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Summer June 14, 2015

Using Network Analysis to Understand Public Health Delivery Systems & Community Health Initiatives

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Available at: https://works.bepress.com/glen_mays/207/

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AcademyHealth Annual Research Meeting • Minneapolis, MN • 14 June 2015

Acknowledgements

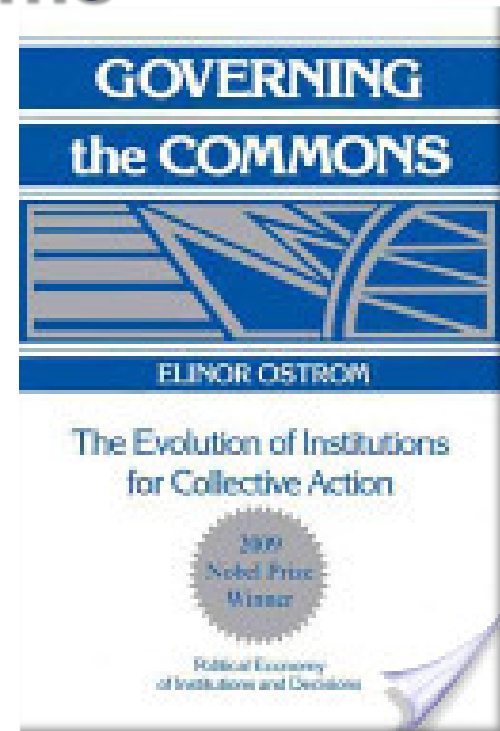
- Funded by the Robert Wood Johnson Foundation through the **Public Health Services & Systems Research National Coordinating Center**
- Collaborators include Cezar Mamaril, Lava Timsina, Rachel Hogg, David Bardach

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
 - Usual and unusual suspects
 - Infrastructure requirements

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 contribute to the implementation of public health activities in local communities?
- How do these contributions change over time?
Recession, recovery, ACA implementation?
- How do patterns of interaction in public health production influence quantity, quality, cost & population health?
 - Complementarities/Synergies
 - Substitutions/Cannibalization

Data: public health production

National Longitudinal Survey of Public Health Systems

- Cohort of 360 communities with at least 100,000 residents
- Followed over time: 1998, 2006, 2012, 2014**
- Local public health officials report:
 - **Scope**: availability of 20 recommended public health activities
 - **Network**: types of organizations contributing to each activity
 - **Effort**: contributed by designated local public health agency
 - **Quality**: perceived effectiveness of each activity

** Stratified sample of 500 communities < 100,000 added in 2014 wave

Data: community & market characteristics

- **Area Health Resource File:** physician, hospital and CHC supply; population size and demographics, socioeconomic status, racial/ethnic composition, health insurance coverage
- **NACCHO Profile data:** public health agency institutional and financial characteristics
- **Medicare Cost Report:** hospital ownership, market share, uncompensated care
- **CDC Compressed Mortality File:** Cause-specific death rates by county

Cluster and network analysis to identify “system capital”

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

- **Scope of activities** contributed by each type of organization
- **Density of connections** among organizations jointly producing public health activities
- **Degree centrality** of the local public health agency

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

Network analytic approach

- Two-mode networks (organization types X activities) transformed to one-mode networks with **tie strength** indicated by number of activities jointly produced

Organization Type	Activities							
	1	2	3	4	5	6	7	...
Local public health agency	X	X		X		X		
State public health agency		X	X		X			
Hospitals		X	X	X			X	
Physician practices					X		X	
CHCs	X		X		X			
Insurers					X	X		
Employers								
Social service organizations		X		X			X	
Schools			X		X	X		

Estimating network effects

Dependent variables:

- **Quantity:** Percent of recommended public health activities performed in the community
- **Quality:** Perceived effectiveness of activities
- **Resource use:** Local governmental expenditures for public health activities
- **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

Estimating network effects

Estimation:

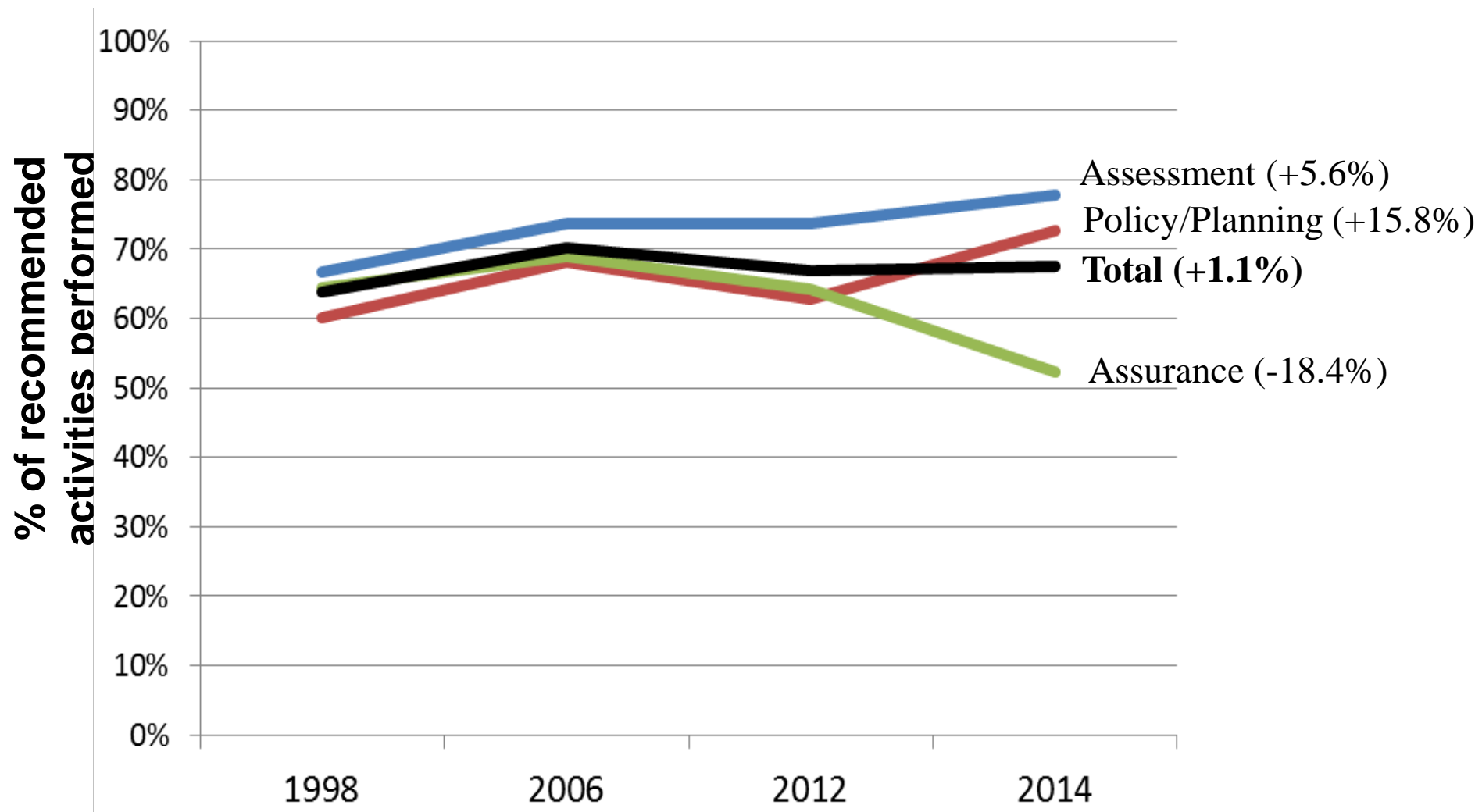
- Log-transformed Generalized Linear Latent and Mixed Models
- Account for repeated measures and clustering of public health jurisdictions within states
- Instrumental variables address endogeneity of network structures

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

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

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.

