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Analyzing Dynamic Systems: A Comparison of System Dynamics and Structural Equation Modeling

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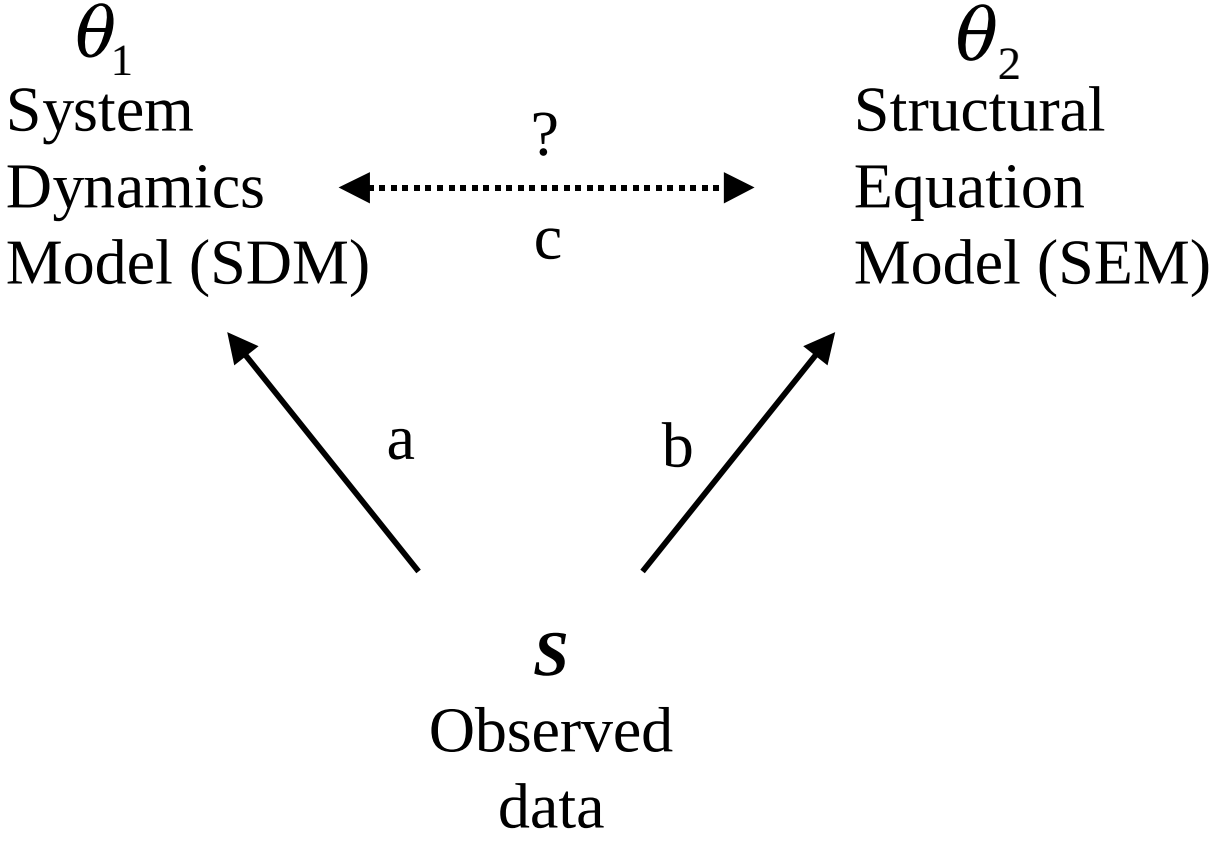
Overview

- Background
- Approach
- Comparisons
- Conclusions

Background

- System dynamics modeling (SDM)
- Structural equation modeling (SEM)
- Similarity of features that are modeled
- Tendency to see SDM and SEM as the same
- Demonstrating differences between SDM and SEM

