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# Using Network Analysis to Explore the Implementation & Impact of Population Health Strategies

Glen P. Mays, *University of Kentucky*



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# Using Network Analysis to Explore the Implementation & Impact of Population Health Strategies

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[systemsforaction.org](http://systemsforaction.org)

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# Acknowledgements

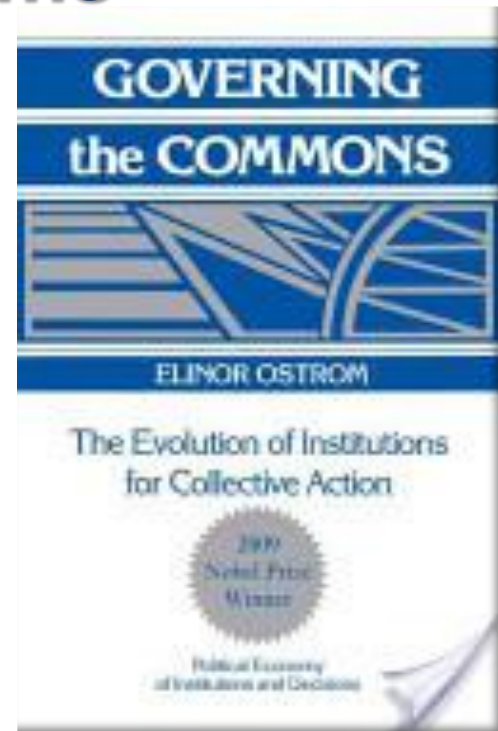
- Funded by the Robert Wood Johnson Foundation through the **Systems for Action National Coordinating Center**
- Collaborators include Cezar Mamaril, Rachel Hogg, Rick Ingram

# Using networks for population health improvement strategies

- Designed to achieve **large-scale** health improvement: neighborhood, city/county, region
- Target **fundamental** and often **multiple** determinants of health
- Mobilize the **collective actions** of multiple stakeholders in government & private sector

# Using networks to overcome collective action problems

- Incentive compatibility → public goods
- Concentrated costs & diffuse benefits
- Time lags: costs vs. improvements
- Uncertainties about what works
- Asymmetry in information
- Difficulties measuring progress
- Weak and variable institutions & infrastructure
- Imbalance: resources vs. needs
- Stability & sustainability of funding



# Research questions of interest

- Which organizations engage in implementation of population health activities in local communities?
- How and why do these contributions change over time?
- How do patterns of interaction influence volume, scope, and effectiveness of pop health activities?
  - Complementarities/Synergies
  - Substitutions
  - Crowd-out