Delivery of recommended public health activities, 1998-2014

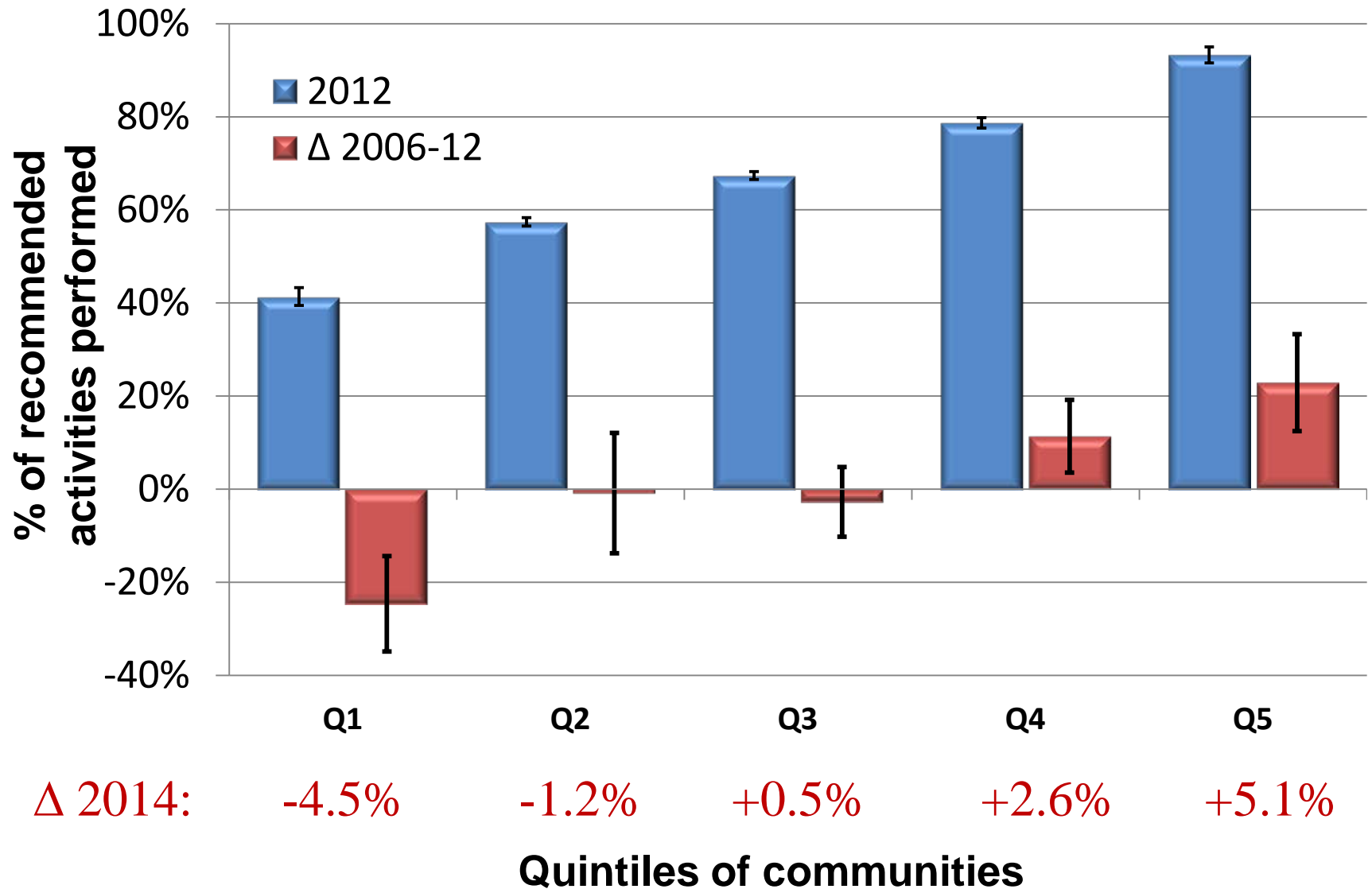


Delivery of recommended public health activities, 1998-2014

Public Health Activity	1998	2014	% Change
1 Community health needs assessment	71.5%	86.0%	20.2%**
2 Behavioral risk factor surveillance	45.8%	70.2%	53.2%**
3 Adverse health events investigation	98.6%	100.0%	1.4%
4 Public health laboratory testing services	96.3%	96.5%	0.2%
5 Analysis of health status and health determinants	61.3%	72.8%	18.7%**
6 Analysis of preventive services utilization	28.4%	39.4%	38.8%**
7 Health information provision to elected officials	80.9%	84.8%	4.8%
8 Health information provision to the public	75.4%	83.8%	11.1%*
9 Health information provision to the media	75.2%	87.5%	16.3%**
10 Prioritization of community health needs	66.1%	82.3%	24.6%**
11 Community participation in health improvement planning	41.5%	67.7%	63.0%**
12 Development of community health improvement plan	81.9%	86.2%	5.2%
13 Resource allocation to implement community health plan	26.2%	43.2%	64.9%**
14 Policy development to implement community health plan	48.6%	57.5%	18.4%*
15 Communication network of health-related organizations	78.8%	84.8%	7.6%
16 Strategies to enhance access to needed health services	75.6%	50.2%	-33.6%**
17 Implementation of legally mandated public health activities	91.4%	92.4%	1.0%
18 Evaluation of public health programs and services	34.7%	38.4%	10.8%**
19 Evaluation of local public health agency capacity/performance	56.3%	55.0%	-2.4%
20 Implementation of quality improvement processes	47.3%	49.6%	5.0%
Composite availability of assessment activities (1-6)	66.7%	77.6%	16.4%**
Composite availability of policy development activities (7-15)	60.2%	72.5%	20.4%
Composite availability of assurance activities (16-20)	64.4%	52.8%	-18.0%*
Composite availability of all activities (1-20)	63.8%	67.6%	6.0%*

