Causal Impact of Masks, Policies, Behavior on Early Covid-19 Pandemic in the U.S.

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Issues

- What is the impact of various policies adopted by the US states on the spread of COVID-19?
- Mandatory face mask policy?
- How do people adjust their behavior to policies and new information on higher transmission risks?

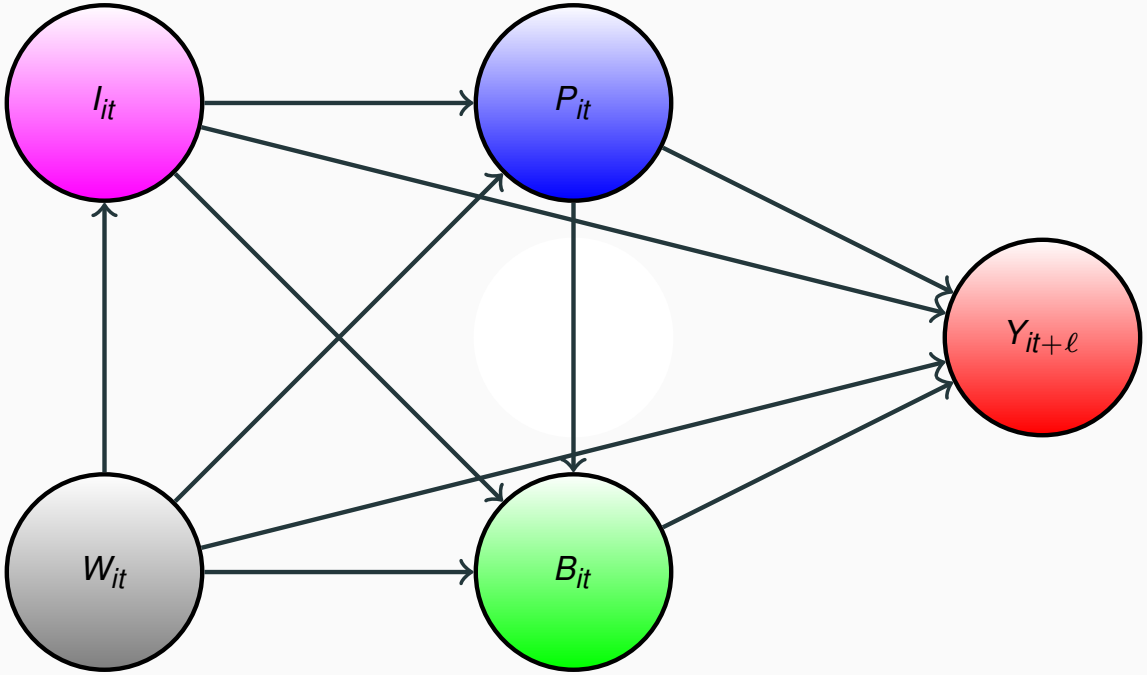
Literature

- The impact of non pharmaceutical interventions on Covid-19 cases: Hsiang et al. (2020), Courtemanche et al. (2020), Avery et al. (2020) for review.
- The impact of social distancing policies on behavior in the US is mixed: Abouk and Heydari (2020), Maloney and Taskin (2020), Gupta et al. (2020), Andersen (2020)
- Pei et al. (2020) provides simulation of implementing all policies 1-2 weeks earlier.
- Model simulations by epidemiologists (e.g., Ferguson et al., 2020). Substantial uncertainty in parameters (Avery et al., 2020; Stock, 2020)
- Fernández-Villaverde and Jones (2020) estimate a SIRD model that captures feedback from daily deaths to future behavior and infections.
- No existing experimental evidence for face mask. Our work is complementary to the medical observational evidence reviewed in Greenhalgh et al. (2020) and Howard et al. (2020), the laboratory findings of Hou et al. (2020), as well as the findings in Abaluck et al. (2020) and Mitze et al. (2020).

Contributions of this paper

1. The causal framework on how the Covid-19 spread is dynamically determined by policies and human behavior.
    - Direct vs. indirect effect of policies.
    - People voluntarily adjust their behavior in response to new information on reported cases/deaths.
    - Dynamic feedback.
2. Regression analysis on how the growth rates of Covid-19 cases/deaths are determined by policies and behavior using the US state-level data.
3. Counterfactual experiments
    - What if mandatory face mask policy had been adopted everywhere on April 1st?
    - What if no stay-at-home (shelter-in-place) orders?

Causal Model



- $Y_{it+\ell}$: the *forward* growth rate of cases/deaths
- P_{it}: the lagged policies (e.g., mandatory face mask policy)
- B_{it}: the lagged behavior variables (Google mobility measures)
- I_{it}: information on transmission risks (past cases and deaths)
- W_{it}: confounders (state-level characteristics, month dummies)

Structural Equation Model and Orthogonality Restrictions

$$Y_{it+\ell} = \alpha' B_{it} + \pi' P_{it} + \mu' I_{it} + \delta_Y' W_{it} + \varepsilon_{it}^y, \quad \varepsilon_{it}^y \perp B_{it}, P_{it}, I_{it}, W_{it} \tag{BPI→Y}$$

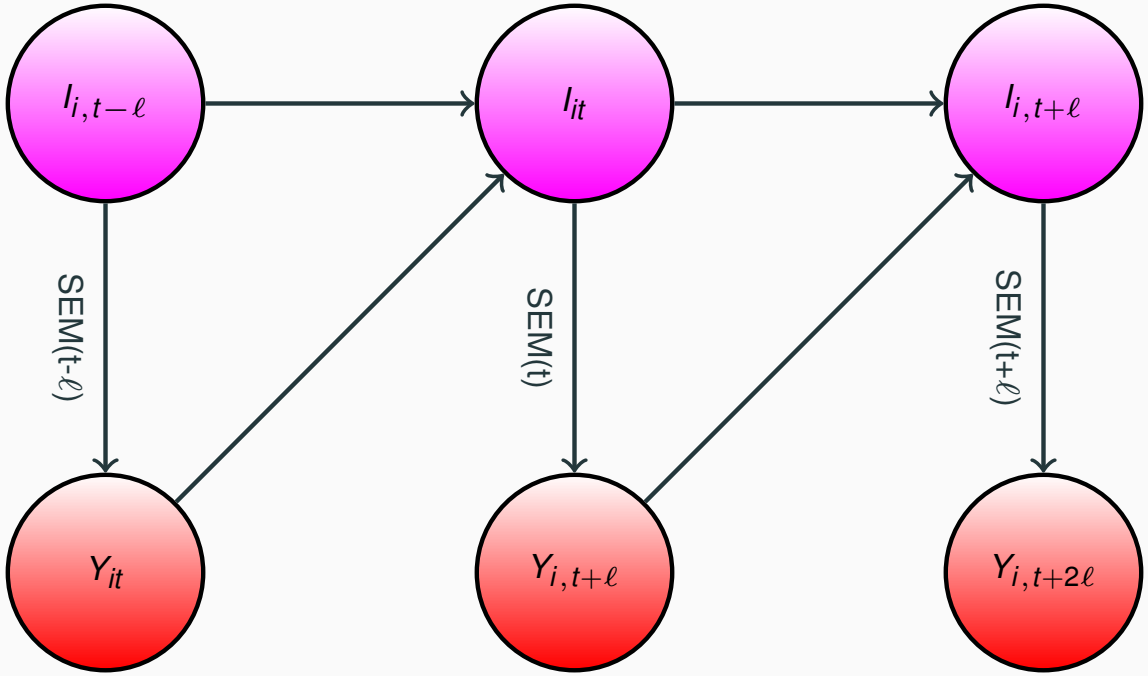
$$B_{it} = \beta' P_{it} + \gamma' I_{it} + \delta_B' W_{it} + \varepsilon_{it}^b, \quad \varepsilon_{it}^b \perp P_{it}, I_{it}, W_{it} \tag{PI→B}$$

and

$$Y_{it+\ell} = (\pi' + \alpha'\beta')P_{it} + (\mu' + \alpha'\gamma')I_{it} + \bar{\delta}' W_{it} + \bar{\varepsilon}_{it}, \quad \bar{\varepsilon}_{it} \perp P_{it}, I_{it}, W_{it}. \tag{PI→Y}$$

- π': direct effect of policy.
- $\alpha'\beta'$: indirect effect of policy on infection through behavior.
- The system is over-identified.

