Biostatistics Seminar Series

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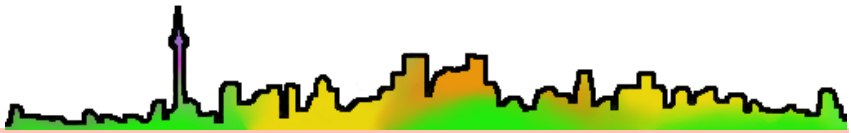


25 January 2022

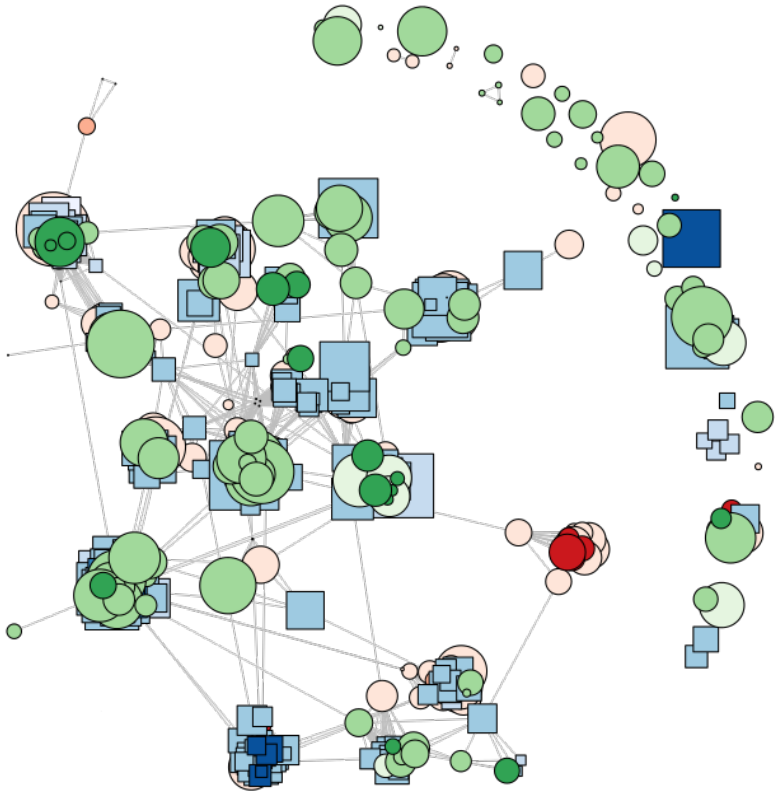
Acknowledgement

I would like to thank Dr. Amy Liu and Dr. Wendy Lou for asking and allowing me to present today at the Biostatistics Seminar Series in the Dalla Lana School of Public Health.

I would also like to thank you as an audience!

I am sincerely grateful to the Centers for Medicare and Medicaid Services in the Department of Health & Human Services of the United States federal government for publishing the Nursing Home Compare open datasets. And for all the reviewer comments I received in getting the discussed project published.

SOCIAL NETWORK



ANALYSIS

APPLICATION

frontiers in Public Health

ORIGINAL RESEARCH
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Check for updates

Care Deficiencies and Super-Organization of American Nursing Homes in Hospital Referral Region

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Inspiration

Source: Calgary Herald

Source: Mission Seniors Living

Condominium corporations are complex structures like a social network. Some with super-organization.

Questions and Background

Who are the owners of nursing homes and/or assisted living facilities? Is the **super-organization** of these facilities associated with *care quality*?

The **ownership structure** of nursing homes has implications on resident **care quality** disseminating through environmental factors such as reported deficiencies, the percentage of long-stay or short-stay residents with depressive symptoms for example, to ratios of nursing home staffing [Aaronson et al., 1994, Harrington et al., 2001].

American Nursing Homes

Longterm care facilities of the following classification reimbursed by the Centers for Medicare and Medicaid Services (CMS) with: an RN director of nursing, an RN on shift for 8 hours every day, and a licensed nurse on shift at all times [Harrington et al., 2000].

- Nursing Facility (NF)
- Skilled Nursing Facility (SNF)
- Intermediate Care Facility (ICF)

These classifications are consistent in all provider states within the United States. Can have broad ownership type of **for-profit**, **non-profit** and **government.**

Where to Obtain Information?

The Centers for Medicare and Medicaid Services (CMS) publishes the **Nursing Home Compare (NHC) open datasets** (updated monthly) that comprises all American nursing homes reimbursed through Medicare and/or Medicaid. Datasets include:

- Online Survey Certification and Reporting (OSCAR) care deficiencies
- Minimum Data Set (MDS) quality measures
- penalties
- provider characteristics
- ownership information

Previous studies determined super-organization (chain affiliation) by manual linkage through name recognition and excluded government nursing homes in public-private partnerships.

Novel Method

- Enacted amendment to **Uniform Commercial Code**, 2010.
  - Exact **organization name** from the "public organic record".
  - Easier to track organizations (corporations, charitable trusts, etc.) within and between states by their **mandated-use** legal name.

⇒ Apply social network analysis.

- **Super-organization** of nursing homes can be determined through ownership networks of **registered organizations**.
- Most nursing home owners are organizations to limit liability.
- Government entities are also registered organizations.

ECOLOGIC UNIT

- Previous studies used **county level** or **provider state** as ecologic unit to infer nursing home super-organization.
- County level is unsuitable for national study, as many counties are sparsely populated and do not contain a nursing home.
- Inferences were made from a handful of provider states for policy, when half the country was excluded for study.

- As hospital discharge is a major admission source for nursing home residents, this study proposes **hospital referral region** (HRR) [Dartmouth Medical School, 1998] as ecologic unit of study for nursing home super-organization.