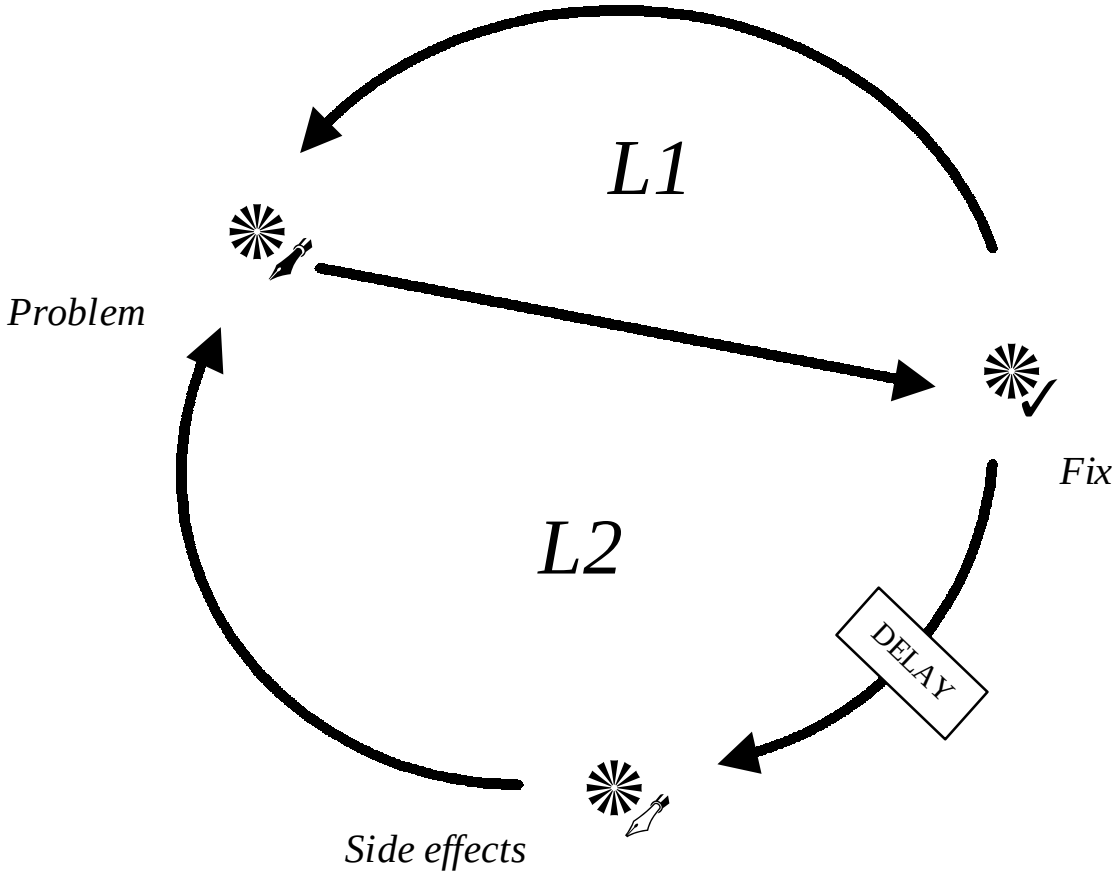
Do SDM and SEM generate "equivalent" models?



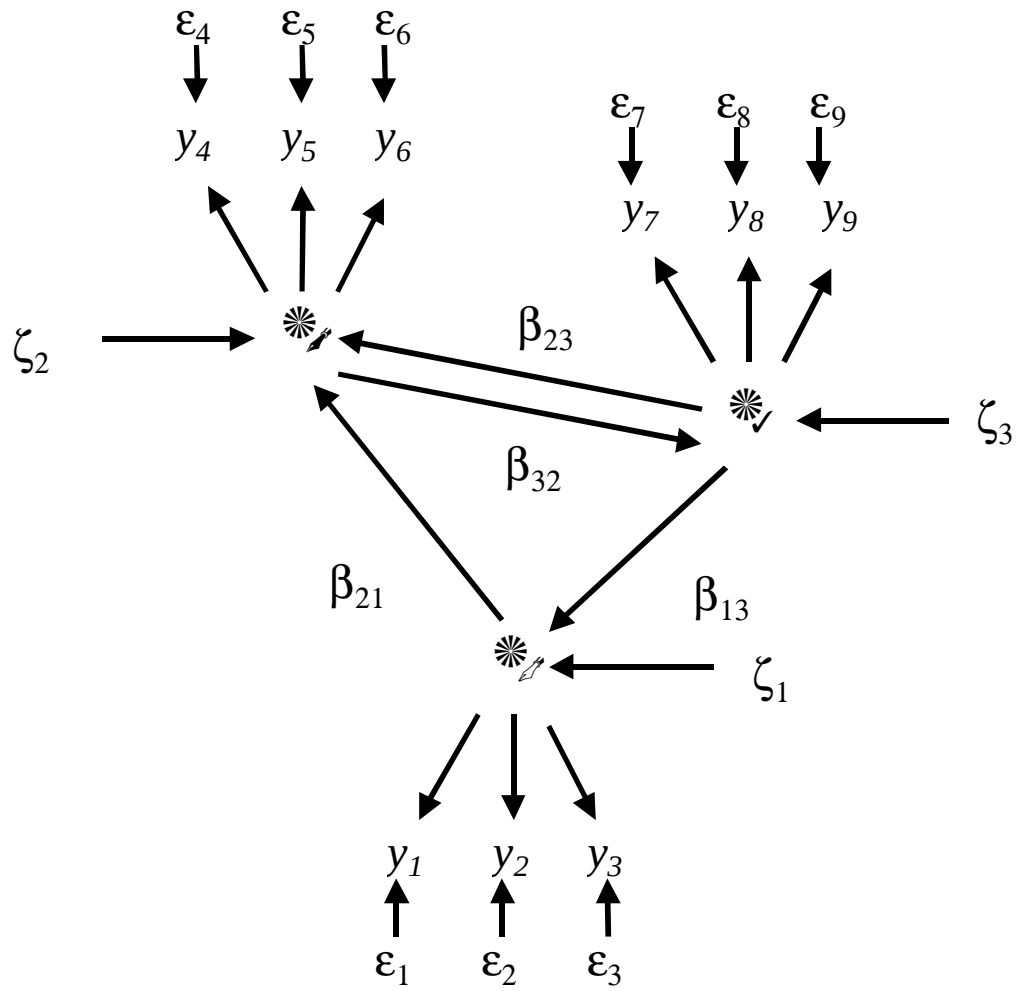
Approach

- Develop a system dynamics model.
- Use the system dynamics model to generate simulated observed data, which implies by definition that the system dynamics model fits the observed data.
- Generate structural equation models that fit the observed data.
- Test structural equation model fit with observed data, which is then a test of fitness with the system dynamics model.

