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Using Instrumental Variables to Estimate the Effects of Multi-Sector Population Health Improvement Activities

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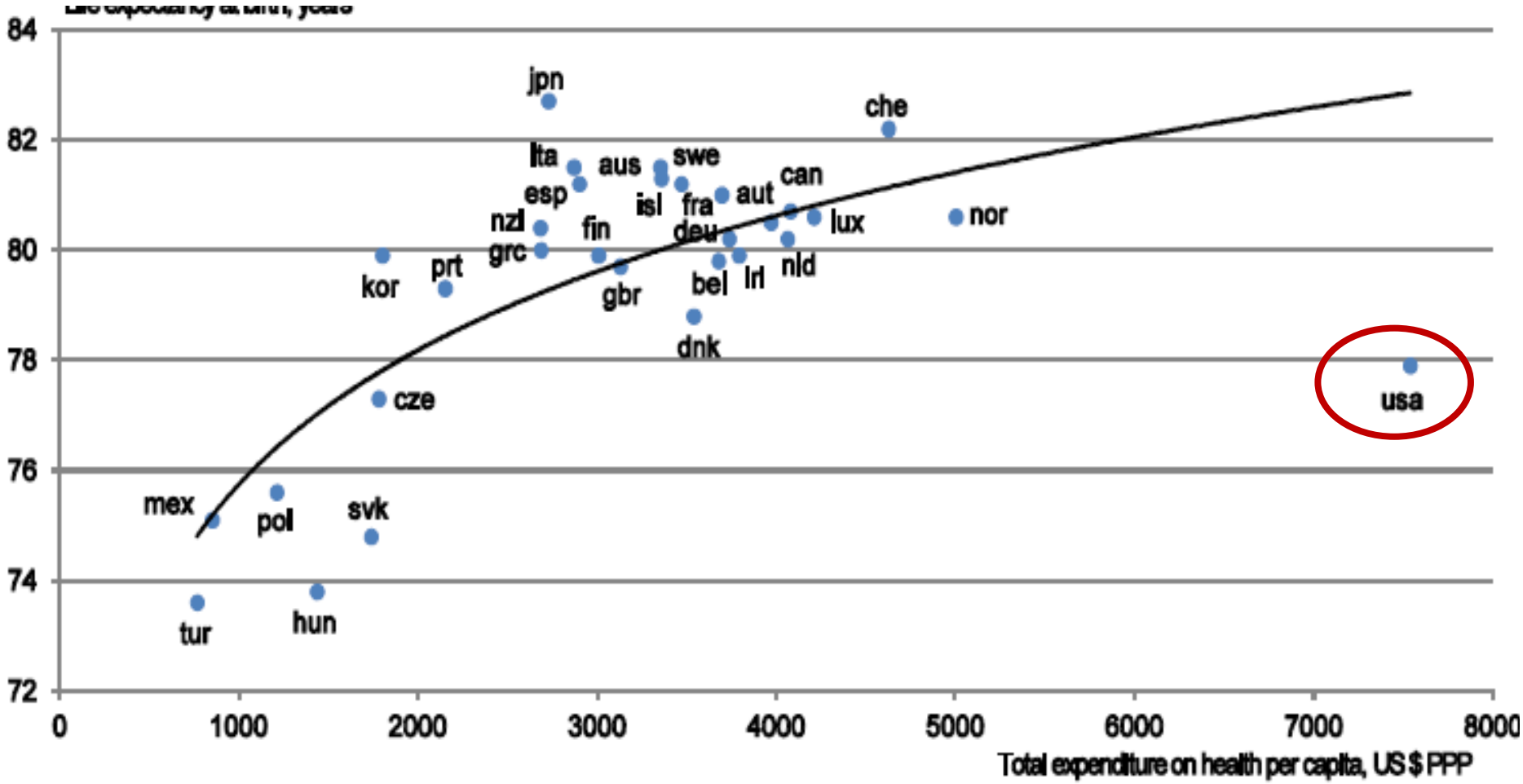
Systems and Services Research to Build a Culture of Health