Dynamic feedback



$$I_{it} = \left(Y_{it}, \sum_{m=0}^{t/\ell} Y_{i,t-\ell m} \right)' = (\text{lagged case growth}, \text{lagged cases})$$

SIR Model and Empirical Specification

SIR Model with confirmed cases $\dot{C}(t)$ and testing $\tau(t)$:

$$\dot{S}(t) = -\frac{S(t)}{N}\beta(t)\mathcal{I}(t), \qquad \dot{\mathcal{I}}(t) = \frac{S(t)}{N}\beta(t)\mathcal{I}(t) - \gamma\mathcal{I}(t),$$

$$\dot{R}(t) = (1-\kappa)\gamma\mathcal{I}(t), \qquad \dot{D}(t) = \kappa\gamma\mathcal{I}(t), \qquad \dot{C}(t) = \tau(t)\mathcal{I}(t).$$

Differentiating $\dot{C}(t) = \tau(t)\mathcal{I}(t)$ and $\dot{D}(t) = \kappa\gamma\mathcal{I}(t)$,

$$\frac{\ddot{C}(t)}{\dot{C}(t)} = \frac{S(t)}{N}\beta(t) - \gamma + \frac{\dot{\tau}(t)}{\tau(t)},$$

$$\frac{\ddot{D}(t)}{\dot{D}(t)} = \frac{S(t)}{N}\beta(t) - \gamma.$$

SIR Model and Empirical Specification

Discrete-time analogue with

$$\frac{S(t)}{N}\beta(t) \approx X'_{i,t-\ell}\theta + \epsilon_{it}$$

$\Rightarrow$

$$\Delta \log \Delta C_{it} = X'_{i,t-14}\theta + \epsilon_{it} - \gamma + \delta_T \Delta \log(T)_{it}$$

$$\Delta \log \Delta D_{it} = X'_{i,t-21}\theta + \epsilon_{it} - \gamma$$

where

$$X_{i,t-\ell} = P_{it-\ell} \text{ and } B_{it-\ell}$$

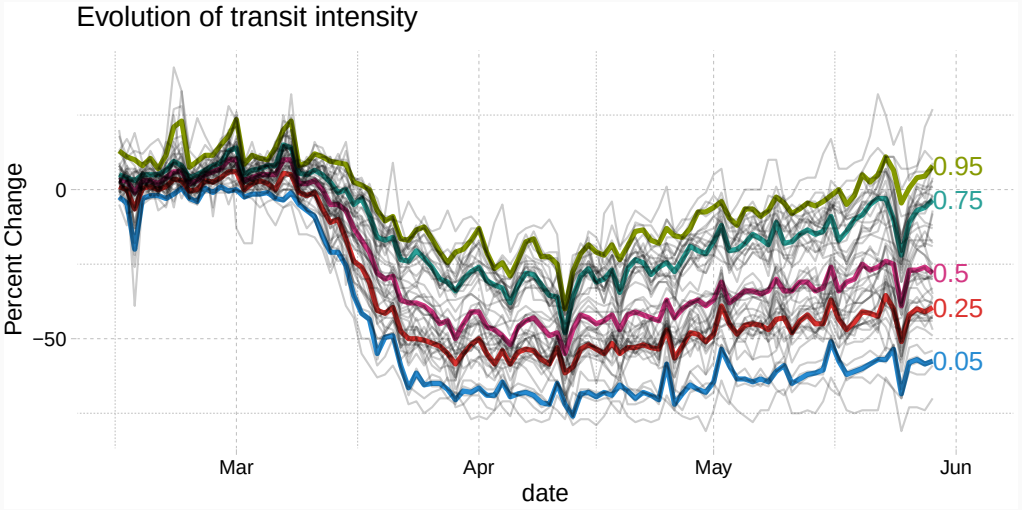
Data

- Data Period: from March 7 to June 3.
- Daily cases and deaths: NYT, JHU, Covid Tracking Project.
- The number of tests: Covid Tracking Project
- US state policies: Raifman et al. (2020).
- Behavior variables: “Transit stations,” “Workplaces,” “Grocery & pharmacy," and “Retail & recreation” from Google Mobility Reports.

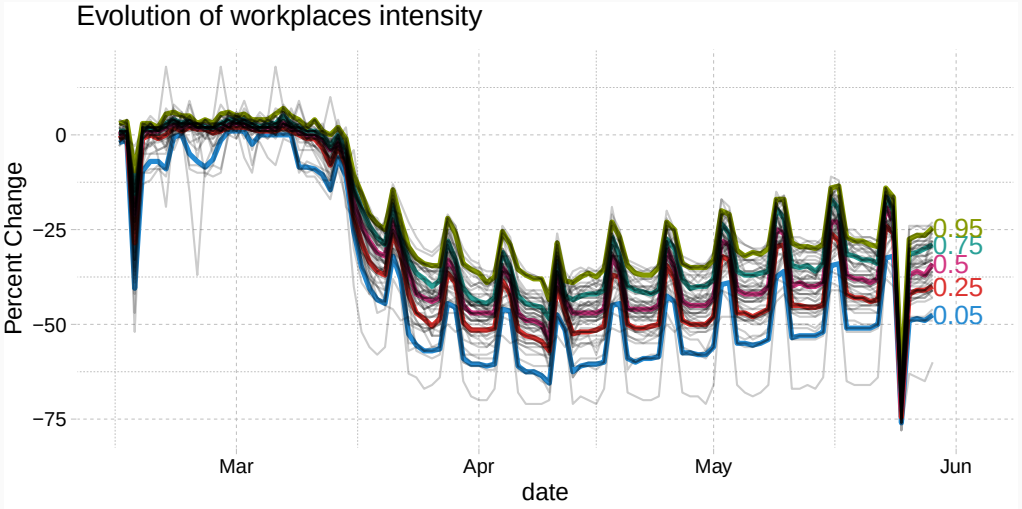
We use 7 days moving averages of all variables

The Evolution of “Transit stations” and “Workplaces”

Transit



Workplaces

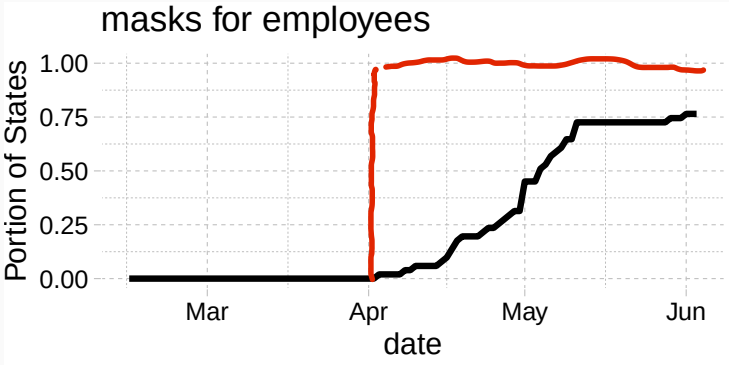


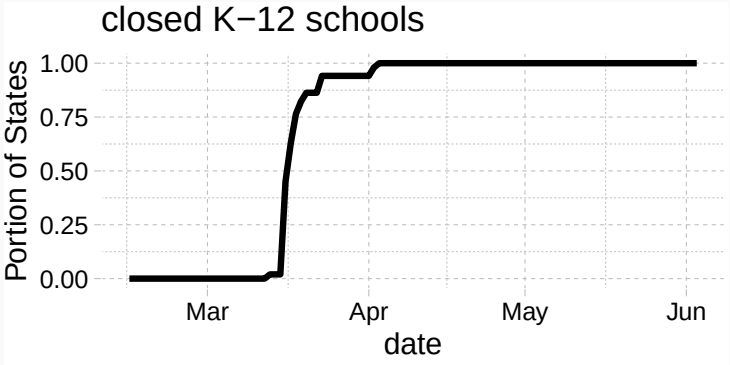
Correlations between policy variables and behavior variables

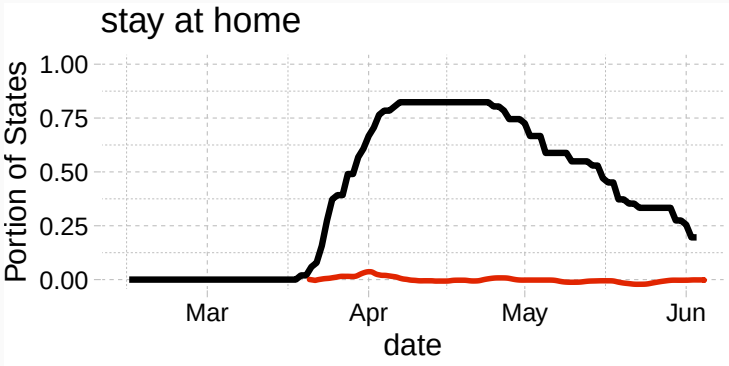
	workplaces	retail	grocery	transit	masks for employees	closed K-12 schools	stay at home	closed movie theaters	closed restaurants	closed businesses
workplaces	1.00									
retail	0.94	1.00								
grocery	0.75	0.82	1.00							
transit	0.90	0.92	0.83	1.00						
masks for employees	-0.32	-0.19	-0.16	-0.30	1.00					
closed K-12 schools	-0.92	-0.81	-0.58	-0.75	0.46	1.00				
stay at home	-0.70	-0.69	-0.71	-0.72	0.31	0.65	1.00			
closed movie theaters	-0.82	-0.77	-0.65	-0.72	0.40	0.85	0.75	1.00		
closed restaurants	-0.79	-0.83	-0.69	-0.77	0.26	0.77	0.74	0.84	1.00	
closed businesses	-0.66	-0.68	-0.68	-0.66	0.12	0.59	0.77	0.69	0.73	1.00

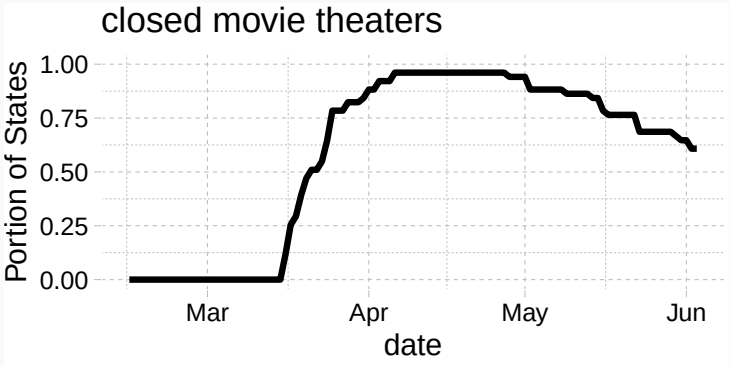
Each off-diagonal entry reports a correlation coefficient of a pair of policy and behavior variables.