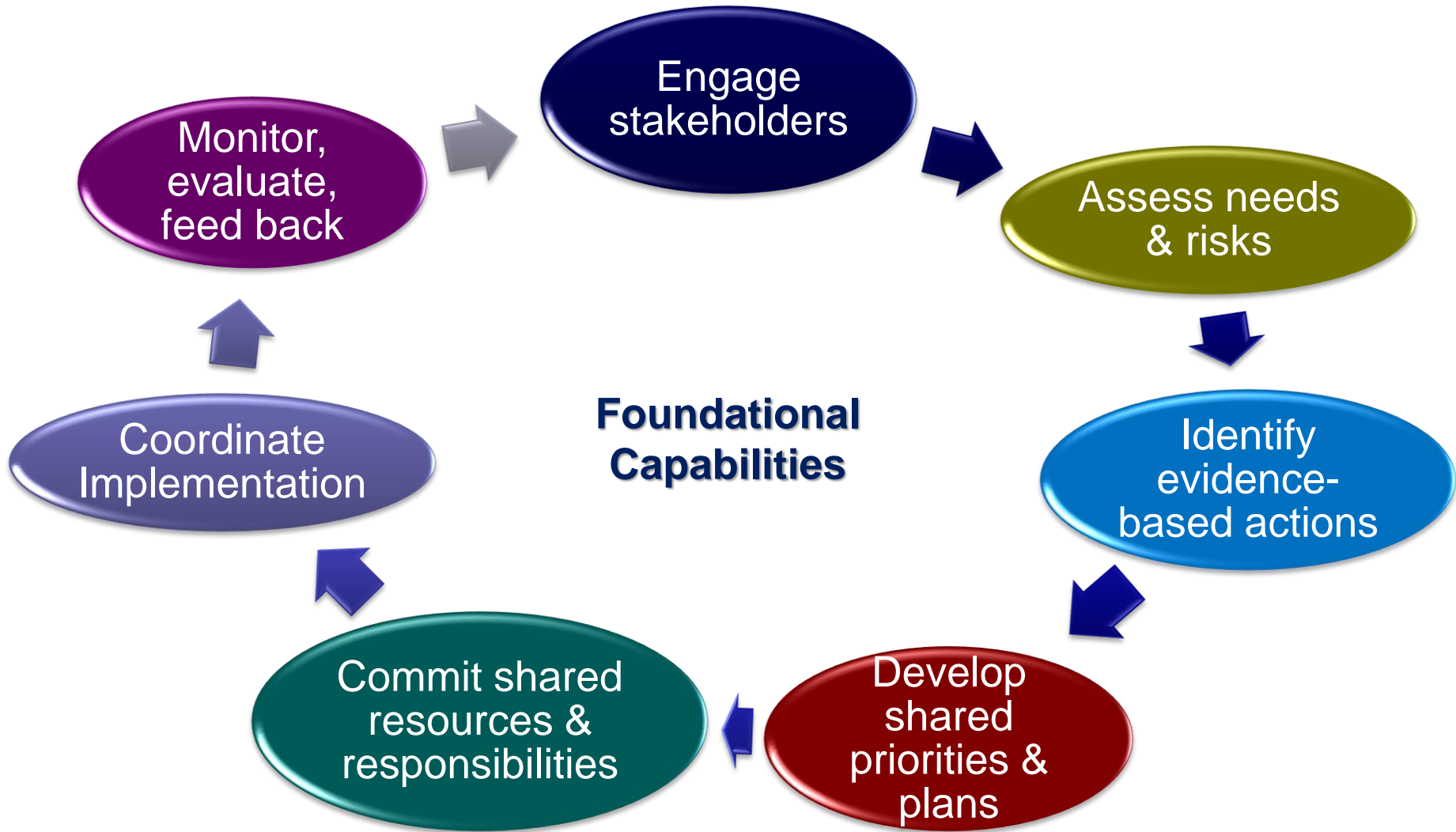
# Data: networks for population health

## National Longitudinal Survey of Public Health Systems

- Cohort of 360 communities with at least 100,000 residents
- Followed over time: 1998, 2006, 2012, 2014\*\*, 2016, 2018
- Local public health officials report:
  - **Scope**: availability of 20 recommended population health activities
  - **Network**: types of organizations contributing to each activity
  - **Perceived effectiveness** of each activity in meeting community needs

\*\* Stratified sample of 500 communities with <100,000 residents added beginning in 2014 wave

# Measures: recommended capabilities that support **implementation** of multi-sector health initiatives







# Data linkages expand analytic possibilities

- **Area Health Resource File:** health resources, demographics, socioeconomic status, insurance coverage
- **NACCHO Profile data:** public health agency institutional and financial characteristics
- **CMS Impact File & Cost Report:** hospital ownership, market share, uncompensated care
- **Dartmouth Atlas:** Area-level medical spending (Medicare)
- **CDC Compressed Mortality File:** Cause-specific death rates by county
- **Equality of Opportunity Project (Chetty):** local estimates of life expectancy by income
- **National Health Interview Survey:** individual-level health
- **HCUP:** area-level hospital and ED use, readmissions

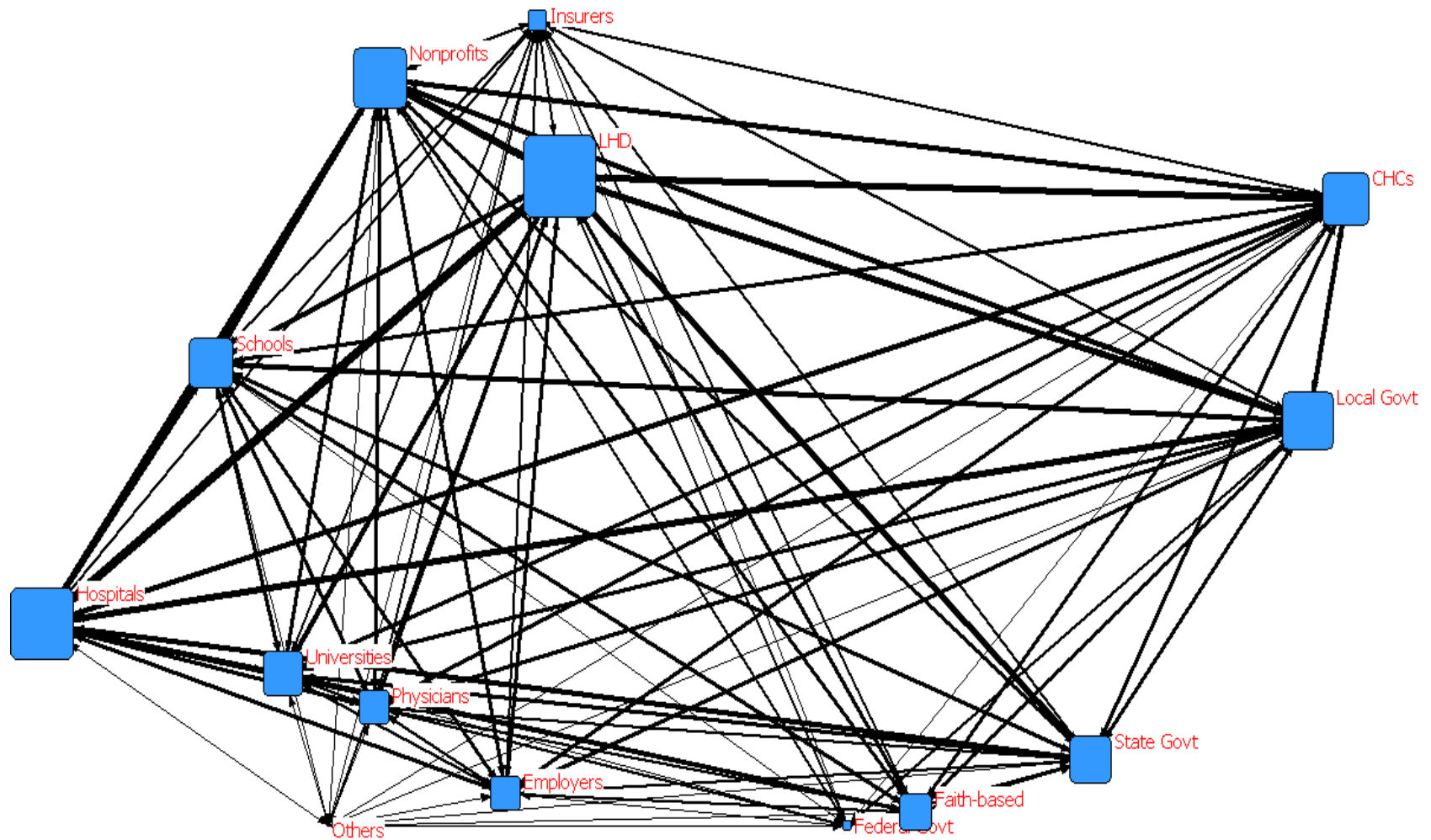
# Cluster and network analysis to identify “system capital”

Cluster analysis is used to classify communities into one of 7 categories of **population health system capital** based on:

- **Scope of activities** contributed by each type of organization
- **Density of connections** among organizations jointly producing activities
- **Degree centrality** of organizational contributors

Mays GP et al. Understanding the organization of public health delivery systems: an empirical typology. *Milbank Q.* 2010;88(1):81–111.