Project on Super-Organization

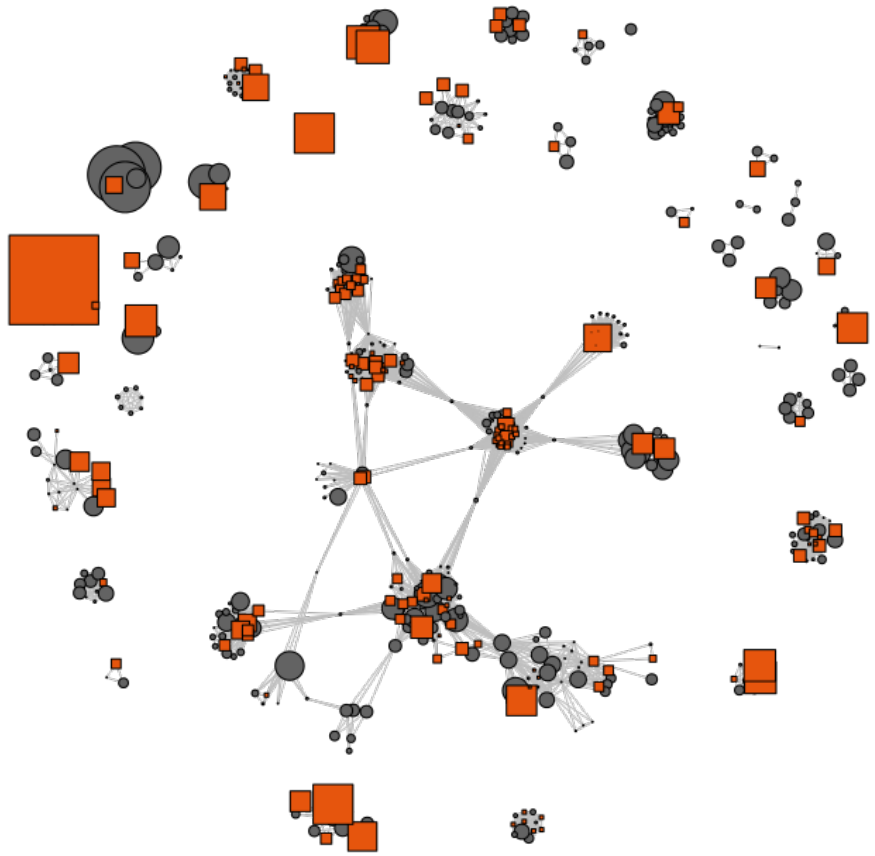
Linking together the NHC open datasets by **Federal Provider Number**, a project can be formulated:

- Bipartite (2 types of actors) projection of nursing home facilities and owners using social network analysis (SNA)
- Five semiannual time periods of Centers of Medicare and Medicaid Services (CMS) Nursing Home Compare (NHC) datasets in the US
- Start: March 2016 (end: March 2018). US Federal Budget usually allocated in February

R packages used for SNA:

- ***igraph*** [Csardi and Nepusz, 2006]
- ***networkD3*** [Allaire et al., 2017]

Time for Social Network Analysis (SNA) Methodology!



SNA Common Terms

Term	Synonym	Application	Interpretation
Bridge	Broker		Point where one group of actors is connected to another group of actors
Brokerage			Where an actor from a subgroup of actors is connected to another subgroup of actors
Clique			Group where every actor is directly connected to one another
Density			Ratio of the number of ties in a network to the total number of ties possible among all nodes
Diameter			Greatest path distance among edges between any pair of nodes on a graph in a network
Distance			Minimum number of edges required to connect two actors
Graph			Relationship encompassing a set of nodes and edges
Key Player	Central Actor	Nursing Home Owner or Facility	Associated with the spread of knowledge or connection from a high degree of centrality or brokerage
Loop			Ties that connects an actor to itself
Modularity			Measures division within network into groups
Node	Vertex, Actor	Nursing Home, Owner	Individual actor
Size			Number of ties for a graph
Tie	Edge, Arc, Arch, Relation, Connection	Link between Owners and Nursing Homes	Relationships between actors. Can be undirected, directed in one-way and unbalanced, or reciprocal directed and balanced

[Freeman, 2004, Snijders et al., 2010, Sorenson and Stuart, 2001].