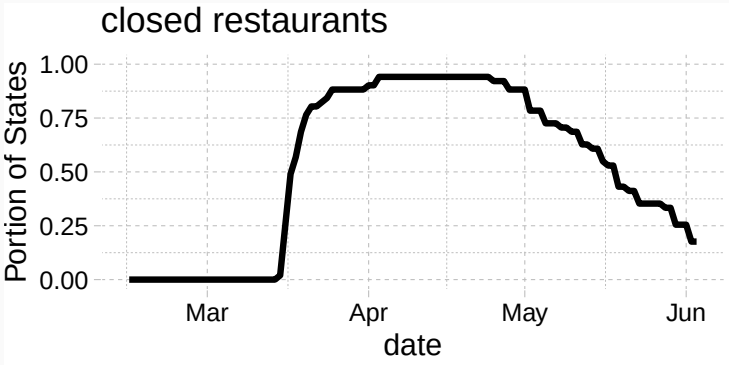
Portion of states with each policy

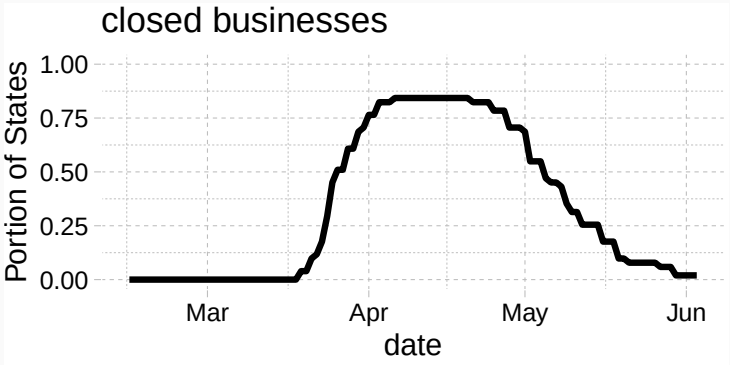




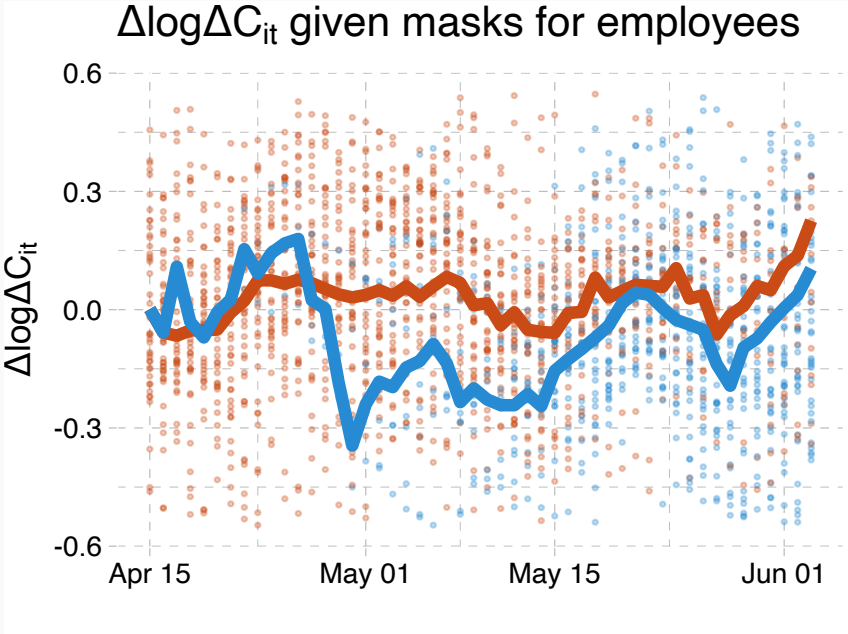




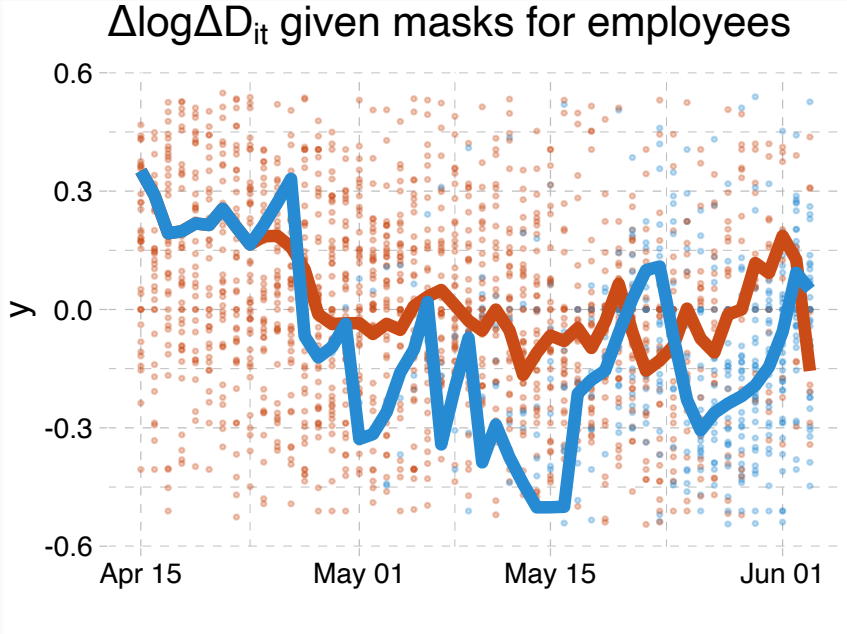




Case and death growth conditional on Mask Mandates

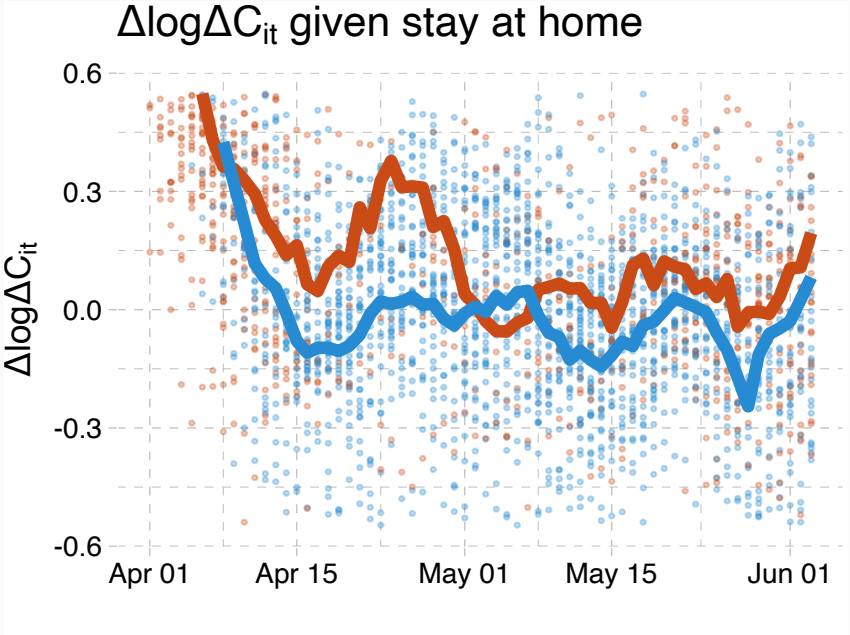


Case Growth

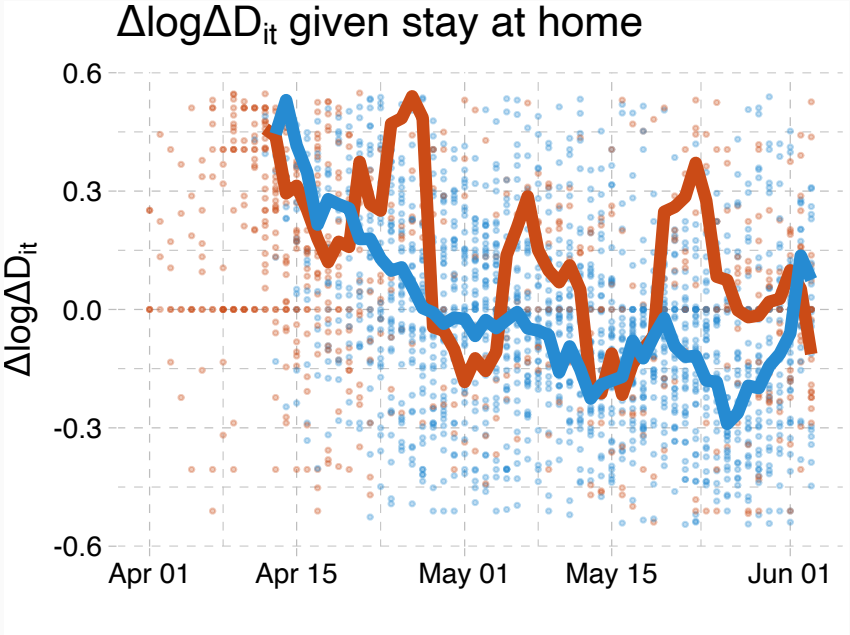


Death Growth

Case and death growth conditional on Stay-at-Home Orders



Case Growth



Death Growth

Regression Analysis

$$Y_{it+\ell} = \alpha' B_{it} + \pi' P_{it} + \mu' I_{it} + \delta_Y' W_{it} + \varepsilon_{it}^{y} \qquad \text{(BPI}\to\text{Y)}$$

$$B_{it}^{j} = \beta' P_{it} + \gamma' I_{it} + \delta_B' W_{it} + \varepsilon_{it}^{b} \qquad \text{(PI}\to\text{B)}$$

$$Y_{it+\ell} = (\pi' + \alpha'\beta')P_{it} + (\mu' + \alpha'\gamma')I_{it} + \bar{\delta}' W_{it} + \bar{\varepsilon}_{it}. \qquad \text{(PI}\to\text{Y)}$$

- $Y_{it+\ell}$: the forward growth rate of cases or deaths
- B_{it}^{j}: “Transit,” “Workplaces” “Grocery," and “Retail”
- P_{it}: various policies lagged by 14 or 21 days
- I_{it}: past cases/deaths, national-level cases/deaths etc.
- W_{it}: state-level characteristics, month dummies, and their interactions.