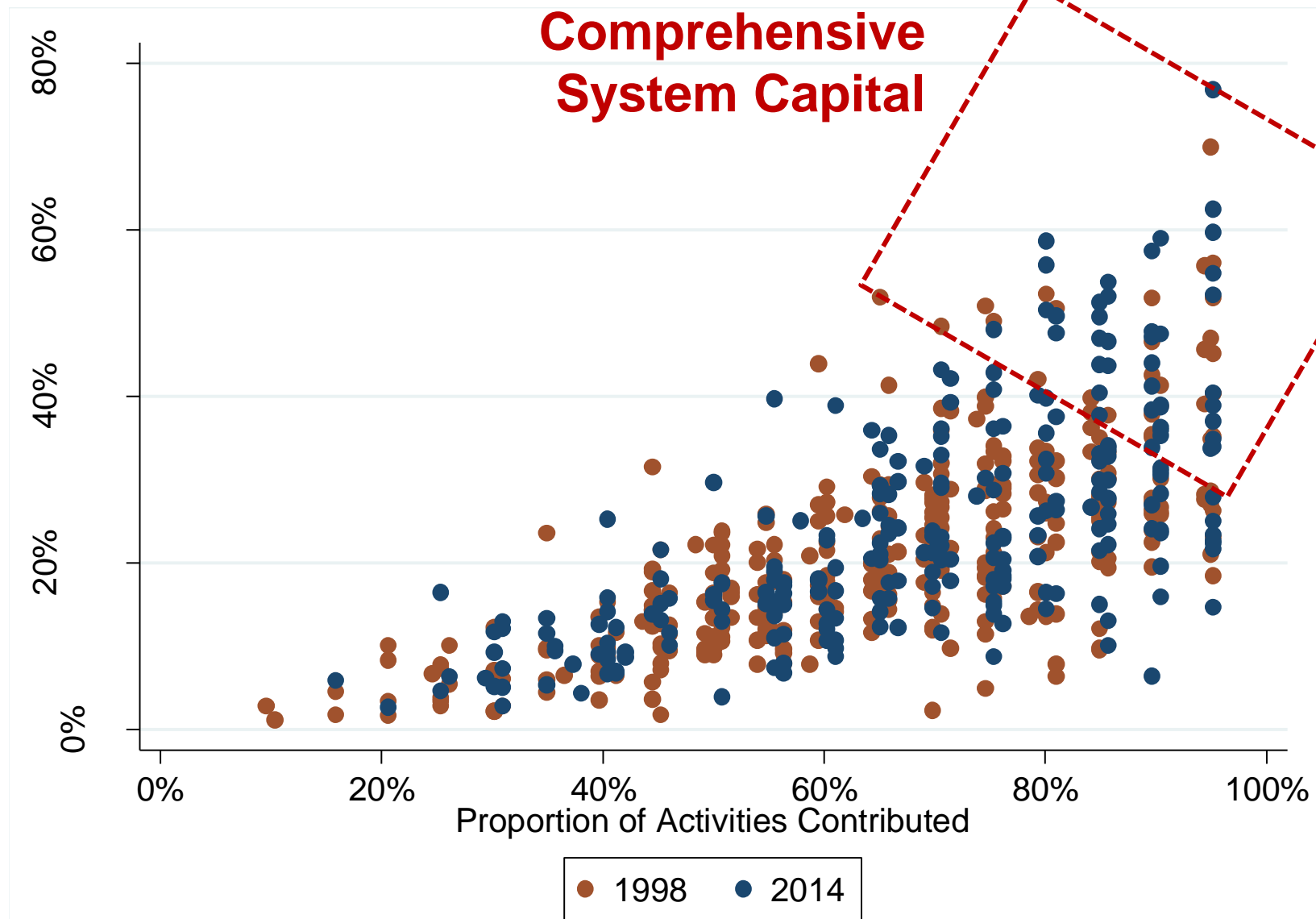
# Average network structure in 2016



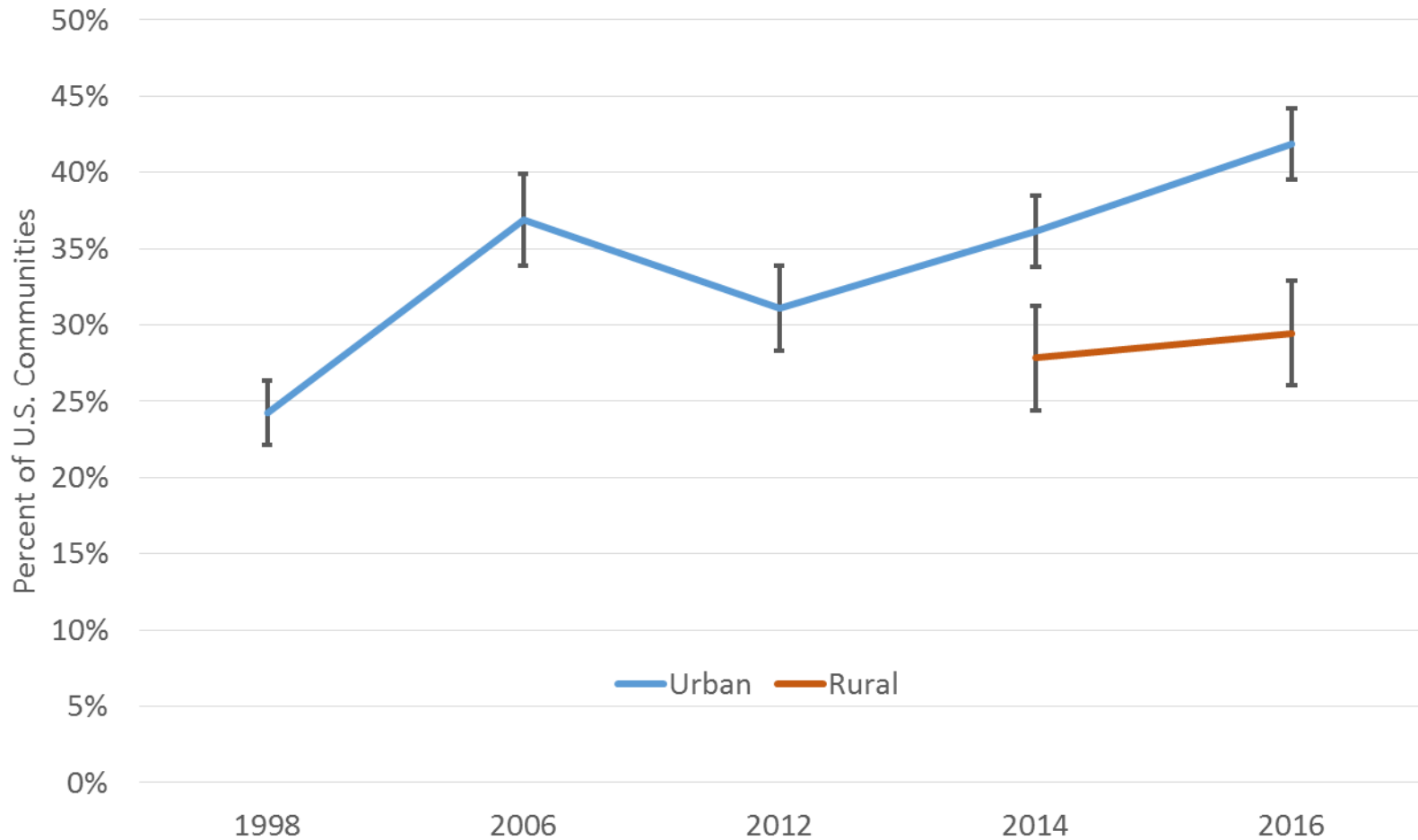
**Node size = degree centrality**

