Network dynamics with a structured node set: Sociability in seven villages in Senegal

Tom A.B. Snijders

University of Groningen
University of Oxford

October, 2019

Overview

Research together with Malick Faye and Julien Brailly
(Sciences Po, Paris and Swinburne University, Melbourne)

- ⇒ Example of a 'multilevel' network where actors are nested in villages, i.e., the node set has a nested structure: 'levels'.
- ⇒ Within-village and between-village relations can be different in nature.
- ⇒ There is additional nesting structure:
  individuals nested in households nested in compounds nested in villages: 4 levels.
- ⇒ Variables can have different meaning depending on the level,
  cf. the ecological fallacy.

Water resources in 7 villages in Senegal

The research setting is a group of 7 villages in rural Senegal.
These villages have a common water supply resource (deep-well).
This resource is managed by a board elected by the villagers
according to rules of equal representation.

Of the villages, two are Fulani (nomadic cattle breeders)
and five are in large majority Wolof (sedentary agriculture).

The inhabitants live in households (families)
nested in compounds (extended families).

A network survey was held in 2010 and 2015 among all inhabitants.
The data analyzed here are of the 406 respondents
for whom data is available for both waves (70 % response).

Dependent variable

Many dependent variables can be defined for this rich data set.

We focus here on the most important network variable

- Sociability network (advice, discussion, help, potential loans, visiting)
  differentiated: within and between villages.

The individuals lived in 140 households,
and these were grouped in 55 compounds (extended families).

Within-village and between-village networks

Relations within villages are of a different nature than between villages, although the same name generators were used.

This could be represented by covariate 'same village',
but perhaps more transparently
by separating this as two dependent networks.

Define two networks W = 'within' and B = 'between',
composed of sociability ties within and between villages,
with structural zero blocks
for the between-village and within-village dyads, respectively.

The within and between relations are separated in two dependent networks, with structurally zero blocks.

For the within-village network W:

$$
\begin{array}{c} \\ V1 \\ V2 \\ V3 \\ V4 \\ V5 \\ V6 \\ V7 \end{array}
\begin{array}{c}
\begin{array}{ccccccc} V1 & V2 & V3 & V4 & V5 & V6 & V7 \end{array} \\
\left(\begin{array}{ccccccc}
V1 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & V2 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & V3 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & V4 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & V5 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & V6 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & V7
\end{array}\right)
\end{array}
$$

Block structure for the between-village network W:

$$
\begin{array}{c} \\ V1 \\ V2 \\ V3 \\ V4 \\ V5 \\ V6 \\ V7 \end{array}
\begin{array}{c}
\begin{array}{ccccccc} V1 & V2 & V3 & V4 & V5 & V6 & V7 \end{array} \\
\left(\begin{array}{ccccccc}
0 & V1V2 & V1V3 & V1V4 & V1V5 & V1V6 & V1V7 \\
V2V1 & 0 & V2V3 & V1V4 & V2V5 & V2V6 & V2V7 \\
V3V1 & V3V2 & 0 & V1V4 & V3V5 & V3V6 & V3V7 \\
V4V1 & V4V2 & V4V3 & 0 & V4V5 & V4V6 & V4V7 \\
V5V1 & V5V2 & V5V3 & V1V4 & 0 & V5V6 & V5V7 \\
V6V1 & V6V2 & V6V3 & V1V4 & V6V5 & 0 & V6V7 \\
V7V1 & V7V2 & V7V7 & V1V4 & V7V5 & V7V6 & 0
\end{array}\right)
\end{array}
$$

Covariates

- Sex
- Age (13-87 years, average 41)
- Ethnic group (Fulani, Wolof)
- Wealth: aggregate of log values of cattle, harvest, and machines.
- Log distances between houses (geocoded).

Model specification: sociability

For the W and B networks:

within-network structural effects:

1. Outdegree, reciprocity
2. three degree effects
3. transitivity: GWESP
4. actor variable: gender
5. actor variable: wealth,
   combined value of harvest, cattle, machines

Between-network structural effects:

1. Because of the definition of W and B,
   no mixed dyadic (entrainment) effects.
2. mixed activity effects
3. mixed triadic effects:

$$i \xrightarrow{A} j,\ i \xrightarrow{A} h \ \Rightarrow\ j \xrightarrow{B} h \qquad \text{same in-choices}$$

$$i \xrightarrow{A} h,\ h \xrightarrow{A} j \ \Rightarrow\ i \xrightarrow{B} j \qquad \text{mixed AAB closure}$$

$$i \xrightarrow{A} h,\ h \xrightarrow{B} j \ \Rightarrow\ i \xrightarrow{B} j \qquad \text{mixed ABB closure}$$

$$i \xrightarrow{B} h,\ h \xrightarrow{A} j \ \Rightarrow\ i \xrightarrow{B} j \qquad \text{mixed BAB closure}$$

With the nesting of individuals in families in extended families,
and the definition of wealth as individual wealth,
we can make ecological fallacies (multilevel analysis!!!)
if we do not also consider wealth at the family level.

