Lockdown Without Loss? A Natural Experiment of Net Payoffs to Covid Lockdowns

Gerard J. Tellis,[1]†* Ashish Sood[2]†,
Nitish Sood[3], † and Sajeev Nair[4]

ONLINE APPENDIX

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[1]University of Southern California Marshall School of Business, CA, USA Neely Chaired Professor of American Enterprise; Director of the Center for Global Innovation; Director of iORB https://orcid.org/0000-0002-2677-3840

[2]University of California, Riverside, CA, Gary Anderson School of Management https://orcid.org/0000-0002-9250-0859

[3]Medical College of Georgia, GA, USA https://orcid.org/0000-0003-1516-0691
[4]University of Kansas School of Business, KS

*Corresponding Author Email: tellis@usc.edu

Web Appendix A: Robustness checks

Effect of lockdowns on disease penetration using Generalized Synthetic Control

The key identification assumption in difference-in-differences is that parallel trends hold, which implies that in the absence of a lockdown, the disease penetration of treated and control states would have followed parallel paths. This assumption may not hold in our setting and is not directly testable. To overcome this limitation, we estimate the causal effect of lockdowns through a Generalized Synthetic Control (GSC) (Xu 2017) with daily disease prevalence as the primary dependent variable and lockdowns as the primary independent variable. GSC creates a synthetic state for each treated state by combining the control states to minimize the pre-lockdown differences in disease prevalence between the treated state and the synthetic state. Thus, differences in disease prevalence between the treated and synthetic states after lockdowns can be attributed to the lockdowns. GSC estimates the average treatment effect of lockdowns on disease prevalence in the treated states relative to the control states. We specify the GSC as follows:

$(W1)\ DP_{it} = \delta_{it} LDN_{it} + \lambda_i' f_t + \epsilon_{it}$ where,

DP_{it}	Disease Penetration (number of total cases per million in state *i* in time *t*)
LDN_{it}	Indicator variable that equals 1 for treated states in the posttreatment period

The first step in GSC involves factorizing the disease prevalence in the control states into a common set of latent factors of length *t*. This is denoted by f_t, an (r x 1) vector of common factors that capture the effect of unobserved time-varying variables on disease prevalence in the control states. GSC assumes that the same set of factors affects the treated units but to different degrees, denoted by λ_i, an (r x1) vector of unknown factor loadings. The two terms f_t and λ_i capture a wide range of unobserved heterogeneities, including unit and time fixed effects. The model assumes that the number of latent factors is fixed. We calculate the average treatment effect on the treated states as $1/N_{tr}\sum_{i\epsilon T} \delta_{it}$, where N_{tr} is the number of treated states and T is the set of treated states. A parametric bootstrap procedure is used to obtain the standard error of the estimated treatment effect. Further details of the algorithm that estimates the treatment effect are available in Xu (2017).

Results

Table W1a shows that the average treatment effect on the treated states using the generalized synthetic control is an increase of 171 cases per million. This estimate is the average over the whole treatment period. Figure W1b shows the estimated treatment effect for each day in the treatment period. This plot shows that the treatment effect is initially positive, reflecting the rapid spread of the disease over time. The reduction in disease prevalence due to lockdowns is realized only over time. By the end of the observation period on April 30, 2020, the lockdowns lead to an average drop of 306 cases per million in the states that locked down.

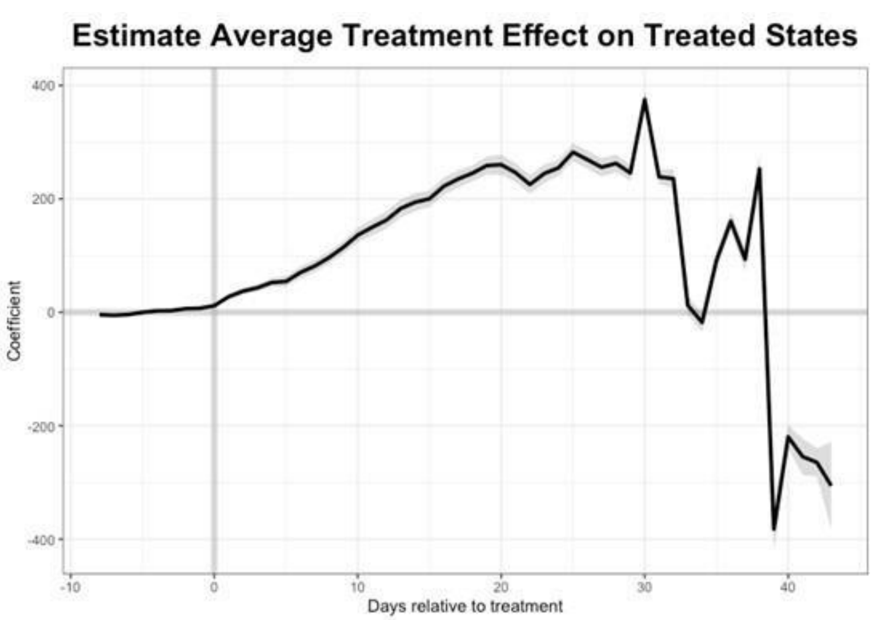
Table W1a: Average Treatment Effect on Disease Prevalence in Treated States Using the Generalized Synthetic Control