“Fixes That Fail”
Causal Loop Diagram



Path Diagram



Latent Model

System Dynamics Model

$$\frac{\partial \eta_1}{\partial t} = \xi_2 \eta_3 + \eta_{1,t=0}$$

$$\frac{\partial \eta_2}{\partial t} = -\eta_2 \eta_3 + \eta_1 + \xi_1$$

$$\frac{\partial \eta_3}{\partial t} = -1.1 \cdot \eta_3 + \eta_2 + \eta_{3,t=0}$$

Structural Equation Model

$$\eta_1 = \beta_{13} \eta_3 + \zeta_1$$

$$\eta_2 = \beta_{21} \eta_1 + \beta_{23} \eta_3 + \zeta_2$$

$$\eta_3 = \beta_{32} \eta_2 + \zeta_3$$

Measurement Model

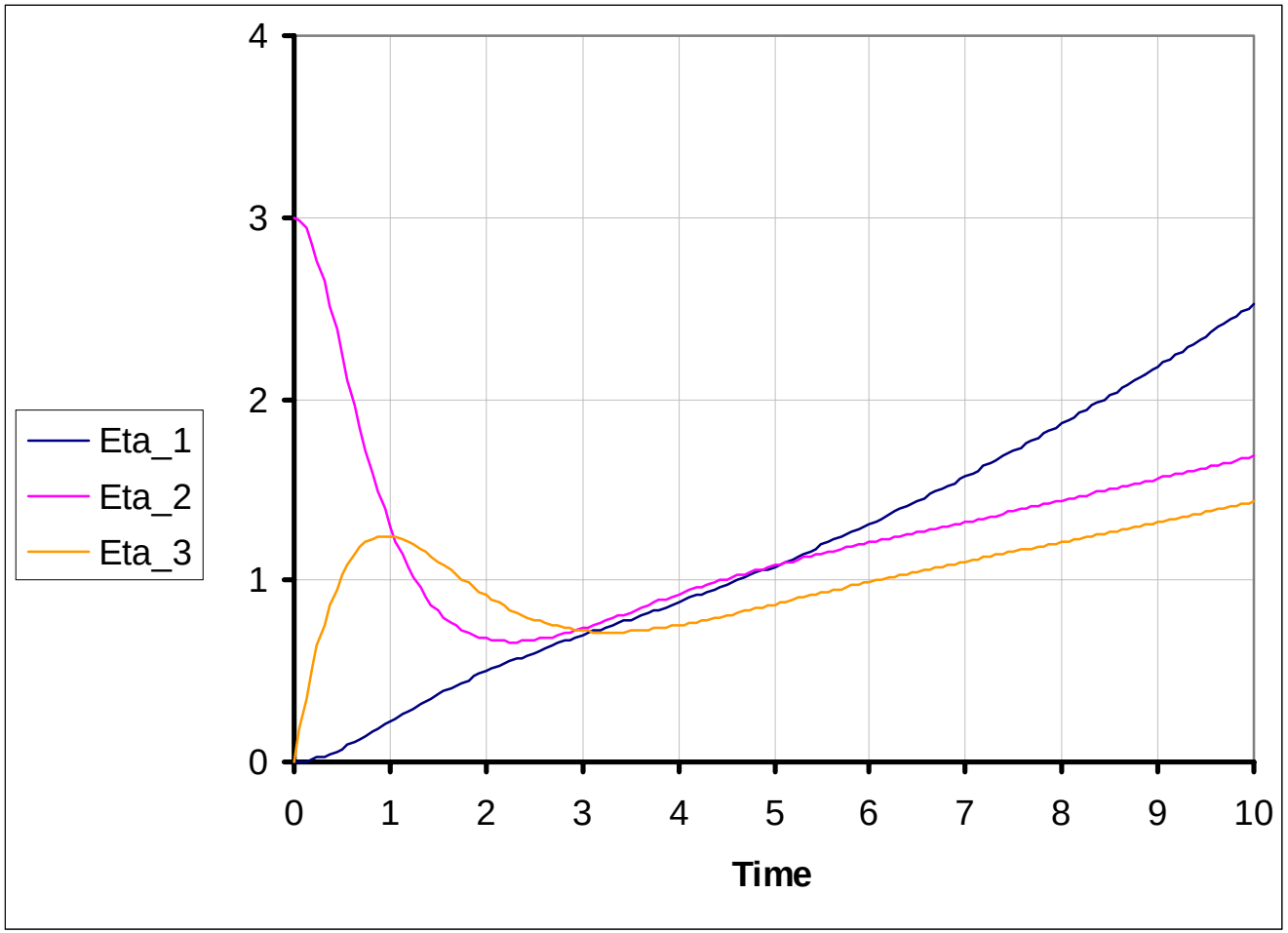
System Dynamics Model

$$y_1(t_s) = \eta_1(t_s) + \varepsilon_1$$
$$y_2(t_s) = \eta_1(t_s) + \varepsilon_2$$
