Public Health Spending and COVID-19

Sneha Lamba, Carrie Wolfson, Carolina Cardona, Sasmira Matta, Alison Gemmill, Arnab Acharya David Bishai
Rationale

The nation’s public health agencies are ailing when they’re needed most

By Chelsea Janes and William Wan

August 31, 2020 at 4:00 p.m. EDT
Two Theories of Public Health “Ailing”

The Solution is Money
• Health departments are staffed with competent professionals
• They know what to do
• They just need more resources

The Solution is New Structure
• Decades of starvation have left behind hollow shells
  • Devolution into vertical programs like TB, STDs, Animal control
  • Propped up by block grants
• No funding for comprehensive multi-sectoral approaches to social determinants
• Nobody on board to do this even if it were funded
Past Research

**US National Survey of Health Depts.**
- Rates US Health Depts.
  - Scope of population health work
  - Density of multi-sector network
- Top rating in 2016 applied to
  - 29% of rural health depts
  - 41% of urban health depts
- Top rated health depts
  - Lower all cause mortality 98-2014

**UK Public Health England**
- Since 2012
  - PH placed under local government
  - Austerity measures cut local govt
- Local PH departments devolved to a bucket of programs
  - STD treatment
  - Family planning
  - Child maltreatment
  - Obesity
  - Alcohol
  - Tobacco
Conceptual Framework and Rationale

Anchor Leadership (often from local health dept)

- Partial List

Organizations to Align*

- Public Health
- Law Enforcement
- Education
- Schools

- Medical Care
- Community Based Orgs.
- Faith Based Orgs.
- Insurers

- Preventing infectious exposures
- Access to quality care
- Outreach to vulnerable groups
- Economic mitigation

Reduced COVID-19:
- Incidence,
- Death,
- Inequity,
- Economic loss
Does Past PH Spending improve COVID Response?

- Hypothesis 1: Counties that have spent more on local public health controlled COVID-19

- Hypothesis 2: Neighbor to neighbor transmission of COVID-19 creates spatial correlation and will dramatically impact estimates
Kent County Delaware
Tenth case on March 24 and peak on April 29
Time to bend curve 36 days
Peak Incidence 25 cases per 100,000

Kent County Michigan
Tenth case on March 20 and peak on May 9
Time to bend curve 50 days
Peak Incidence 73 cases per 100,000
Unfortunately by July many counties not bent
Dependent Variable

• For counties that bent the curve and did not have a 2\textsuperscript{nd} wave
  • Elapsed time from 10\textsuperscript{th} case to day of first peak
  • Height of first peak

• For counties that did not bend curve or had a 2\textsuperscript{nd} wave
  • Estimated doubling time
Right Hand Side (USA models)

Treatment Variables from 2017 Logged

• Non Hospital Health $ per Capita County
• Comm Dis. Control $ per Capita State
• Hazard Prep $ per Capita
• $ sent from state to County for Comm Dis. Control

Control Variables from 2017 Logged

• Total County Revenue per Capita
• Hospital $ per Cap at County
• % Black, Hispanic, >65, <18
• Rural and Population Density
• Avg peak cases in adjacent counties
• % college
• Median income
• Obesity, smoking, death rate
• State testing rate
• % voted for Trump 2016
• Avg Temperature March, April, May
Methods
Statistical Approach

For Bent Curve Counties

• Hazard(Bend Curve_t )=Weibull(Treatment, RHS Vars)
  • Weibull had better fit than log and logistic by AIC
  • Shared hazard by State

• Height of first peak in cases per 100,000=C+β_1 Treatment + β_2 RHS +ε
  • Used spatial autocorrelation weighting matrix by distance and contiguity

For Not Bent Curve Counties

• Estimate doubling time by log(incidence_{it})=C+β_{it}(time) → DT=log2/b_{it}

• DT= C+β_1 Treatment + β_2 RHS +ε
Robustness Checks

• Does spatial autocorrelation affect results
• Weibull vs. Exp vs. Logistic
• Statistical confounding
• Outliers
US Results
# Weibull Model Results in US (\(>1\) slower to peak)