Losing ground in population health

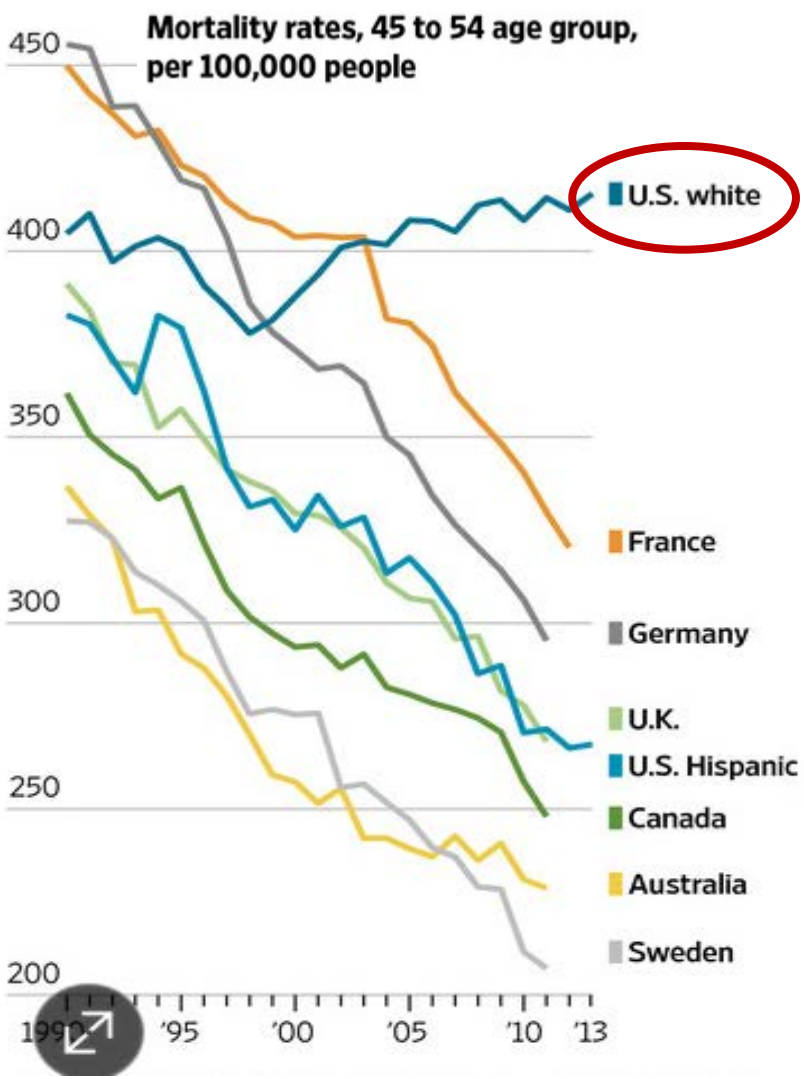


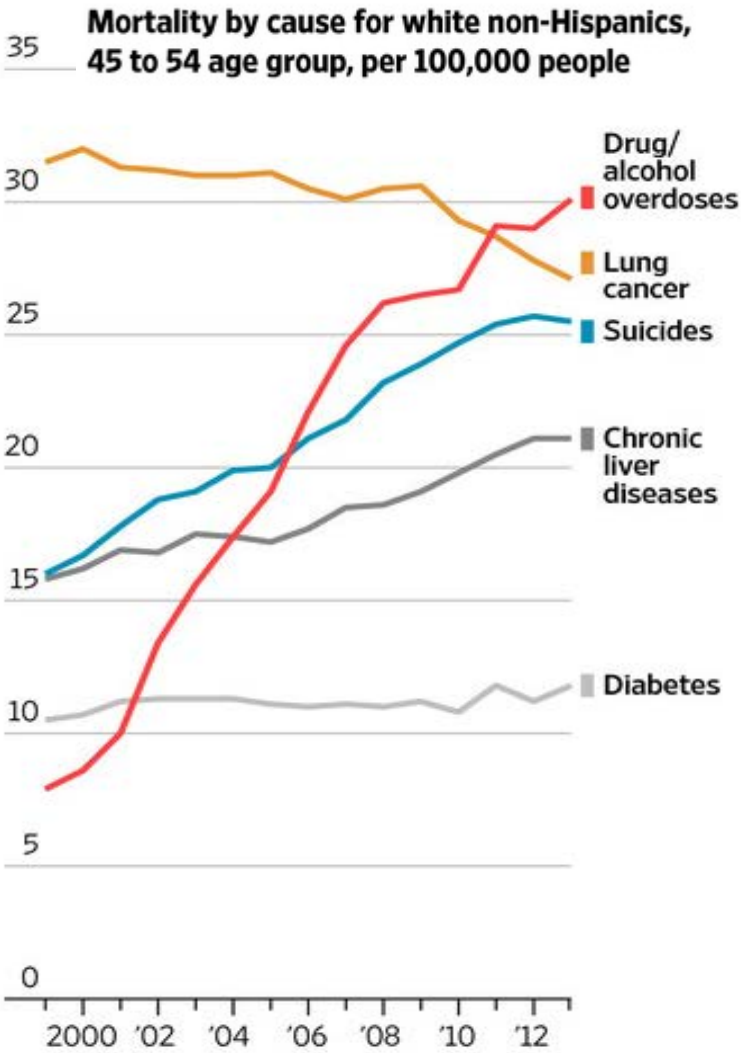
1. Or latest year available.

Source: OECD Health Data 2010.

WHO 2010

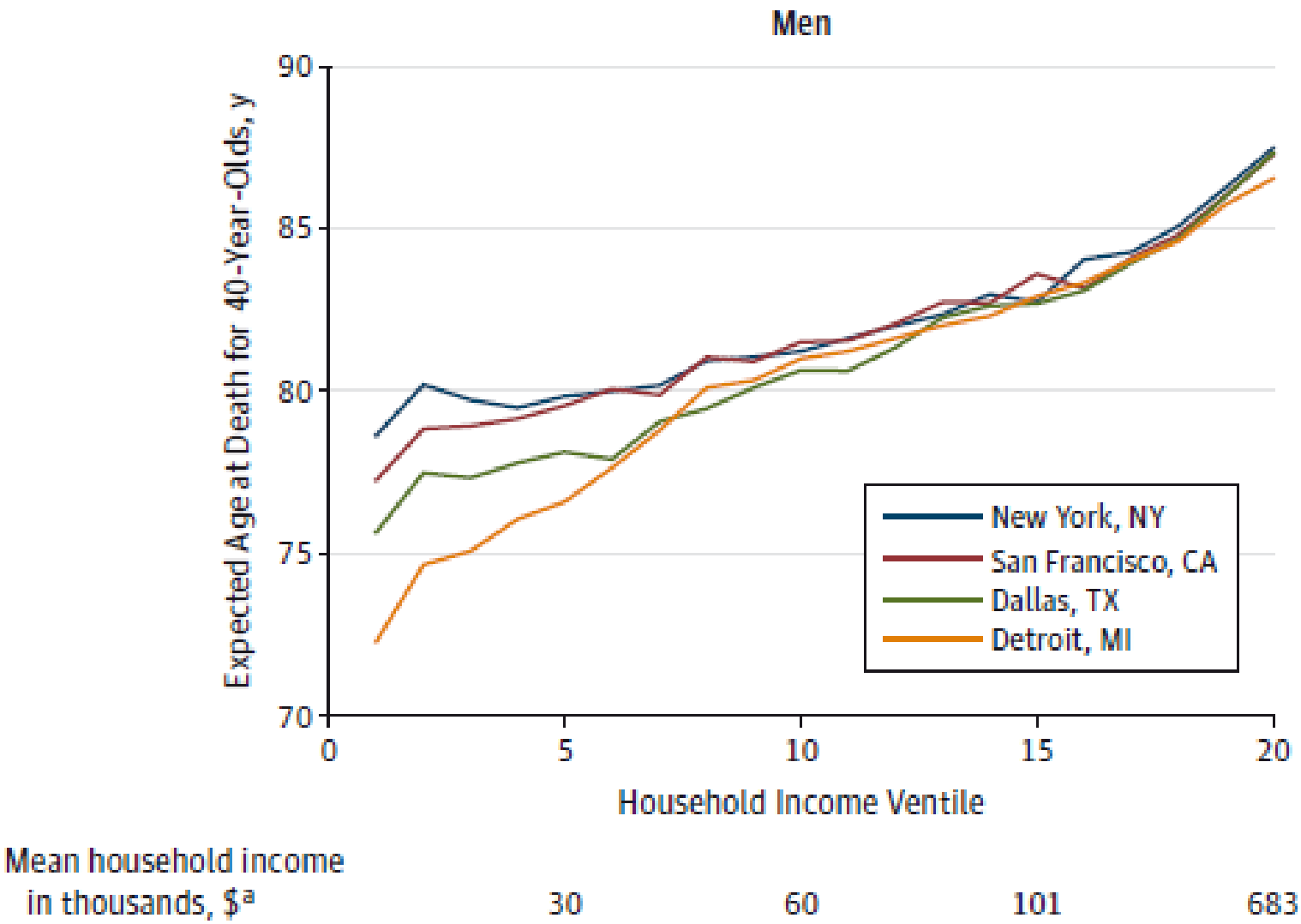
Losing ground in population health





Case A, Deaton A. Proceedings of the National Academy of Sciences 2015

Income disparities in population health



Chetty et al. JAMA 2016

How do we support effective 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