Direct and Indirect Policy Effects for Case Regression

Case Growth Regression without national case variables

	PI→B Coef. & PBI→Y Coef.			PI→Y Coef.	Average	Difference
	Direct	Indirect	Total	Total	Total	(over-id test)
	π'	$\alpha'\beta'$	$\pi' + \alpha'\beta'$	$\pi' + \alpha'\beta'$	$\pi' + \alpha'\beta'$	
Mask for Employees	-0.084**	-0.008	-0.092**	-0.081**	-0.086**	-0.011
	(0.034)	(0.024)	(0.044)	(0.040)	(0.041)	(0.015)
School Closures	-0.095	-0.337***	-0.432***	-0.240**	-0.336***	-0.192***
	(0.093)	(0.091)	(0.118)	(0.095)	(0.105)	(0.047)
Stay-at-Home	-0.041	-0.065**	-0.106**	-0.126**	-0.116**	0.020
	(0.046)	(0.031)	(0.053)	(0.055)	(0.054)	(0.013)
$\sum_j \text{Policy}_j$	-0.155	-0.550***	-0.704***	-0.508***	-0.606***	-0.196***
	(0.136)	(0.140)	(0.188)	(0.157)	(0.171)	(0.052)

Other policies include closures of movie theaters, restaurants, and non-essential businesses. State characteristics, month dummies, and their interactions are included.

Direct and Indirect Policy Effects for Case Regression

Case Growth Regression with national case variables

	PI→B Coef. & PBI→Y Coef.			PI→Y Coef.	Average	Difference
	Direct	Indirect	Total	Total	Total	(over-id test)
	π'	$\alpha'\beta'$	$\pi' + \alpha'\beta'$	$\pi' + \alpha'\beta'$	$\pi' + \alpha'\beta'$	
Mask for Employees	-0.097***	-0.019	-0.116***	-0.105***	-0.111***	-0.011
	(0.033)	(0.017)	(0.040)	(0.038)	(0.039)	(0.011)
School Closures	0.025	-0.021	0.004	0.009	0.007	-0.005
	(0.103)	(0.040)	(0.110)	(0.108)	(0.109)	(0.015)
Stay-at-Home	-0.064	-0.047**	-0.112**	-0.117**	-0.114**	0.005
	(0.047)	(0.023)	(0.049)	(0.049)	(0.049)	(0.009)
$\sum_j \text{Policy}_j$	-0.078	-0.140**	-0.218	-0.199	-0.209	-0.019
	(0.160)	(0.065)	(0.168)	(0.166)	(0.167)	(0.018)

Other policies include closures of movie theaters, restaurants, and non-essential businesses. State characteristics, month dummies, and their interactions are included.

Direct and Indirect Policy Effects for Death Regression

Death Growth Regression without national death variables

	PI→B Coef. & PBI→Y Coef.			PI→Y Coef.	Average	Difference
	Direct	Indirect	Total	Total	Total	(over-id test)
	π'	$\alpha'\beta'$	$\pi' + \alpha'\beta'$	$\pi' + \alpha'\beta'$	$\pi' + \alpha'\beta'$	
Mask for Employees	-0.145***	-0.004	-0.149***	-0.133***	-0.141***	-0.016
	(0.050)	(0.023)	(0.055)	(0.051)	(0.052)	(0.015)
School Closures	-0.271***	-0.451***	-0.722***	-0.641***	-0.681***	-0.081***
	(0.092)	(0.082)	(0.111)	(0.107)	(0.108)	(0.026)
Stay-at-Home	-0.040	-0.034	-0.074	-0.080	-0.077	0.006
	(0.064)	(0.035)	(0.064)	(0.064)	(0.064)	(0.015)
$\sum_j \text{Policy}_j$	-0.334**	-0.644***	-0.979***	-0.889***	-0.934***	-0.090**
	(0.160)	(0.154)	(0.171)	(0.165)	(0.167)	(0.035)

Other policies include closures of movie theaters, restaurants, and non-essential businesses.

Discussion on Regression Results

- The estimated effect of mandatory mask policy is robust.
- The estimated effect of stay-at-home orders is robust for cases but it is less precisely estimated for deaths.
- The estimated effect of school closures is sensitive to an inclusion of national case variables.

  $\Rightarrow$ little cross-sectional variation in the timing of school closures across states.

The Effect of Policies and Information on Behavior (PI$\rightarrow$ B)

	Dependent variable:			
	Workplaces	Transit	Workplaces	Transit
	(1)	(2)	(3)	(4)
Mask for Employees	−0.011	−3.104	−0.812	−4.044*
	(-0.873)	(-2.213)	(-0.660)	(2.094)
School Closures	−19.678***	−22.694***	−4.908***	−5.147
	(-2.83	(-5.597	(-1.526	(4.868)
Stay-at-Home	−2.943***	−8.577***	−3.222***	−8.881***
	(-1.045)	(-2.366)	(-0.957)	(2.347)
$\Delta \log \Delta C_{it}$	1.791***	1.857***	1.596***	1.591***
	(-0.356)	(-0.553)	(-0.221)	(0.601)
$\log \Delta C_{it}$	−2.107***	−1.092	−0.366	0.997
	(-0.493)	(-1.175)	(-0.340)	(1.285)
$\Delta \log \Delta C_{it}$.national			−2.998***	−3.294***
			(-0.452)	(1.187)
$\log \Delta C_{it}$.national			−6.610***	−7.854***
			(-0.440)	(1.396)
$\sum_j \text{Policy}_j$	-29.699***	-42.515***	-13.972***	-23.772***
	(-3.296)	(-6.813)	(-1.953)	(5.127)

Other policies include closures of movie theaters, restaurants, and non-essential businesses. State characteristics, month dummies, and their interactions are included.

The Direct Effect of Policies, Behavior, and Information on Case Growth (BPI$\rightarrow$Y)

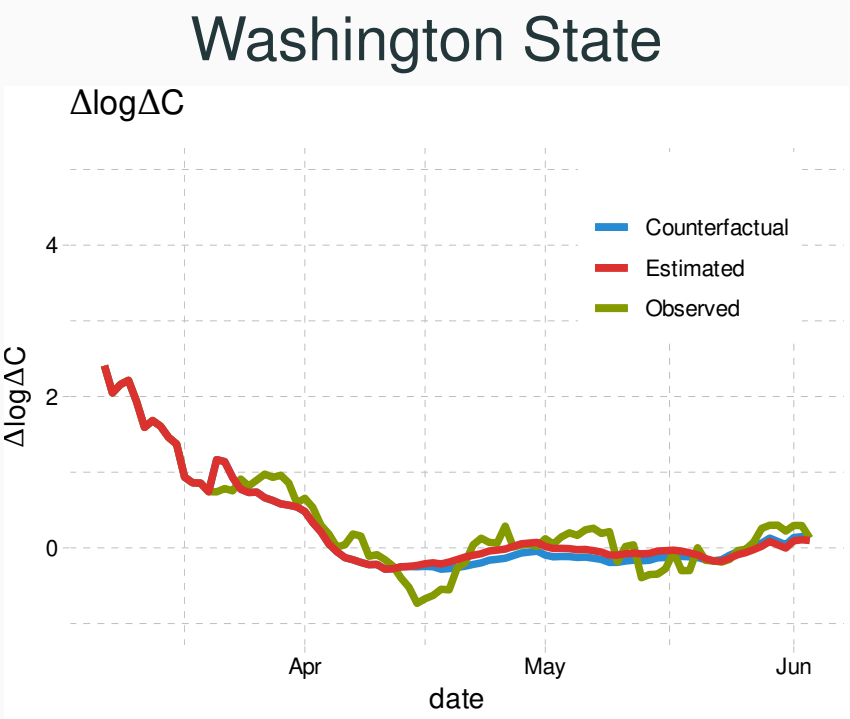
	Dependent variable:			
	$\Delta \log \Delta C_{it}$			
	(1)	(2)	(3)	(4)
lag(masks for employees, 14)	−0.084**		−0.097***	
	(0.035)		(0.032)	
lag(masks*April, 14)		−0.098*		−0.111**
		(0.051)		(0.051)
lag(masks*May, 14)		−0.080**		−0.094***
		(0.038)		(0.034)
lag(closed K-12 schools, 14)	−0.095	−0.096	0.025	0.024
	(0.089)	(0.089)	(0.103)	(0.103)
lag(stay at home, 14)	−0.041	−0.042	−0.064	−0.065
	(0.047)	(0.048)	(0.048)	(0.049)
lag(workplaces, 14)	0.010*	0.010*	0.003	0.003
	(0.006)	(0.006)	(0.006)	(0.006)
lag(retail, 14)	0.005*	0.005*	0.003	0.003
	(0.003)	(0.003)	(0.003)	(0.003)
lag(grocery, 14)	−0.004	−0.004	−0.002	−0.002
	(0.003)	(0.003)	(0.003)	(0.003)
lag(transit, 14)	0.003	0.003	0.003	0.003
	(0.003)	(0.003)	(0.003)	(0.003)
lag($\Delta \log \Delta C_{it}$, 14)	0.017	0.017	0.023	0.023
	(0.025)	(0.025)	(0.028)	(0.028)
lag($\log \Delta C_{it}$, 14)	−0.110***	−0.110***	−0.089***	−0.089***
	(0.019)	(0.019)	(0.021)	(0.021)
lag($\Delta \log \Delta C_{it}$.national, 14)			−0.090**	−0.089**
			(0.044)	(0.044)
lag($\log \Delta C_{it}$.national, 14)			−0.184***	−0.184***
			(0.048)	(0.048)
$\Delta \log T_{it}$	0.153***	0.153***	0.158***	0.158***
	(0.044)	(0.044)	(0.042)	(0.042)
$\sum_j \text{Policy}_j$	-0.155	-0.252	-0.078	-0.189
	(0.136)	(0.156)	(0.160)	(0.178)
$\sum_k w_k \text{Behavior}_k$	-0.756***	-0.753***	-0.372**	-0.368**
	(0.143)	(0.144)	(0.153)	(0.152)

