Appendix A: Allowing for Contact Rate Heterogeneity

The canonical SEIR framework assumes homogeneous mixing: every individual in a population is equally likely to encounter every other individual. This assumption allows for a tractable model but abstracts from more complex, heterogeneous patterns of interaction among some population subgroups. Contact rate heterogeneity can affect the dynamics of epidemic, especially if uniformly-applied NPIs disproportionately impact contact rates among subgroups. If the NPI-caused reduction in aggregate contact is concentrated among relatively vulnerable subgroups, the homogenous mixture assumption might underestimate the interventions' positive health impacts. Modeling contact rate heterogeneity is also important for analyzing NPIs that specific target certain groups; see Acemoglu and others (2020) and Baqaee and others (2020) for studies that identify channels of contact reduction that minimize economic harm (e.g. leaving businesses open but reducing nonwork contact).

We relax this assumption by extending the SEIR framework to include two population subgroups. Members interact among themselves (intragroup contact) and with those in the other group (intergroup contact). For a given state *i* at time *t*, the differential equation governing population transition out of the susceptible compartment becomes:

$$\frac{dS_a}{dt} = -\sum_{b=1}^{2} \beta_{ab} I_b \frac{S_a}{N}$$

for $a = 1$ and 2. This setup allows for different baseline levels of intra- and intergroup contact via the transmission rate β_{ab} and, critically, different relative magnitudes of NPI effects on contact rates – that is, heterogeneous treatment effects. Data limitations prevent us from decomposing changes in the contact rate by demographics. Here, we conduct a simple stylized experiment using plausible, directionally-informative assumed values to illustrate the impact of the homogenous mixture assumption.

We begin with two population subgroups *a* and *b*, roughly corresponding with "younger" and "older" respectively. The younger group is larger and has a higher baseline level of intragroup contact than the older group (both specified as ratios relative to the overall contact rate). Intergroup contact, calculated as a residual, is assumed to be low. The older group has a substantially higher IFR than the younger group, again specified relative to the overall IFR. Table A1 shows the values of the assumed parameters.

Table A1. Parameter definitions and values

Parameter	Definition	Value
$\frac{\kappa_{aa}}{\kappa}$	ratio of younger group's intergroup contact rate to the overall average contact rate	1.25
$\frac{\kappa_{bb}}{\kappa}$	ratio of older group's intergroup contact rate to the overall average contact rate	0.8
$\frac{\mu_a}{\mu}$	ratio of younger group's IFR to the overall average IFR	0.2
$\frac{N_a}{N}$	younger group's share of the population	0.8

We then run a counterfactual scenario without NPIs under different assumptions regarding the concentration of treatment effects across subgroups. We vary the younger group's share of the NPI effect on contact rate, with five values: 0% (i.e. all of the reduction in the contact rate comes from the older group), 40%, 80% (contact rate reductions are proportional across subgroups as is the case in the standard homogenous mixing SEIR model), 90%, and 100%. We compare the results from the two-group SEIR model to those of the standard SEIR model presented in the main text. Table A2 shows the results.

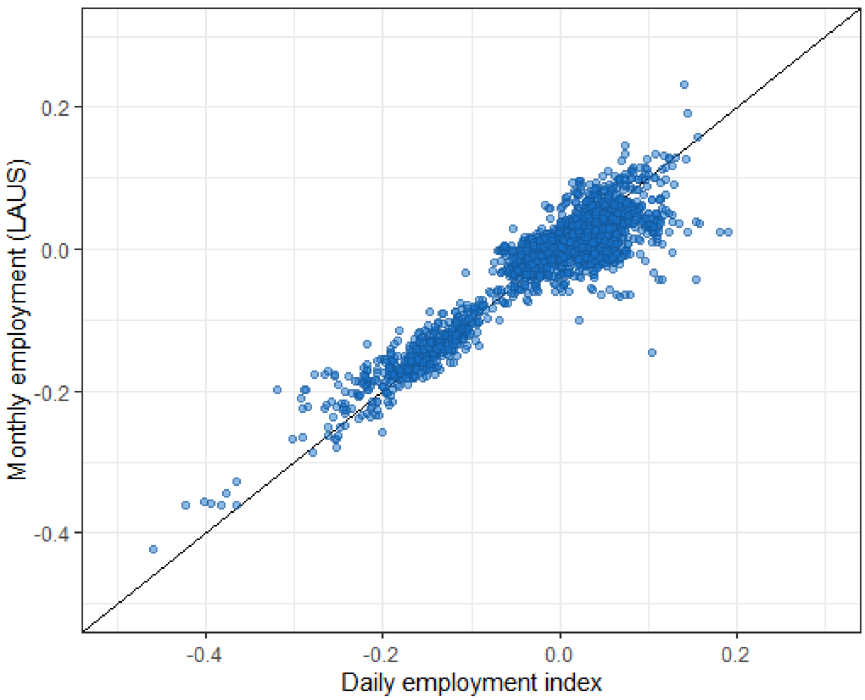
Table A2. Epidemiological Outcomes under Two-Group Model: Percent Change Relative to Standard Model

Younger group's contribution to decline in contact rate	Cumulative infections on May 31st	Cumulative deaths on May 31st
0%	-97%	-71%
40%	-60%	-57%
80%	-5%	-31%
90%	12%	-23%
100%	31%	-13%

The results are intuitive: if NPIs worked to reduce contact disproportionately among the less-vulnerable, then the homogenous mixture assumption somewhat overstates the number of lives saved. Given the conceivably younger-skewing demographics of the areas of economic life most heavily targeted by lockdown policy – the workplace and schools, namely – our view is that this is a directionally plausible bias in our headline results. Researchers who can collect and leverage data on contact rates by demographic group would provide a valuable contribution to this literature.