  - Infrastructure

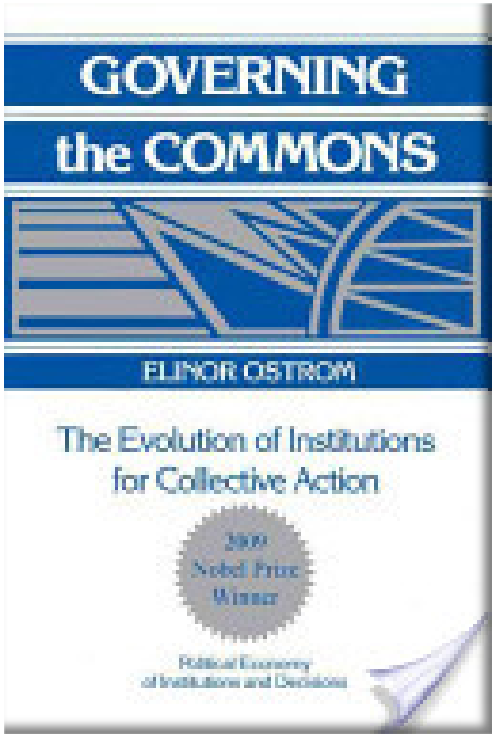
  - Information

  - Incentives

Mays GP. Governmental public health and the economics of adaptation to population health strategies. ***National Academy of Medicine Discussion Paper.*** 2014. http://nam.edu/wp-content/uploads/2015/06/EconomicsOfAdaptation.pdf

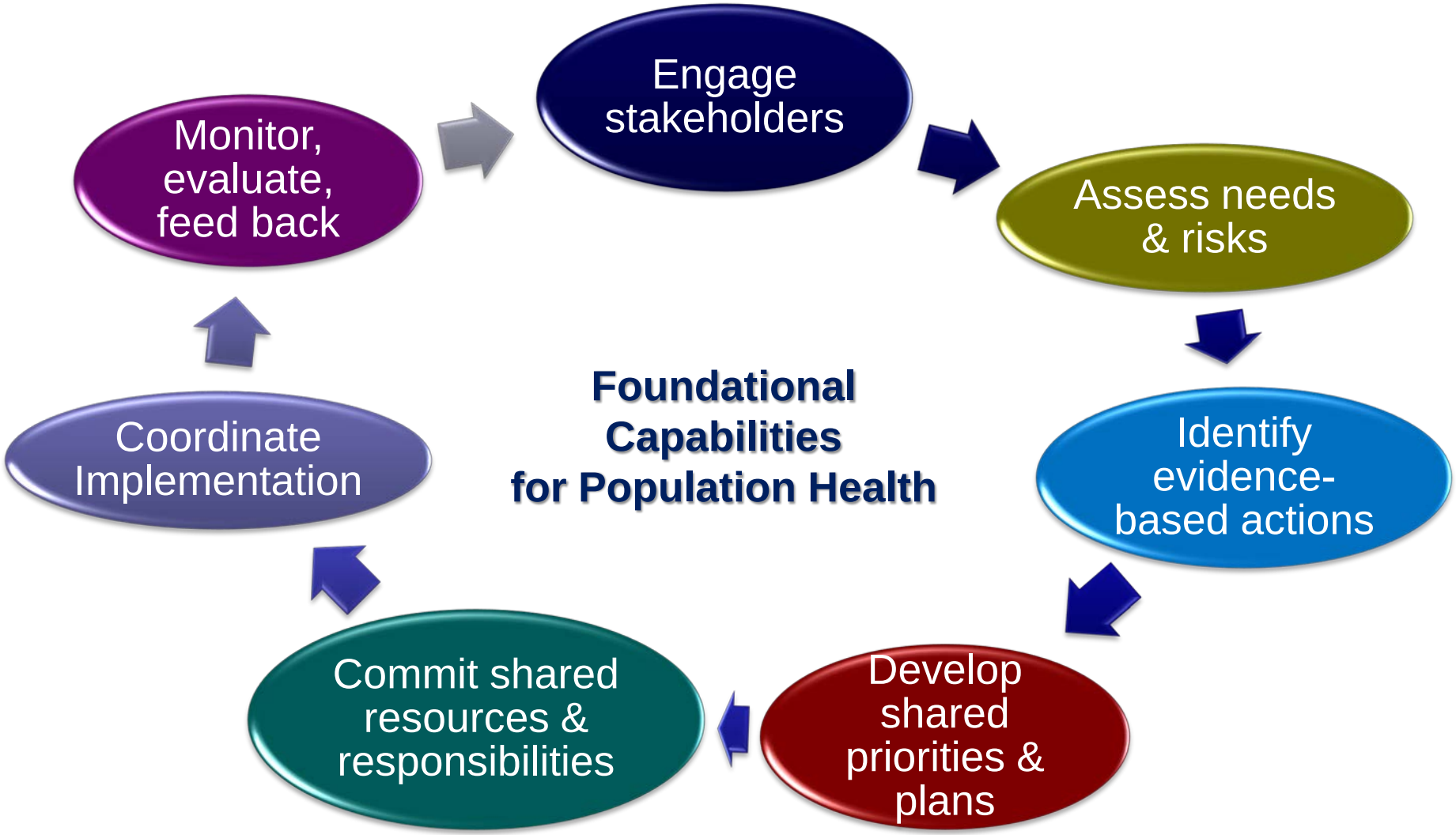
Challenge: overcoming collective action problems across systems & sectors

- 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



Ostrom E. 1994

Widely recommended activities to support multi-sector initiatives in population health



National Academy of Medicine: ***For the Public's Health: Investing in a Healthier Future.*** Washington, DC: National Academies Press; 2012.