<table>
<thead>
<tr>
<th></th>
<th>Model 1</th>
<th>Model 2</th>
<th>Model 3</th>
<th>Model 4</th>
<th>Model 5</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Time Ratio (SE)</td>
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<td>Time Ratio (SE)</td>
</tr>
<tr>
<td>PH Spending per Capita</td>
<td>1.005</td>
<td>1.002</td>
<td>1.002</td>
<td>0.998</td>
<td>1.001</td>
</tr>
<tr>
<td>Total County Spending per Capita</td>
<td>1.005</td>
<td>1.002</td>
<td>1.002</td>
<td>0.998</td>
<td>1.001</td>
</tr>
<tr>
<td>Log Testing Rate</td>
<td>0.766***</td>
<td>0.786***</td>
<td>0.781***</td>
<td>0.785***</td>
<td>0.810***</td>
</tr>
<tr>
<td>Log of People per Sq Mile</td>
<td>1.046</td>
<td>1.054</td>
<td>1.058</td>
<td>1.064</td>
<td>1.085*</td>
</tr>
<tr>
<td>% Under 18 Years</td>
<td>1.050**</td>
<td>1.043**</td>
<td>1.045**</td>
<td>1.059***</td>
<td>1.063***</td>
</tr>
<tr>
<td>% Over 65 Years</td>
<td>0.985</td>
<td>0.986</td>
<td>0.985</td>
<td>0.993</td>
<td>0.999</td>
</tr>
<tr>
<td>% some college</td>
<td>1.016*</td>
<td>1.014*</td>
<td>1.015*</td>
<td>1.018**</td>
<td>1.016**</td>
</tr>
<tr>
<td>Rural</td>
<td>0.844**</td>
<td>0.869*</td>
<td>0.859*</td>
<td>0.866*</td>
<td>0.872*</td>
</tr>
<tr>
<td>N (County Days Observed)</td>
<td>17,960</td>
<td>17,960</td>
<td>17,960</td>
<td>17,960</td>
<td>17,830</td>
</tr>
<tr>
<td>AIC</td>
<td>611.1</td>
<td>608</td>
<td>608.3</td>
<td>604</td>
<td>590</td>
</tr>
</tbody>
</table>

Other Covariates Included: Model % Hispanic, %African American, Migration, Male/Female, Smoking, Median Income, Income Inequ, Food Insecurity, Uninsured adults, Physicians/cap, Uninsured % Obesity Model 1 adds mortality, Model 2 adds obesity, Model 3 adds temperature, Model 5 adds % voting for Trump in 2016  *p<.1, p<.05, **p<.01
## Results: US Peak COVID-19 Incidence if Bent Curve Model

<table>
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<tr>
<th></th>
<th>Model 1 Time Ratio (SF)</th>
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<th>Model 5 Time Ratio (SF)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ln State Comm. Dis. $/capita</td>
<td>-0.0418**</td>
<td>-0.0353**</td>
<td>-0.0340*</td>
<td>-0.0341*</td>
<td>-0.0379**</td>
</tr>
<tr>
<td>Ln State Total Spend $/capita</td>
<td>-0.0442</td>
<td>-0.0506</td>
<td>-0.0514*</td>
<td>-0.0732**</td>
<td>-0.0726**</td>
</tr>
<tr>
<td>Population/Sq Mile</td>
<td>-0.000284</td>
<td>-0.000288</td>
<td>-0.000265</td>
<td>-0.000422*</td>
<td>-0.000467**</td>
</tr>
<tr>
<td>State Testing Rate</td>
<td>-0.000159***</td>
<td>-0.000151***</td>
<td>-0.000149***</td>
<td>-0.000193***</td>
<td>-0.000193***</td>
</tr>
<tr>
<td>Adjacent Incidence</td>
<td>0.694***</td>
<td>0.680***</td>
<td>0.677***</td>
<td>0.666***</td>
<td>0.664***</td>
</tr>
<tr>
<td>Ln(% Hispanic)</td>
<td>0.131***</td>
<td>0.159***</td>
<td>0.154***</td>
<td>0.177***</td>
<td>0.174***</td>
</tr>
<tr>
<td>% African American</td>
<td>8.046***</td>
<td>8.408***</td>
<td>8.428***</td>
<td>8.426***</td>
<td>8.387***</td>
</tr>
<tr>
<td>%&gt;65</td>
<td>-1.742***</td>
<td>-1.587***</td>
<td>-1.585***</td>
<td>-1.311**</td>
<td>-1.285**</td>
</tr>
<tr>
<td>%&lt;18</td>
<td>1.328**</td>
<td>0.916</td>
<td>1.058</td>
<td>1.197*</td>
<td>1.269*</td>
</tr>
<tr>
<td>Other Covariates</td>
<td></td>
<td>Add Obesity</td>
<td>Add Death Rate</td>
<td>Add Temperature</td>
<td>Add Trump Votes</td>
</tr>
</tbody>
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* + Rural, Intl Migration, Domestic Migration, Male/Female, Smoking, College, Median income, Income Ineq, Food Insecurity, Uninsured
* p<.1, p<.05, **p<.01
### Results: US Peak COVID-19 Incidence if Bent Curve Model