Variation and Change in Delivery

Delivery of recommended public health activities, 2006-12

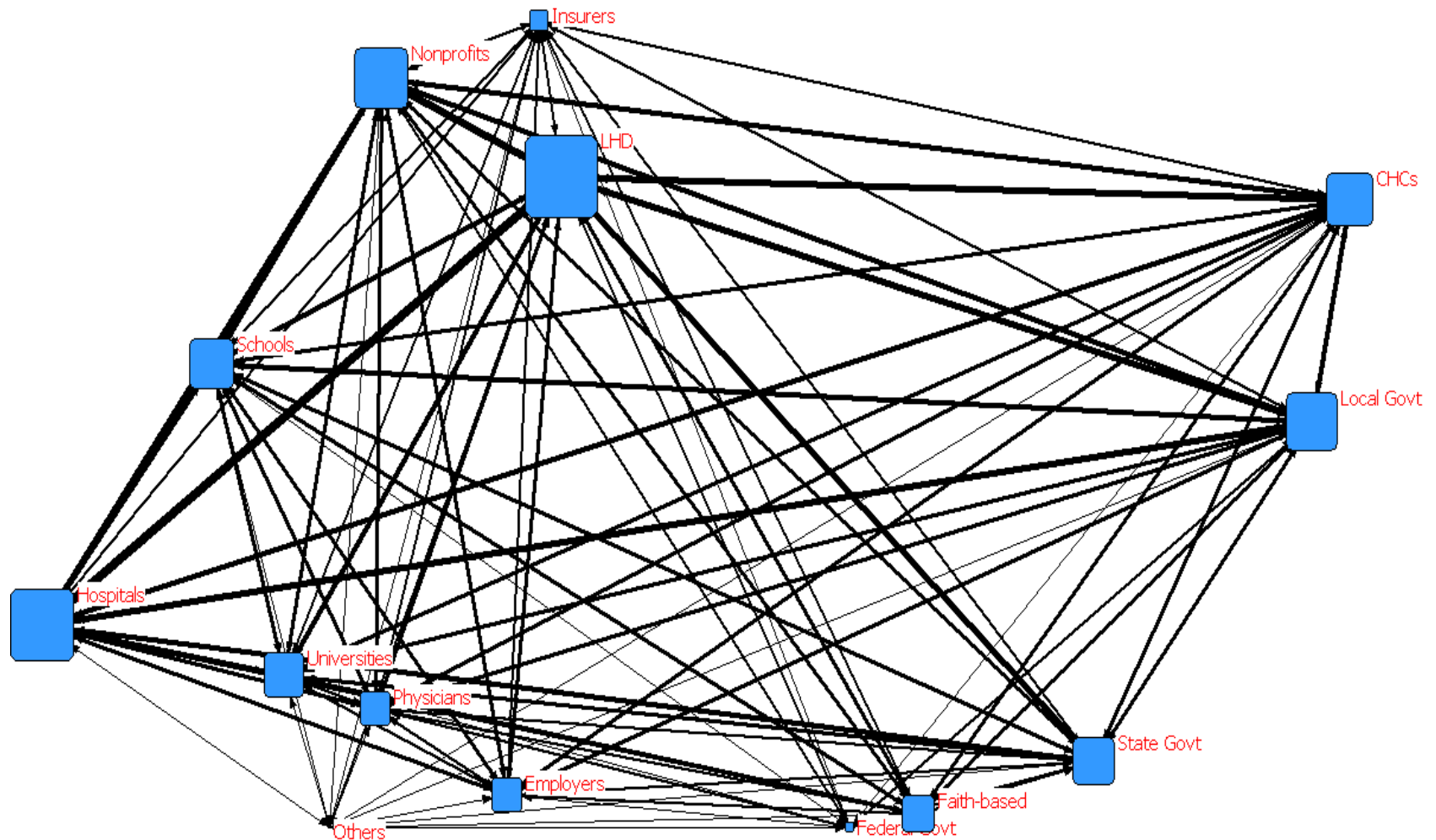


Organizational contributions to recommended public health activities, 1998-2014

Type of Organization	<u>1998</u>	<u>2006</u>	<u>2012</u>	<u>2014</u>
Local public health agency	60.7%	66.5%	62.0%	67.4%
Other local govt agencies	31.8%	50.8%	26.3%	32.7%
State public health	46.0%	45.3%	36.4%	34.0%
Other state govt agencies	17.2%	16.4%	13.0%	12.7%
Federal agencies	7.0%	12.0%	8.7%	7.1%
Hospitals	37.3%	41.1%	39.3%	47.2%
Physician practices	20.2%	24.1%	19.5%	18.0%
Community health centers	12.4%	28.6%	26.9%	28.3%
Health insurers	8.6%	10.0%	9.8%	11.1%
Employers/business	25.5%	16.9%	13.4%	15.0%
Schools	30.7%	27.6%	24.9%	24.7%
Universities/colleges	15.6%	21.6%	21.2%	22.2%
Faith-based organizations	24.0%	19.2%	15.7%	16.8%
Other nonprofits	31.9%	34.2%	31.6%	33.6%
Other organizations	8.5%	8.8%	5.4%	5.4%

**% of recommended
activities performed**

Average public health network structure in 2014



Node size = degree centrality

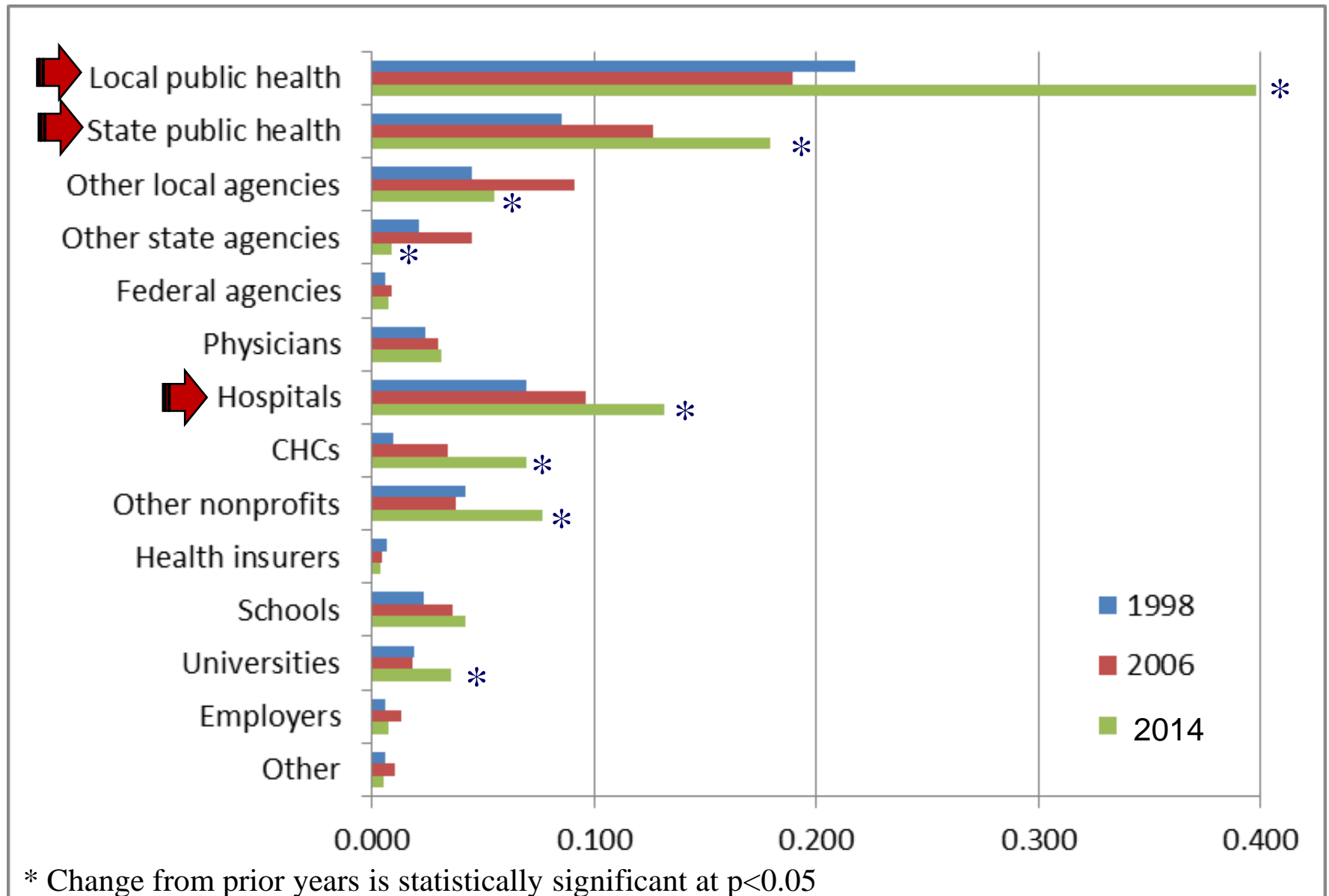
Line size = % activities jointly contributed (tie strength)