**Line size = % activities jointly contributed (tie strength)**

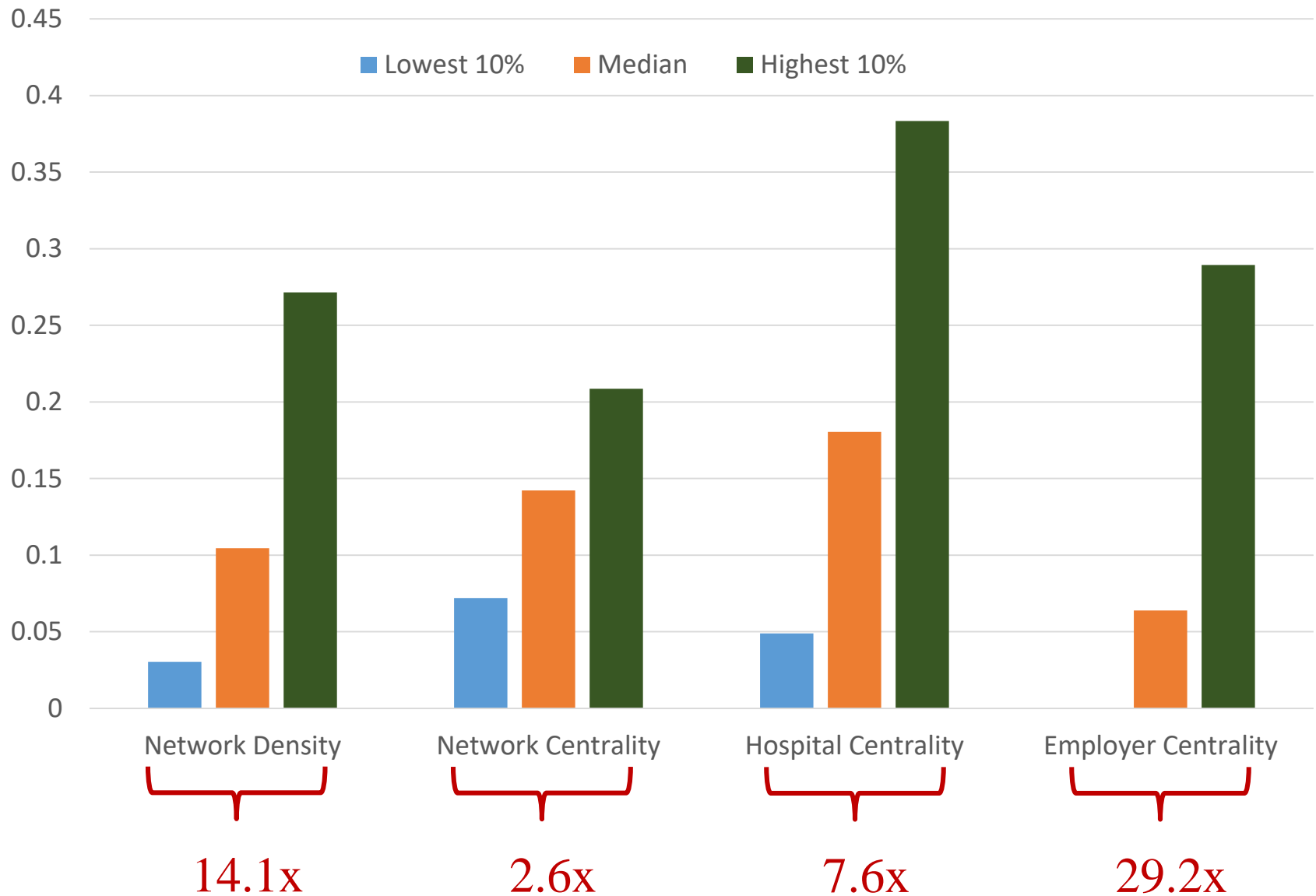
# Network density and scope of activities