<table>
<thead>
<tr>
<th>Covariate</th>
<th>Model 1 Time Ratio (SF)</th>
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<th>Model 5 Time Ratio (SF)</th>
</tr>
</thead>
<tbody>
<tr>
<td>COUNTY Public Health Spending</td>
<td>0.0187***</td>
<td>0.0179***</td>
<td>0.0187***</td>
<td>0.0195***</td>
<td>0.0196***</td>
</tr>
<tr>
<td>County Revenue $/capita</td>
<td>-1.29e-05</td>
<td>-1.04e-05</td>
<td>-1.17e-05</td>
<td>-7.46e-06</td>
<td>-8.06e-06</td>
</tr>
<tr>
<td>Population/Sq Mile</td>
<td>-0.000194</td>
<td>-0.000239</td>
<td>-0.000186</td>
<td>-0.000451*</td>
<td>-0.000472**</td>
</tr>
<tr>
<td>State Testing Rate</td>
<td>-0.000134***</td>
<td>-0.000128***</td>
<td>-0.000123***</td>
<td>-0.000174***</td>
<td>-0.000172***</td>
</tr>
<tr>
<td>Adjacent Incidence</td>
<td>0.612***</td>
<td>0.610***</td>
<td>0.600***</td>
<td>0.578***</td>
<td>0.576***</td>
</tr>
<tr>
<td>Ln(% Hispanic)</td>
<td>0.130***</td>
<td>0.157***</td>
<td>0.147***</td>
<td>0.171***</td>
<td>0.167***</td>
</tr>
<tr>
<td>% African American</td>
<td>4.927***</td>
<td>5.377***</td>
<td>5.439***</td>
<td>6.220***</td>
<td>6.112***</td>
</tr>
<tr>
<td>%&gt;65</td>
<td>-1.019*</td>
<td>-0.914</td>
<td>-0.876</td>
<td>-0.466</td>
<td>-0.405</td>
</tr>
<tr>
<td>%&lt;18</td>
<td>1.718**</td>
<td>1.166</td>
<td>1.460*</td>
<td>1.899**</td>
<td>1.958**</td>
</tr>
</tbody>
</table>

Other Covariates: Add Obesity, Add Death Rate, Add Temperature, Add Trump Votes

+ Rural, Intl Migration, Domestic Migration, Male/Female, Smoking, College, Median income, Income Ineq, Food Insecurity, Uninsured

*p<.1, p<.05, **p<.01
What sign were other covariates?

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<thead>
<tr>
<th>Covariate</th>
<th>Multivariate Model Effect on Peak County COVID Incidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Domestic Migration</td>
<td>NS</td>
</tr>
<tr>
<td>Intl Migration</td>
<td>NS</td>
</tr>
<tr>
<td>Male/Female ratio</td>
<td>Pos</td>
</tr>
<tr>
<td>Smoking</td>
<td>Pos</td>
</tr>
<tr>
<td>College</td>
<td>Pos</td>
</tr>
<tr>
<td>Median Income</td>
<td>Pos</td>
</tr>
<tr>
<td>Income Inequality Ratio</td>
<td>Neg</td>
</tr>
<tr>
<td>Food Insecurity</td>
<td>Pos</td>
</tr>
<tr>
<td>% Uninsured</td>
<td>Pos</td>
</tr>
<tr>
<td>% Obese</td>
<td>Pos</td>
</tr>
<tr>
<td>Death rate</td>
<td>NS</td>
</tr>
<tr>
<td>Temp</td>
<td>NS except May (pos)</td>
</tr>
<tr>
<td>% Trump Votes</td>
<td>NS</td>
</tr>
</tbody>
</table>
UK Results

