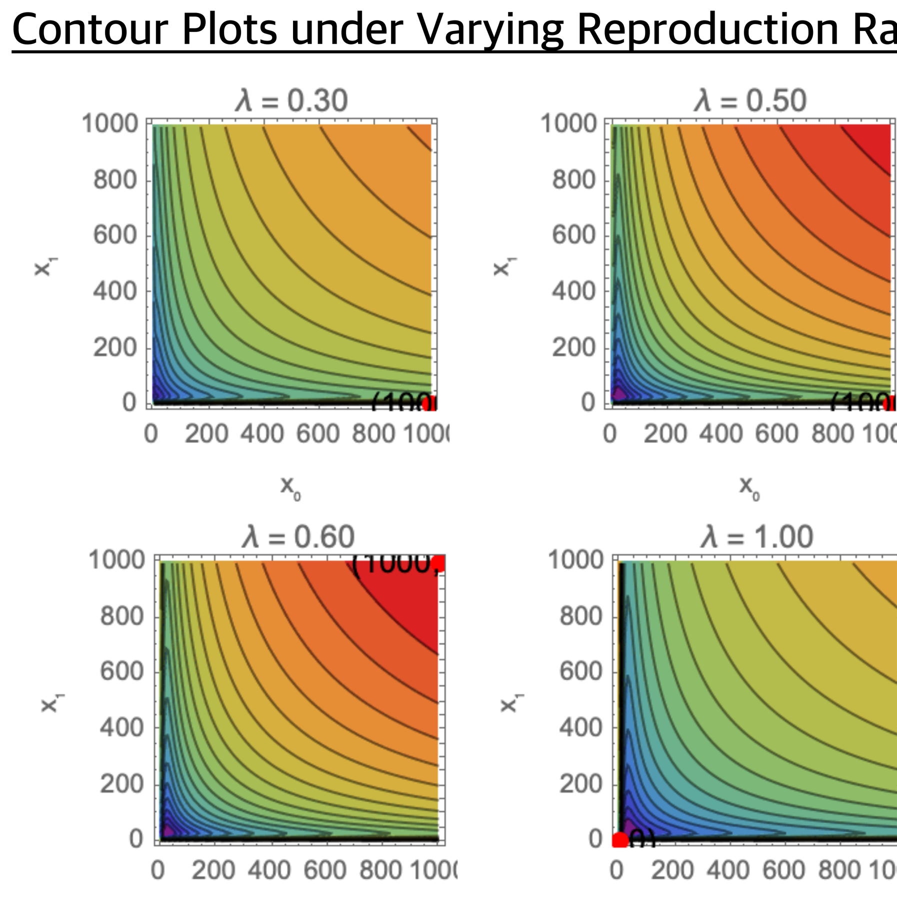
Table 1: Model Parameters and Functional Forms

Description	Symbol / Function	Value / Specification
Contact level domain (control)	$x_t \in [0, \bar{x}_t]$	$[0, 1000]$ (grid search)
State variable 1. Reproduction Capacity	$s_t \in [0, \bar{s}_t]$	(IC) $s_0 = 100$
State variable 2. The number of children	c_t	
Utility function	$B(x_t)$	$\ln(x_t)$
Weight on the biological fitness	α	2
A law of motion for reproductive capacity	$f(s_t, x_t)$	$s_t - k \cdot p(x_t) \cdot s - (1-k) \cdot p(x_t) \cdot \left(\frac{\mathbb{C}^s}{s_t+1}\right)$
A law of motion for number of children	$g(c_t, x_t)$	$c_t - k \cdot p(x_t) \cdot c_t - (1-k) \cdot p(x_t) \cdot \left(\frac{\mathbb{C}^c}{c_t+1}\right)$
Reproduction rate parameter	λ	varies in $[0.3, 1.0]$
Probability of infection	$p(x_t)$	$1 - q^{x_t}$
Infection rate	$1 - q$	0.1
Mortality risk under infection	k	0.01
Sublethal infection cost on s_t	$\mathbb{C}^s$	100
Sublethal infection cost on c_t	$\mathbb{C}^c$	100

Optimal Contact Levels under Varying Reproduction Rates



Contour Plots under Varying Reproduction Rates



Conclusions

- This study models the dynamic trade-off between infection risk—considering both self-infection and subsequent transmission to offspring—and the fitness benefits of contact, using the reproductive period as the planning horizon.
- In particular, we examine how variations in reproductive rate influence behavioral immune responses by incorporating fertility effects into the model.
- Comparative statics on Reproduction rate (λ) has been conducted.
- We observe bang-bang transitions in the optimal contact level occurring around a reproduction rate (λ) of ≈ 0.6. This discontinuity reflects the locally non-concave structure of the law of motion, particularly when combined with the nonlinear effect of λ.
- This result suggests that a low birth rate can lead to heightened disgust responses, potentially resulting in a drastic behavioral shift.