Appendix B: Additional Figures

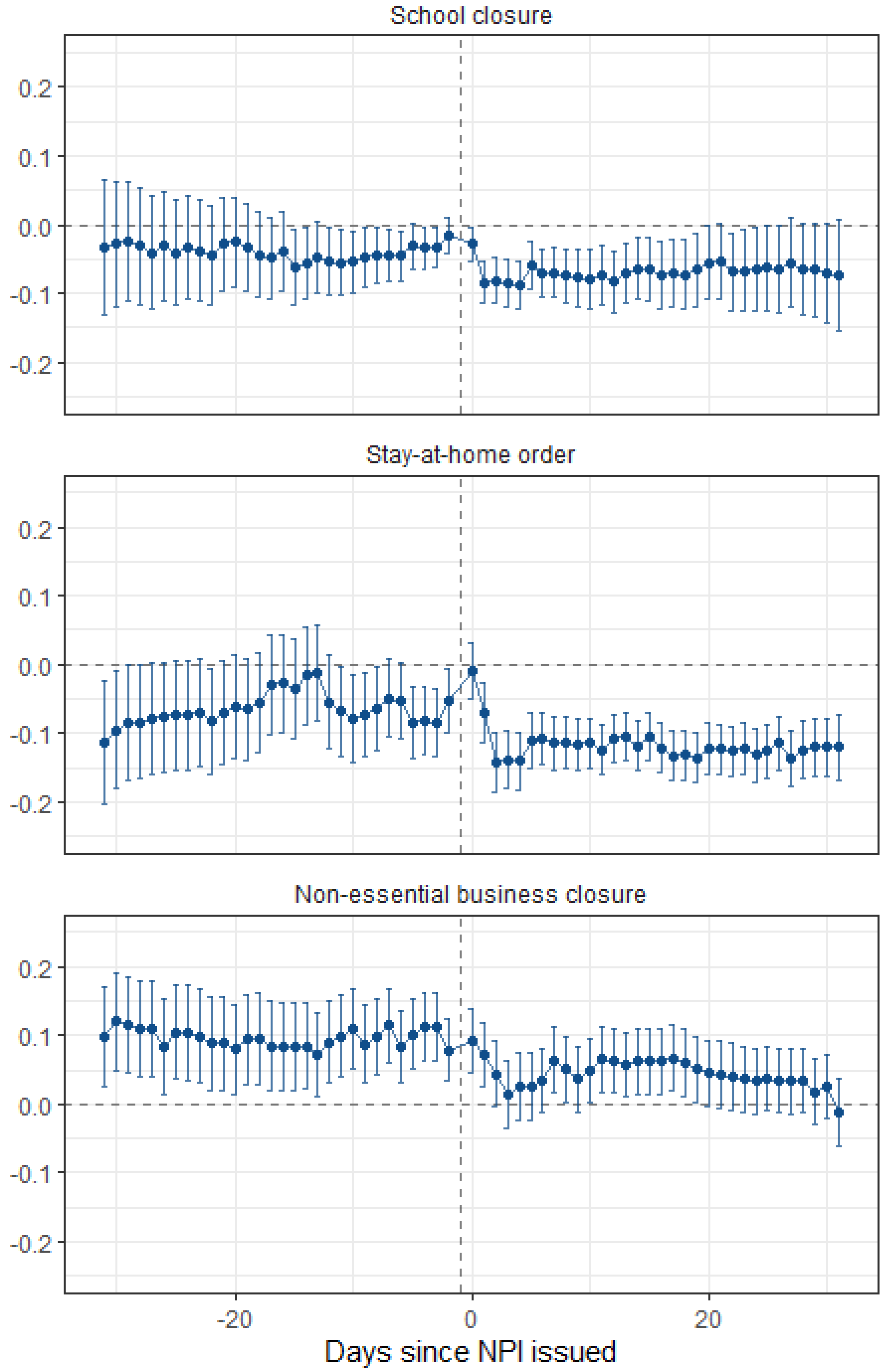
Figure B1. Monthly Log Change in County Employment: Daily Employment Index vs. Monthly Official Employment



Sources: Bureau of Labor Statistics (BLS); authors' calculations.

Notes: The figure plots county-level monthly changes in the log of the daily employment index against actual monthly changes in the log of employment from LAUS from February to July of 2020. To align with the BLS reference week, monthly changes in the daily employment index are calculated based on the weekly average for week containing the 12th of each month.