Changes in network structure 1998-2014

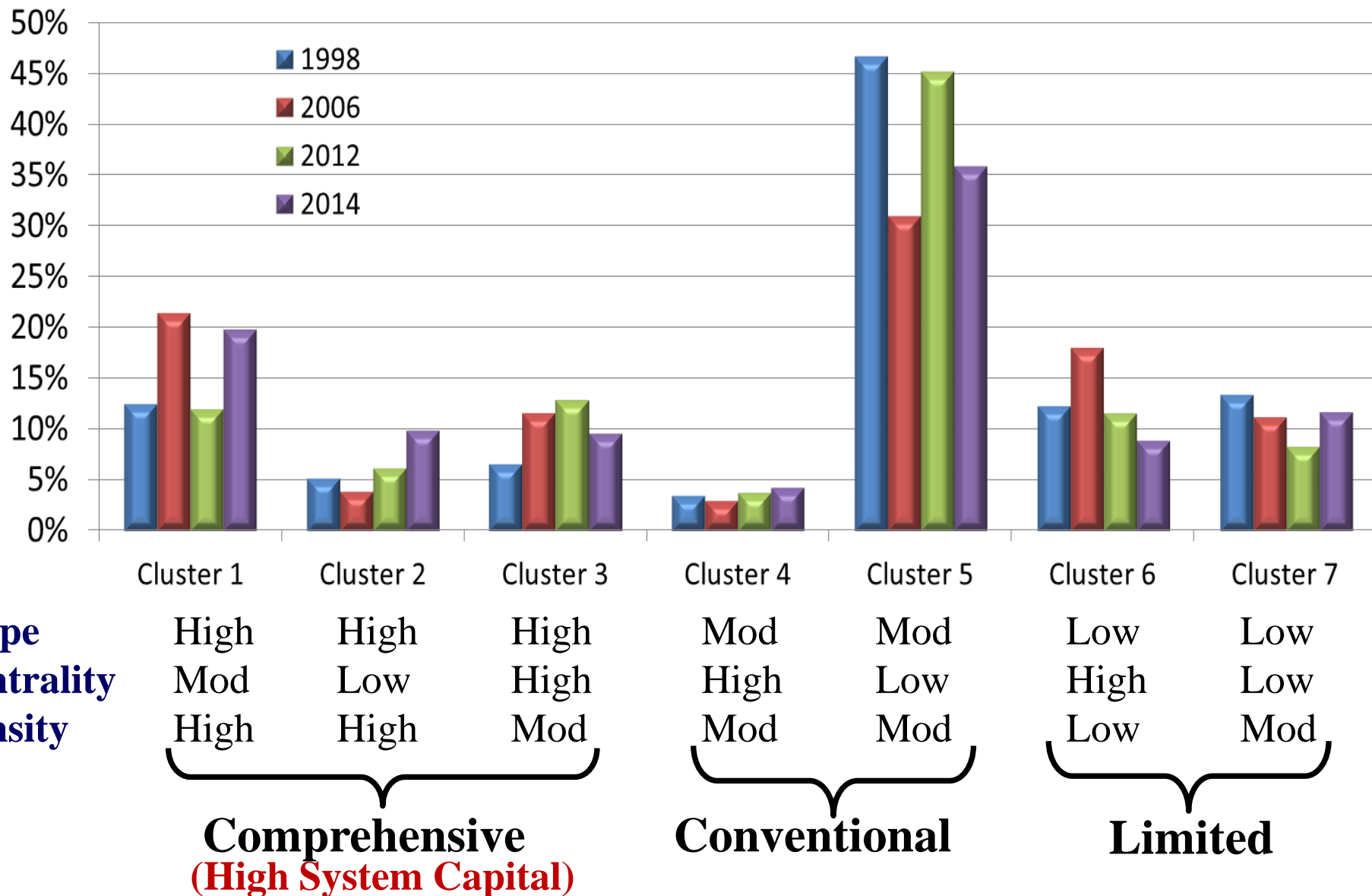
					<100k
Network Structure	1998	2006	2012	2014	2014
Network density	11.3%	16.3%	13.0%	13.6%	7.8%
Network centralization	14.4%	15.0%	13.3%	14.2%	11.7%
Betweenness centrality:					
Public health agencies	21.7%	19.1%	39.8%	31.5%	24.5%
Hospitals	6.9%	9.7%	13.1%	13.2%	9.4%

Bridging capital in public health delivery systems

Trends in betweenness centrality



Prevalence of Public Health System Configurations, 1998-2014



Changes in system capital prevalence and coverage

System Capital Measures	1998	2006	2012	2014	2014 (<100k)
Comprehensive systems					
% of communities	24.2%	36.9%	31.1%	32.7%	25.7%
% of population	25.0%	50.8%	47.7%	47.2%	36.6%
Conventional systems					
% of communities	50.1%	33.9%	49.0%	40.1%	57.6%
% of population	46.9%	25.8%	36.3%	32.5%	47.3%
Limited systems					
% of communities	25.6%	29.2%	19.9%	20.6%	16.7%
% of population	28.1%	23.4%	16.0%	19.6%	16.1%