# Variation and change in prevalence of comprehensive system capital



# Variation in network structure in 2016



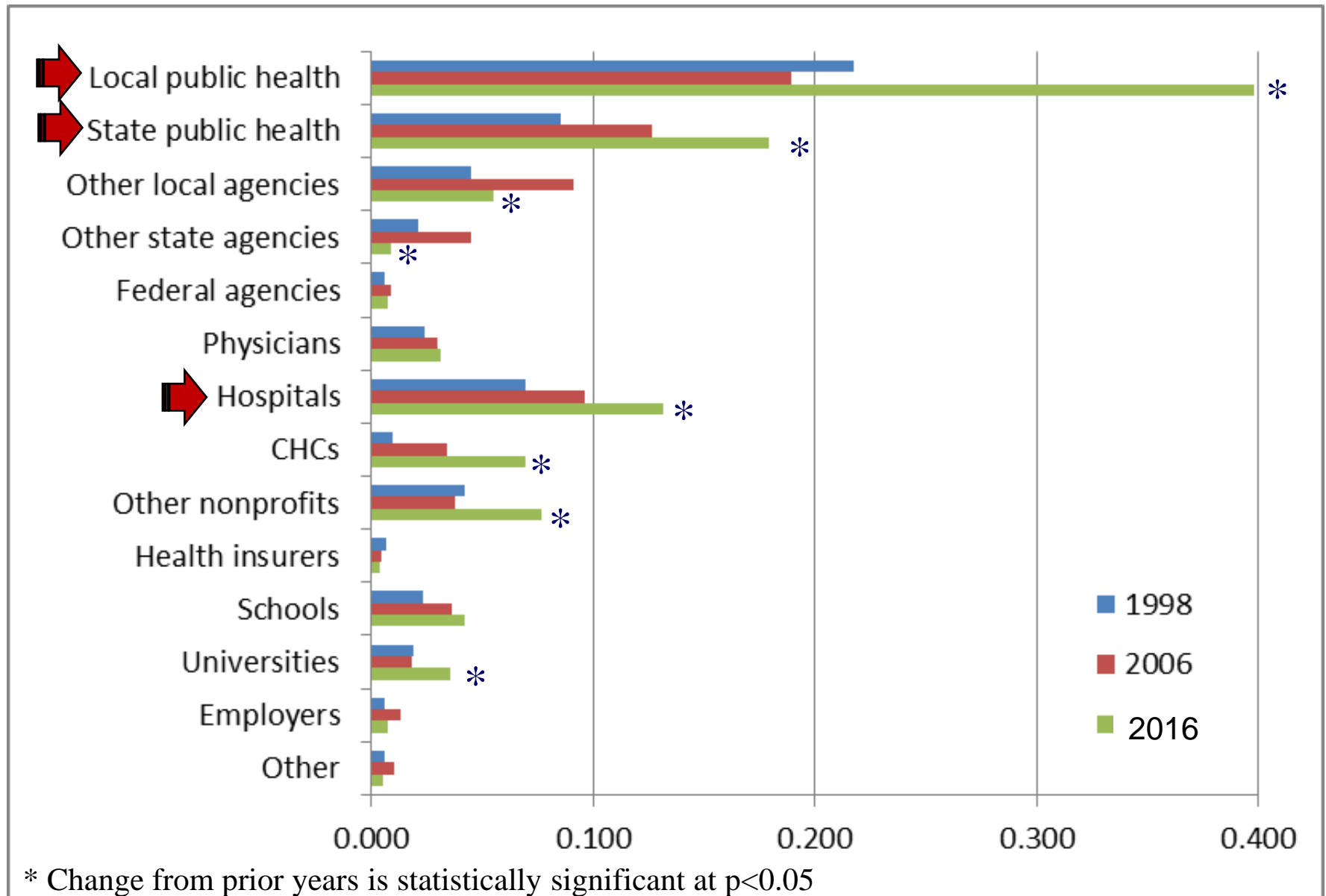
# Organizational contributions to population health activities

% of recommended activities performed

Type of Organization	1998	2016	Percent Change
Local public health agencies	60.7%	67.5%	11.1%
Other local government agencies	31.8%	33.2%	4.4%
State public health agencies	46.0%	34.3%	-25.4%
Other state government agencies	17.2%	12.3%	-28.8%
Federal government agencies	7.0%	7.2%	3.7%
Hospitals	37.3%	46.6%	24.7%
Physician practices	20.2%	18.0%	-10.6%
Community health centers	12.4%	29.0%	134.6%
Health insurers	8.6%	10.6%	23.0%
Employers/businesses	16.9%	15.3%	-9.6%
Schools	30.7%	25.2%	-17.9%
Universities/colleges	15.6%	22.6%	44.7%
Faith-based organizations	19.2%	17.5%	-9.1%
Other nonprofit organizations	31.9%	32.5%	2.0%
Other	8.5%	5.2%	-38.4%



# Bridging capital in population health networks: Trends in betweenness centrality



\* Change from prior years is statistically significant at  $p < 0.05$



# Estimating network effects

## Dependent variables:

- **Scope:** Percent of population activities implemented
- **Quality:** Perceived effectiveness of activities
- **Resource use:** Local public health spending;  
Area-level Medicare spending
- **Health outcomes:** premature mortality(<75), infant mortality,  
death rates for heart disease, diabetes, cancer, influenza

## Independent variables:

- **Contribution scores:** percent of activities contributed by  
each type of organization
- **Network characteristics:** network density, organizational  
degree centrality, betweenness centrality
- **Composite network measure:** comprehensive system capital

# Estimating network effects

## Estimation:

- Log-transformed Generalized Linear Latent and Mixed Models
- Account for repeated measures and clustering of communities within states
- Instrumental variables address endogeneity of network structures