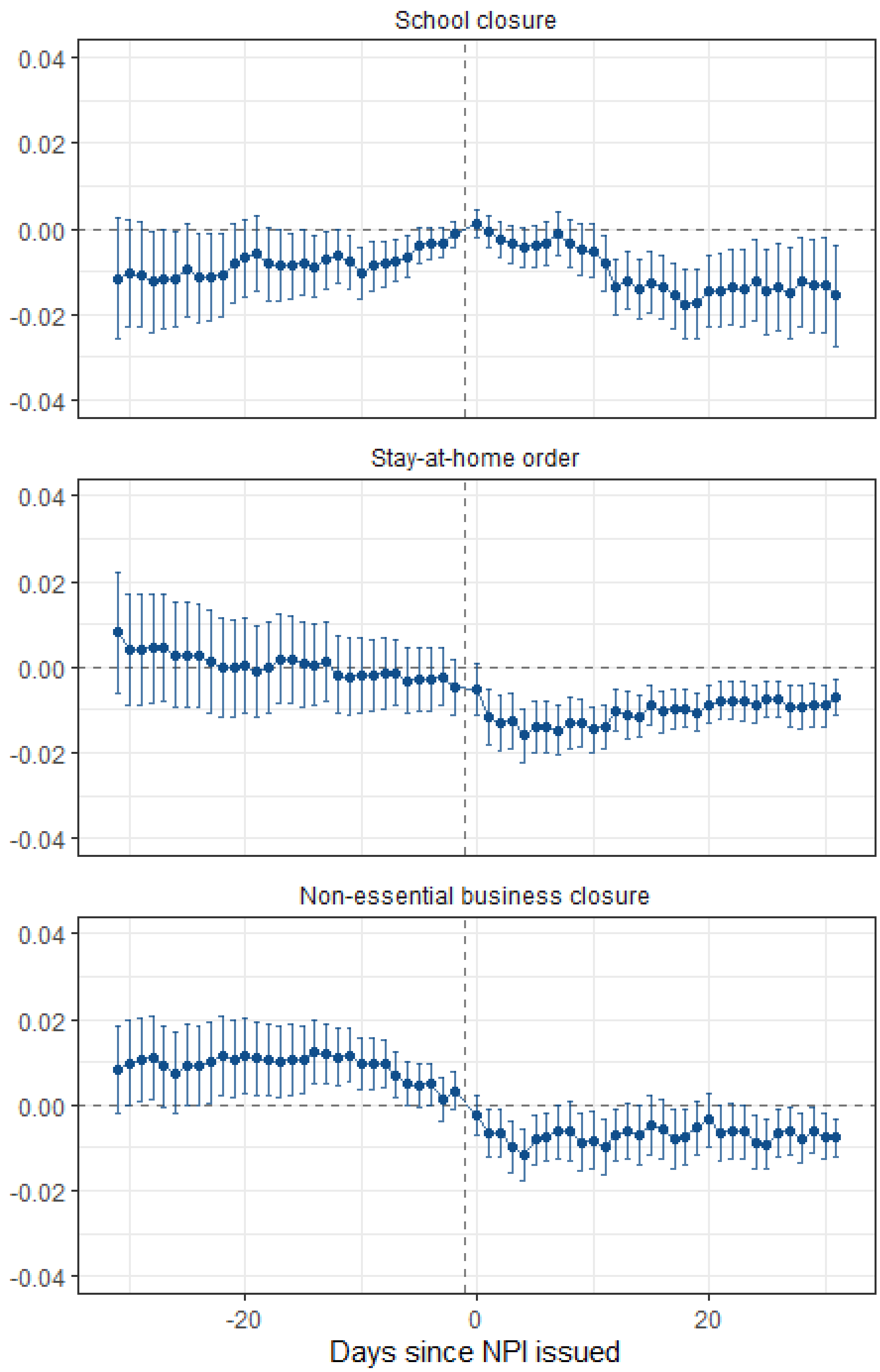
Figure B2. Event Study Estimates Without County Characteristics: Contact Rate



Source: Authors' calculations.

Notes: This figure shows coefficient estimates and 95% confidence intervals for ϕ_{jk}^{κ} from (7) with $X_{xi} = \vec{\mathbf{1}}$. Standard errors are clustered at the county level.

