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

Glen P. Mays, University of Kentucky

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systemsforaction.org

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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

**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

Engage stakeholders

Assess needs & risks

Identify evidence-based actions

Develop shared priorities & plans

Commit shared resources & responsibilities

Coordinate Implementation

Monitor, evaluate, feed back

Foundational Capabilities for Population Health

Guided by Culture of Health Action Framework

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
- 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)

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

Scope
High  High  High  Mod  Mod  Low  Low

Centrality
Mod  Low  High  High  Low  High  Low

Density
High  High  Mod  Mod  Mod  Low  Mod

Motivation
Approach
Results
Discussion

Comprehensive
(High System Capital)

Conventional

Limited
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).

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)

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

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

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

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

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%

### Motivation

### Approach

### Results

### Discussion
### Organizational contributions to population health activities, 1998-2014

<table>
<thead>
<tr>
<th>Type of Organization</th>
<th>1998</th>
<th>2014</th>
<th>Percent Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Local public health agencies</td>
<td>60.7%</td>
<td>67.5%</td>
<td>11.1%</td>
</tr>
<tr>
<td>Other local government agencies</td>
<td>31.8%</td>
<td>33.2%</td>
<td>4.4%</td>
</tr>
<tr>
<td>State public health agencies</td>
<td>46.0%</td>
<td>34.3%</td>
<td>-25.4%</td>
</tr>
<tr>
<td>Other state government agencies</td>
<td>17.2%</td>
<td>12.3%</td>
<td>-28.8%</td>
</tr>
<tr>
<td>Federal government agencies</td>
<td>7.0%</td>
<td>7.2%</td>
<td>3.7%</td>
</tr>
<tr>
<td>Hospitals</td>
<td>37.3%</td>
<td>46.6%</td>
<td>24.7%</td>
</tr>
<tr>
<td>Physician practices</td>
<td>20.2%</td>
<td>18.0%</td>
<td>-10.6%</td>
</tr>
<tr>
<td>Community health centers</td>
<td>12.4%</td>
<td>29.0%</td>
<td>134.6%</td>
</tr>
<tr>
<td>Health insurers</td>
<td>8.6%</td>
<td>10.6%</td>
<td>23.0%</td>
</tr>
<tr>
<td>Employers/businesses</td>
<td>16.9%</td>
<td>15.3%</td>
<td>-9.6%</td>
</tr>
<tr>
<td>Schools</td>
<td>30.7%</td>
<td>25.2%</td>
<td>-17.9%</td>
</tr>
<tr>
<td>Universities/colleges</td>
<td>15.6%</td>
<td>22.6%</td>
<td>44.7%</td>
</tr>
<tr>
<td>Faith-based organizations</td>
<td>19.2%</td>
<td>17.5%</td>
<td>-9.1%</td>
</tr>
<tr>
<td>Other nonprofit organizations</td>
<td>31.9%</td>
<td>32.5%</td>
<td>2.0%</td>
</tr>
<tr>
<td>Other</td>
<td>8.5%</td>
<td>5.2%</td>
<td>-38.4%</td>
</tr>
</tbody>
</table>

## Discussion

### Results

- **Approach**
  - **Motivation**
  - **Organizational contributions to population health activities, 1998-2014**
  - | Type of Organization | 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

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Comprehensive systems</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>% of communities</td>
<td>24.2%</td>
<td>36.9%</td>
<td>31.1%</td>
<td>39.5%</td>
</tr>
<tr>
<td>% of population</td>
<td>25.0%</td>
<td>50.8%</td>
<td>47.7%</td>
<td>47.2%</td>
</tr>
<tr>
<td><strong>Conventional systems</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>% of communities</td>
<td>50.1%</td>
<td>33.9%</td>
<td>49.0%</td>
<td>40.2%</td>
</tr>
<tr>
<td>% of population</td>
<td>46.9%</td>
<td>25.8%</td>
<td>36.3%</td>
<td>32.5%</td>
</tr>
<tr>
<td><strong>Limited systems</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>% of communities</td>
<td>25.6%</td>
<td>29.2%</td>
<td>19.9%</td>
<td>20.3%</td>
</tr>
<tr>
<td>% of population</td>
<td>28.1%</td>
<td>23.4%</td>
<td>16.0%</td>
<td>19.6%</td>
</tr>
</tbody>
</table>

## Predictors of Comprehensive System Capital

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

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

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coeff.</th>
<th>S.E.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Single-equation estimates</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bottom income quartile</td>
<td>2.36</td>
<td>1.21</td>
</tr>
<tr>
<td>Top income quartile</td>
<td>-0.04</td>
<td>0.09</td>
</tr>
<tr>
<td>Difference</td>
<td>-2.21</td>
<td>1.09</td>
</tr>
<tr>
<td><strong>IV Estimates</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bottom income quartile</td>
<td>4.11</td>
<td>1.86</td>
</tr>
<tr>
<td>Top income quartile</td>
<td>0.85</td>
<td>0.48</td>
</tr>
<tr>
<td>Difference</td>
<td>-3.02</td>
<td>1.44</td>
</tr>
</tbody>
</table>

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 $\frac{\partial O}{\partial P}$ 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 $\frac{\partial O}{\partial P}$ across the subset.


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

Estimated Impact of Comprehensive Systems Based on Income Per Capita in Communities

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

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