CAUSAL IMPACT OF MASKS, POLICIES, BEHAVIOR ON EARLY COVID-19 PANDEMIC IN THE U.S.

VICTOR CHERNOZHUKOV, HIROYUKI KASAHARA, AND PAUL SCHRIMPF

Abstract.

1. Robustness

In this section, we examine the robustness of our results by including additional controls and examining the sub-sample that excludes the state of New York.

Table 1 presents the regression result for robustness check, where dependent variable is the weekly growth rate of cases (left panel) or deaths (right panel). Column (1) replaces four policy variables (stay-at-home, closure of movie theaters, closure of restaurants, and closure of non-essential businesses) that are highly correlated to each other with the variable of their average values. Column (2) excludes the state of New York, which could be viewed as an outlier in the early pandemic period, from the sample. Column (3) adds the percentage of people who wears masks to protect themselves between March 26-April 29, 2020, which controls for people's attitude toward mask wearing in the first half of sample.[1] Column (5) controls for the log of Trump voting shares in 2016 presidential election. Column (6) includes four weeks lagged behavior variables as an additional set of controls; under this specification, our causal interpretation is valid when policy variables are sufficiently random conditional on past behavior variables. Finally, column (6) includes all additional controls in column (3)-(5) using the sample that excludes New York. The estimated coefficients of mask mandates on case or death growths are significantly negative in all specifications, confirming the importance of mask policy on reducing case and death growths. [**here, instead of table, we may present "dot-and-whisker plot" for mask coefficients as well as stay-at-home and pindex.**]

Date: August 1, 2020; *First public* version posted to ArXiv: May 28, 2020.

Key words and phrases. Covid-19, causal impact, masks, non-essential business, policies, behavior.

We are grateful to Daron Acemoglu, V.V. Chari, Raj Chetty, Christian Hansen, Glenn Ellison, Ivan Fernandez-Val, David Green, Ido Rosen, Konstantin Sonin, James Stock, and Ivan Werning for helpful comments. We also thank Chiyoung Ahn, Joshua Catalano, Jason Chau, Samuel Gyetvay, Sev Chenyu Hou, Jordan Hutchings, and Dongxiao Zhang for excellent research assistance. All mistakes are our own.

[1]The survey is conducted online by YouGov and is based on the interviews of 89,347 US adults aged 18 and over between March 26-April 29, 2020. The survey question is "Which, if any, of the following measures have you taken in the past 2 weeks to protect yourself from the Coronavirus (COVID-19)?".

In Table 2 of the appendix, we find that the estimated coefficients of mask mandates are significantly negative even when we include state fixed effects. In contrast, the estimated coefficients of stay-at-home order and closures of movie theaters, restaurants, and non-essential businesses under fixed effects specification are sometimes different from those under random effects specification, especially when bias correction is applied to the fixed effects estimator. Non-robustness of the estimated coefficients of these four policy variables is likely due to high correlations among them (see Table **??**). In fact, as shown in columns (3)-(4) of Table 2, the estimated effects of the average of four policy variables under fixed effects specification are negative and significant, indicating that the total effect of four policies is robustly estimated.

1.1. **Fixed Effects Regressions (in Appendix).** Table 2 in the appendix reports the regression result when we include state fixed effects and month dummies. Column (1) reports our baseline estimation when we include state fixed effects while column (2) report the estimate when we apply the bias correction to the fixed effects estimator. Columns (3) and (4) are similar to columns (1) and (2) except that we replace four policy variables (stay-at-home, closure of movie theaters, closure of restaurants, and closure of non-essential businesses) with their average values. Again, the estimated coefficients of mask mandates are significantly negative across different specifications, confirming the importance of mask policy on reducing case and death growths. On the other hand, the estimated coefficients of stay-at-home order as well as closures of movie theaters, restaurants, and non-essential businesses under fixed effects specification are substantially different from the estimates under random effects specification. This is likely due to muti-colinearity problem as implied by high correlations among these four policy variables as shown in Table **??**. When we replace these four policy variables with their average variable in columns (3) and (4), the estimated effect of the sum of four policy variables under fixed effects specification is similar to that under random effects specification in column (1) of Table 1.