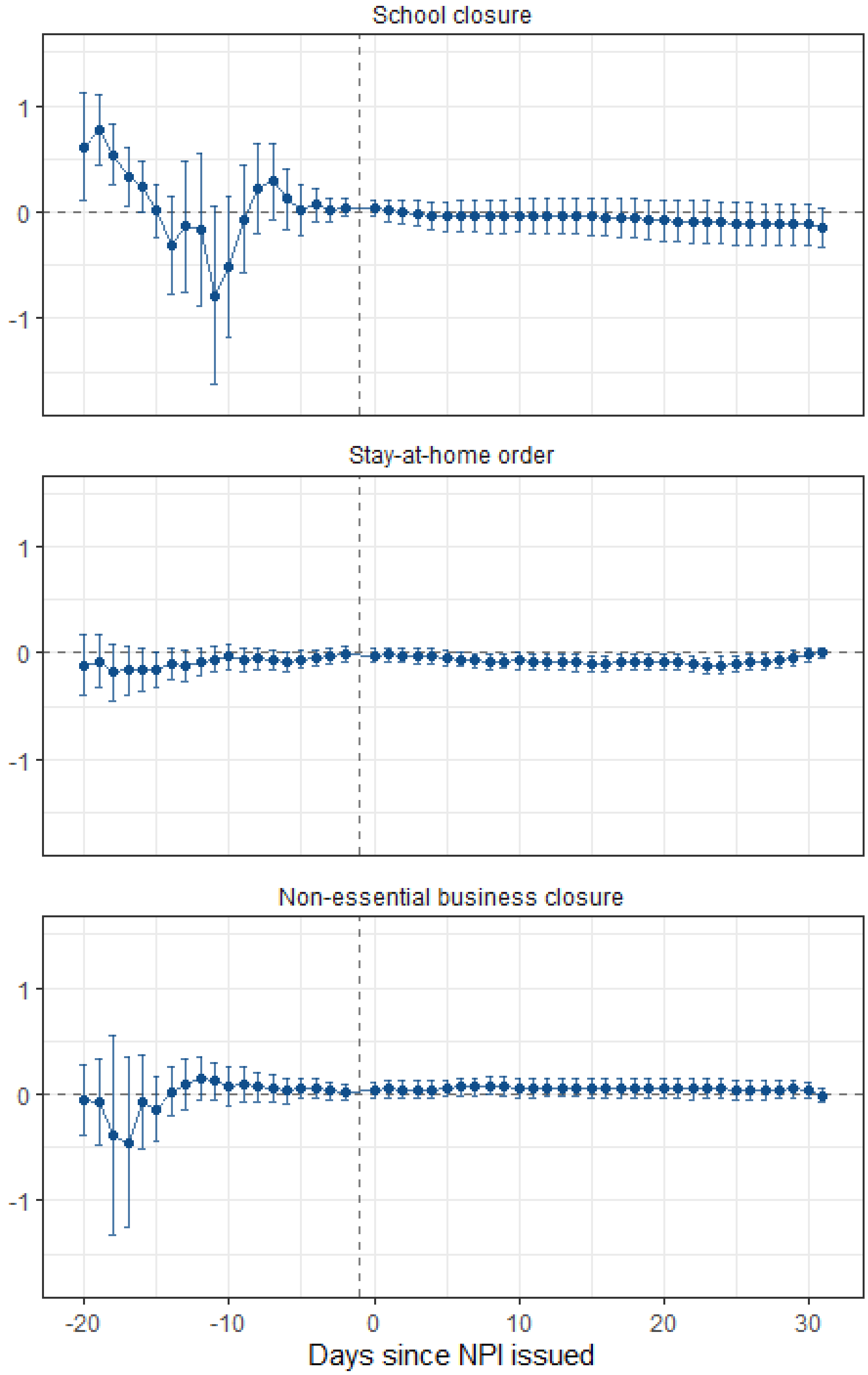
Figure B3. Event Study Estimates Without County Characteristics: Employment



Source: Authors' calculations.

Notes: This figure shows coefficient estimates and 95% confidence intervals for ϕ_{jk}^{W} from (7) with $X_{xi} = \vec{\mathbf{1}}$. Standard errors are clustered at the county level.

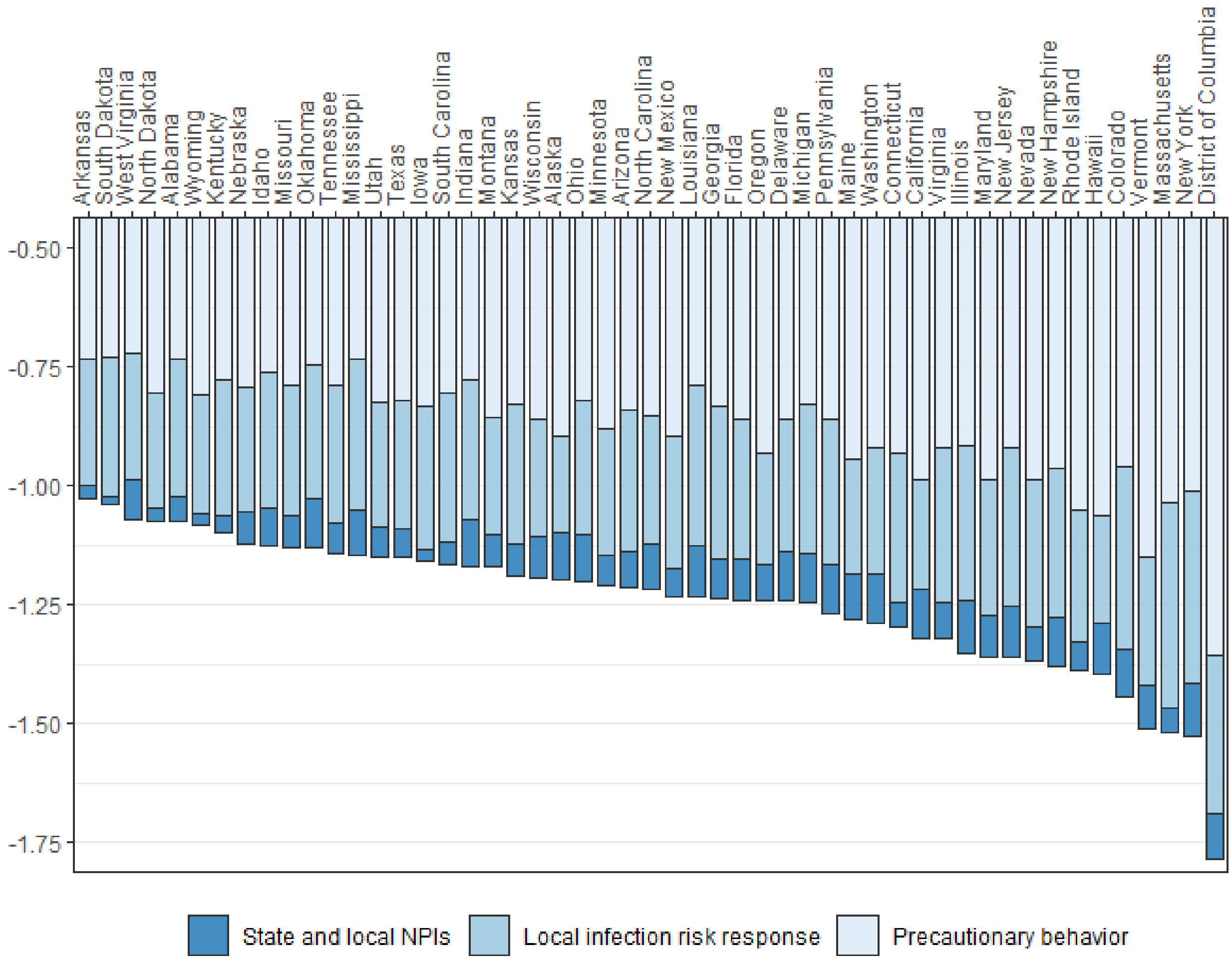
Figure B4. Event Study Estimates: Reproduction Number (R)