Determinants of public health system structure

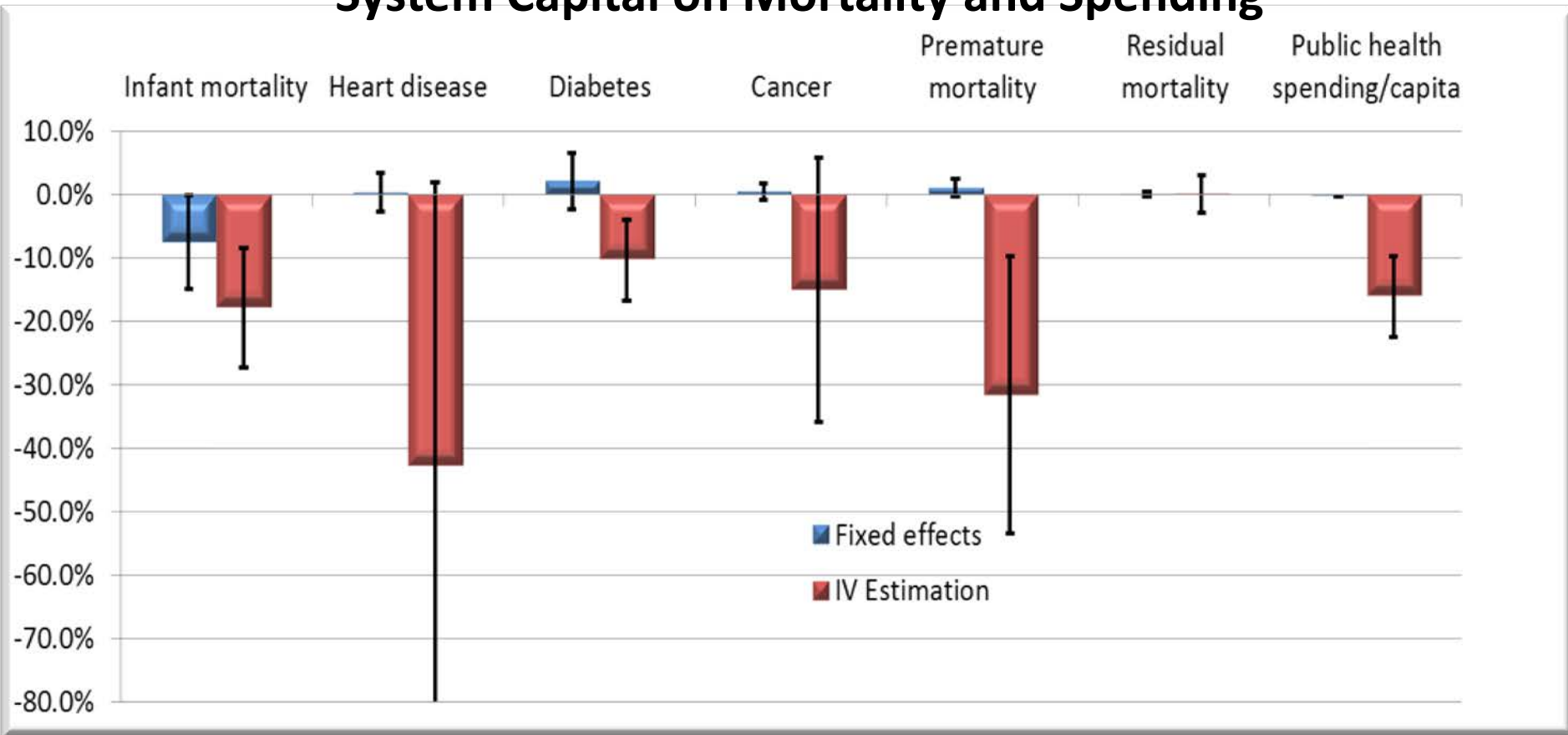
Probit Estimates of Factors Influencing the Probability of Comprehensive System Capital

Variable	Marginal Effect on Probability of System Capital	
Local board of health with decentralized governance	14.2%**	} IVs
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%**	