Guided by Culture of Health Action Framework

http://www.rwjf.org/en/culture-of-health/2015/11/measuring_what_matte.html

Robert Wood Johnson Foundation

Questions of interest

- How strong are the delivery systems that support foundational population health activities?
- How do these delivery systems change over time?

  Recession | Recovery | ACA implementation
- How do these delivery systems influence health and health disparities?

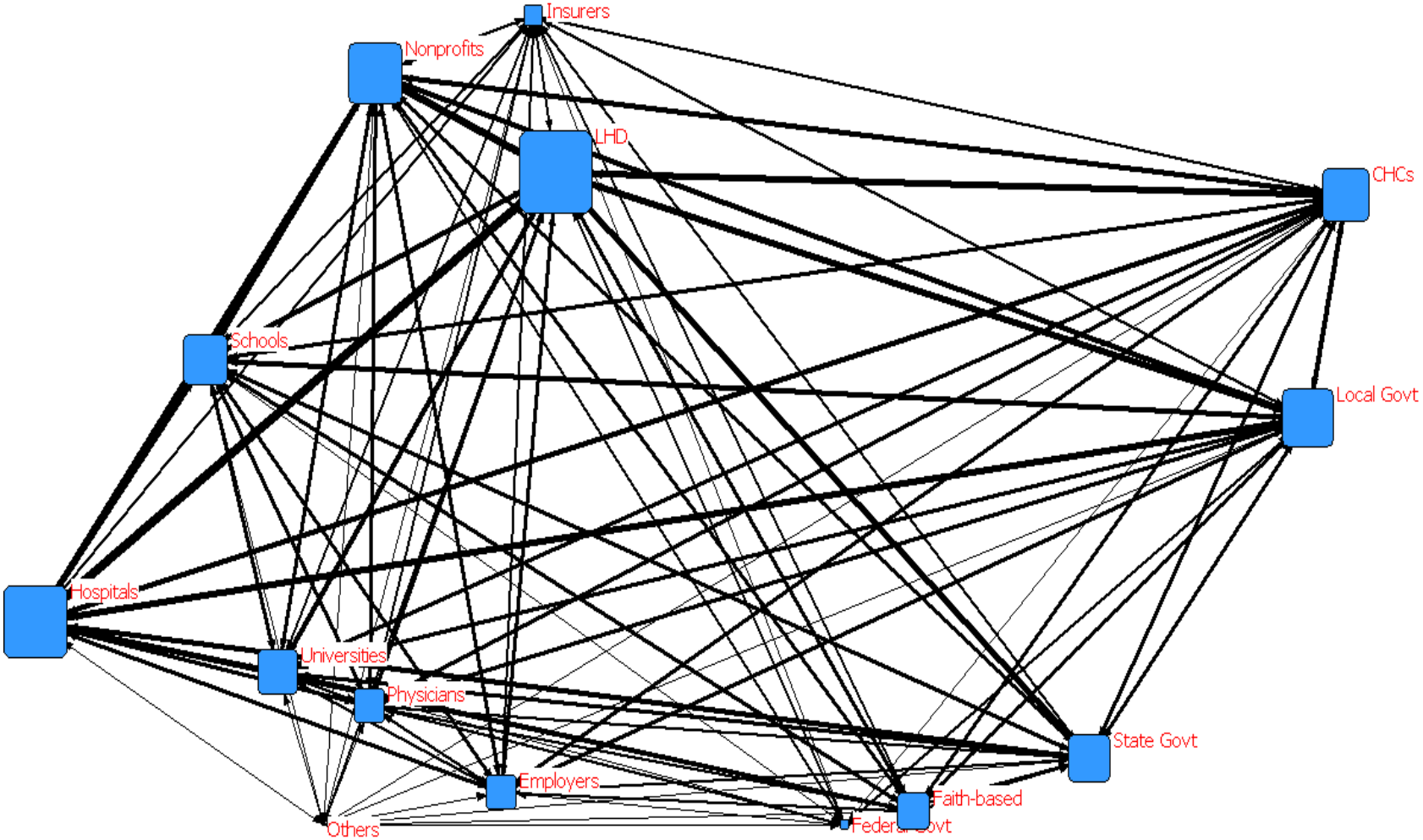
A useful lens for studying multi-sector work

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
- Local public health officials report:
  - ***Scope***: availability of 20 recommended population health activities
  - ***Network***: organizations contributing to each activity
  - ***Centrality of effort***: contributed by governmental public health agency
  - ***Quality***: perceived effectiveness of each activity