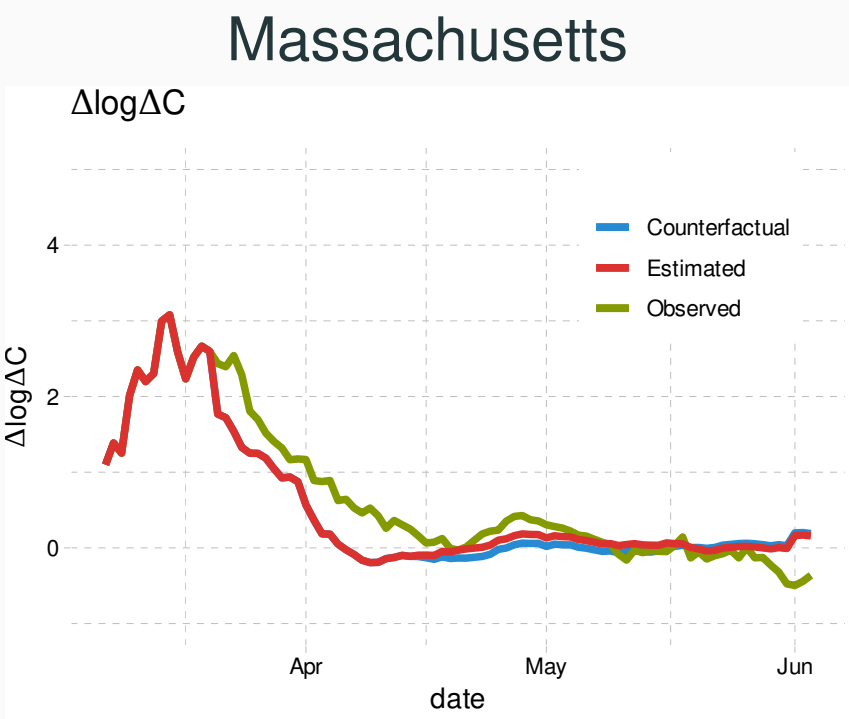
The Total Effect of Policies and Information on Case Growth (PI$\rightarrow$ Y)

	Dependent variable:			
	$\Delta \log \Delta C_{it}$			
	(1)	(2)	(3)	(4)
lag(masks for employees, 14)	-0.081^{**}		-0.105^{***}	
	(0.041)		(0.037)	
lag(masks*April, 14)		-0.157^{**}		-0.146^{**}
		(0.067)		(0.061)
lag(masks*May, 14)		-0.062		-0.094^{***}
		(0.039)		(0.036)
lag(closed K-12 schools, 14)	-0.240^{**}	-0.241^{**}	0.009	0.007
	(0.097)	(0.097)	(0.109)	(0.108)
lag(stay at home, 14)	-0.126^{**}	-0.128^{**}	-0.117^{**}	-0.118^{**}
	(0.055)	(0.055)	(0.052)	(0.052)
lag($\Delta \log \Delta C_{it}$, 14)	0.040^{*}	0.039^{*}	0.033	0.032
	(0.024)	(0.024)	(0.028)	(0.028)
lag($\log \Delta C_{it}$, 14)	-0.138^{***}	-0.138^{***}	-0.091^{***}	-0.091^{***}
	(0.024)	(0.023)	(0.026)	(0.026)
lag($\Delta \log \Delta C_{it}$.national, 14)			-0.123^{***}	-0.121^{***}
			(0.043)	(0.042)
lag($\log \Delta C_{it}$.national, 14)			-0.241^{***}	-0.239^{***}
			(0.044)	(0.044)
$\Delta \log T_{it}$	0.157^{***}	0.158^{***}	0.161^{***}	0.161^{***}
	(0.044)	(0.044)	(0.042)	(0.042)
state variables	Yes	Yes	Yes	Yes
Month $\times$ state variables	Yes	Yes	Yes	Yes
$\sum_j \text{Policy}_j$	-0.508^{***}	-0.644^{***}	-0.199	-0.336^{*}
	(0.162)	(0.198)	(0.164)	(0.187)
Observations	3,823	3,823	3,823	3,823
R^2	0.748	0.749	0.761	0.762
Adjusted R^2	0.746	0.747	0.759	0.759