Source: Authors' calculations.

Figure B5. Decomposition of Contact Rate Response to COVID-19 by State

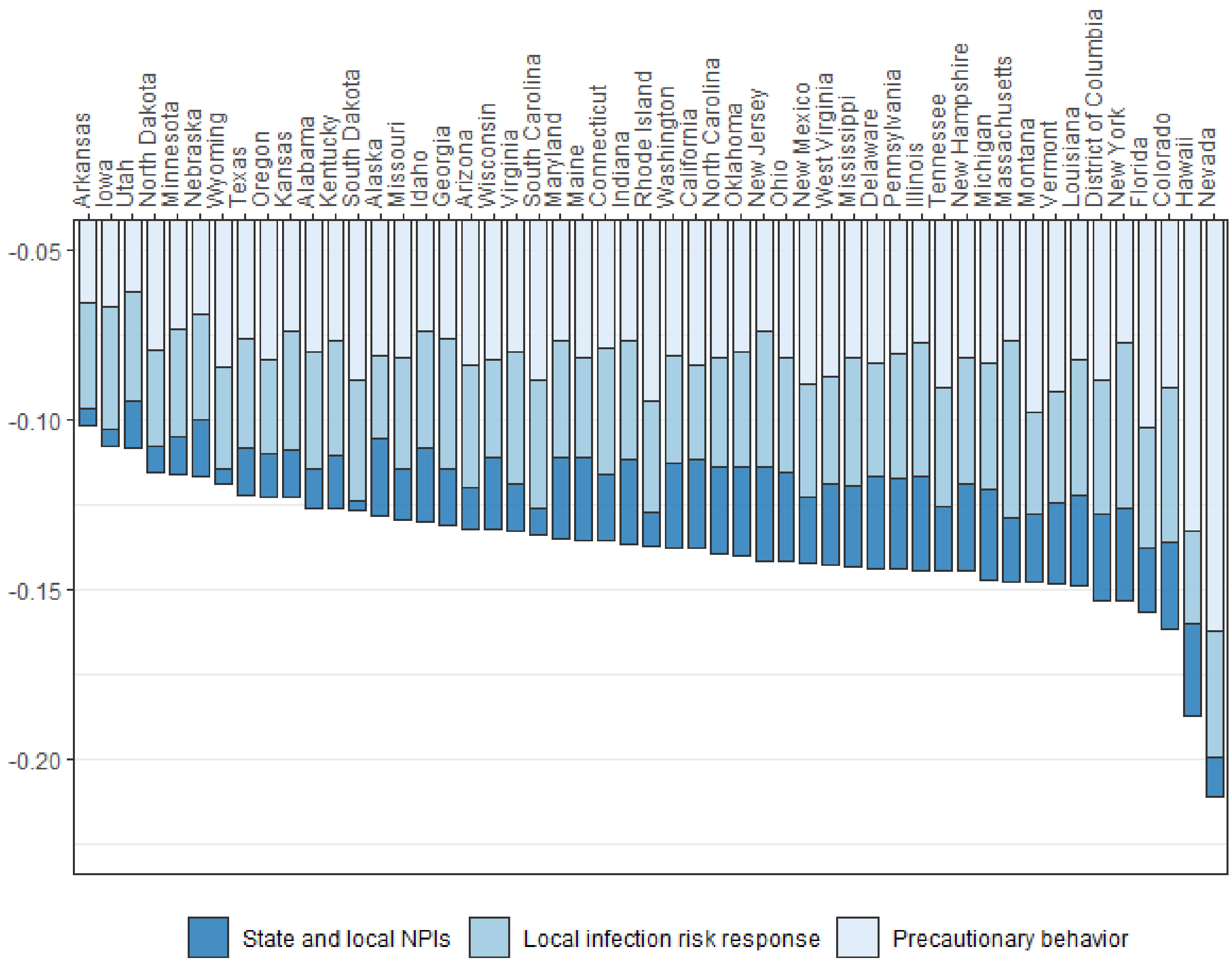
Average contribution to log difference from March 1st, March 1st – May 31st



Source: Authors' calculations.