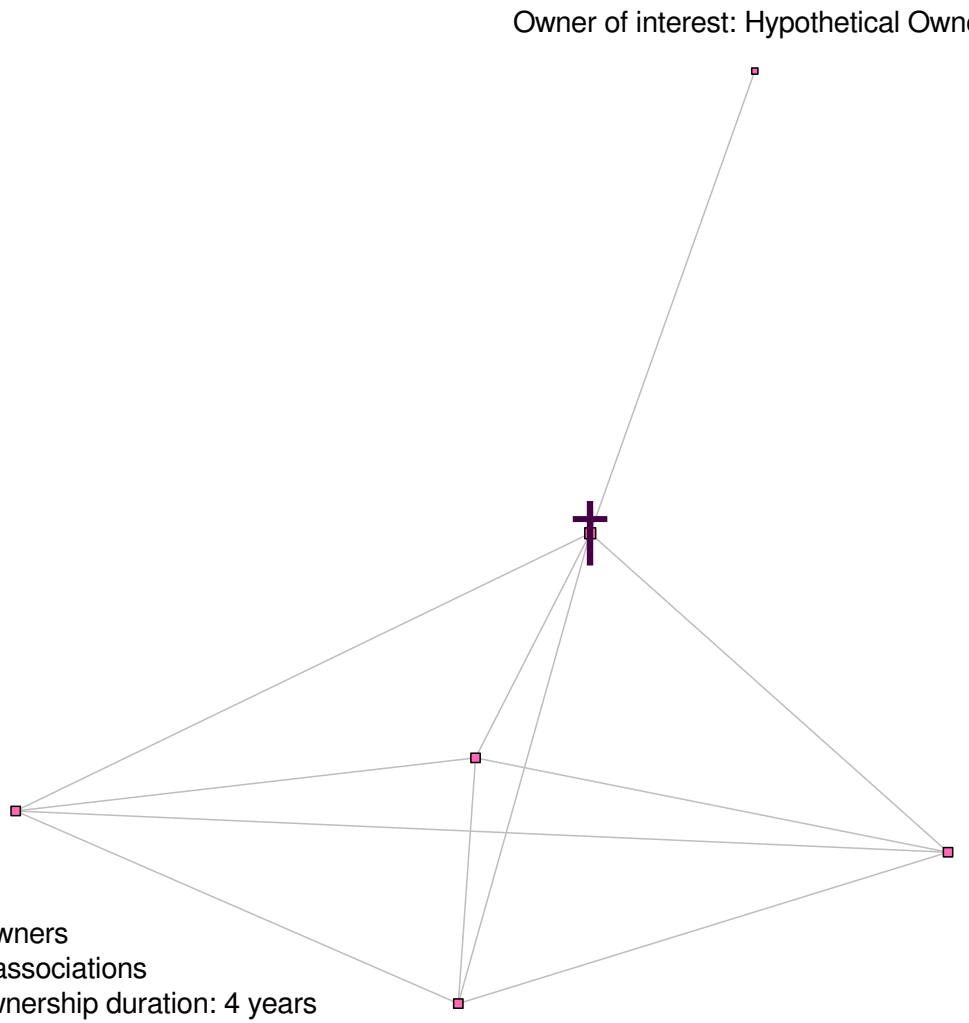
Ego-Centric Approach

Bipartite projection -- facilities connected to other facilities accepting Medicare or Medicaid through owners

Nodes: 4 nursing homes
Edges: 6 associations
Smallest facility: 25 residents
Largest facility: 176 residents
Number of residents in certified beds: 318
Number of certified beds: 345
Processing date: 2016-03-01

Ego-Centric Approach

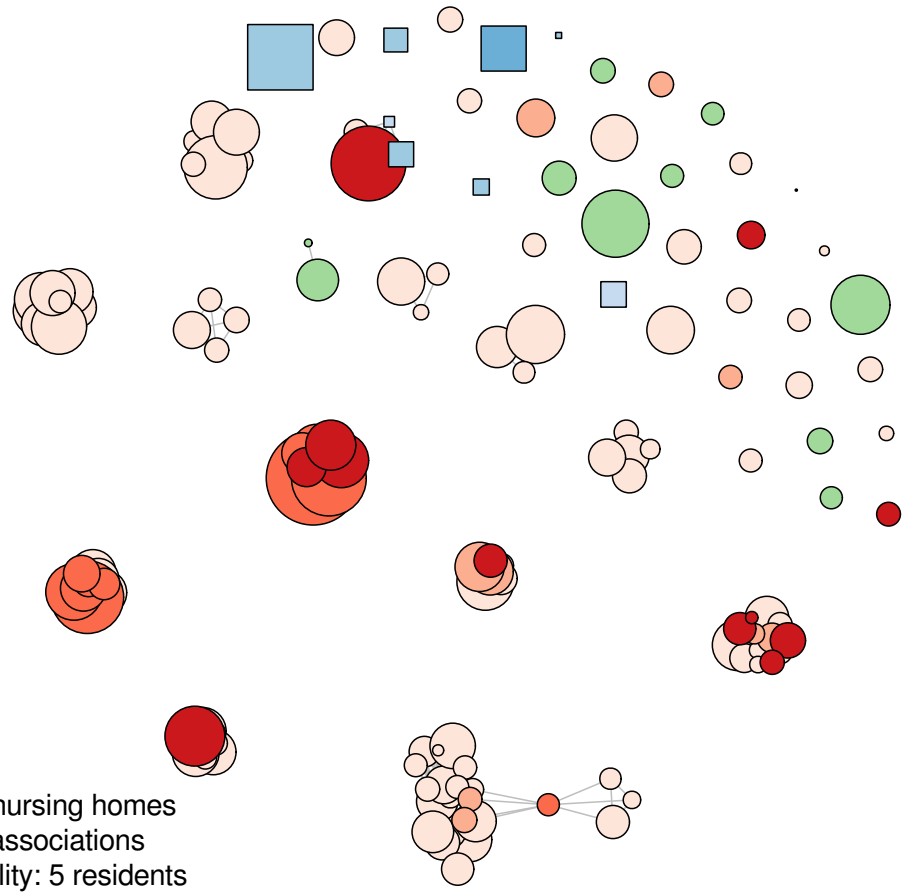
Bipartite projection -- owners connected to other owners through facilities accepting Medicare or Medicaid



Nodes: 6 owners
Edges: 11 associations
Shortest ownership duration: 4 years
Longest ownership duration: 7 years
Cumulative years of ownership: 39
Processing date: 2016-03-01

Socio-Centric Approach

Hypothetical region facilities accepting Medicare or Medicaid connected to each other through owners