$$y_3(t_s) = \eta_1(t_s) + \varepsilon_3$$
$$y_4(t_s) = \eta_2(t_s) + \varepsilon_4$$
$$y_5(t_s) = \eta_2(t_s) + \varepsilon_5$$
$$y_6(t_s) = \eta_2(t_s) + \varepsilon_6$$
$$y_7(t_s) = \eta_3(t_s) + \varepsilon_7$$
$$y_8(t_s) = \eta_3(t_s) + \varepsilon_8$$
$$y_9(t_s) = \eta_3(t_s) + \varepsilon_9$$

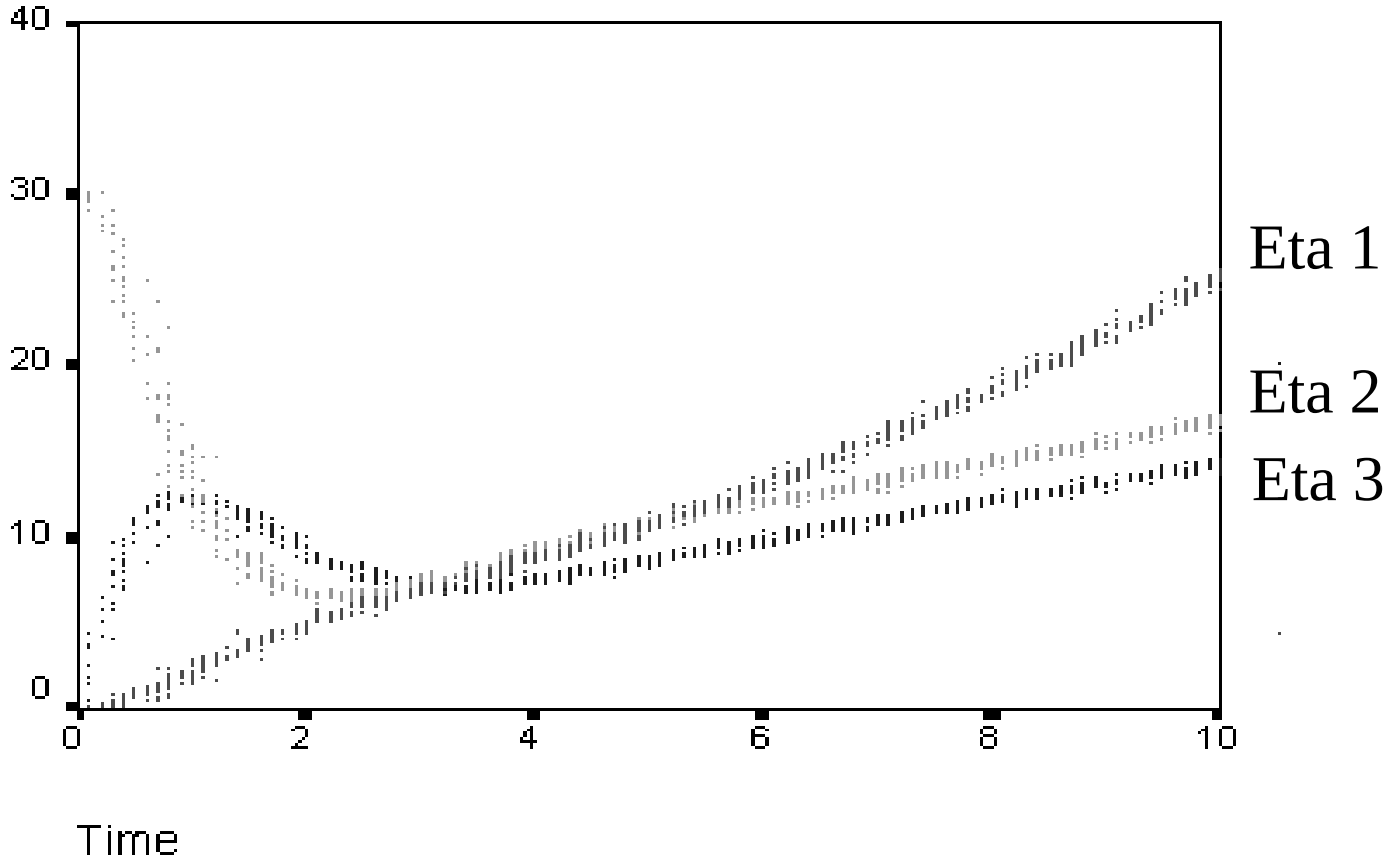
Structural Equation Model

$$y_1 = \eta_1 + \varepsilon_1$$
$$y_2 = \eta_1 + \varepsilon_2$$
$$y_3 = \eta_1 + \varepsilon_3$$
$$y_4 = \eta_2 + \varepsilon_4$$
$$y_5 = \eta_2 + \varepsilon_5$$
$$y_6 = \eta_2 + \varepsilon_6$$
$$y_7 = \eta_3 + \varepsilon_7$$
$$y_8 = \eta_3 + \varepsilon_8$$
$$y_9 = \eta_3 + \varepsilon_9$$

