6_Dynamic+Networks

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Advanced Network Analysis
6. Dynamic Network Analysis

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Outline

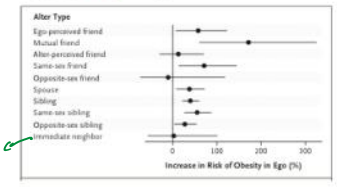
Recall that it is difficult to estimate peer effects in social networks with cross-sectional data (unless instrumental variables or experiments are available). With dynamic network data, two models have been used to estimate "causal" peer effects.

- Dynamic logit model
- Stochastic actor-oriented model

1. Dynamic Logit Model

- The dynamic logit model is popularized by Christakis and Fowler (2007).

$$\text{logit}(Y_{it}) = \theta_1 Y_{jt} + \theta_2 Y_{jt-1} + \theta_3 Y_{it-1} + \alpha_1 X_{it} + e_{it}. \quad (1)$$



- Inclusion of Y_{it-1} helps control for intrinsic, stable predisposition.
- Inclusion of Y_{jt-1} helps control for homophily. (?)
- What about contextual confounding?

- Cohen-Cole and Fletcher (2008) added school fixed effects to the model.

$$\text{logit}(Y_{it}) = \theta_1 Y_{jt} + \theta_2 Y_{jt-1} + \theta_3 Y_{it-1} + \alpha_1 X_{it} + C_{it} + e_{it}. \quad (2)$$

2. The Stochastic Actor-Oriented Model

- The stochastic actor-oriented model (SAOM) includes two parts: one for network dynamics and the other for behavior dynamics. By modeling the two processes jointly, it helps separate peer selection from peer influence.
- Actor i has two objective functions.

Network Dynamics: $f_i^N(w, w', z) = \theta' S^N(i, w, w', z)$, (3)
Behavior Dynamics: $f_i^B(w, z, z') = \beta' S^B(i, w, z, z')$. (4)

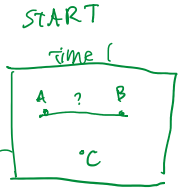
falsification test → is the model correct?
Pick two things that should not be connected / correlated
Run the model
If they're connected/correlated, bad
E.g. height should not be socially transmissible except assumption that you don't pick friends based on height
Means your model is overestimating

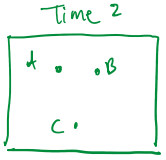
regress your outcome vs. your neighbor's ... to combat

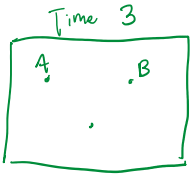
e.g. genetic effects → some ppl more likely to drink etc.

is it sufficient? e.g. maybe selection process is not a function of this single variable

school fixed effects, important. Specifically control environmental factors







① Network: ERGM (how ties are formed)
Net = X + Y + Z + ...

network dynamics and the other for behavior dynamics. By modeling the two processes jointly, it helps separate peer selection from peer influence.

- Actor i has two objective functions.

$$\text{Network Dynamics: } f_i^N(w, w', z) = \theta' S^N(i, w, w', z), \quad (3)$$

$$\text{Behavior Dynamics: } f_i^B(w, z, z') = \beta' S^B(i, w, z, z'). \quad (4)$$

w and w' are networks and z and z' behaviors before & after the change.

$$f_i^N(w, w', z) = \theta_1 \text{Reciprocity} + \theta_2 \text{Transitivity} + \theta_3 \text{Indegree} + \theta_4 \text{Drinking-Alter} + \theta_5 \text{Drinking-Ego} + \theta_6 \text{Drinking-Same} \quad (5)$$

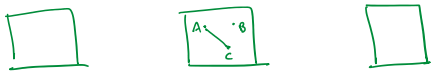
$$f_i^B(w, z, z') = \beta_1 \text{Indegree} + \beta_2 \text{Outdegree} + \beta_3 \text{Smoking} + \beta_4 \text{Average Alter-Drinking} \quad (6)$$

- Alter indicates receiver effect and ego indicates sender effect.

① Network: ERGM (how ties are formed)
Net = x+y+z+...

② Behavior: Behavior = covariates + centrality

How do you measure if the network is good?
⇒ Assimilate a sequence of networks



Estimation

- Find "the recipe for cooking a sequence of networks" similar to the observed.
- Simulate networks based on a guess of the parameters. At any one moment, an actor changes one tie or her/his behavior with the following probability.
  - Choose which tie to change: $\frac{\exp\{f_i^N(w,w',z)\}}{\sum_W \exp\{f_i^N(w,W,z)\}}$
  - Choose what behavior to change to: $\frac{\exp\{f_i^B(w,z,z')\}}{\sum_Z \exp\{f_i^B(w,z,Z)\}}$
  - The coefficients are interpretable as log odds.
- Update the parameter values by the Robbins-Monro algorithm.

$$\theta_{k+1} = \theta_k - \alpha_{k+1} D_{\theta_k}^{-1} (S_{k+1}^{sim} - S^{obs})$$

where $S = \sum_t \sum_i F_i$ indicating the model statistics (taste), $D_{\theta_k} = \frac{\partial S}{\partial \theta}|_{\theta_k}$ transforming the space from statistics (taste) to parameters (recipe), and $\alpha_k = k^{-c}$ with $c \in (0.5, 1)$ reducing the range of adjustment over time.