TABLE 1. Robustness Check for the Total Effect of Policies on Case and Death Growth ($PI \rightarrow Y$)

	Dependent variable: $\Delta \log \Delta C_{it}$					
	(1)	(2)	(3)	(4)	(5)	(6)
lag(masks for employees, 14)	-0.107^{**}	-0.096^{**}	-0.074^{**}	-0.077^{**}	-0.093^{**}	-0.066^{*}
	(0.043)	(0.044)	(0.036)	(0.034)	(0.040)	(0.038)
lag(closed K-12 schools, 14)	-0.240^{***}	-0.269^{***}	-0.260^{***}	-0.273^{***}	-0.247^{***}	-0.263^{***}
	(0.081)	(0.100)	(0.093)	(0.090)	(0.087)	(0.080)
lag(ave of four policy vars, 14)	-0.205^{**}					
	(0.091)					
lag(closed movie theaters, 14)		0.062	0.055	0.052	0.029	0.019
		(0.051)	(0.055)	(0.051)	(0.055)	(0.055)
lag(stay at home, 14)		-0.145^{**}	-0.139^{**}	-0.099^{*}	-0.129^{**}	-0.111^{**}
		(0.059)	(0.056)	(0.054)	(0.051)	(0.053)
lag(closed restaurants, 14)		-0.051	-0.047	-0.017	-0.041	-0.012
		(0.049)	(0.047)	(0.049)	(0.043)	(0.046)
lag(closed businesses, 14)		-0.049	-0.050	-0.056	-0.064	-0.070
		(0.050)	(0.047)	(0.047)	(0.048)	(0.046)
lag(workplaces, 28)					-0.278	-0.028
					(0.506)	(0.437)
lag(retail, 28)					-0.479	-0.448
					(0.385)	(0.375)
lag(grocery, 28)					-0.303	-0.455^{*}
					(0.273)	(0.266)
lag(transit, 28)					0.787^{**}	0.567^{*}
					(0.369)	(0.328)
lag($\Delta \log \Delta C_{it}$, 14)	0.039	0.031	0.035	0.039	0.048^{*}	0.043^{*}
	(0.024)	(0.024)	(0.025)	(0.025)	(0.027)	(0.025)
lag($\log \Delta C_{it}$, 14)	-0.144^{***}	-0.147^{***}	-0.145^{***}	-0.154^{***}	-0.153^{***}	-0.162^{***}
	(0.025)	(0.028)	(0.023)	(0.021)	(0.022)	(0.020)
$\Delta \log T_{it}$	0.134^{***}	0.124^{***}	0.140^{***}	0.135^{***}	0.124^{***}	0.103^{**}
	(0.044)	(0.041)	(0.044)	(0.044)	(0.045)	(0.042)
mask_percent			-0.767			-0.491
			(0.611)			(0.549)
log(Trump voting shares)				0.364^{**}		0.332^{***}
				(0.154)		(0.121)
state variables	Yes	Yes	Yes	Yes	Yes	Yes
Month × state variables	Yes	Yes	Yes	Yes	Yes	Yes
$\sum_j$ Policy$_j$	-0.552^{***}	-0.549^{***}	-0.516^{***}	-0.470^{***}	-0.545^{***}	-0.502^{***}
	(0.160)	(0.169)	(0.146)	(0.130)	(0.141)	(0.128)
Observations	3,624	3,550	3,624	3,624	3,624	3,550
R^2	0.753	0.752	0.757	0.760	0.759	0.762
Adjusted R^2	0.750	0.749	0.755	0.757	0.756	0.759