The Fit of the Estimated and Observed Growth Rate

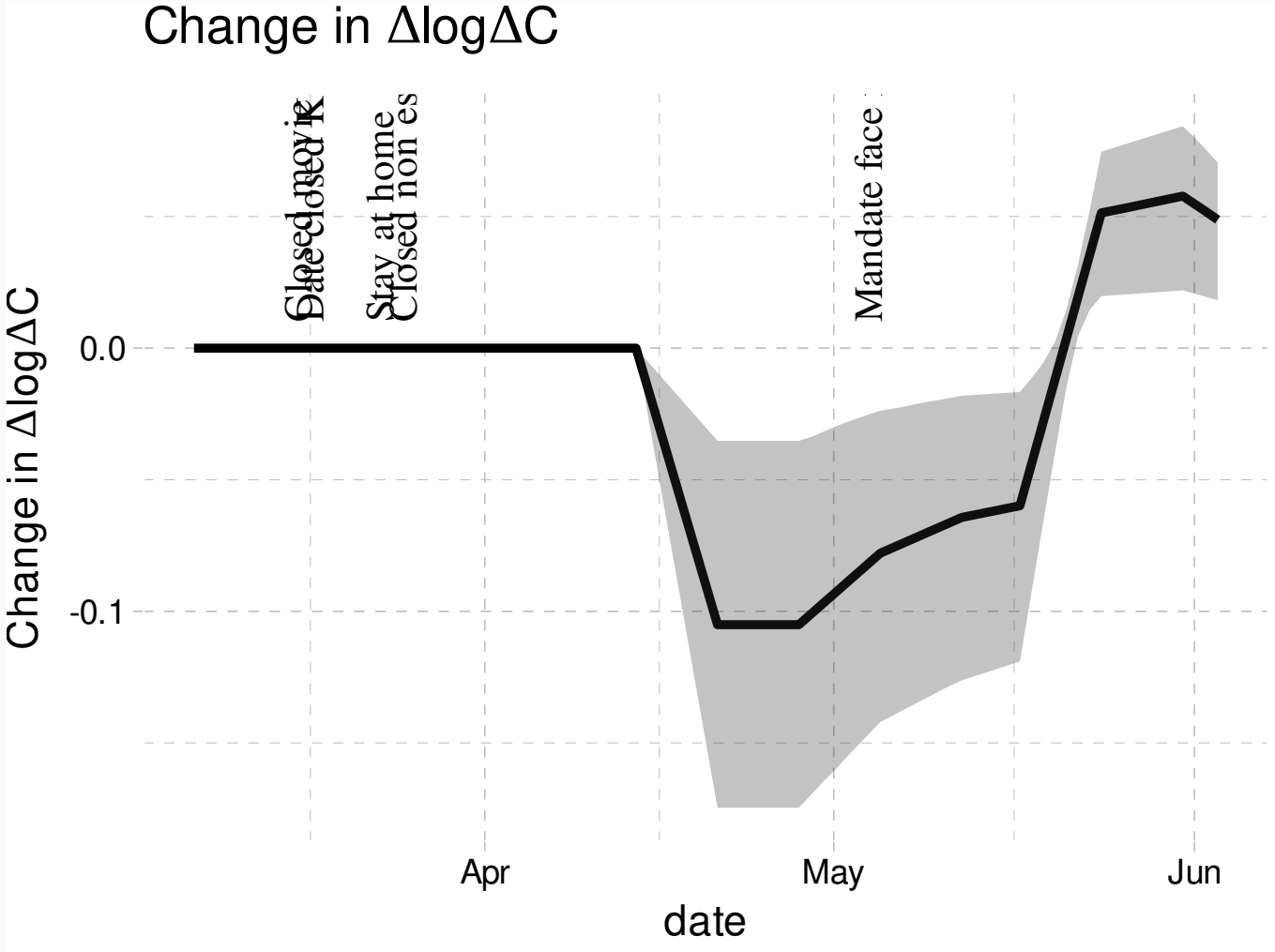
Fit of Case Growth Rates





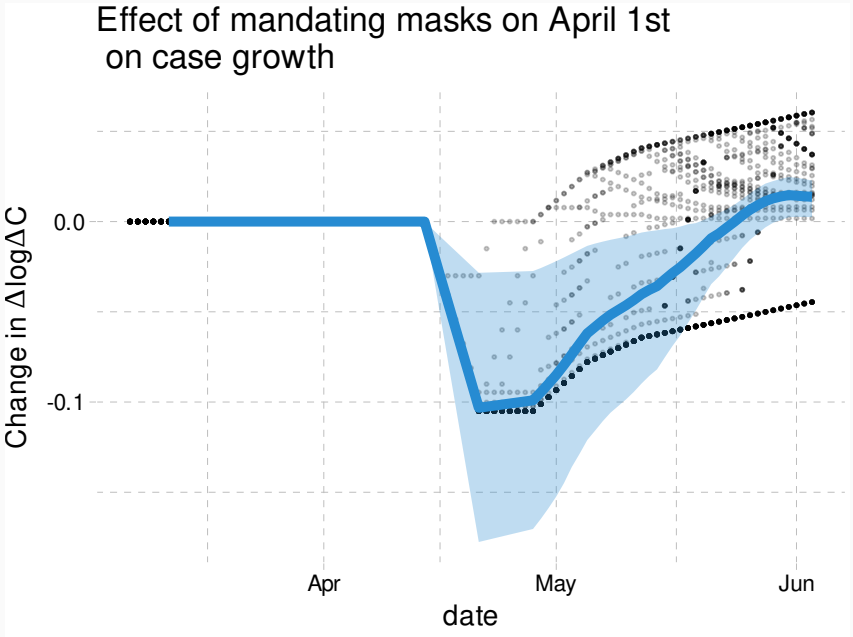
Counterfactual Effect of Mandating Masks on April 1st in Washington State

Change in Case Growth Rates

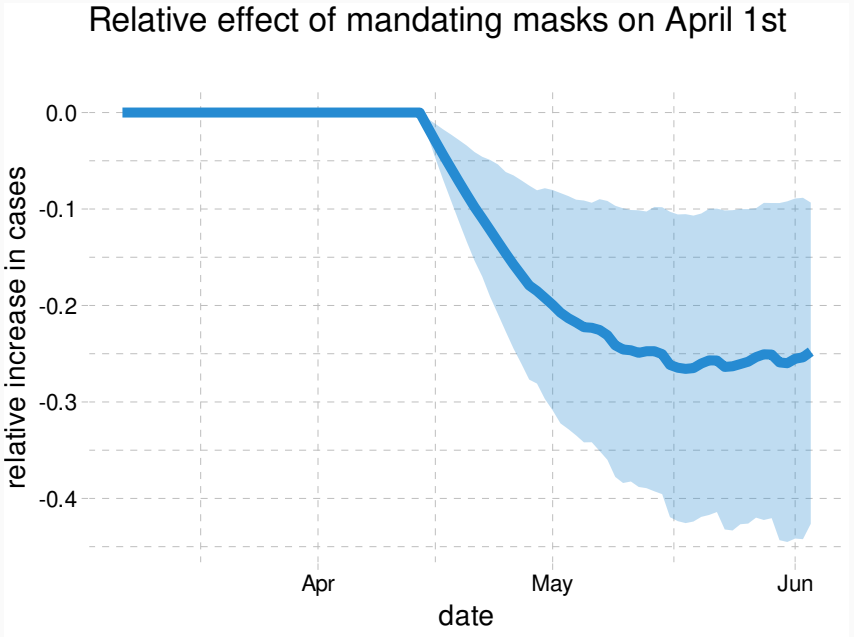


Counterfactual Effect of Nationally Mandating Masks on April 1st in the U.S.

Change in Case Growth

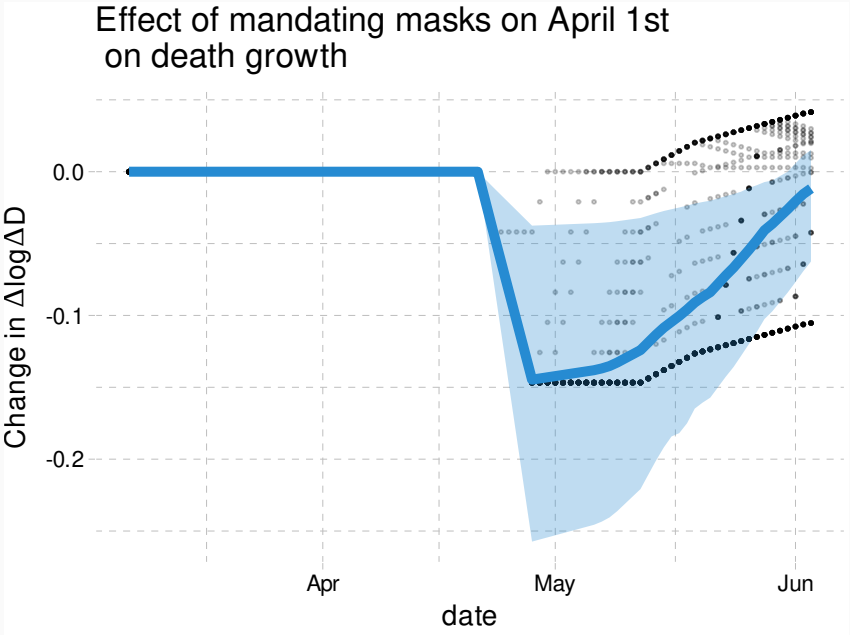


Relative Decrease in Cases

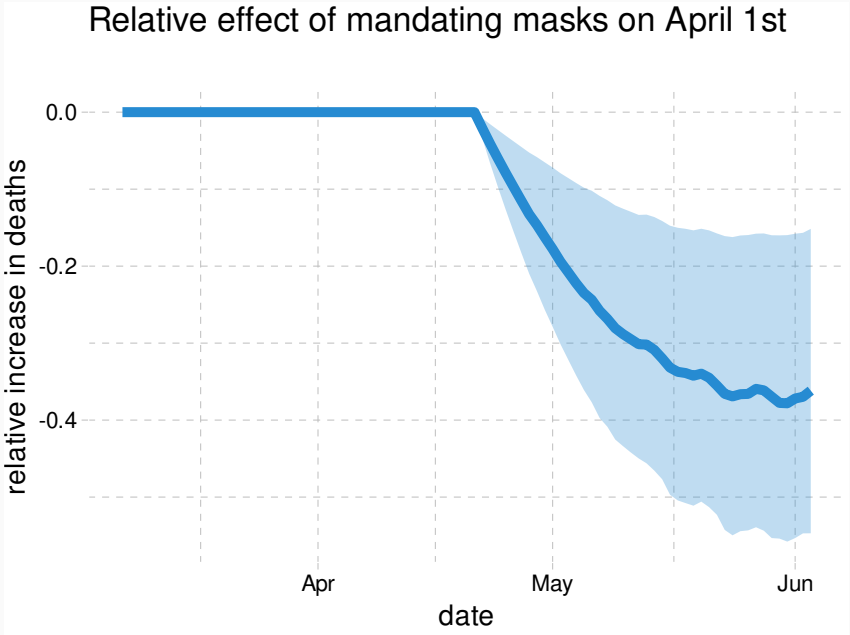


Counterfactual Effect of Nationally Mandating Masks on April 1st in the U.S.

Change in Death Growth



Relative Decrease in Deaths

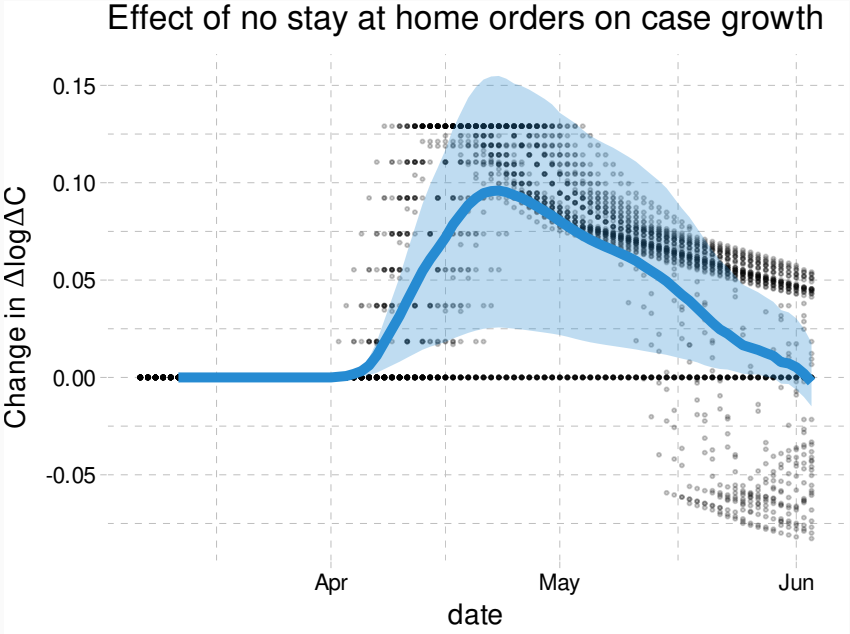


17 to 55 percent less deaths nationally by the end of May

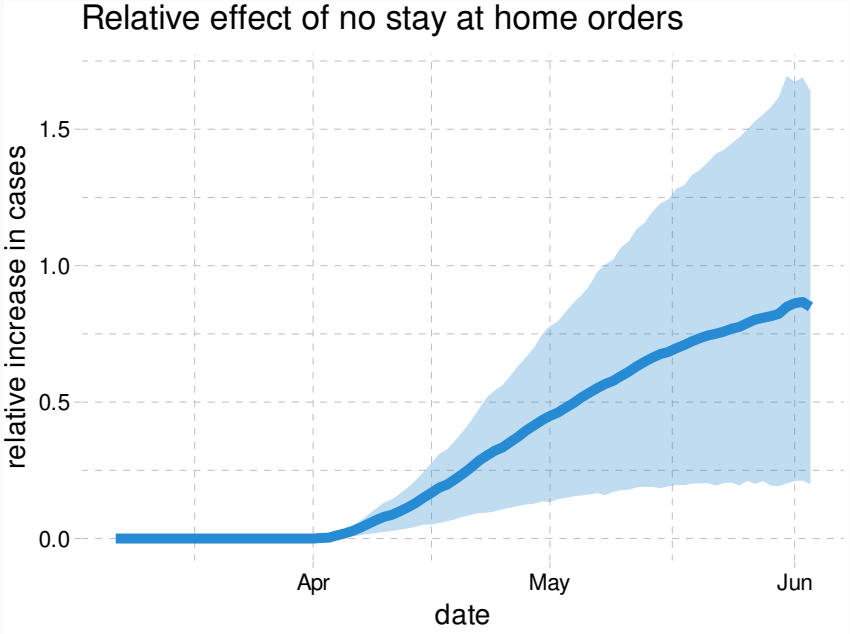
$\Rightarrow$ 17,000 to 55,000 saved lives!!