1) n_1 simulations based on θ_0 to estimate D_{θ_0} (e.g., by finite difference).
2) Update θ multiple times to obtain the final estimate: $\hat{\theta} = \theta_r$.
3) Conduct n_3 simulations based on θ_r to evaluate convergence by

$$\rightarrow T = (\bar{S}^{sim} - S^{obs}) \sigma_s^{-1} \cdot (\bar{S}^{sim} - S^{obs})$$

where σ_s is the square root of the simulated covariance matrix of S.

S is number of triangles
e.g. if lots of transitivity in simulated, the next time they'll reduce the transitivity to try and match observed network.

Over time, amount of change is smaller & more fine-tuned

Too salty? Reduce amount of salt

D transforms the statistics (the S stuff) into parameters

if not then θ and S stuff are on different scales

Table 1. SOAM Results for the Co-evolution of Friendships and Drinking

	Est	SE	T
Network Dynamics			
constant friendship rate (period 1)	6.87	1.34	-0.06
constant friendship rate (period 2)	5.42	1.09	0.06
outdegree (density)	7.30	0.65	0.05
reciprocity	2.56	0.27	-0.01
transitive triplets	0.73	0.09	-0.04
indegree - popularity (sqrt)	-0.09	0.46	-0.07
outdegree - popularity (sqrt)	-0.62	0.41	-0.01
age alter	0.04	0.15	-0.05
age ego	-0.09	0.21	0.01
age similarity	-0.35	0.68	-0.04
drinking alter	0.03	0.13	-0.01
drinking ego	0.12	0.21	-0.03
drinking similarity	1.10	0.93	-0.07
smoke alter	0.06	0.17	0.04
smoke ego	0.02	0.13	0.00
smoke similarity	0.43	0.31	-0.01
drinking × reciprocity	-0.21	0.29	-0.06
Behavior Dynamics			
rate drinking (period 1)	1.17	0.36	-0.07
rate drinking (period 2)	1.57	0.55	0.00
behavior drinking linear shape	-0.15	2.05	-0.10
behavior drinking quadratic shape	-1.73	6.62	0.05
behavior drinking indegree	-0.96	4.92	-0.07
behavior drinking outdegree	1.41	6.56	-0.16
behavior drinking average alter	4.20	16.06	0.02
behavior drinking: effect from age	0.47	2.11	0.01
behavior drinking: effect from smoke	-0.80	3.13	0.06

Log odds
significant change in friendships
All these coefficients are log odds
how much change from time 1→2
divide estimate by SE
>2 = significant
ties are more likely to be mutual over time
neg = sparse compared to other networks
ties more likely to form triangles over time
drinkers more likely to be friends with drinkers
lots of change in drinking behaviors over period
do ppl really cut a lot of ties because more popular over time? Not really
drinking behavior becoming similar to their friends? Not significant
older students more likely to drink?

Quadratic shape

neg  time

pos  time

odds of drinkers become friends w each other is $e^{1.10}$ times the odds of drinkers becoming friends w non-drinkers

Interpretations

- The coefficients are log odds. Alter indicates receiver effect; ego sender effect.
- The interpretation of the estimates in the network dynamics is just like in ERGMs. More precisely, the SAOM estimates are conditional on the immediate past period. For example, positive reciprocity means ties are more likely to be reciprocated over time, namely, if there is a tie from A to B in wave t-1 then the chance that there will be a tie from B to A in wave t is higher.
- Friendship rates describe general tie changes in between two waves. If positive, more changes. Behavior rates describe general behavior changes in between two waves. If positive, more changes.
- Behavior shapes describe the general distribution of behavior over time. Look at the quadratic term first. If it is positive and significant, then it is a U-shape distribution over time. Behavior first decreases and then increases. If it not significant, look at the linear term. If it is positive and significant, behavior increases linearly over time.
- Average alter models the peer effect on behavior. Behavior: indgree and outdegree model the effect of indegree and outdegree on behavior, respectively.

Comments

- By modeling the co-evolution of networks and behaviors, SAOM helps to separate peer selection from peer influence.
- The model can also be used to model network dynamics only.
- Computational expensive because of the reliance on MCMC.
- Be aware of the assumptions made in the model.
  - Single and independent change at any one time point.
  - Markov evolution.
  - Decision making is based on full information of the network.
  - Omitted variable bias may diffuse across dynamics.
  - Need to more neatly account for the effects of lagged networks.
- Other software for dynamic network analysis
  - tergm: modeling network evolution only
  - btergm: modeling network evolution and dependence on prior networks.

<- Not behavioral evolution

Stiglich 2010 table 2 and 3 for interpretations