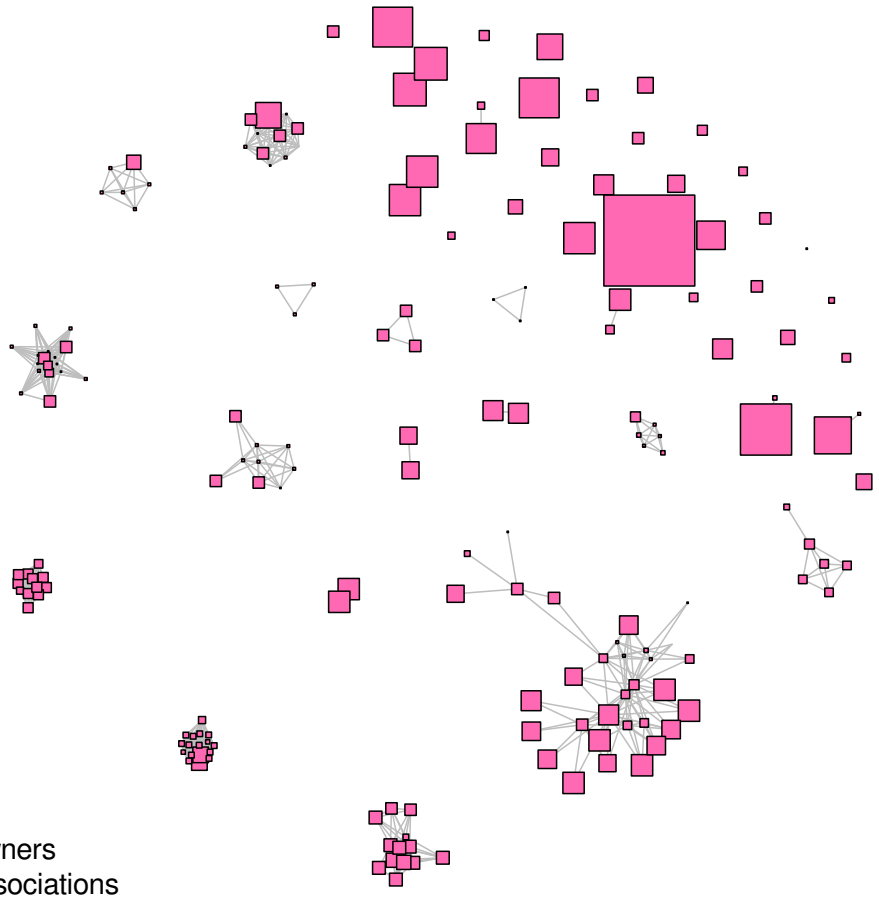
- For-profit -- Corporation
- For-profit -- Individual
- For-profit -- Limited Liability company
- For-profit -- Partnership
- Government -- City
- Government -- City/county
- Government -- County
- Government -- Federal
- Government -- Hospital district
- Government -- State
- Non-profit -- Church related
- Non-profit -- Corporation
- Non-profit -- Other

Size based on number of residents in certified beds

Nodes: 144 nursing homes
Edges: 471 associations
Smallest facility: 5 residents
Largest facility: 221 residents
Number of residents in certified beds: 11582
Number of certified beds: 13319
Processing date: 2016-03-01

Socio-Centric Approach

Hypothetical region owners connected to each other through facilities accepting Medicare or Medicaid



Individual
Organization

Size based on years of ownership

Nodes: 183 owners
Edges: 613 associations
Shortest ownership duration: 0 years
Longest ownership duration: 64 years
Cumulative years of ownership: 1535
Processing date: 2016-03-01

SNA Concepts

Measures of Centrality

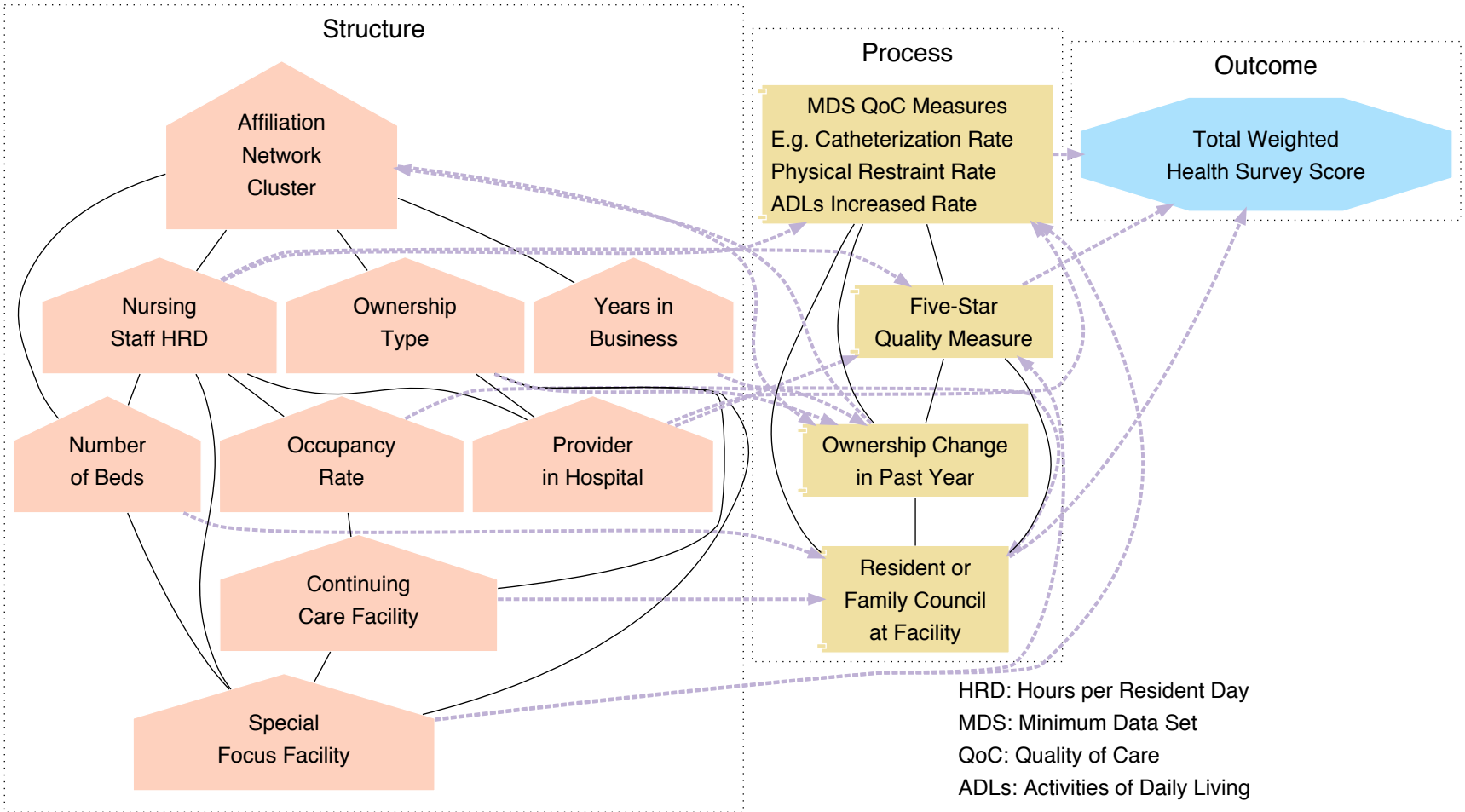
Term	Interpretation
Betweenness	How many times a node is on the shortest path between two other actors
Closeness	Reciprocal of the sum of the number of edges along a shortest path from a given node to all the other nodes in a network
Degree	Number of ties per node
Reach	Proportion of network nodes that can be connected through varying degrees