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

Mapping who contributes to population health

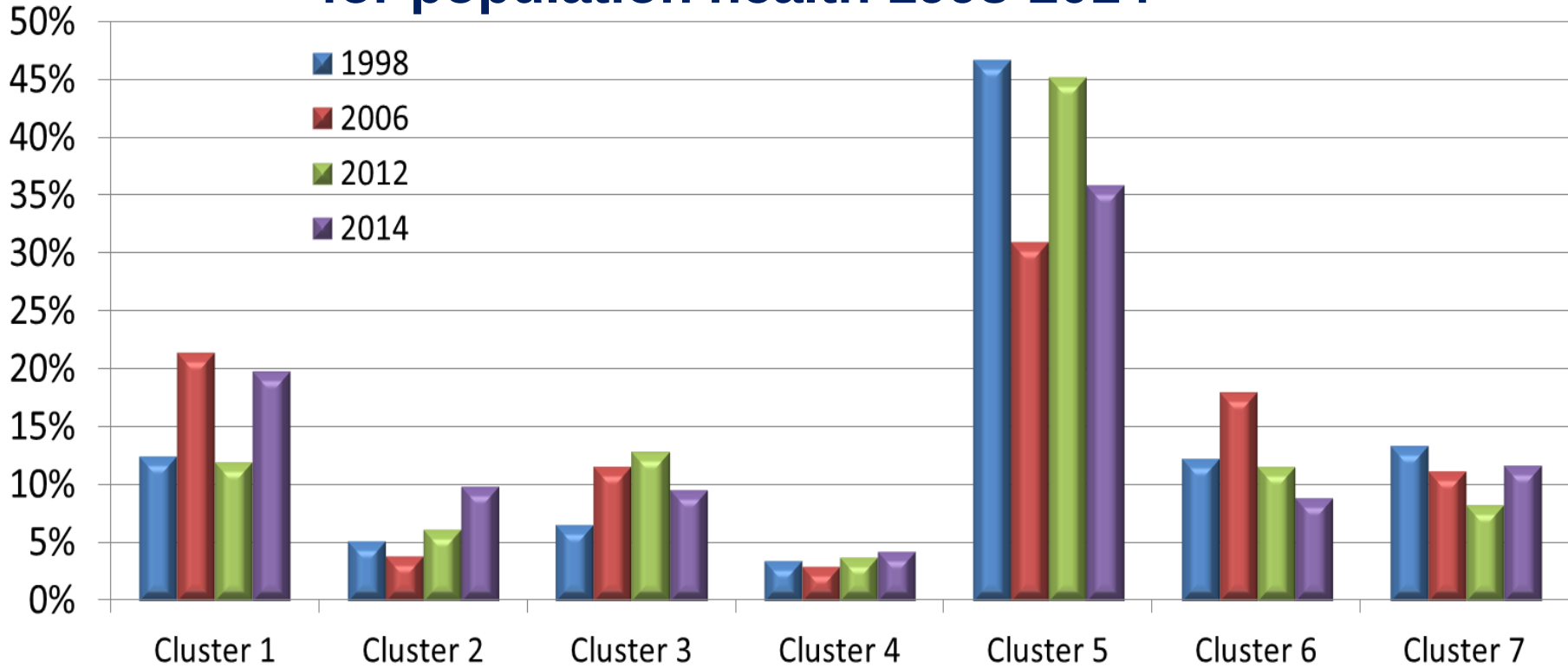


Node size = degree centrality

Line size = % activities jointly contributed (tie strength)

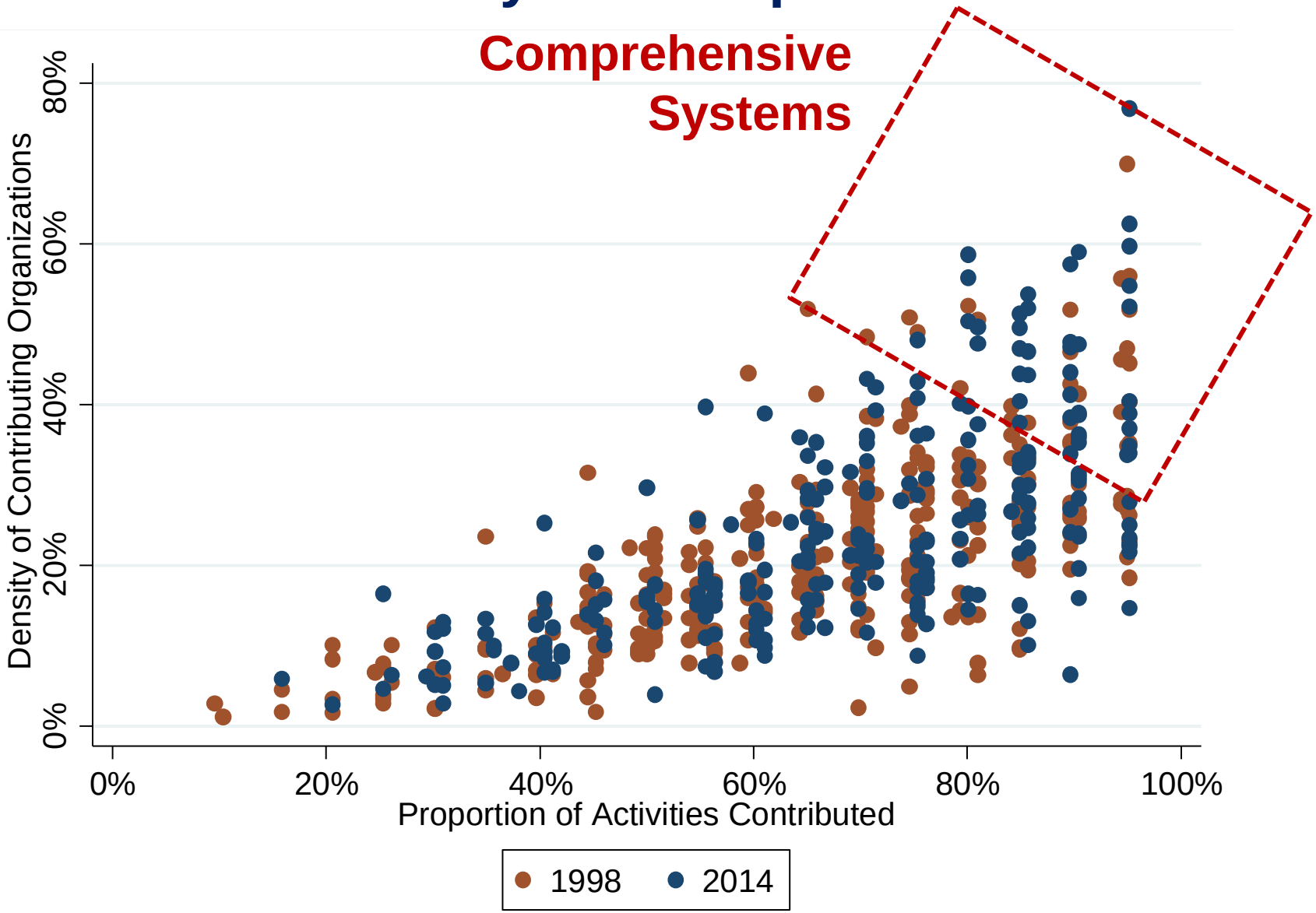
Mays GP et al. Understanding the organization of public health delivery systems: an empirical typology. *Milbank Q.* 2010;88(1):81–111.

Classifying multi-sector delivery systems for population health 1998-2014



	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5	Cluster 6	Cluster 7
Scope	High	High	High	Mod	Mod	Low	Low
Centrality	Mod	Low	High	High	Low	High	Low
Density	High	High	Mod	Mod	Mod	Low	Mod
	Comprehensive (High System Capital)			**Conventional**		**Limited**	

Network density and scope of activities



Comprehensive Systems

One of RWJF's Culture of Health National Metrics

- ***Broad scope*** of population health activities
- ***Dense network*** of multi-sector relationships
- ***Central actors*** to coordinate actions

Access to public health

Overall, 47.2 percent of the population is covered by a comprehensive public health system. Individuals are more likely to have access if they are non-White (51.5 percent vs. 45.5 percent White) or live in a metropolitan area (48.7 percent vs. 34.1 percent in nonmetropolitan areas).