Counterfactual Effect of No Stay-at-Home Orders in the U.S.

Change in Case Growth



Relative Increase in Cases

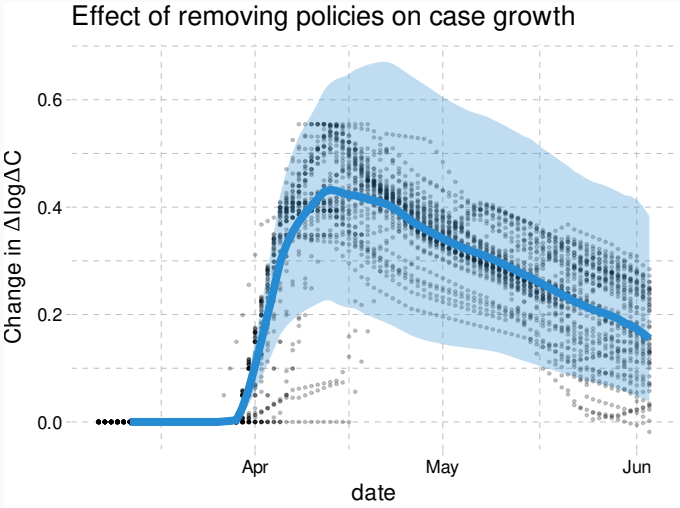


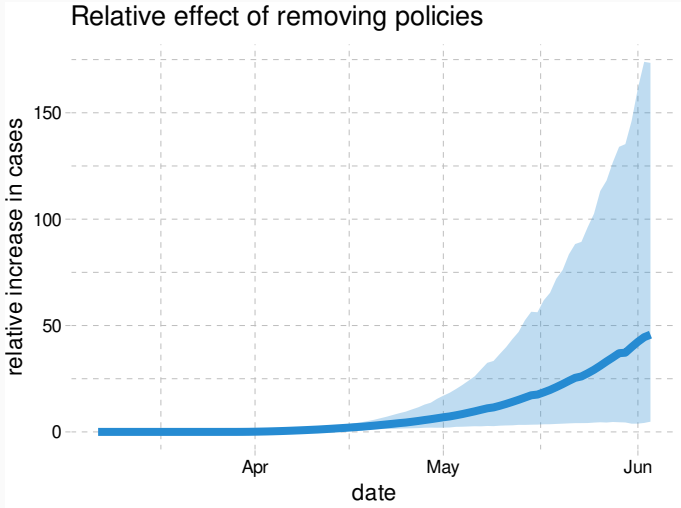
Cases would have been larger by 25 to 170 percent

$\Rightarrow$ 0.5 to 3.4 million more infections

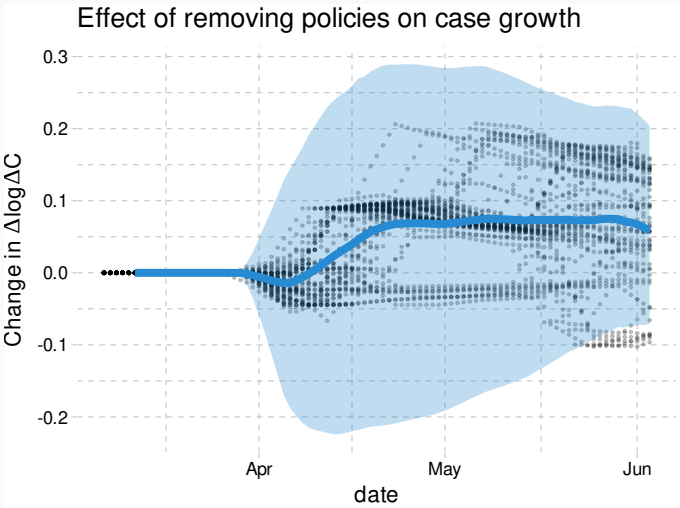
Counterfactual Effect of Removing All Policies

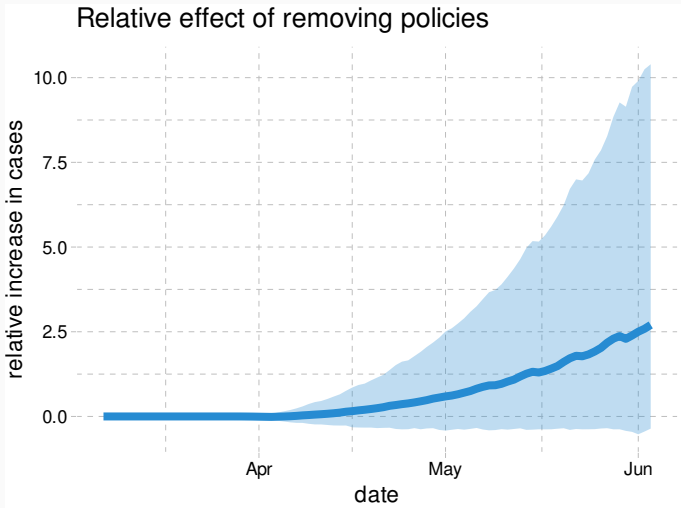
Regression without national case variables



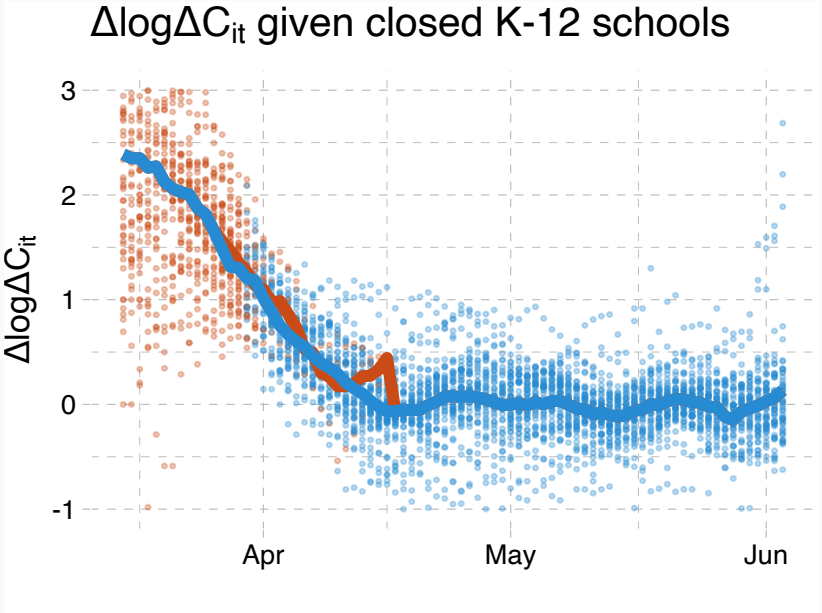


Regression with national case variables

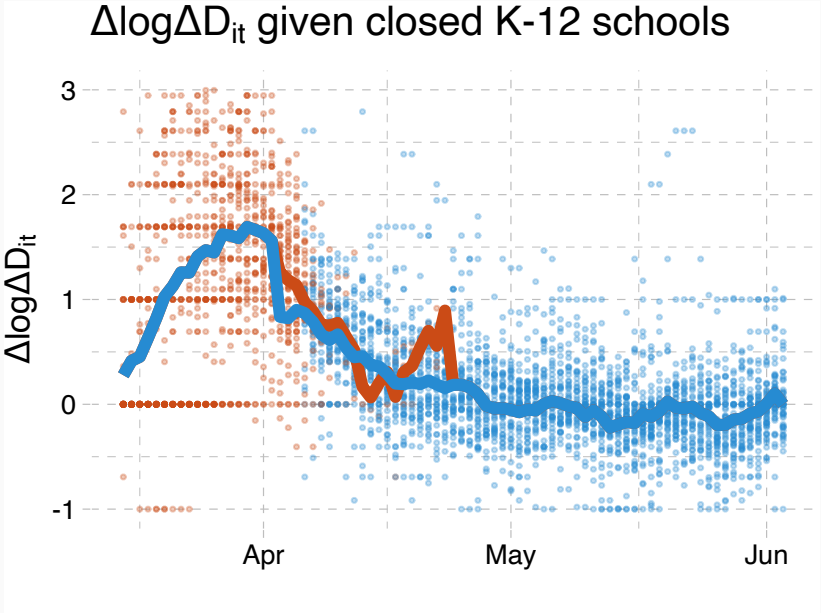




Case and death growth conditional on School Closures



Case Growth



Death Growth

The effect of school closures is not well identified.