Therefore three wealth variables are constructed:

- individual wealth
- total family wealth ('household')
- total extended family wealth ('compound')

For each of these, the five-parameter model of
Snijders & Lomi (*Network Science*, 2019) is used:
$V(\text{ego})$, $V(\text{alter})$, $V^2(\text{ego})$, $V^2(\text{alter})$, $\Big(V(\text{ego}) - V(\text{ego})\Big)^2$

A reasoned stepwise model selection procedure is followed.

Results

Results cover several pages.

For numerical actor covariates,
results are reported in figures.

Effect	par.	(s.e.)
Within: structure, some covariates		
outdegree	–2.644***	(0.300)
reciprocity	1.142***	(0.109)
GWESP	1.059***	(0.075)
GWESP × reciprocity	–0.394*	(0.165)
indegree-popularity	–0.010	(0.019)
outdegree-activity	–0.076***	(0.014)
indegree-activity	–0.003	(0.029)
log distance	–0.231***	(0.016)
ethnicity (W) alter	0.549†	(0.283)
ethnicity (W) ego	–0.721*	(0.287)
same ethnicity	0.435	(0.278)
gender (M) alter	0.244***	(0.065)
gender (M) ego	–0.257***	(0.072)
same gender	0.569***	(0.063)

† $p < 0.1$; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$;

Effect	par.	(s.e.)
Within: effects from between		
indegree between popularity	0.048	(0.039)
indegree between activity	–0.060	(0.070)
outdegree between popularity	0.027	(0.020)
outdegree between activity	0.002	(0.043)
same B choices	–0.337	(0.521)
mixed BBW closure	1.352	(0.941)

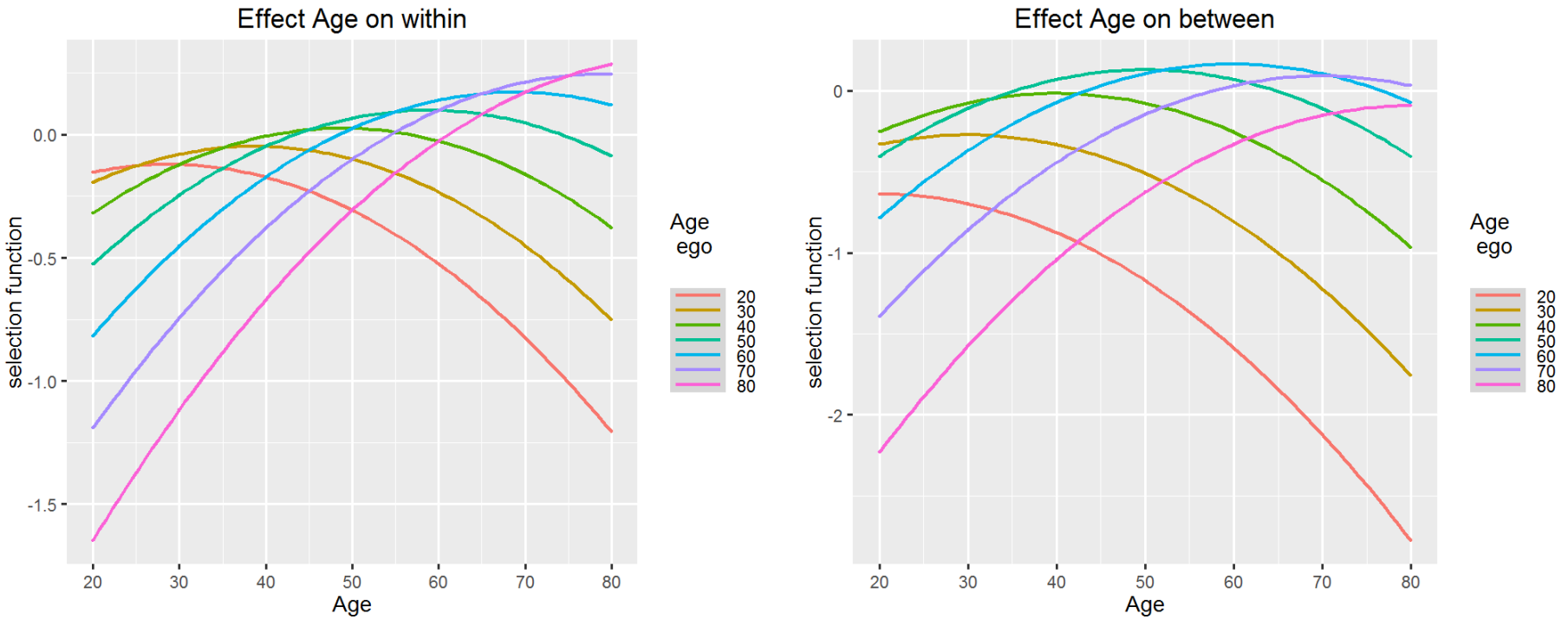
† $p < 0.1$; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$;