- All UK counties had a bent curve
- Weibull model fit best
- No need for exponential growth models like US
Heat Map of Unadjusted Time to Bent Curve
Heat Map of Peak Incidence Rate of COVID-19 per 100,000 on Day of Bent Curve
### Weibull Model Results in UK

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<th>Model 5 Time Ratio (SE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PH Spending per Capita Q2</td>
<td>1.13 (0.183)***</td>
<td>1.249 (0.179)***</td>
<td>1.197 (0.161)***</td>
<td>1.12 (0.146)</td>
<td>1.105 (0.144)</td>
</tr>
<tr>
<td>PH Spending per Capita Q3</td>
<td>1.586 (0.279)***</td>
<td>1.578 (0.268)***</td>
<td>1.538 (0.25)***</td>
<td>1.152 (0.208)</td>
<td>1.112 (0.206)</td>
</tr>
<tr>
<td>PH Spending per Capita Q4</td>
<td>1.98 (0.403)***</td>
<td>1.923 (0.406)***</td>
<td>1.965 (0.394)***</td>
<td>1.26 (0.297)</td>
<td>1.224 (0.291)</td>
</tr>
<tr>
<td>Log of People per Sq Mile</td>
<td>0.855 (0.056)***</td>
<td>0.76 (0.058)***</td>
<td>0.784 (0.058)***</td>
<td>0.782 (0.057)***</td>
<td></td>
</tr>
<tr>
<td>% Under 18 Years</td>
<td></td>
<td>1.077 (0.027)***</td>
<td>1.056 (0.03)*</td>
<td>1.054 (0.03)*</td>
<td></td>
</tr>
<tr>
<td>% Over 65 Years</td>
<td></td>
<td></td>
<td>0.97 (0.021)</td>
<td>0.959 (0.02)**</td>
<td>0.961 (0.02)*</td>
</tr>
<tr>
<td>Median Weekly Income Q2</td>
<td></td>
<td></td>
<td>0.626 (0.089)***</td>
<td>0.619 (0.087)***</td>
<td></td>
</tr>
<tr>
<td>Median Weekly Income Q3</td>
<td></td>
<td></td>
<td>0.589 (0.096)***</td>
<td>0.599 (0.099)***</td>
<td></td>
</tr>
<tr>
<td>Median Weekly Income Q4</td>
<td></td>
<td></td>
<td>0.464 (0.1)***</td>
<td>0.485 (0.107)***</td>
<td></td>
</tr>
<tr>
<td>AIC</td>
<td>299.8</td>
<td>253.4</td>
<td>238.1</td>
<td>231.3</td>
<td>234.4</td>
</tr>
</tbody>
</table>

Other Covariates Included: Model 1-5 Log of net current expenditure per capita; Model 2-5 London; Model 4-5 Ratio of house price to earning, unemployment, fuel poverty; Model 5 self reported isolation of social care users over 18 years, self report isolation of social carers over 18 years

Excludes 9 counties that reached peak in 3 days or fewer

*p<.1, p<.05, **p<.01
Discussion

• Finding 1: US State PH spending on communicable diseases lowered COVID-19 Peaks

• Finding 2: Local public health spending in US and UK was not associated with lower time to COVID-19 control or reduced Peak COVID-19
Policy Implication

• Question was whether to
  A) Just send money to counties?
  B) Restructure county health departments?

• Little evidence that “Send money” would be effective
• Limitation that only had 2017 data on PH spending in US and UK
Future Work

• Find best performing counties
  • On time to peak
  • On racial equity
  • On death rate

• Qualitative interviews with PH staff for pos and neg deviants

• Grant pending at RWJF
Thank You