Note: *p<0.1; **p<0.05; ***p<0.01

	Dependent variable: $\Delta \log \Delta D_{it}$					
	(1)	(2)	(3)	(4)	(5)	(6)
lag(masks for employees, 21)	-0.184^{***}	-0.182^{***}	-0.162^{***}	-0.163^{***}	-0.158^{***}	-0.136^{**}
	(0.054)	(0.060)	(0.059)	(0.057)	(0.055)	(0.060)
lag(closed K-12 schools, 21)	-0.592^{***}	-0.621^{***}	-0.616^{***}	-0.635^{***}	-0.600^{***}	-0.612^{***}
	(0.117)	(0.124)	(0.118)	(0.115)	(0.125)	(0.121)
lag(ave of four policy vars, 21)	-0.136^{*}					
	(0.082)					
lag(closed movie theaters, 21)		0.045	0.042	0.029	0.016	0.006
		(0.097)	(0.101)	(0.095)	(0.094)	(0.094)
lag(stay at home, 21)		-0.104	-0.101	-0.064	-0.071	-0.058
		(0.069)	(0.068)	(0.068)	(0.062)	(0.065)
lag(closed restaurants, 21)		-0.032	-0.032	-0.0003	-0.023	0.001
		(0.058)	(0.062)	(0.060)	(0.056)	(0.056)
lag(closed businesses, 21)		-0.038	-0.038	-0.039	-0.053	-0.057
		(0.063)	(0.063)	(0.059)	(0.064)	(0.062)
lag(workplaces, 35)					1.235^{**}	1.473^{***}
					(0.610)	(0.555)
lag(retail, 35)					-1.112^{***}	-1.078^{***}
					(0.413)	(0.391)
lag(grocery, 35)					0.223	0.055
					(0.453)	(0.402)
lag(transit, 35)					0.234	-0.029
					(0.274)	(0.278)
lag($\Delta \log \Delta D_{it}$, 21)	-0.005	-0.013	-0.010	-0.009	-0.023	-0.023
	(0.033)	(0.036)	(0.034)	(0.033)	(0.042)	(0.044)
lag($\log \Delta D_{it}$, 21)	-0.086^{***}	-0.079^{***}	-0.083^{***}	-0.088^{***}	-0.075^{***}	-0.072^{***}
	(0.026)	(0.028)	(0.025)	(0.023)	(0.027)	(0.026)
mask_percent			-0.653			-0.436
			(0.438)			(0.427)
log(Trump voting shares)				0.328^{*}		0.257
				(0.175)		(0.195)
state variables	Yes	Yes	Yes	Yes	Yes	Yes
Month × state variables	Yes	Yes	Yes	Yes	Yes	Yes
$\sum_j$ Policy$_j$	-0.911^{***}	-0.932^{***}	-0.907^{***}	-0.873^{***}	-0.889^{***}	-0.856^{***}
	(0.160)	(0.170)	(0.151)	(0.152)	(0.168)	(0.165)
Observations	3,283	3,216	3,283	3,283	3,283	3,216
R^2	0.500	0.491	0.503	0.504	0.505	0.498
Adjusted R^2	0.495	0.485	0.497	0.499	0.499	0.492

Note: *p<0.1; **p<0.05; ***p<0.01

Dependent variable is the weekly growth rate of confirmed cases (in the left panel) or deaths (in the right panel) as defined in equation (??). Columns (2) and (6) exclude the observations of the state of New York. The covariates include lagged policy variables, which are constructed as 7 day moving averages between t to $t-7$ of corresponding daily measures. The row "$\sum_j$ Policies$_j$" reports the sum of six policy coefficients. Standard errors are clustered at the state level.