Figure B6. Decomposition of Employment Response to COVID-19 by State

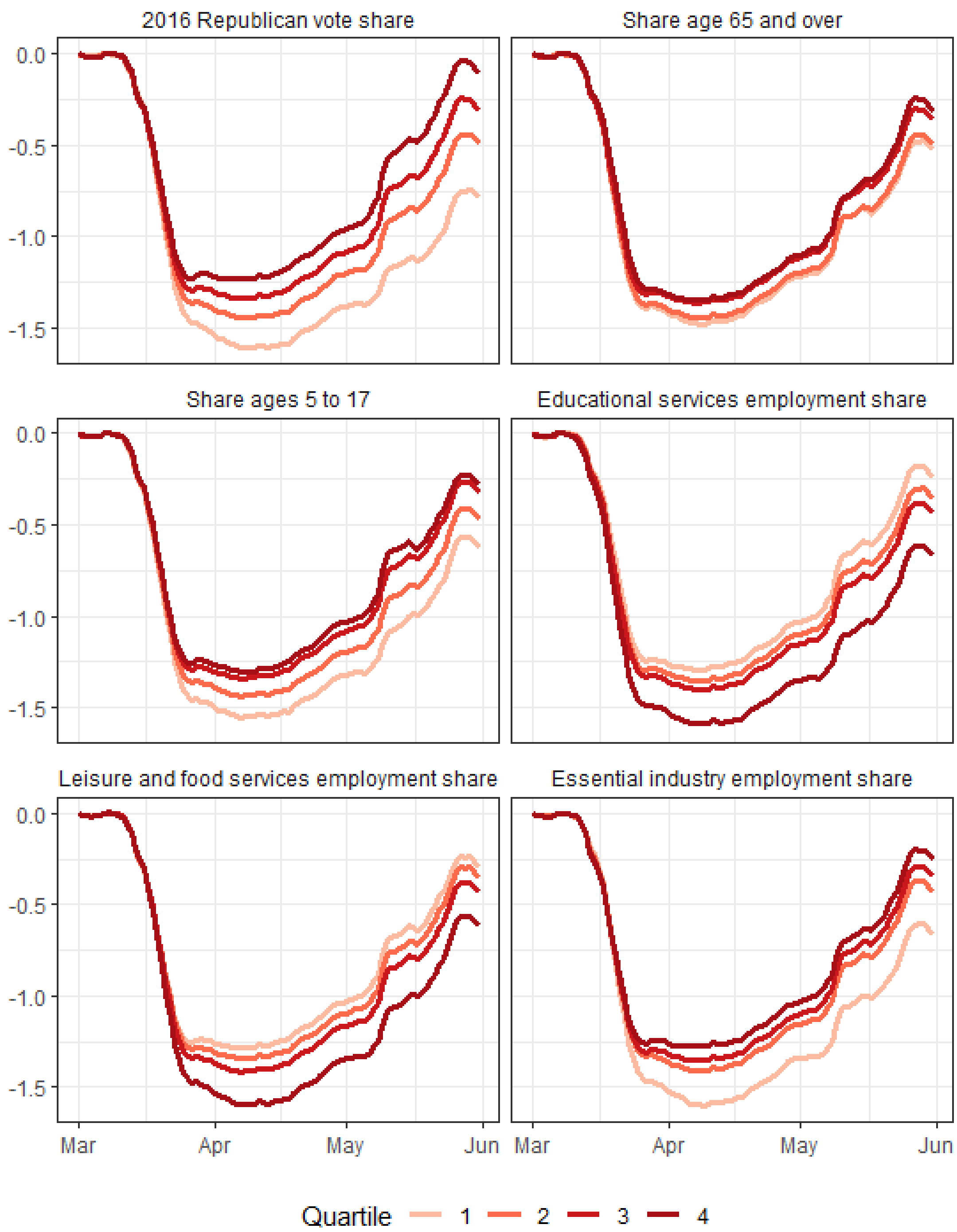
Average contribution to log difference from March 1st, March 1st – May 31st



Source: Authors' calculations.