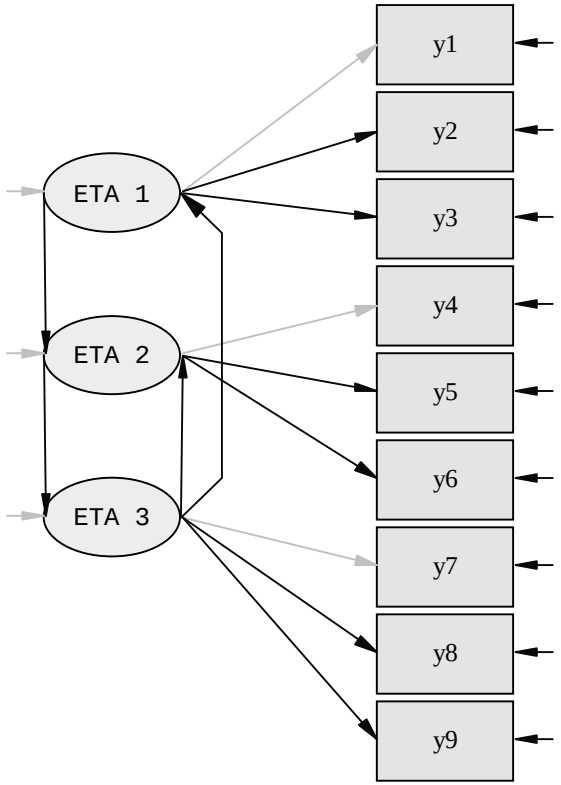
SDM



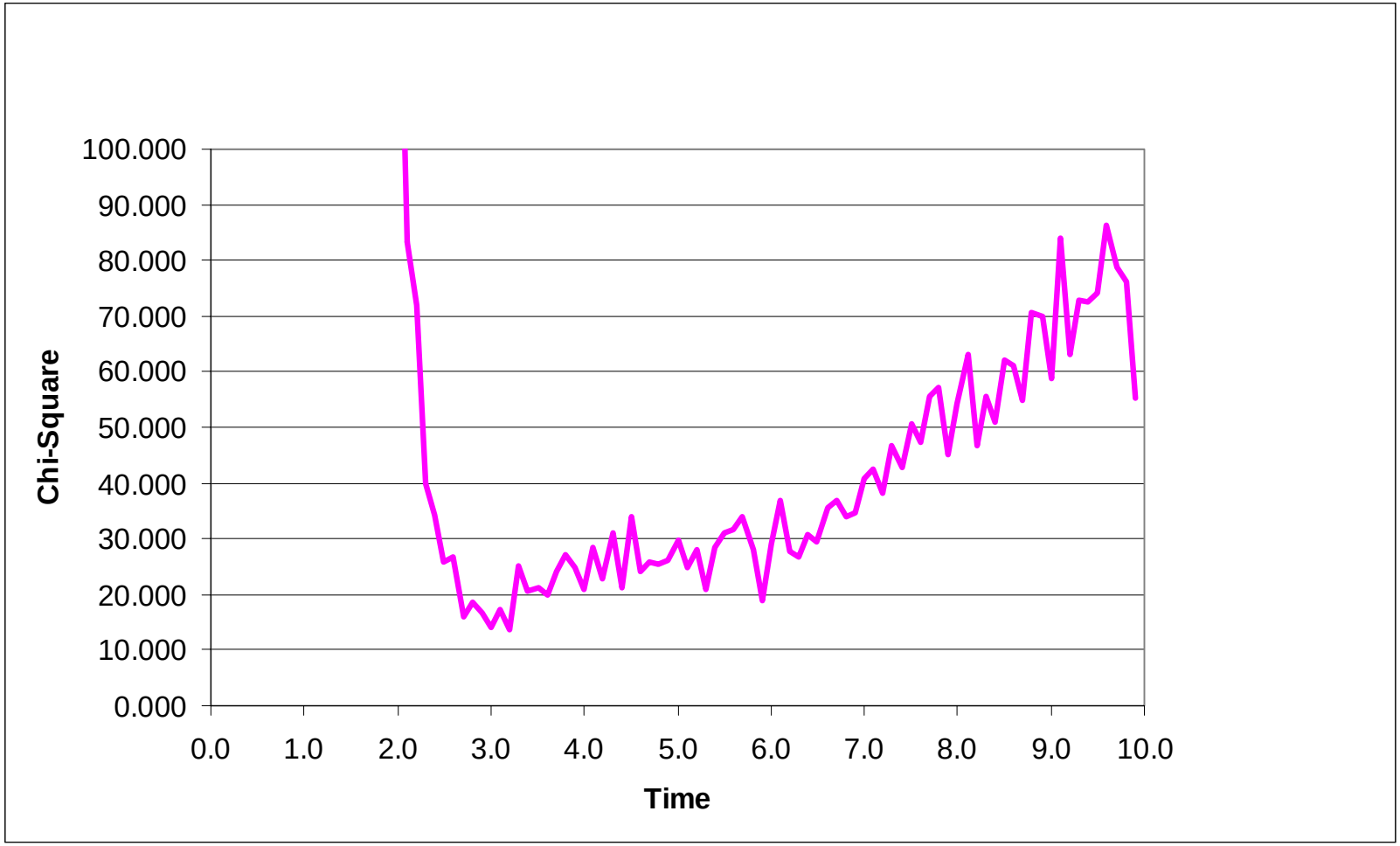
1% of simulated values



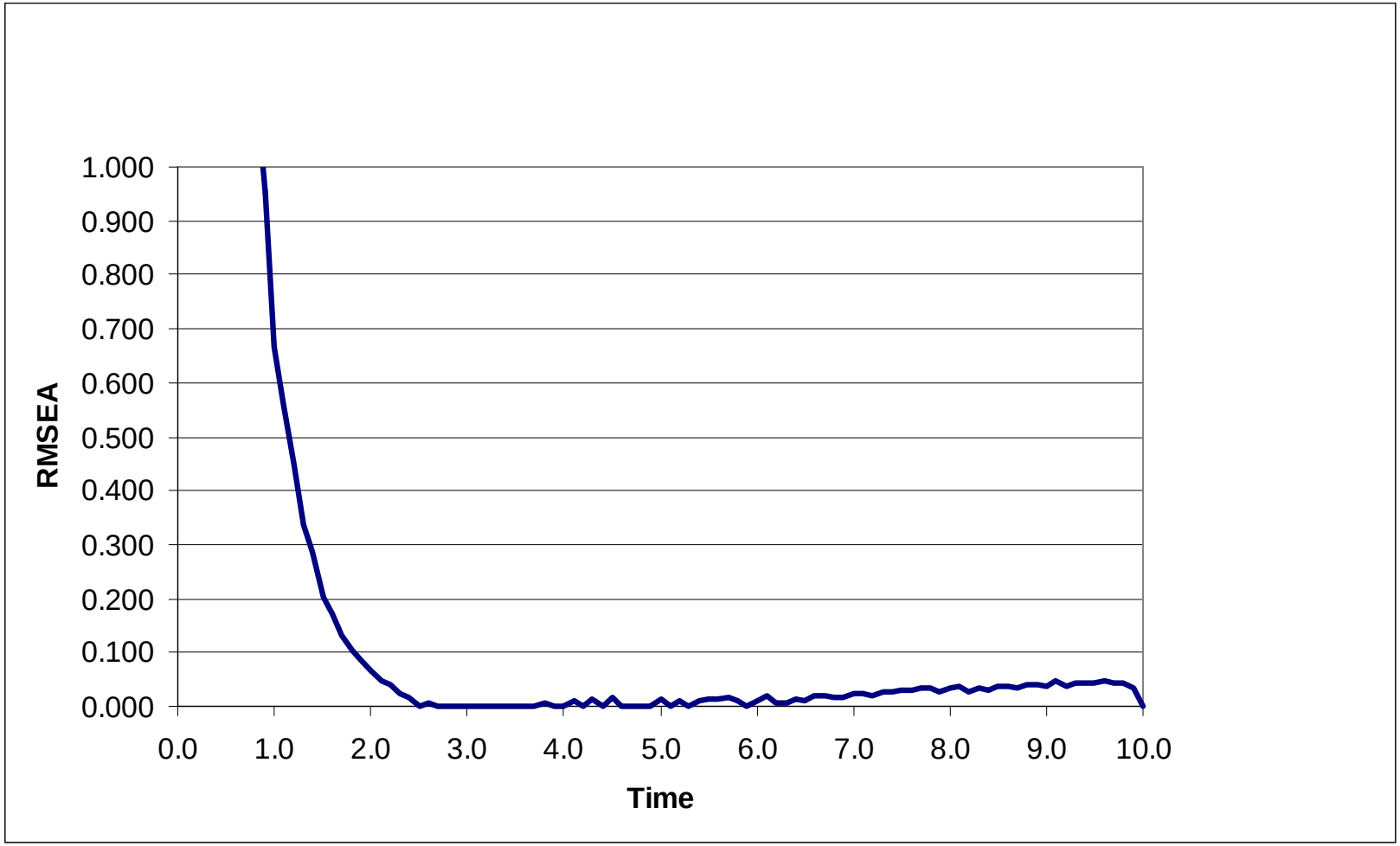
LISREL Model 1



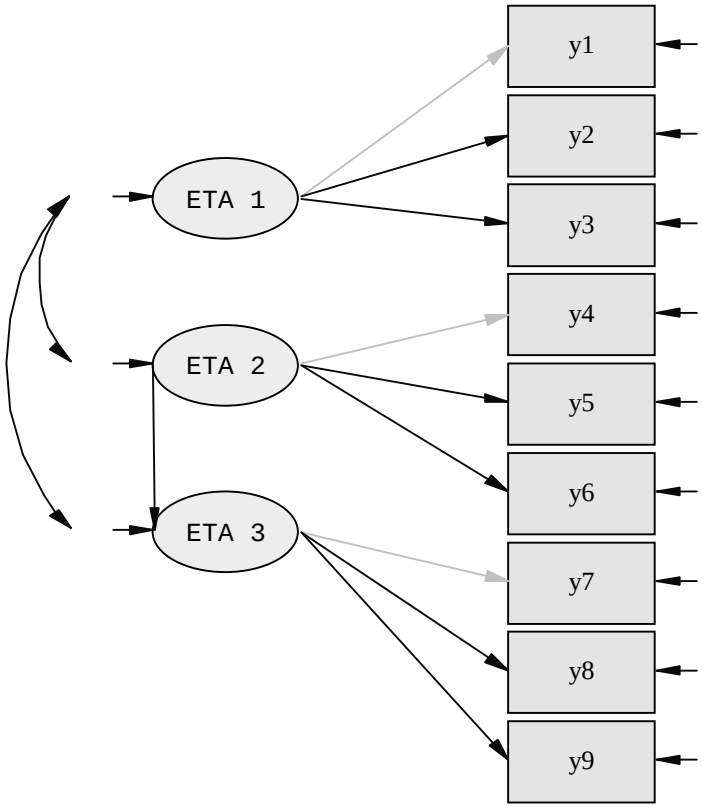
Model 1 Chi-Square



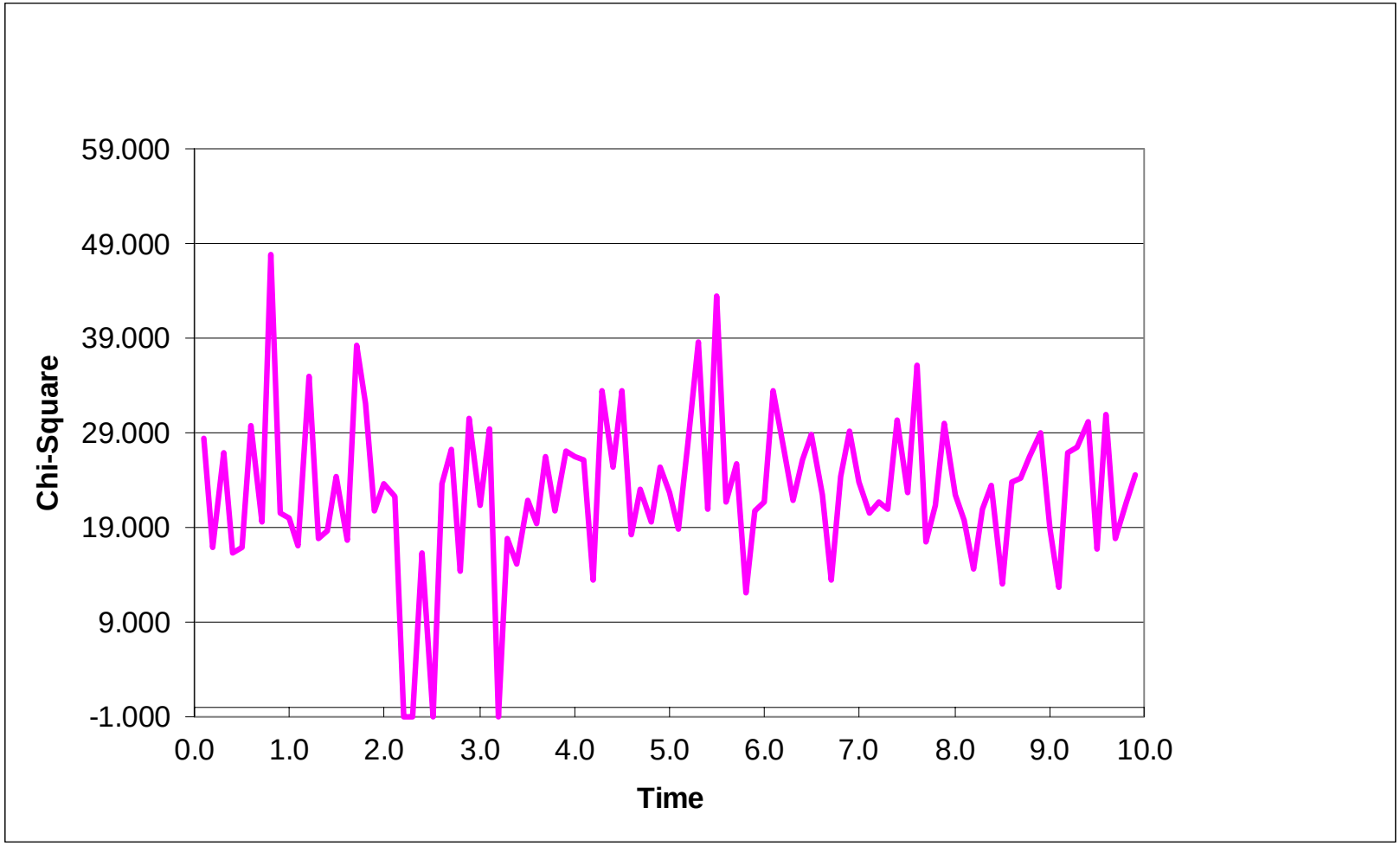