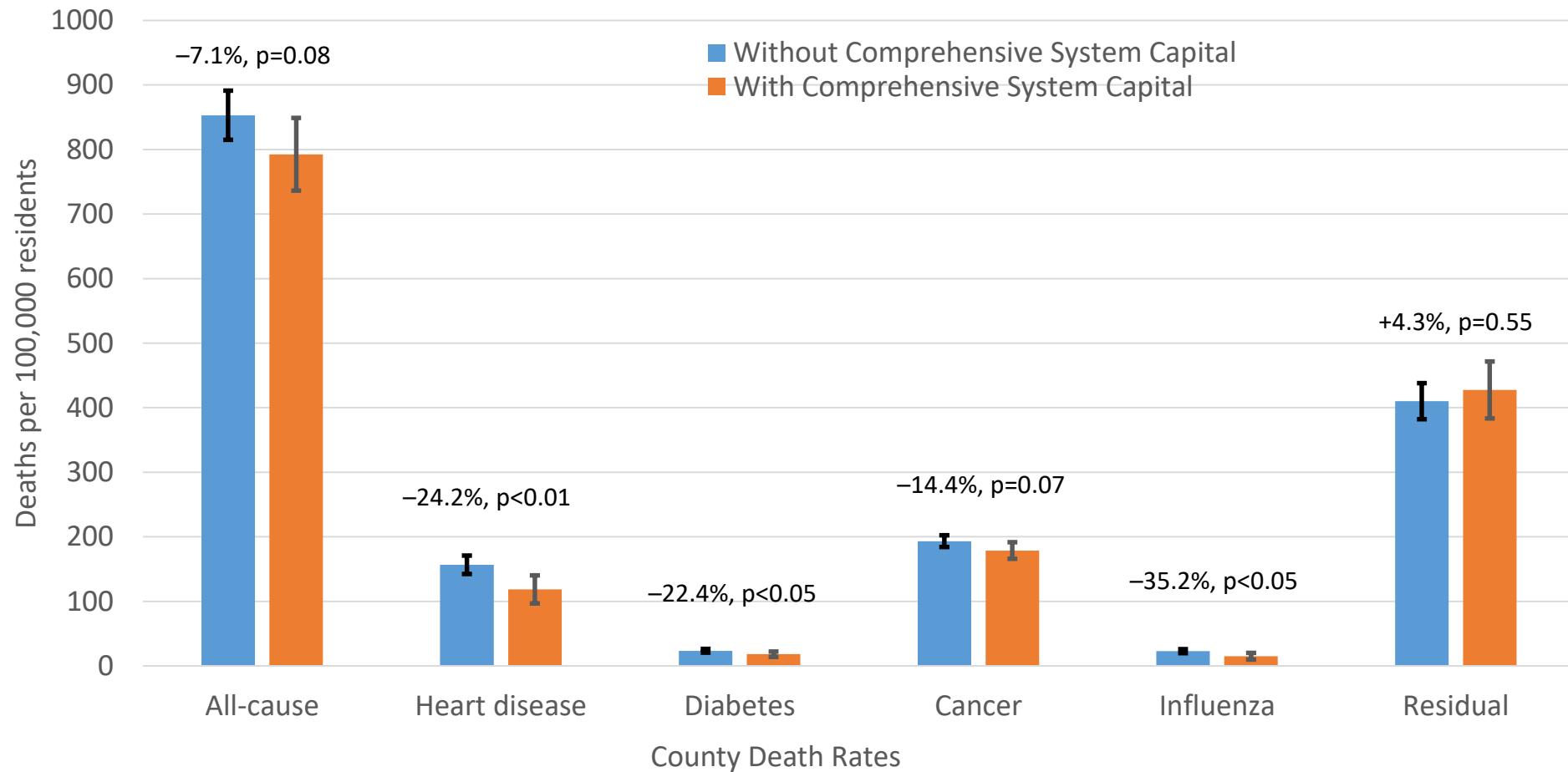
$$\ln(\text{Network}_{z,ijt}) = \sum \alpha_z \text{Governance}_{ijt} + \beta_1 \text{Agency}_{ijt} + \beta_2 \text{Community}_{ijt} + \mu_j + \varphi_t + \varepsilon_{ijt}$$

$$\ln(\text{Quantity/Quality/Cost}_{ijt}) = \sum \alpha_z \ln(\hat{\text{Network}}_z)_{ijt} + \beta_1 \text{Agency}_{ijt} + \beta_2 \text{Community}_{ijt} + \mu_j + \varphi_t + \varepsilon_{ijt}$$

All models control for type of jurisdiction, population size and density, metropolitan area designation, income per capita, unemployment, racial composition, age distribution, educational attainment, and physician availability.