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

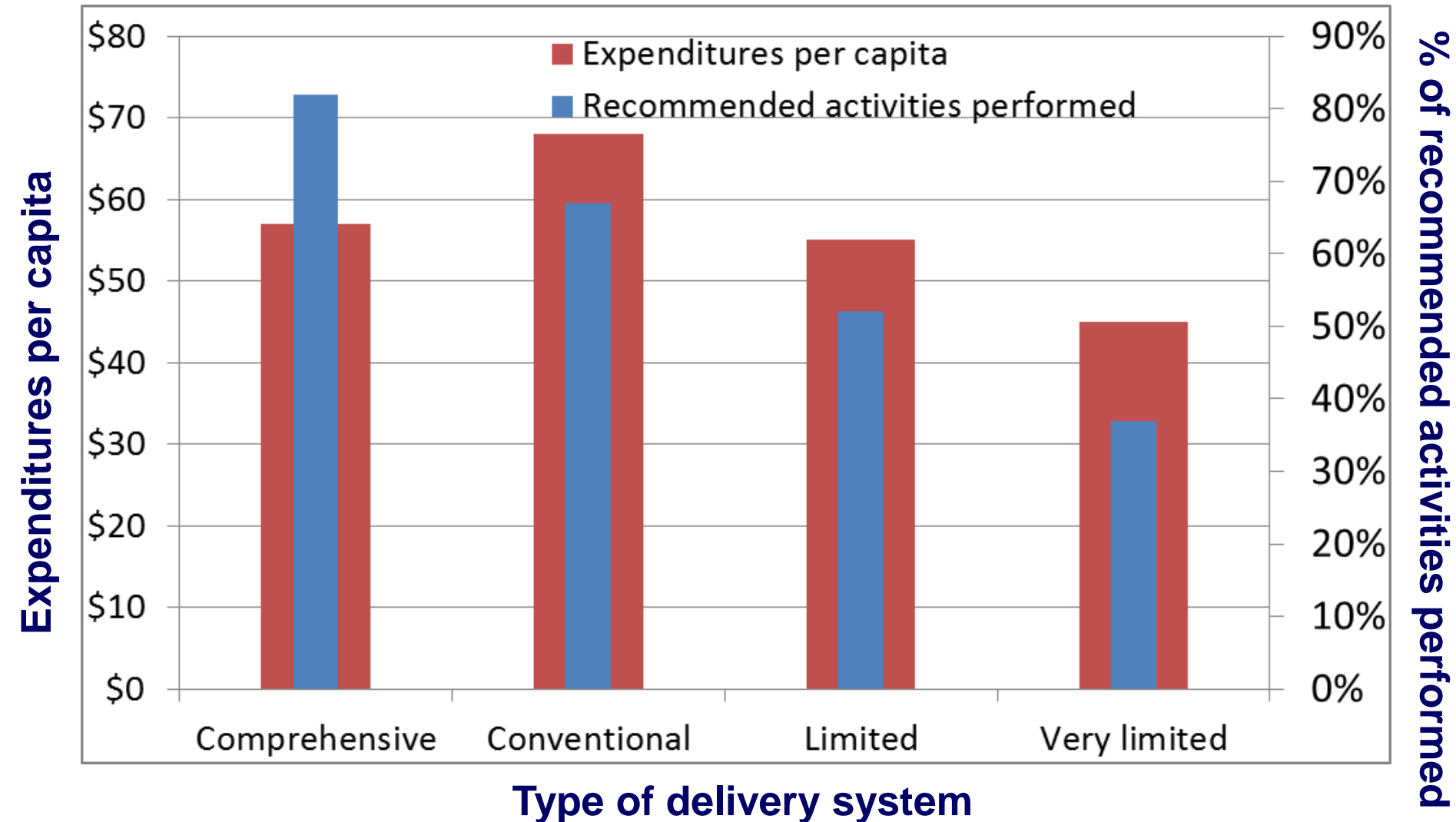
Health and economic impact of system structures

Fixed Effects and IV Estimates: Effects of Comprehensive System Capital on Mortality and Spending



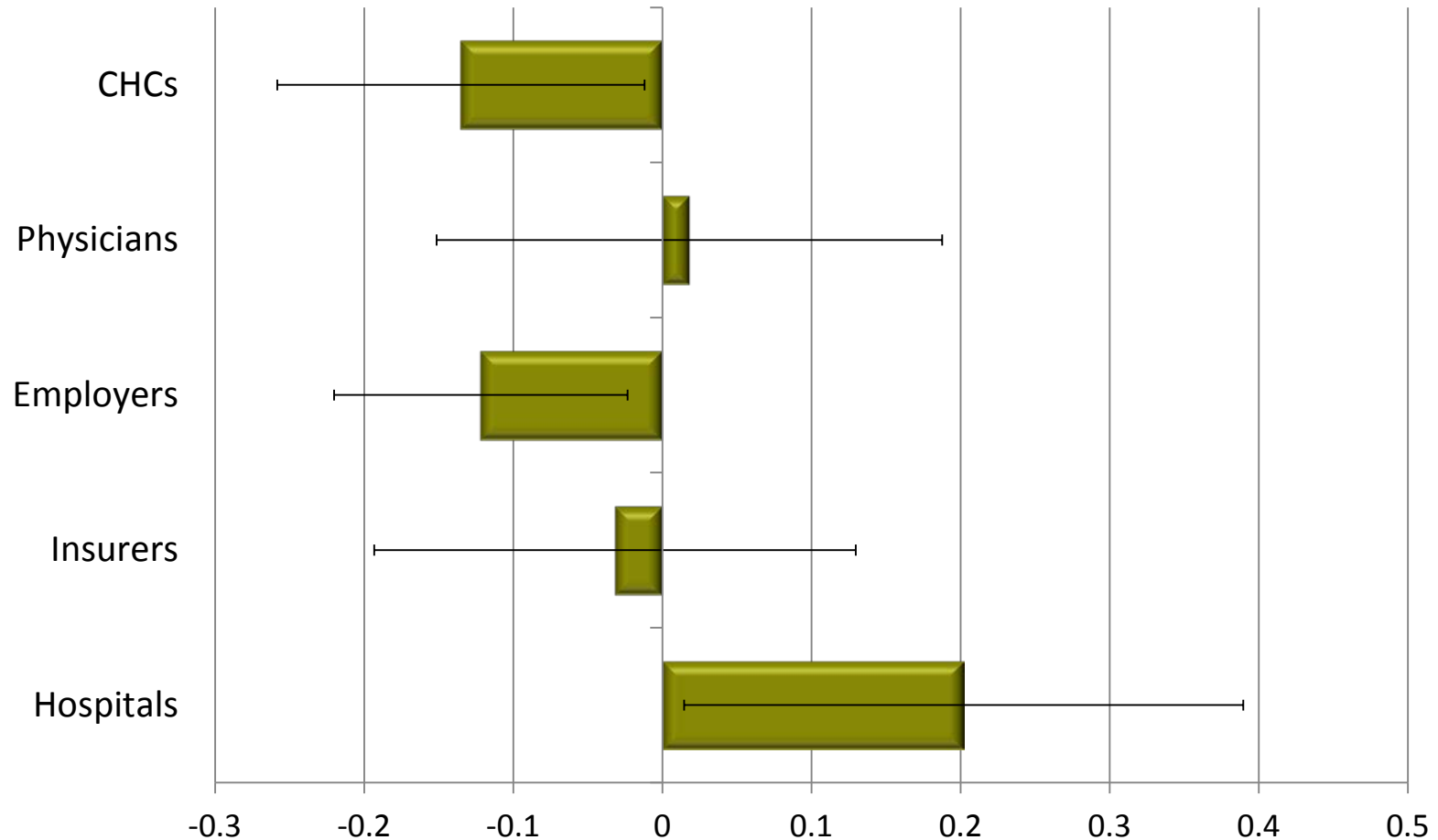
Models also control for racial composition, unemployment, health insurance coverage, educational attainment, age composition, and state and year fixed effects.
N=779 community-years **p<0.05 *p<0.10