Effect	par.	(s.e.)
Between: structure, some covariates		
outdegree (density)	–5.386***	(0.421)
reciprocity	2.067***	(0.394)
GWESP	1.063	(0.793)
indegree-popularity	–0.280†	(0.162)
outdegree-activity	0.172***	(0.031)
indegree-activity	–0.350	(0.300)
logDist	–0.707***	(0.205)
ethnicity (W) alter	0.518*	(0.232)
ethnicity (W) ego	–0.691***	(0.205)
same ethnicity	0.955***	(0.217)
gender (M) alter	0.906***	(0.244)
gender (M) ego	–0.255	(0.289)
same gender	0.955***	(0.222)

† $p < 0.1$; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$;

Effect	par.	(s.e.)
Between: effects from Within		
indegree within popularity	0.268^{***}	(0.077)
indegree within activity	0.130	(0.122)
outdegree within popularity	$-0.211^{\dagger}$	(0.120)
outdegree within activity	$-0.311^{\dagger}$	(0.178)
mixed WBB closure	0.904^{***}	(0.265)
mixed BWB closure	0.053	(0.138)

† $p < 0.1$; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$;



Plot of selection functions for age for within-village (left) and between-village (right) networks.
Horizontal axis is age of alter; curves are for egos of different age.

Mainly homophily.

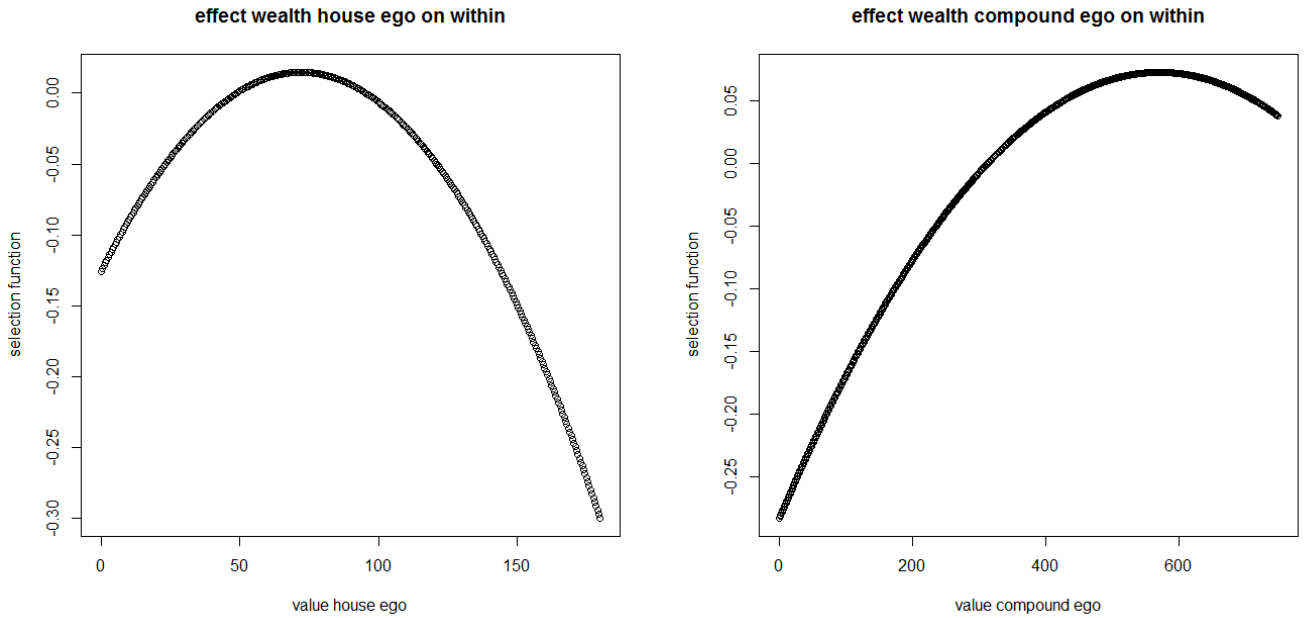
Effects of wealth

The effects of wealth can best be given through plots
of the selection function
(i.e., the total contribution of wealth to the evaluation function).

Effect sizes have not yet been developed.

In the logit scale of the SAOM parameters,
the range of the contributions of household and compound wealth
to the within-village network selection function is less than 0.36;
range of contributions to the between-village network selection function
is 2.3 for individual, 1.6 for household, and 2.0 for compound wealth.