# Health effects attributable to network structures

## Fixed effects IV Estimates on Mortality



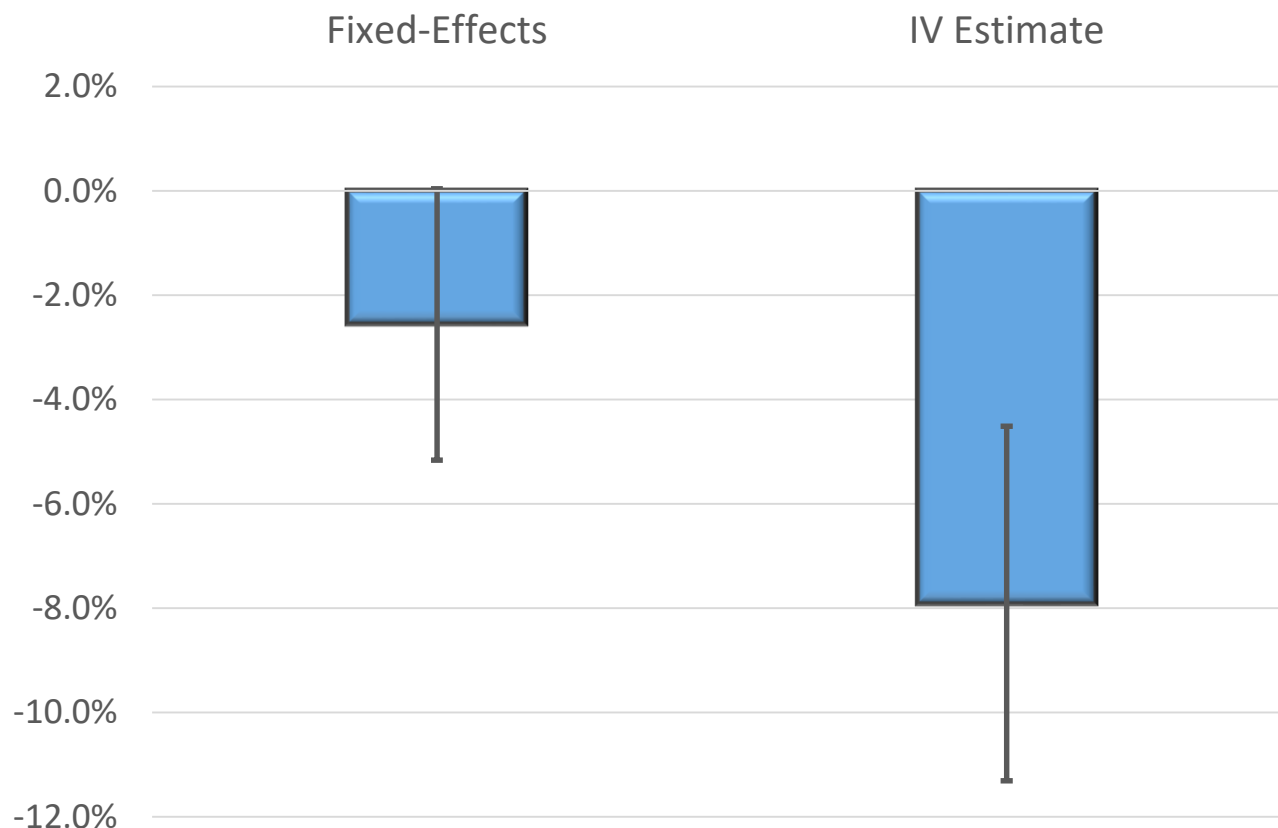
**Models also control for racial composition, unemployment, health insurance coverage, educational attainment, age composition, and state and year fixed effects.**

**N=1019 community-years**

Mays GP et al. *Health Affairs* 2016

# Economic effects attributable to network structure

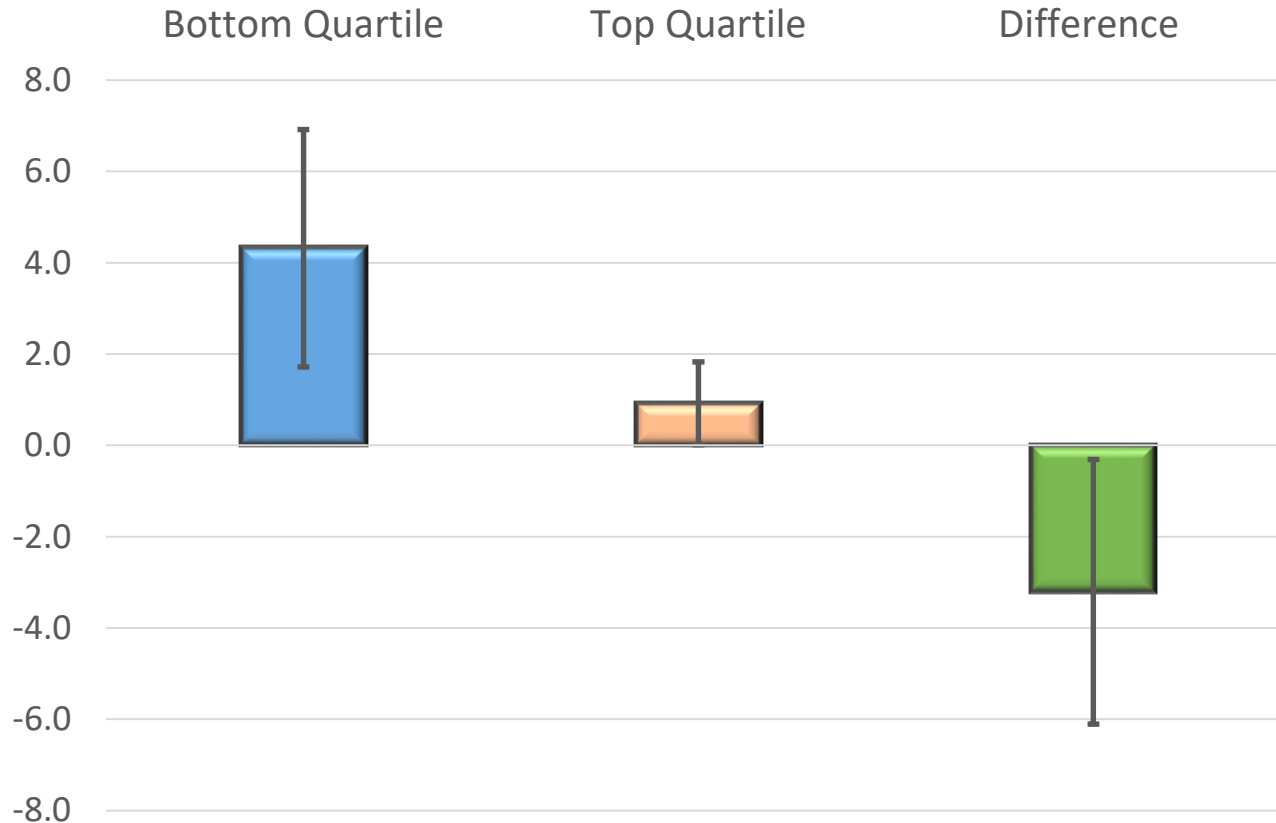
## Impact of Comprehensive Systems on **Medical Spending** (Medicare)



Models also control for racial composition, unemployment, health insurance coverage, educational attainment, age composition, and state and year fixed effects. N=1019 community-years. Vertical lines are 95% confidence intervals

# Equity effects attributable to network structure

## Impact of Comprehensive Systems on **Life Expectancy by Income**



Models also control for racial composition, unemployment, health insurance coverage, educational attainment, age composition, and state and year fixed effects. N=1019 community-years. Vertical lines are 95% confidence intervals