Conclusion

- A useful framework to estimate the roles of policies and information on determining the spread of Covid-19.
- If US-wide mask mandates had been adopted on April 1st, as much as 17,000 to 55,000 lives could have been saved by the end of May.
- Not having implemented Stay-at-Home Orders would have lead to 25% to 170% increase in cases.

Conclusion

- Some evidence that people voluntarily reduce their mobility in response to a higher number of cases and deaths.
- There is much ambiguity related to the total effect of policies vs voluntary behavior, which can not be identified well from the US data.
- Closure of schools has potentially large effects via behavior, keeping people at home, but school policy has almost no cross-sectional variation.

Direct and Indirect Policy Effects for Death Regression

Death Growth Regression without national death variables

	PI→B Coef. & PBI→Y Coef.			PI→Y Coef.	Average	Difference
	Direct	Indirect	Total	Total	Total	(over-id test)
	π'	$\alpha'\beta'$	$\pi' + \alpha'\beta'$	$\pi' + \alpha'\beta'$	$\pi' + \alpha'\beta'$	
Mask for Employees	-0.145***	-0.004	-0.149***	-0.133***	-0.141***	-0.016
	(0.050)	(0.023)	(0.055)	(0.051)	(0.052)	(0.015)
School Closures	-0.271***	-0.451***	-0.722***	-0.641***	-0.681***	-0.081***
	(0.092)	(0.082)	(0.111)	(0.107)	(0.108)	(0.026)
Stay-at-Home	-0.040	-0.034	-0.074	-0.080	-0.077	0.006
	(0.064)	(0.035)	(0.064)	(0.064)	(0.064)	(0.015)
$\sum_j \text{Policy}_j$	-0.334**	-0.644***	-0.979***	-0.889***	-0.934***	-0.090**
	(0.160)	(0.154)	(0.171)	(0.165)	(0.167)	(0.035)

Other policies include closures of movie theaters, restaurants, and non-essential businesses.

Direct and Indirect Policy Effects for Death Regression

Death Growth Regression with national death variables

	PI→B Coef. & PBI→Y Coef.			PI→Y Coef.	Average	Difference
	Direct	Indirect	Total	Total	Total	(over-id test)
	π'	$\alpha'\beta'$	$\pi' + \alpha'\beta'$	$\pi' + \alpha'\beta'$		
Masks for Employees	-0.148***	-0.018	-0.166***	-0.161***	-0.164***	-0.005
	(0.048)	(0.023)	(0.053)	(0.050)	(0.051)	(0.016)
School Closures	-0.199**	-0.038	-0.238**	-0.250**	-0.244**	0.012
	(0.091)	(0.038)	(0.100)	(0.099)	(0.099)	(0.020)
Stay-at-Home	-0.047	-0.030	-0.077	-0.075	-0.076	-0.002
	(0.065)	(0.032)	(0.063)	(0.063)	(0.063)	(0.014)
$\sum_j \text{Policy}_j$	-0.262	-0.135	-0.397**	-0.402**	-0.399**	0.005
	(0.167)	(0.085)	(0.179)	(0.174)	(0.176)	(0.024)
	(0.038)	(0.029)	(0.032)	(0.029)	(0.030)	(0.012)

Other policies include closures of movie theaters, restaurants, and non-essential businesses.

Counterfactual Experiments

- Set initial $\Delta \log \Delta D$ and $\log \Delta D$ to their first observed values.
- Other regressors at their observed values.
- Error terms are drawn with replacement from the residuals.
- Do this many times and report the average over draws of the residuals to obtain counterfactual results.
- To obtain a point-wise 90% confidence interval, we repeat the above with coefficients drawn randomly from their asymptotic distribution.

The Effect of Policies and Information on Behavior (PI→ B)

Cases as Information

	Dependent variable:							
	Workplaces	Retail	Grocery	Transit	Workplaces	Retail	Grocery	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	
masks for employees	−0.011	−1.207	−2.178**	−3.104	−0.812	−2.422*	−2.422***	−
	(0.873)	(1.513)	(0.952)	(2.213)	(0.660)	(1.347)	(0.902)	
closed K-12 schools	−19.678***	−21.898***	−13.021***	−22.694***	−4.908***	−1.873	−7.923***	
	(2.830)	(4.409)	(2.536)	(5.597)	(1.526)	(1.979)	(2.944)	
stay at home	−2.943***	−5.625***	−5.598***	−8.577***	−3.222***	−6.306***	−5.620***	−8
	(1.045)	(1.346)	(1.361)	(2.366)	(0.957)	(1.154)	(1.356)	
closed movie theaters	−1.975*	−3.444**	−2.897**	1.129	−1.464*	−3.061**	−2.643**	
	(1.103)	(1.607)	(1.200)	(2.359)	(0.820)	(1.310)	(1.150)	
closed restaurants	−3.151***	−7.682***	−1.431*	−7.969***	−1.435**	−5.095***	−0.903	−
	(1.012)	(1.500)	(0.756)	(2.557)	(0.698)	(1.002)	(0.623)	
closed businesses	−1.942*	−1.742	−2.390**	−1.300	−2.131**	−2.147*	−2.418**	
	(1.116)	(1.362)	(1.044)	(2.039)	(0.908)	(1.125)	(0.981)	
$\Delta \log \Delta C_{it}$	1.791***	1.046**	1.870***	1.857***	1.596***	1.155***	1.710***	1.
	(0.356)	(0.532)	(0.376)	(0.553)	(0.221)	(0.378)	(0.403)	
$\log \Delta C_{it}$	−2.107***	−1.934**	0.225	−1.092	−0.366	0.210	0.880	
	(0.493)	(0.900)	(0.481)	(1.175)	(0.340)	(0.784)	(0.542)	
$\Delta \log \Delta C_{it}$.national					−2.998***	−6.952***	−0.319	−3
					(0.452)	(0.759)	(0.680)	
$\log \Delta C_{it}$.national					−6.610***	−8.957***	−2.283***	−7
					(0.440)	(0.853)	(0.826)	
state variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	
Month × state variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	
$\sum_j \text{Policy}_j$	-29.699***	-41.597***	-27.515***	-42.515***	-13.972***	-20.904***	-21.931***	-23
	(3.296)	(5.343)	(3.246)	(6.813)	(1.953)	(2.859)	(3.325)	
Observations	4,284	4,284	4,284	4,284	4,284	4,284	4,284	
R^2	0.912	0.854	0.788	0.812	0.945	0.902	0.794	
Adjusted R^2	0.912	0.853	0.786	0.810	0.945	0.901	0.793	

The Effect of Policies and Information on Behavior (PI→ B)

Deaths as Information

	Dependent variable:							
	Workplaces	Retail	Grocery	Transit	Workplaces	Retail	Grocery	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	
masks for employees	−0.477	−2.217	−2.720**	−3.914*	−1.335**	−3.487**	−3.156***	−
	(0.753)	(1.415)	(1.059)	(2.320)	(0.642)	(1.389)	(0.989)	
closed K-12 schools	−24.156***	−26.171***	−12.250***	−24.946***	−5.355***	−1.900	−3.859	
	(2.253)	(3.220)	(1.771)	(3.818)	(1.703)	(1.934)	(2.378)	
stay at home	−2.579***	−5.589***	−6.090***	−8.761***	−2.799***	−5.998***	−6.229***	−9
	(0.985)	(1.347)	(1.523)	(2.513)	(0.959)	(1.188)	(1.518)	
closed movie theaters	−2.298**	−4.148**	−3.102**	0.658	−1.032	−2.661*	−2.585**	
	(1.140)	(1.693)	(1.229)	(2.364)	(0.820)	(1.379)	(1.144)	
closed restaurants	−3.479***	−7.579***	−1.317*	−7.934***	−1.507**	−4.919***	−0.400	−
	(1.104)	(1.559)	(0.752)	(2.583)	(0.707)	(1.016)	(0.660)	
closed businesses	−2.106**	−2.351*	−2.516**	−1.656	−1.072	−0.977	−2.042*	
	(1.055)	(1.343)	(1.126)	(2.077)	(0.896)	(1.160)	(1.050)	
$\Delta \log \Delta D_{it}$	−0.922**	−2.050***	−0.469	−1.263**	0.115	−0.278	0.136	
	(0.407)	(0.595)	(0.418)	(0.619)	(0.237)	(0.438)	(0.422)	
$\log \Delta D_{it}$	−1.077***	−0.185	0.057	−0.262	−0.644	0.155	0.179	
	(0.389)	(0.741)	(0.565)	(1.195)	(0.409)	(0.790)	(0.609)	
$\Delta \log \Delta D_{it}$.national					−4.066***	−6.883***	−2.351***	−4
					(0.353)	(0.619)	(0.449)	
$\log \Delta D_{it}$.national					−6.322***	−7.884***	−2.731***	−6
					(0.420)	(0.594)	(0.561)	
state variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	
Month × state variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	
$\sum_j \text{Policy}_j$	-35.094***	-48.055***	-27.995***	-46.554***	-13.100***	-19.941***	-18.270***	-23
	(2.253)	(3.604)	(2.982)	(5.781)	(2.119)	(3.144)	(3.258)	
Observations	4,284	4,284	4,284	4,284	4,284	4,284	4,284	
R^2	0.902	0.850	0.778	0.810	0.943	0.905	0.792	
Adjusted R^2	0.902	0.849	0.776	0.809	0.943	0.904	0.791	

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