Figure B7. Precautionary Changes in the Contact Rate by County Characteristics

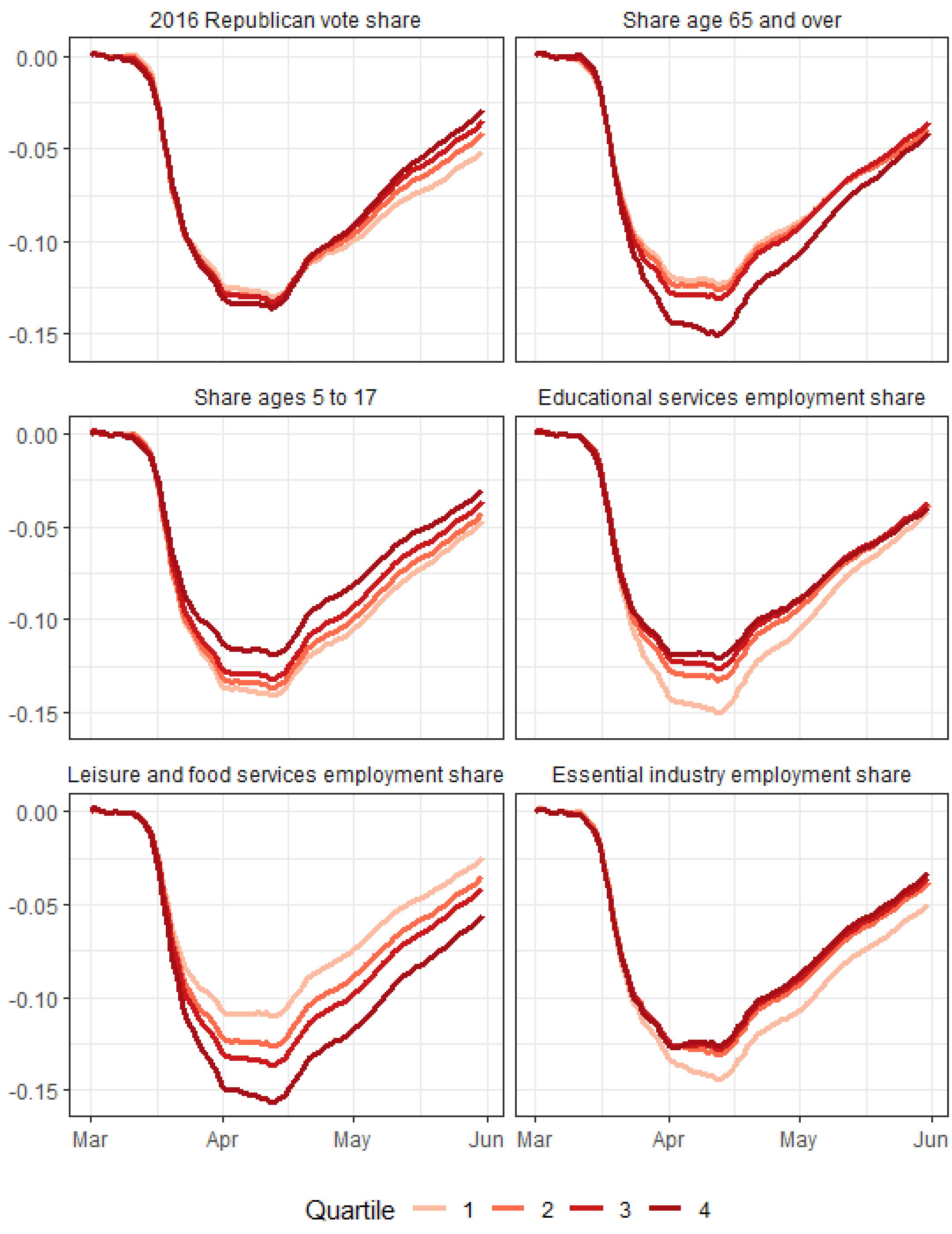
Contribution to log difference from March 1st, 7-day average



Source: Authors' calculations.

Figure B8. Precautionary Changes in Employment by County Characteristics

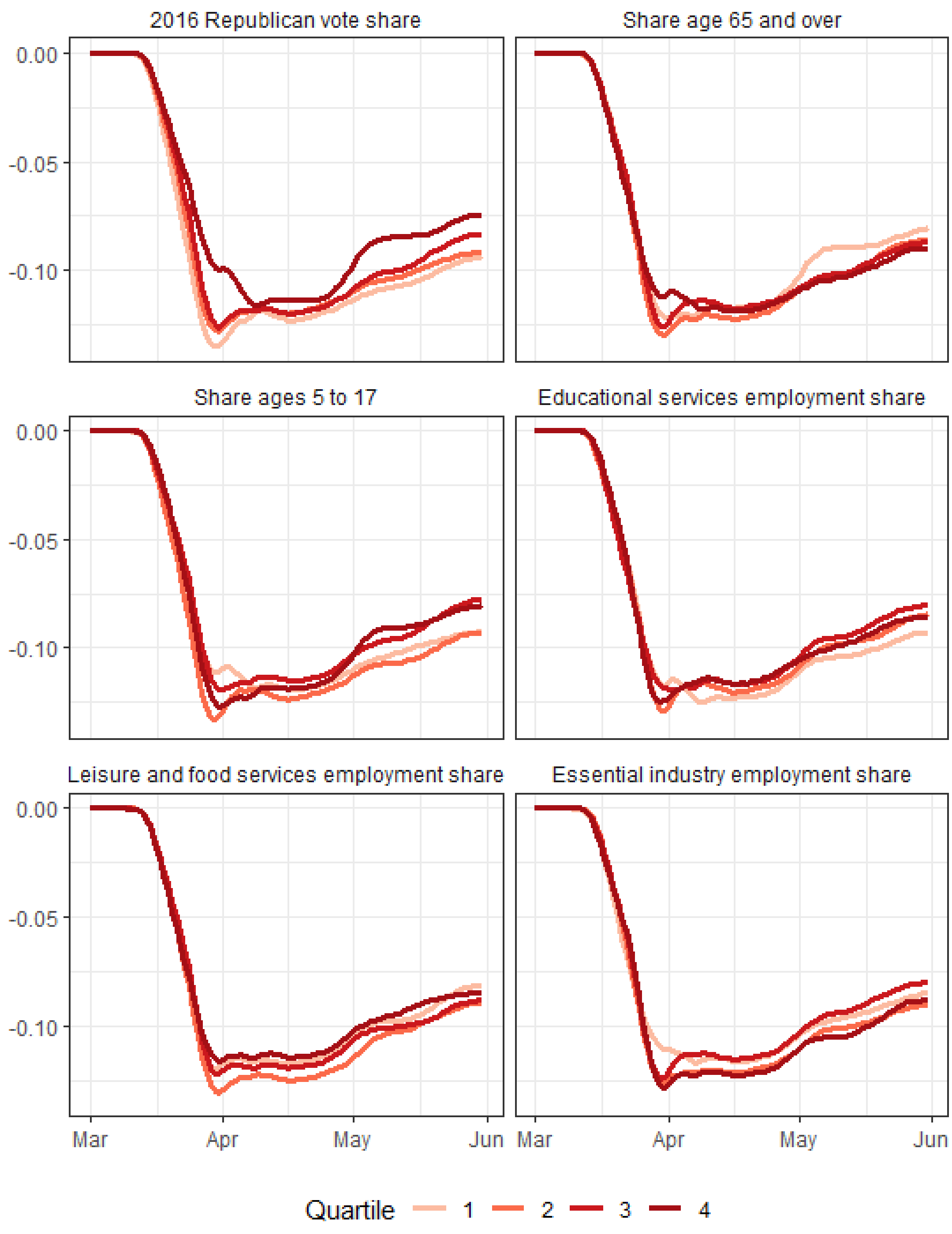
Contribution to log difference from March 1st, 7-day average