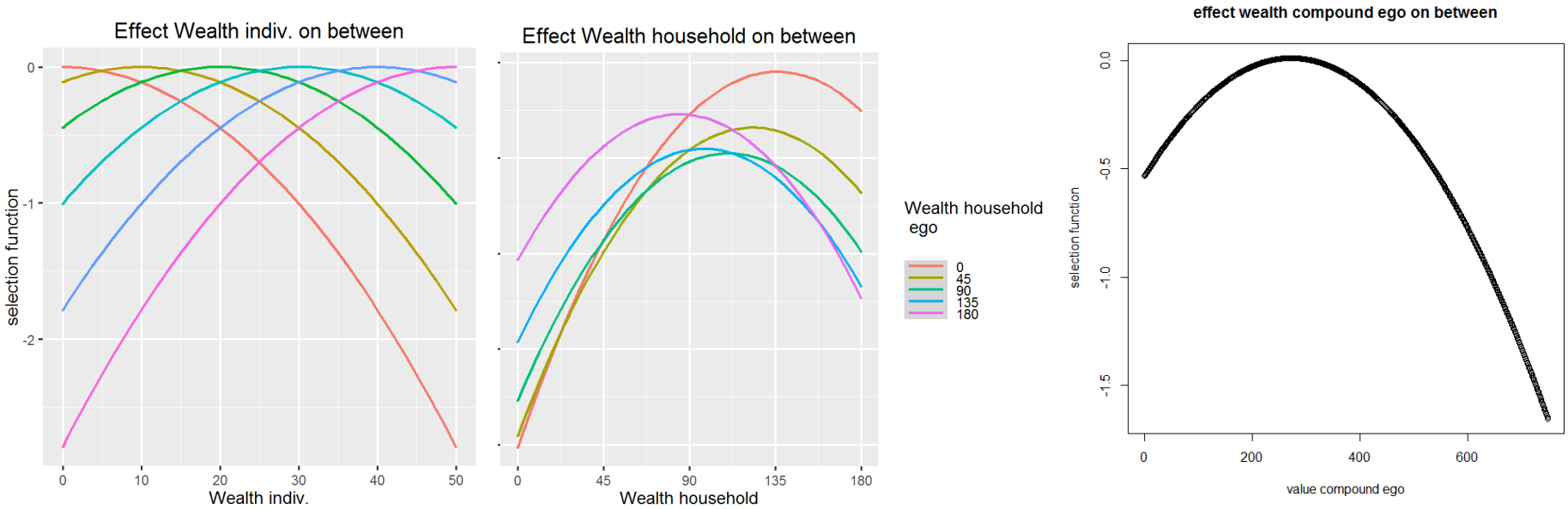
This implies that the effect of wealth on between-village ties
is much larger than for within-village ties.



Plot of selection functions for ego's wealth for within-village network.

No effect of alter's wealth.

Left household, right compound level.



Plot of selection functions for wealth for between-village network.

Left individual, middle household, right compound level.

For two left plots, horizontal axis is wealth of alter,

curves are for egos of different wealth.

For right plot, horizontal axis is wealth of ego.

Conclusions of the analysis: covariates

1. Rich differences *W*-*B*.
2. Covariate gender:
   homophily *W* and *B*, males receive more ties *W* and *B*, send fewer ties *W*;
3. Covariate age: mainly homophily;
4. Covariate wealth, *W*:
   depends only on ego for household and compound,
   with most contacts for egos with medium household wealth
   and high compound wealth;
5. Covariate wealth, *B*:
   for individual mainly homophily, most contacts to alters with medium household wealth
   and from egos with medium compound wealth.
6. Covariate ethnicity: homophily *B*.

Conclusions of the analysis: structural

1. reciprocity for all relations.
2. internal transitivity only for W;
   mixed transitivity $\{i \xrightarrow{W} h \xrightarrow{B} j\} \Rightarrow \{i \xrightarrow{B} j\}$:
   'outsiders are introduced to village friends'
   (but note: no distinction creation–maintenance).
3. outdegree activity negative for W, positive for B.
4. mixed degree effects:
   high W indegrees lead to high B indegrees.

These structural results depend strongly
on the covariates included in the model.

Overall conclusions

- ⇒ The analysis was done for an outcome space of two dependent networks using structurally zero blocks to differentiate within-village (W) from between-village (B) sociability;
- ⇒ individual wealth and the total wealth of the household or the extended family play different roles:
  analogous to differences within- and between-group regression in regular multilevel analysis (ecological fallacy issues!);
- ⇒ for actor covariates,
  ego and alter effects can have a complex interplay,
  the five-parameter model is useful for a flexible approach.