# Some conclusions

- Population health activities are produced through highly inter-organizational and multi-sectoral efforts (62% of contributions from outside governmental public health sector)
- Structure of population health networks varies widely and changes over time
- Structure appears closely related to performance & outcomes
- Network structure is endogenous – ignoring this can lead to biased estimates of impact



# **Caveats: methodological trade-offs in systems science**

In order to follow large numbers of community networks over long periods of time:

- Single respondent in each community
- Low-resolution measures of population health activities
- Networks defined by organization types/sectors, not individual organizations

# Testing mechanisms for aligning medical, social, and public health systems

A Robert Wood Johnson Foundation program

## Systems for Action

*Systems and Services Research to Build a Culture of Health*



## Research Agenda

*Delivery and Financing System Innovations  
for a Culture of Health*

September 2015

<http://www.systemsforaction.org>

# For More Information

## Systems for Action

National Coordinating Center

*Systems and Services Research to Build a Culture of Health*

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**Journal:** [www.FrontiersinPHSSR.org](http://www.FrontiersinPHSSR.org)

**Archive:** [works.bepress.com/glen\\_mays](http://works.bepress.com/glen_mays)

**Blog:** [publichealtheconomics.org](http://publichealtheconomics.org)



# **Appendix: Ancillary Results**

# Determinants of system structure

## Probit Estimates of Factors Influencing the Probability of Comprehensive System Capital

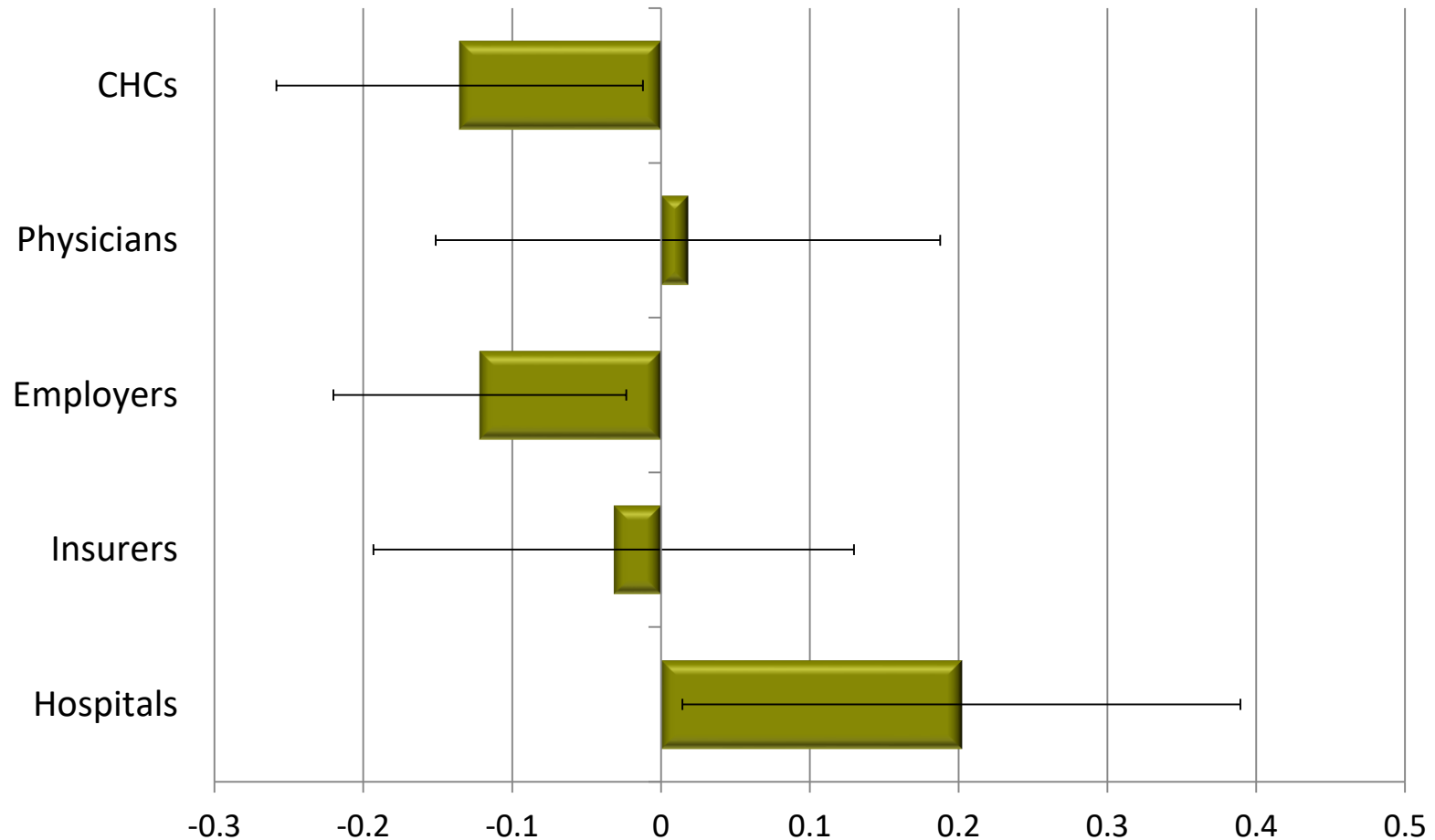
Variable	Marginal Effect on Probability of System Capital
Local board of health with decentralized governance	14.2%**
Local board of health with centralized governance	9.7%**
Centralized governance without local board of health	-4.5%**
Decentralized governance without local board of health	Reference
Population size (100,000s)	4.2%**
Population density (1000s)	4.9%*
Household income per capita (1000s)	2.5%**

} IVs

Models also control for racial composition, unemployment, health insurance coverage, educational attainment, age composition, and state and year fixed effects.  
 N=779 community-years \*\*p<0.05 \*p<0.10

# Do other organizations complement or substitute for public health agency work?

## Results from Multivariate GLLAMM Models



# How does organizational centrality affect the scope of population health activities?

## Results from Multivariate GLLAMM Models