Social Network Theories

Term	Interpretation
Closure	Exclusion against dense groups of actors based upon competition for resources
Embeddedness	Central nodes benefit from accessibility to other nodes when it comes to knowledge transfer
Homophily	Scope to which actors have ties with similar actors based on an attribute
Prestige	Accounts for number of ties originating from a node, and other nodes connected to a given node
Propinquity	Geographical closeness between nodes
Proximity	Nodes closer to one another have more interaction
Reciprocity	Nodes mutually linked to one another by ties makes for a more stable network
Scale-Free	A network that is heavy-tailed, in that most actors have no or few ties and some actors have many
Small Worldness	Groups of interconnected nodes are neighbors of one another through a central hub
Structural Equivalence	Actors playing similar roles or positions may be found in other groups or networks
Structural Holes	Absence of relationships between groups of actors
Transitivity	Nodes do not have to be directly connected to have a relationship with one another
Trust	Actors have high degree of reciprocity

PROJECT FRAMEWORK

Overview: Structure-Process-Outcome (SPO) Model



- [Chung, 2009, Towsley, 2007, Laberge et al., 2008, Chen and Shea, 2002].

Outcome - Total Weighted Health Survey Score

Calculated from deficiencies reported during three cycles of standard survey health inspections, with non-duplicate deficiencies from complaint inspections included (if applicable).

I. health inspection deficiencies:
   - most recent period (cycle 1) assigned a weighting factor of **1/2**
   - previous period (cycle 2) assigned a weighting factor of **1/3**
   - second prior survey (cycle 3) assigned a weighting factor of **1/6**

II. complaint inspection deficiencies:
   - within 0-12 months assigned a weighting factor of **1/2**
   - within 13-24 months assigned a weighting factor of **1/3**
   - within 25-36 months assigned a weighting factor of **1/6**

For facilities with missing data for one period, data from the previous period is utilized using the same relative weights as more recent period [Centers for Medicare and Medicaid Services, 2017].

Deficiency Score Grading

Noted during approimately annual health inspection or complaint inspection cycle. Points in parentheses are for deficiencies of continual subpar care quality.

Severity	Isolated	Pattern	Widespread
Immediate jeopardy to resident health or safety	J 50 points (75 points)	K 100 points (125 points)	L 150 points (175 points)
Actual harm that is not immediate jeopardy	G 20 points	H 35 points (40 points)	I 45 points (50 points)
No actual harm, but potential for more than minimal harm that is not immediate jeopardy	D 4 points	E 8 points	F 16 points (20 points)
No actual harm, but potential for minimal harm	A 0 points	B 0 points	C 0 points

As taken from Table 1 of the *Design for Nursing Home Compare Five-Star Quality Rating System* [Centers for Medicare and Medicaid Services, 2017].

Explanatory (Structure) - Case-Mix Adjustment

CMS creates case-mix adjusted staffing metrics for RN, LPN and CNA from MDS QoC Indicators. This is the Resource Utilization Group (RUG-III) case-mix system for nursing staffing hours per resident day (HRD).

$$HRD = \frac{\text{total hours for each nursing discipline}}{\text{resident census over 14 days}}$$

$$HRD_{\text{Adjusted}} = \frac{HRD_{\text{Reported}}}{HRD_{\text{Expected}}} * HRD_{\text{National Average}}$$

Use of case-mix adjusted HRD metrics for nurse staffing is recommended [Centers for Medicare and Medicaid Services, 2017].

Explanatory (Structure) - NH Facility Characteristics

Eight measures that are included:

- Affiliation Network Cluster
- Ownership Type
- Years in Business
- Number of Beds
- Occupancy Rate
- Provider in Hospital
- Continuing Care Facility
- Special Focus Facility

Explanatory (Process) - MDS QoC Characteristics

Twenty-one measures stratified by long-stay (15) or short-stay (6) care. These include:

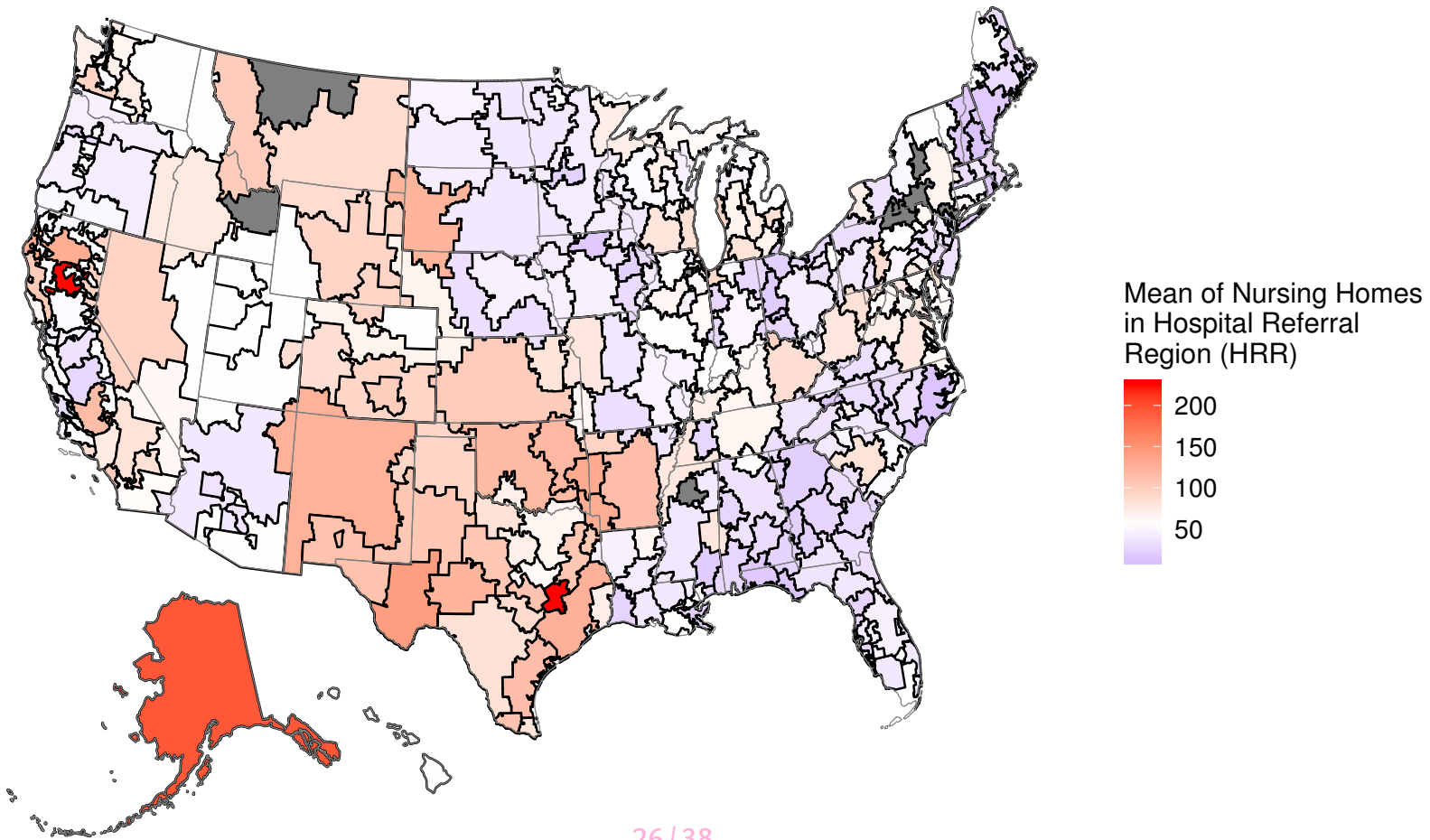
- Need for help with daily activities has increased
- Self-report moderate to severe pain
- Have pressure ulcers
- Lose too much weight
- Lose control of their bowels or bladder
- Have depressive symptoms

Five-Star Quality Measure is derived from the Minimum Dataset (MDS) quality of care (QoC) measures as a summary measure [Centers for Medicare and Medicaid Services, 2017].

HRRs are Cross-Classified within Provider States

Mean Total Weighted Health Survey Score by HRR of Nursing Homes Accepting Medicare or Medicaid Funding in the United States Owned by Organizations

Overall Mean of Total Weighted Health Survey Score for Nursing Homes: 56.93
Processing Date: 2016-03-01