Table 2. Fixed Effects Specification for the Total Effect of Policies on Case and Death Growth ($PI \to Y$)

	Dependent variable:			
	$\Delta \log \Delta C_{it}$			
	(1)	(2)	(3)	(4)
lag(masks for employees, 14)	-0.114^{***}	-0.235^{***}	-0.122^{***}	-0.206^{***}
	(0.042)	(0.042)	(0.041)	(0.041)
lag(closed K-12 schools, 14)	-0.046	0.027	-0.011	0.076
	(0.079)	(0.079)	(0.069)	(0.069)
lag(closed movie theaters, 14)	0.071	0.152		
	(0.060)	(0.060)		
lag(stay at home, 14)	-0.081	0.051		
	(0.057)	(0.057)		
lag(closed restaurants, 14)	-0.048	-0.121		
	(0.053)	(0.053)		
lag(closed businesses, 14)	-0.074	-0.167		
	(0.047)	(0.047)		
lag(ave of four policy vars, 14)			-0.181^{**}	-0.167^{**}
			(0.082)	(0.082)
lag($\Delta \log \Delta C_{it}$, 14)	0.028	-0.003	0.026	-0.007
	(0.027)	(0.027)	(0.026)	(0.026)
lag($\log \Delta C_{it}$, 14)	-0.222^{***}	-0.178^{***}	-0.220^{***}	-0.176^{***}
	(0.018)	(0.018)	(0.017)	(0.017)
$\Delta \log T_{it}$	0.113^{***}	0.173^{***}	0.110^{***}	0.168^{***}
	(0.039)	(0.039)	(0.039)	(0.039)
Observations	3,624	3,624	3,624	3,624
R^2	0.780	0.780	0.779	0.779
Adjusted R^2	0.776	0.776	0.776	0.776
Note:				*p<0.1; **p<0.05; ***p<0.01

	Dependent variable:			
	$\Delta \log \Delta D_{it}$			
	(1)	(2)	(3)	(4)
lag(masks for employees, 21)	-0.187^{***}	-0.113^{***}	-0.187^{***}	-0.148^{***}
	(0.045)	(0.045)	(0.045)	(0.045)
lag(closed K-12 schools, 21)	-0.506^{***}	-0.144^{***}	-0.488^{***}	-0.236^{***}
	(0.142)	(0.142)	(0.122)	(0.122)
lag(closed movie theaters, 21)	0.046	-0.158		
	(0.120)	(0.120)		
lag(stay at home, 21)	-0.022	-0.161		
	(0.078)	(0.078)		
lag(closed restaurants, 21)	-0.068	-0.065		
	(0.107)	(0.107)		
lag(closed businesses, 21)	-0.108	0.149		
	(0.074)	(0.074)		
lag(ave of four policy vars, 21)			-0.175^{*}	-0.109^{*}
			(0.090)	(0.090)
lag($\Delta \log \Delta D_{it}$, 21)	-0.018	0.033	-0.019	0.035
	(0.029)	(0.029)	(0.028)	(0.028)
lag($\log \Delta D_{it}$, 21)	-0.105^{***}	-0.230^{***}	-0.105^{***}	-0.233^{***}
	(0.022)	(0.022)	(0.022)	(0.022)
Observations	3,283	3,283	3,283	3,283
R^2	0.518	0.518	0.518	0.518
Adjusted R^2	0.509	0.509	0.509	0.509
Note:				*p<0.1; **p<0.05; ***p<0.01

Dependent variable is the weekly growth rate of confirmed cases (in the left panel) or deaths (in the right panel) as defined in equation (**??**). The covariates include lagged policy variables, which are constructed as 7 day moving averages between t to $t-7$ of corresponding daily measures. The row "$\sum_j$ Policies$_j$" reports the sum of six policy coefficients. Standard errors are clustered at the state level.

Department of Economics and Center for Statistics and Data Science, MIT, MA 02139

Email address: vchern@mit.edu

Vancouver School of Economics, UBC, 6000 Iona Drive, Vancouver, BC.

Email address: hkasahar@mail.ubc.ca

Vancouver School of Economics, UBC, 6000 Iona Drive, Vancouver, BC.

Email address: schrimpf@mail.ubc.ca