Comprehensive systems do more with less



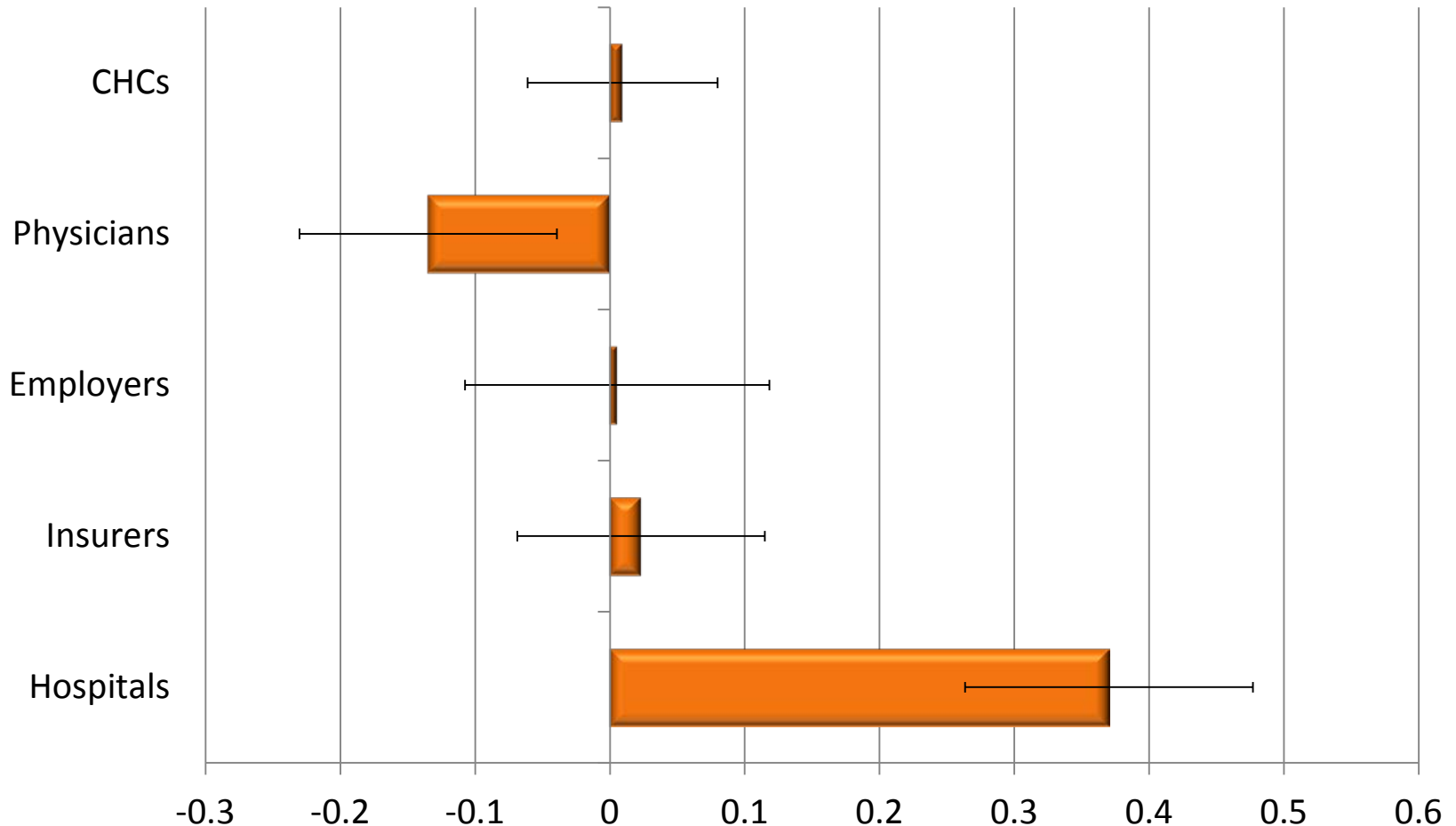
Do other organizations complement or substitute for local public health agency centrality?

Results from Multivariate GLLAMM Models



How does organizational centrality affect the total supply of public health activities?

Results from Multivariate GLLAMM Models



Conclusions

- Comprehensive and highly-integrated public health systems appear to offer considerable health and economic benefits over time.
 - 10-40% larger reductions in preventable mortality rates
 - 15% lower public health resource use
- Low-income communities are less likely to achieve comprehensive public health system capital, as are communities without local governance structures.
- Failure to account for endogenous network structure can lead to biased estimates of impact

Policy and Practice Implications

- Strategies to improve population health and health system efficiency should include initiatives to build public health system capital.
- Public health delivery has become increasingly reliant on nongovernmental & health care contributions
- Increased resiliency during economic shocks
- Heightened need for coordination, monitoring, and accountability
- Vulnerability to instability in contributions over time

Limitations and Next Steps

- Organization types – lacking institutional granularity
- Single perspective – local health officials
- Future possible comparisons:
 - ACA effects
 - Hospital community benefit activities
 - PHAB accreditation

For More Information



Supported by The Robert Wood Johnson Foundation

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