Model 1 RMSEA



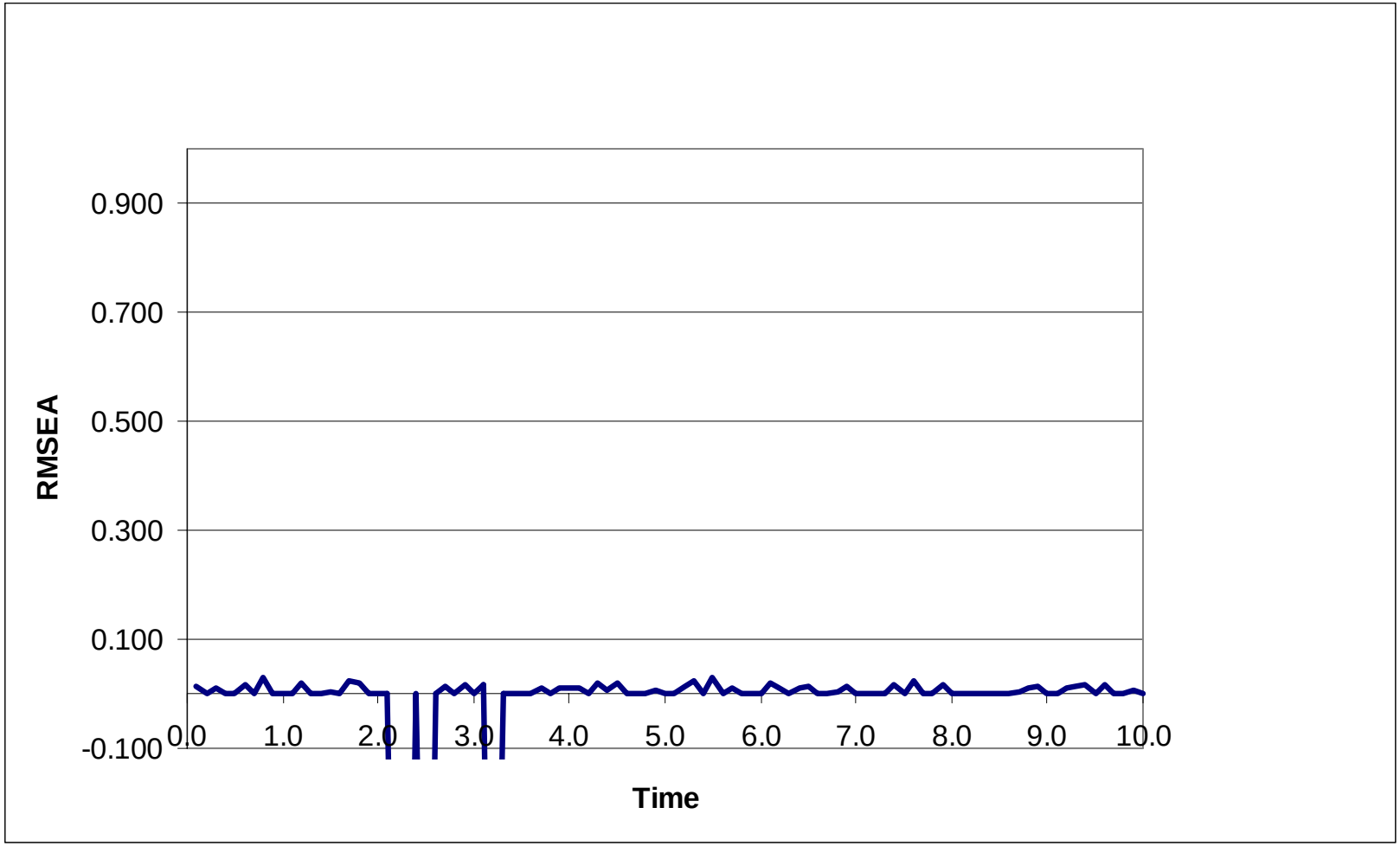
LISREL Model 2



Model 2 Chi-Square



Model 2 RMSEA



Summary of results

Phase of loop dominance	Time interval	Dominant loop(s)	Model 1 fit	Model 2 fit
P1	0.0 to 0.6	L1 and L2	No	Yes
Transition	0.6	-	No	Yes
P2	0.6 to 2.4	L1	No	Yes
Transition	2.4	-	Yes	No[2,3]
P3	2.4 to 3.7	L2	Yes	Yes
Transition	3.7	-	Yes	No[2,3]
P4	3.7 to 6.3	L1	Yes	Yes
Transition	6.3	-	Yes	Yes
P5	6.3 to 10.0	L1 and L2	Yes[1]	Yes

[1] RMSEA increases up to about 0.045 and then decreases again.

[2] Fails to converge.

[3] Not admissible after 50 iterations.

Conclusions

- The structural equation model that corresponded to the system dynamics model did not fit the data during the initial shifts in loop dominance.
- The structural equation model that did fit the data did not correspond to the system dynamics model.