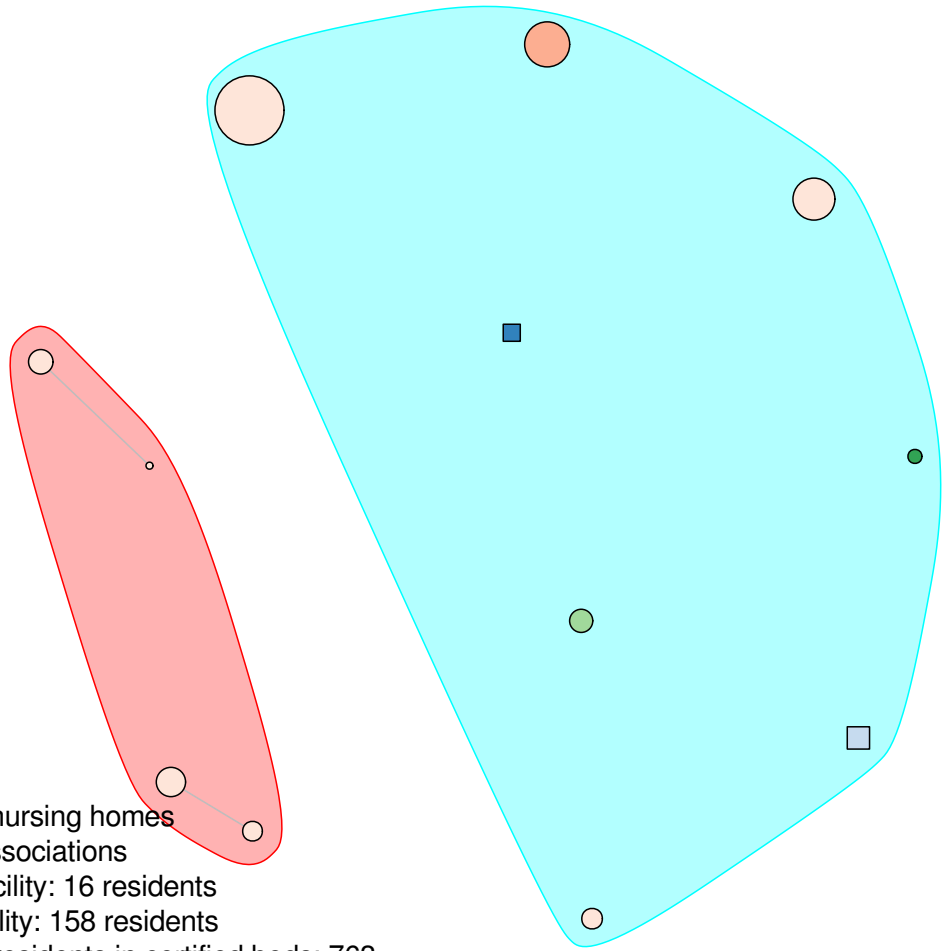


Data Check

A	D	E	H	J	K	L	N	O	P	Q	R
ovnum	city	s	SurveyTyp	tag	tag_desc	scop	statdate	cycle	standa	comp	filedate
675564	GIDDINGS	TX	Health	520	Set up an ongoing quality assessment and ass	K	2013-04-30	3	Y	N	2016-03-01
675366	COLLEGE STA	TX	Health	518	Train all employees on what to do in an emer	K	2013-02-20	3	Y	N	2016-03-01
675366	COLLEGE STA	TX	Health	517	Have a detailed, written plan for disasters an	K	2013-02-20	3	Y	N	2016-03-01
455589	COLLEGE STA	TX	Health	490	Make sure that the facility is administered in	K	2013-11-22	3	N	Y	2016-03-01
675564	GIDDINGS	TX	Health	490	Make sure that the facility is administered in	K	2013-05-11	3	Y	N	2016-03-01
455589	COLLEGE STA	TX	Health	323	Ensure that a nursing home area is free from	H	2013-11-22	3	N	Y	2016-03-01
455589	COLLEGE STA	TX	Health	314	Give residents proper treatment to prevent ne	K	2013-11-22	3	N	Y	2016-03-01
675564	GIDDINGS	TX	Health	314	Give residents proper treatment to prevent ne	K	2013-05-14	3	Y	N	2016-03-01
455589	COLLEGE STA	TX	Health	309	Provide necessary care and services to mainta	K	2013-11-22	3	N	Y	2016-03-01
455589	COLLEGE STA	TX	Health	281	Ensure services provided by the nursing facilit	H	2013-11-22	3	N	Y	2016-03-01
675564	GIDDINGS	TX	Health	281	Ensure services provided by the nursing facilit	K	2013-05-11	3	Y	N	2016-03-01
455589	COLLEGE STA	TX	Health	226	Develop and implement policies for 1) screen	K	2014-08-25	2	N	Y	2016-03-01
455589	COLLEGE STA	TX	Health	226	Develop and implement policies for 1) screen	K	2013-11-22	3	N	Y	2016-03-01
455589	COLLEGE STA	TX	Health	224	Protect each resident from mistreatment, neg	K	2014-08-25	2	N	Y	2016-03-01
455589	COLLEGE STA	TX	Health	224	Protect each resident from mistreatment, neg	K	2013-11-22	3	N	Y	2016-03-01
455589	COLLEGE STA	TX	Health	157	Immediately tell the resident, the resident's c	K	2013-11-22	3	N	Y	2016-03-01
675564	GIDDINGS	TX	Health	157	Immediately tell the resident, the resident's c	K	2013-05-11	3	Y	N	2016-03-01
675366	COLLEGE STA	TX	Fire Safety	48	A written emergency evacuation plan.	K	2013-02-20	3	Y	N	2016-03-01

Super-Organization in HRR

Nursing homes connected to other facilities accepting Medicare or Medicaid through owners who are organizations in Hospital Referral Region of 457: Casper, WY.



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- Government -- City/county
- Government -- County
- Government -- Federal
- Government -- Hospital district
- Government -- State
- Non-profit -- Church related
- Non-profit -- Corporation
- Non-profit -- Other

Size based on number of residents

Multiple and single cluster subgroups

Nodes: 12 nursing homes
Edges: 2 associations
Smallest facility: 16 residents
Largest facility: 158 residents
Number of residents in certified beds: 763
Number of certified beds: 943
Processing date: 2016-03-01

STATISTICAL MODELING

- Bayesian analysis of the Poisson random effects model with repeated measures was utilized.
- Total Health Weighted Survey Score was discretized (rounded).
- Mean-centering of continuous explanatory variables was performed.

R packages used for modeling:

- ***MCMCglmm*** [Hadfield, 2010]
- ***postMCMCglmm*** [Wiley, 2013]

Models:

- Two Bayesian hierarchical models were formulated to prevent multicollinearity between distinct resident quality measures in the MDS (Model 2), and the Five-Star Quality Measure (Model 1).
- To account for cross-classification, the random effects of HRR and provider state were fitted additively.
- Prevalence ratios (PRs) from the exponentiated coefficients.
- Proportion of variation in outcome that is attributable to random effect was deduced from the intraclass correlation coefficient (ICC).