47.2%

of population served by a comprehensive public health system

http://www.cultureofhealth.org/en/integrated-systems/access.html

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

Chetty's data: life expectancy by income

- **Income data**: federal tax records for every filer for every year 1999-2014 (pre-tax household earnings): 1.4B person-years
- **Mortality data**: SSA death records: 6.8M deaths
- **Period life expectancy**: estimated conditional on income percentile at 40 years of age
- **Geography**: Life expectancy by income quartile estimated for counties (n>3000) and for commuting zones (n=741) by year

Estimating how population health delivery systems relate to life expectancy by income

- Panel regression estimation with fixed and random effects to account for repeated measures and clustering of public health jurisdictions within states
- Two-stage instrumental-variables model to estimate effect of system changes on life expectancy (residual inclusion method)

$$\text{Prob}(\text{System}_{ijt}=\text{Comprehensive}) = f(\text{Governance}, \text{Agency}, \text{Community})_{ijt} + \text{State}_j + \text{Year}_t$$

$$E(\text{LE}_{ijt}) = f(\text{System+resid}, \text{Agency}, \text{Community})_{ijt} + \text{State}_j + \text{Year}_t + \varepsilon_{ijt}$$

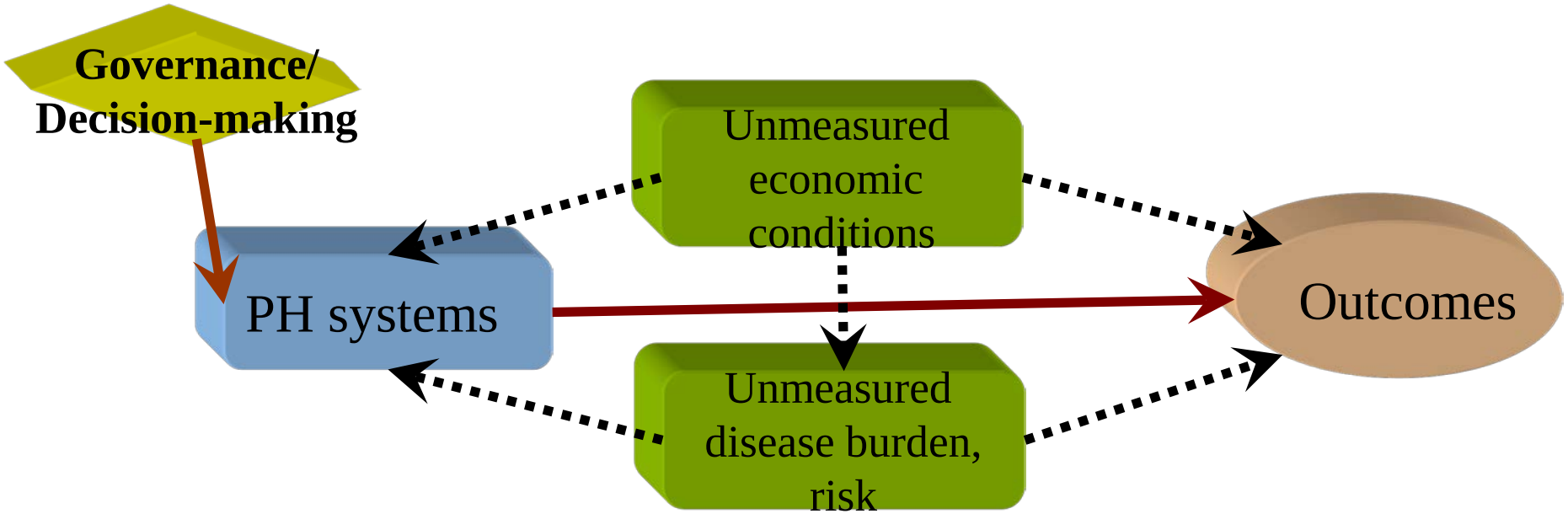
All models control for type of jurisdiction, population size and density, metropolitan area designation, income per capita, unemployment, poverty rate, racial composition, age distribution, physician and hospital availability, insurance coverage, and state and year fixed effects. **N=1019 community-years**

Instrumental variables: a review

- IVs influence treatment choices/exposures but are independent of factors that determine outcomes
- IVs serve as natural randomizers: they approximate RCTs with observational studies
- IVs can be used to estimate causal treatment effects while accounting for both observed and hidden confounding and selection bias

Analytical approach: IV estimation

- Identify exogenous sources of variation in system strength that are unrelated to outcomes
  - Governance structures: local boards of health
  - Decision-making authority: agency, board, local, state
- Controls for unmeasured factors that jointly influence systems and outcomes



Implementation of population health activities, 1998-2014

	Activity	1998	2014	% Change
Assessment	1. Conduct periodic assessment of community health status and needs	71.5%	87.1%	21.8%
	2. Survey community for behavioral risk factors	45.8%	71.1%	55.2%
	3. Investigate adverse health events, outbreaks and hazards	98.6%	100.0%	1.4%
	4. Conduct laboratory testing to identify health hazards and risks	96.3%	96.1%	-0.2%
	5. Analyze data on community health status and health determinants	61.3%	72.7%	18.6%
	6. Analyze data on preventive services use	28.4%	39.0%	37.3%
Policy/Planning	7. Routinely provide community health information to elected officials	80.9%	84.0%	3.8%
	8. Routinely provide community health information to the public	75.4%	82.3%	9.1%
	9. Routinely provide community health information to the media	75.2%	89.0%	18.3%
	10. Prioritize community health needs	66.1%	83.6%	26.5%
	11. Engage community stakeholders in health improvement planning	41.5%	68.8%	65.7%
	12. Develop a community-wide health improvement plan	81.9%	87.9%	7.3%
	13. Identify and allocate resources based on community health plan	26.2%	41.9%	59.9%
	14. Develop policies to address priorities in community health plan	48.6%	56.8%	16.9%
	15. Maintain a communication network among health-related organizations	78.8%	85.3%	8.2%
Assurance	16. Link people to needed health and social services	75.6%	50.0%	-33.8%
	17. Implement legally mandated public health activities	91.4%	92.4%	1.1%
	18. Evaluate health programs and services in the community	34.7%	37.9%	9.4%
	19. Evaluate local public health agency capacity and performance	56.3%	56.1%	-0.3%
	20. Monitor and improve implementation of health programs and policies	47.3%	46.4%	-1.9%
	Mean performance of assessment activities (#1-6)	67.0%	77.7%	15.9%
	Mean performance of policy and planning activities (#7-15)	63.9%	75.5%	18.3%
	Mean performance of implementation and assurance activities (#16-20)	61.1%	56.6%	-7.3%
	Mean performance of all activities	63.8%	67.6%	6.0%