Source: Authors' calculations.

Figure B9. Contribution of NPIs to Changes in the Contact Rate by County Characteristics

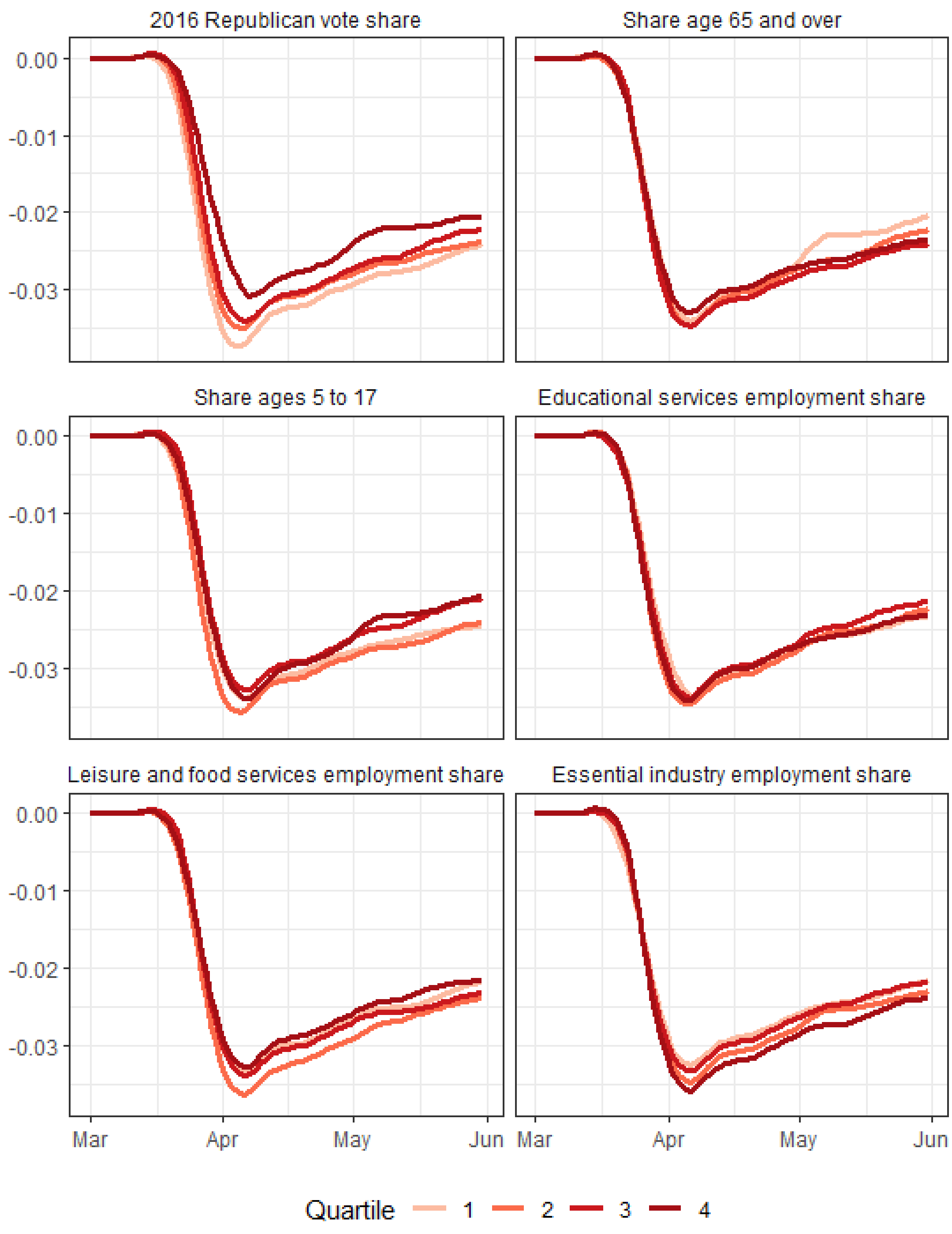
Contribution to log difference from March 1st, 7-day average



Source: Authors' calculations.

Figure B10. Contribution of NPIs to Changes in Employment by County Characteristics

Contribution to log difference from March 1st, 7-day average



Source: Authors' calculations.