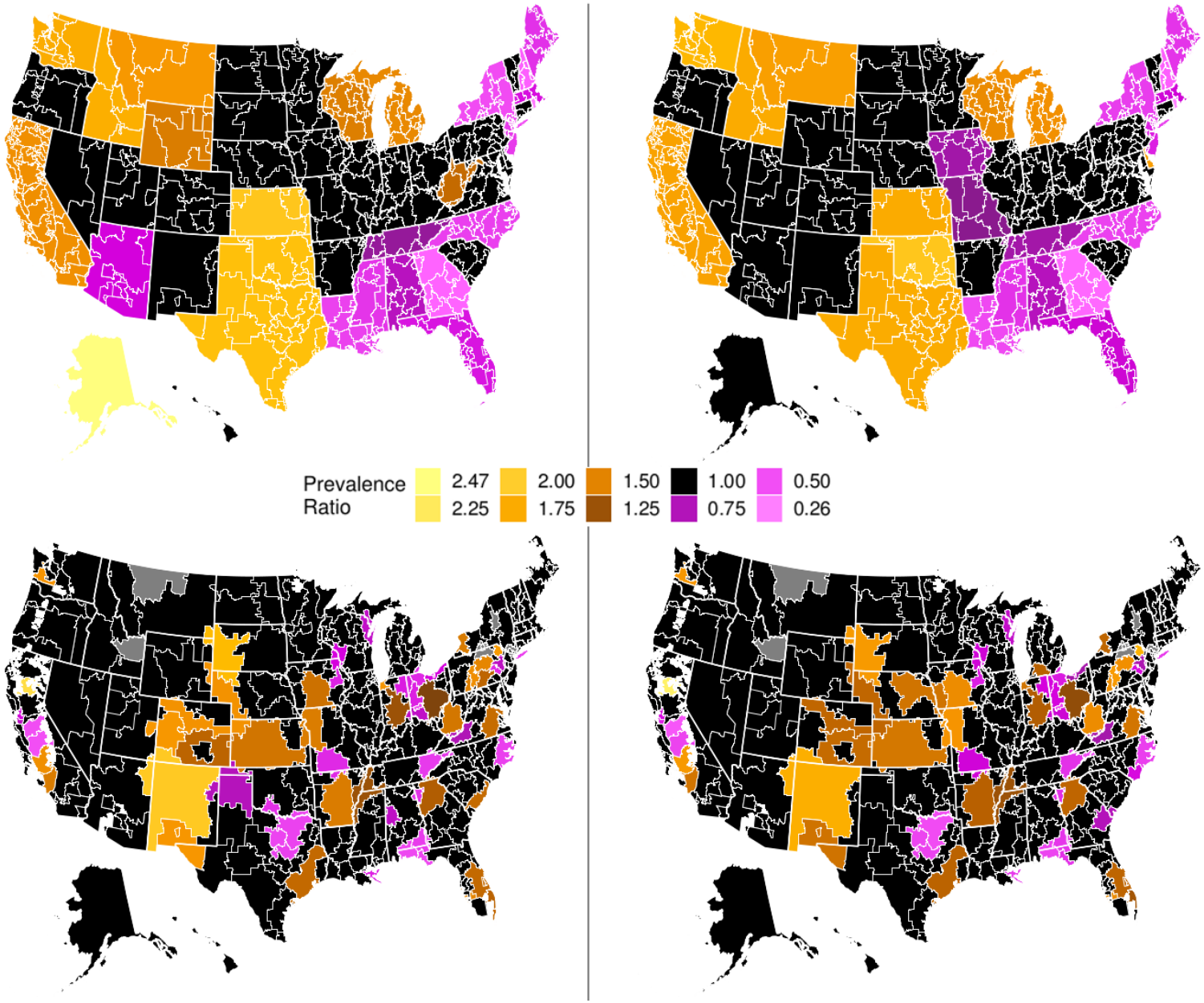
MCMC specifics:

- Non-informative priors were specified to generate robust estimates of model parameters in the posterior distribution.
- Sampling phase of 115,000 iterations with a burn-in of 15,000 iterations, and a thinning interval of 10 was specified to obtain 10,000 samples in the posterior distribution.

Prevalence Ratios

Variable	Model 1 (NHs = 9,001; HRRs = 294)				Model 2 (NHs = 6,693; HRRs = 293)			
	PR	l-95 HPDI	u-95 HPDI	MCMC p	PR	l-95 HPDI	u-95 HPDI	MCMC p
Nurse staffing								
Adjusted CNA staffing (HRD)	0.967	0.956	0.980	<0.001	0.963	0.950	0.977	<0.001
Adjusted LPN staffing (HRD)	1.013	0.998	1.030	0.102	1.010	0.991	1.028	0.290
Adjusted RN staffing (HRD)	0.795	0.770	0.820	<0.001	0.822	0.789	0.854	<0.001
Facility characteristics								
Number of residents in certified beds (n)	1.003	1.002	1.003	<0.001	1.003	1.002	1.003	<0.001
Occupancy ratio (%)	0.995	0.994	0.995	<0.001	0.995	0.994	0.996	<0.001
Years in business (n)	1.006	1.004	1.007	<0.001	1.004	1.003	1.006	<0.001
Ownership type								
For-profit	Ref				Ref			
Government	0.954	0.909	0.999	0.047	0.950	0.901	0.997	0.045
Non-profit	0.878	0.845	0.911	<0.001	0.893	0.859	0.930	<0.001
•••								
Five-Star Quality Measure from MDS								
Category 1	Ref							
Category 2	0.959	0.940	0.977	<0.001				
Category 3	0.936	0.917	0.955	<0.001				
Category 4	0.899	0.881	0.919	<0.001				
Category 5	0.839	0.821	0.859	<0.001				
Derived from social network analysis at HRR-Level								
Prevalence of NHs in multiple affiliation	0.999	0.997	1.000	0.026	0.999	0.997	1.000	0.084
Mean size of nursing home ownership group	0.983	0.975	0.992	<0.001	0.978	0.969	0.987	<0.001
Delta Herfindahl-Hirschman Index	1.032	0.655	1.635	0.898	1.082	0.668	1.780	0.759
Overall ownership network class by HRR								
Multiple affiliation	Ref				Ref			
Single affiliation	1.022	0.995	1.049	0.103	1.030	1.002	1.058	0.037

Models 1 (Left) and 2 (Right): Additive Significant Prevalence Ratios Different from 1.00 of Total Weighted Health Survey Score by American State (Above) and HRR (Below) of Nursing Homes Accepting Medicare or Medicaid Funding Owned by Organizations



DISCUSSION

- Overall, super-organization in hospital referral region is not associated with care deficiencies in American nursing homes.
- However, being part of an ownership group with more facilities is beneficial for care quality among nursing homes with super-organization.

- Prevalence of American nursing homes having super-organization increased from 56.8 to 56.9% over the 2-year period.
- Mean size of nursing home ownership group in hospital referral region increased from 3.11 to 3.23 facilities.

- Proportion of the total variation in scope of cited care deficiencies attributable to American state after controlling for HRR was approximately 17.6% in Model 1, and 19.3% in Model 2.
- Proportion of total variation in care deficiencies that was explained by HRR after controlling for American state was 7.3% in Model 1, and 8.1% in Model 2.

- Medicaid reimbursement rate varies by provider state.
- Contextual effects within these administrative units have a large impact on care quality, and include variation in the minimum threshold of registered nurse HRD staffing levels.

Questions?

Thank you!

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