Organizational contributions to population health activities, 1998-2014

Type of Organization	% of Recommended Activities Implemented 1998	2014	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%

Changes in system prevalence and coverage

System Capital Measures	1998	2006	2012	2014
Comprehensive systems				
% of communities	**24.2%**	**36.9%**	**31.1%**	**39.5%**
% of population	**25.0%**	**50.8%**	**47.7%**	**47.2%**
Conventional systems				
% of communities	50.1%	33.9%	49.0%	40.2%
% of population	46.9%	25.8%	36.3%	32.5%
Limited systems				
% of communities	25.6%	29.2%	19.9%	20.3%
% of population	28.1%	23.4%	16.0%	19.6%

Mays GP, Hogg RA. Economic shocks and public health protections in US metropolitan areas. Am J Public Health. 2015;105 Suppl 2:S280-7.

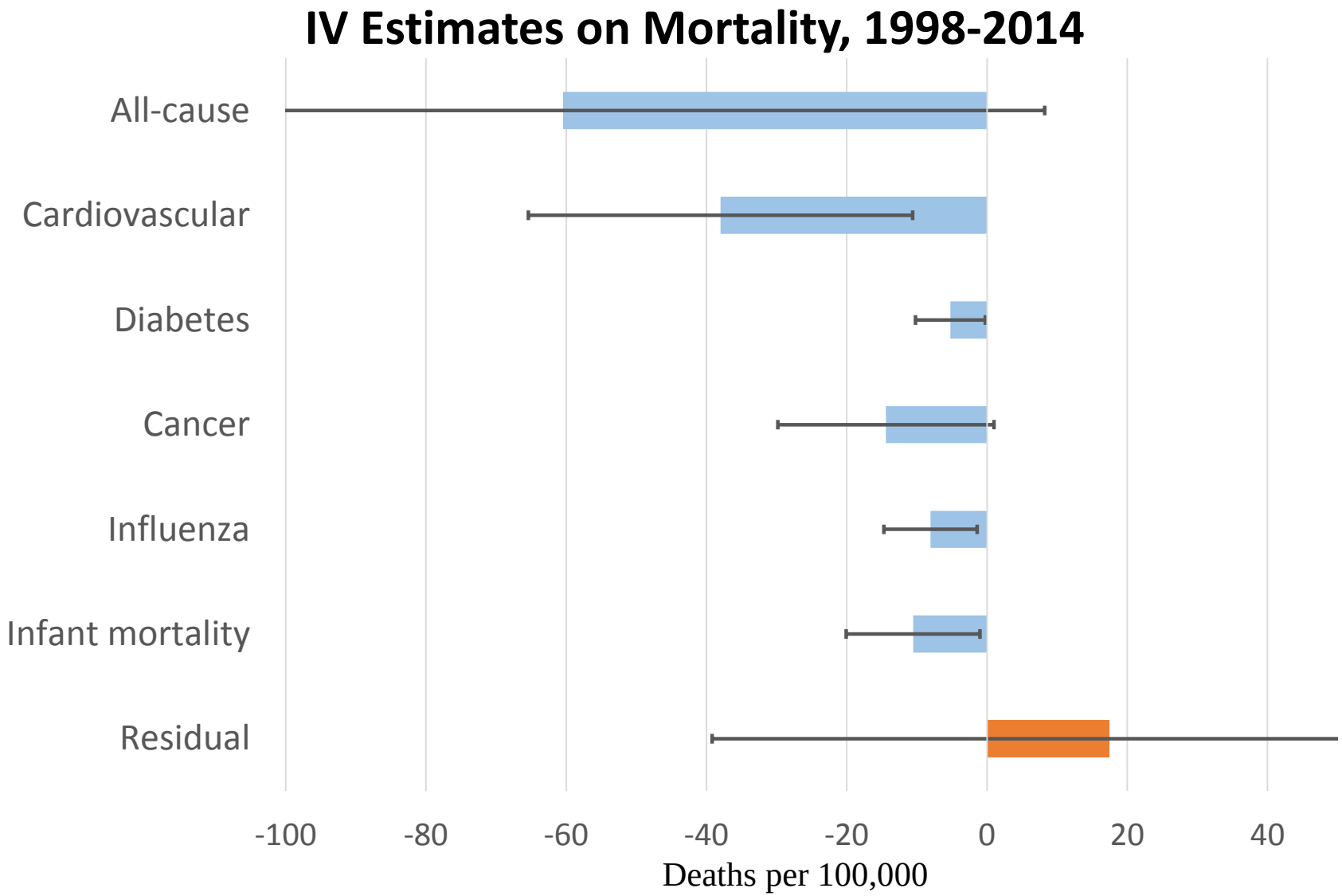
Predictors of Comprehensive System Capital

Variable	Marginal Effect	S.E.	
Population size (10,000s)	0.033	0.009	***
Poverty rate (10%)	-0.033	0.016	**
Policy-making local BOH (0,1)	0.046	0.016	***
Centralized local health agency (0,1)	-0.087	0.036	**
Local control of health budget (0,1)	0.043	0.022	*
Local health tax/fee authority (0,1)	0.028	0.011	**

IVs

Models also control for racial composition, unemployment, health insurance coverage, educational attainment, age composition, and year fixed effects. N=1019 community-years

IV estimates of mortality effects attributable to comprehensive systems



Models also control for racial composition, unemployment, health insurance coverage, educational attainment, age composition, and state and year fixed effects. N=1019 community-years

IV estimates of impact of comprehensive systems on life expectancy by income

Variable	Coeff.	S.E.	
Single-equation estimates			
Bottom income quartile	2.36	1.21	
Top income quartile	-0.04	0.09	
Difference	-2.21	1.09	
IV Estimates			
Bottom income quartile	4.11	1.86	**
Top income quartile	0.85	0.48	
Difference	-3.02	1.44	**

Models also control for racial composition, unemployment, health insurance coverage, educational attainment, age composition, and year fixed effects. N=1019 community-years

Community-centered treatment effect estimation

- Treatment effects vary across communities based on factors observed by decision-makers
- Treatment is “sorted” across communities based in part on differential potential benefit
  - No single treatment effect
  - Average treatment effects vary across subgroups based on chosen treatment levels

Heckman et al. 2006; Basu et al 2007

Community-centered treatment effect estimation

- PCTE is a conditional treatment effect that conditions on observed risk factors AND averages over the conditional distribution of unobserved risk factors, conditional on treatment choices
- Identifies community-level treatment effect heterogeneity better than other methods
- Superior at identifying/controlling for self-selection
- Requires IVs to isolate distribution of unobserved risk factors

Heckman et al. 2006; Basu et al. 2007

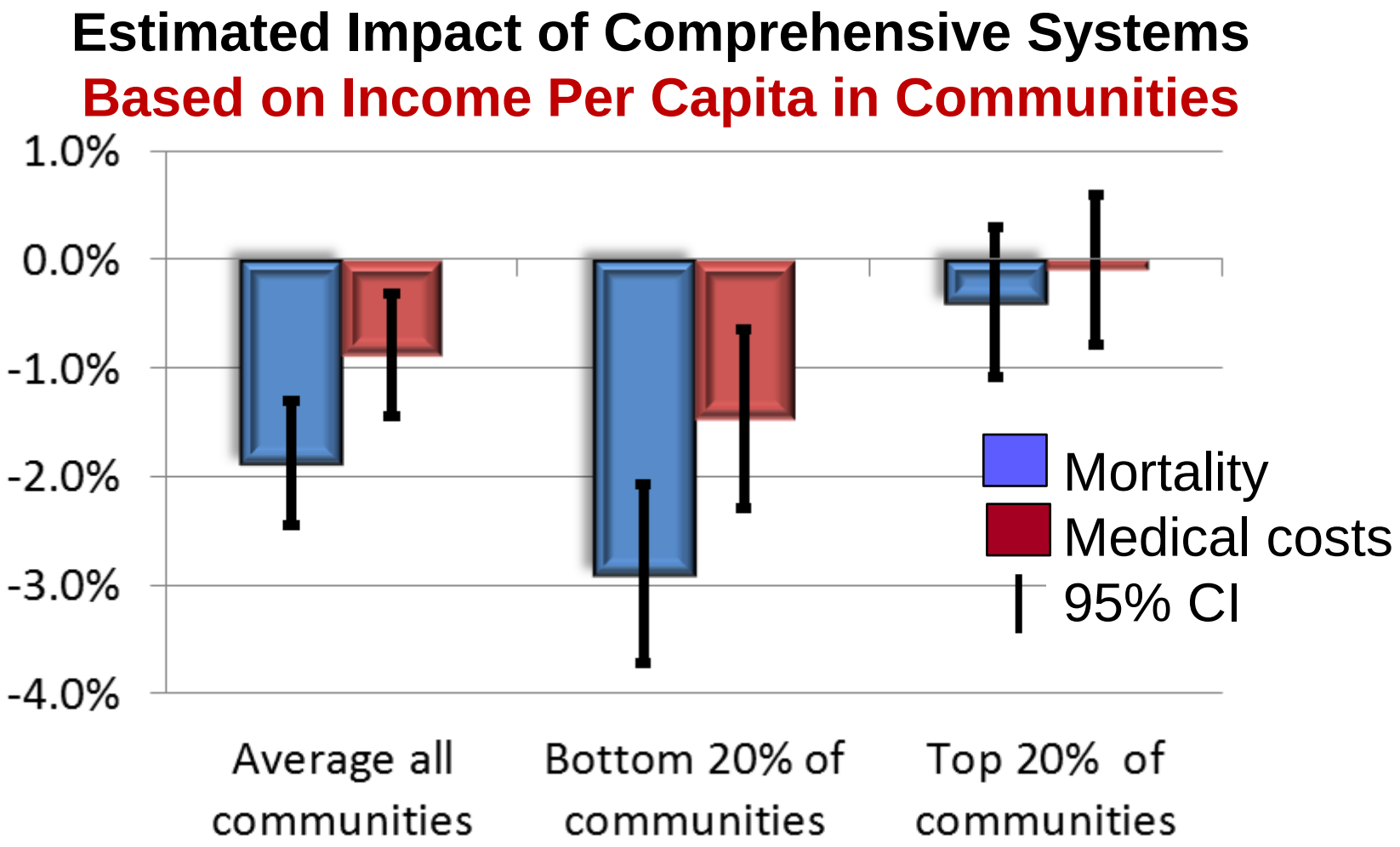
Local IV Approach

- Estimate predicted system capital (P) as a function of all measured covariates (X) and instruments (Z)
- Model outcome (O) as nonlinear function of P(X,Z) and X
- Estimate $\partial O / \partial P$ the effect of a change in predicted system capital on the outcome
- Find the distribution of P(X,Z) for the subset of communities of interest
- Estimate the average treatment effect for each subset as the average weighted value of $\partial O / \partial P$ across the subset

Heckman JJ, Vytlacil EJ. 1999. Local instrumental variables and latent variable models for identifying and bounding treatment effects. *Proceedings of the National Academy of Sciences USA* **96**(8): 4730–4734.

Basu A. 2013. Estimating person-centered treatment (PET) effects using instrumental variables. *Journal of Applied Econometrics*, in press.

Community-specific estimates of system capital on mortality and medical costs



Log IV regression estimates controlling for community-level and state-level characteristics

Mays et al. forthcoming 2013

Conclusions and implications

- Large health gains accrue to comprehensive systems
- Health gains are larger for low-income populations and low-income communities
- Dense collaborative networks do more than just plan: prioritize, invest, evaluate, repeat (crowd-sourcing)
- Equity and opportunity: two-thirds of communities currently lack comprehensive systems
- ACA incentives and resources may help:
  - Hospital community benefit
  - Value-based health care payments
  - Insurer and employer incentives
  - Public health agency accreditation
- Sustainability and resiliency are not automatic

Ongoing work

- Robustness to alternative specifications
- Lagged and cumulative effects
- Trajectories of system strength over time
- Proximal outcomes
- Value-added of specific combinations of activities and organizations

For More Information

Systems for Action

National Coordinating Center

Systems and Services Research to Build a Culture of Health

Supported by The Robert Wood Johnson Foundation

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