DV: Disease prevalence (cases per million)	
Lockdowns	171.2*** (2.78)
State fixed effects	Yes
Time fixed effects	Yes
Latent factors	2
Observations	1352

**p* < .05; ***p* < .01; ****p* < .001*

Notes: Standard error of the estimate in paratheses is obtained using a parametric bootstrap procedure run 1000 times. The treatment effect is evaluated at the mean counterfactual.

Figure W1b: Average Treatment Effect on States that Implemented Lockdowns Using the Generalized Synthetic Control



Web Appendix B: Generalizability Analysis

Web Appendix B Table W2: What drove Adoption of Masks by Consumers – (50 states)

Variable	Model 1		Model 2		Model 3		Model 4		Model 5	
	Estimate	t-stat	Estimate	t-stat	Estimate	t-stat	Estimate	t-stat	Estimate	t-stat
Intercept	0.191	**2.21**	0.023	0.32	0.026	0.33	-0.661	-1.72	0.111	0.13
Disease Penetration	3.7E-05	**3.02**	1.7E-05	**2.75**	1.9E-05	**2.62**	1.6E-05	**1.93**	1.9E-05	**2.05**
Political Polarization	0.039	0.54	-0.051	-0.83	-0.057	-0.83	-0.048	-0.72	-0.007	-0.14
Lockdown	0.233	**2.72**			0.130	**3.32**	0.132	**3.31**	0.110	**3.16**
Mask Mandate			0.004	**4.02**	0.004	**3.01**	0.003	**2.74**	0.002	**2.44**
Population Density							0.003	1.54	0.001	1.36
GDP per capita							0.008	**2.54**	0.008	**2.56**
March Humidity (%)							-0.001	-1.42	-0.002	-1.73
Average Temperature (°C)							-0.007	**-1.99**	-0.000	-1.41
Average Metro Traffic							0.001	1.85	0.000	**2.23**
Cohort 1 (KY-TN)									-0.149	-1.41
Cohort 2 (WV-VA)									-0.118	-0.93
Cohort 3 (CA-NV)									-0.014	-0.12
Cohort 4 (OH-PA)									-0.218	-1.41
Cohort 5 (VT-ME)									-0.045	-0.24
Cohort 6 (MD-DE)									-0.181	-0.76
Cohort 7 (MT-WY)									-0.322	-1.83
Cohort 8 (WI-IA)									-0.210	-1.26
Cohort 9 (KS-NE)									-0.367	**-3.27**
Cohort 10 (MN-ND)									-0.411	-1.93
Cohort 11 (OK-AK)									-0.162	-1.22
Cohort 12 (NM-UT)									-0.085	-0.71
N	50		50		50		50		50	
Adj. R^2	0.43		0.53		0.55		0.64		0.74	

* We include disease penetration since higher disease incidence may promote self-driven consumer usage. We include political polarization as this factor influenced governor's decisions on mandating lockdowns and mask usage. We include two measures of mask mandates – extent and duration of government regulations. Control variables that were commonly known to influence disease spread like population density, economic activity (GDP per capita), humidity, temperature, and metro traffic were also included.

Web Appendix B Table W3a: Hazard Model to Test Why Governors Ordered *Emergency Declaration NPI*

Independent Variables		Model 1		Model 2		Model 3	
		Hazard Ratio^	Confidence Interval	Hazard Ratio^	Confidence Interval	Hazard Ratio^	Confidence Interval
Theoretical Variables	Disease Penetration	1.0***	[1.0 - 1.0]	1.0***	[1.0 - 1.0]	1.0**	[1.0 - 1.0]
	Political Polarization[#]	1.2***	[1.1 - 1.3]	1.3***	[1.2 - 1.4]	1.2***	[1.1 - 1.3]
	Information Cascades	0.6***	[0.6 - 0.6]	0.6***	[0.6 - 0.6]	0.6***	[0.6 - 0.6]
	Social Learning	2.9***	[2.8 - 3.0]	3.1***	[3.0 - 3.2]	3.1***	[3.0 - 3.2]
Control Variables / Interactions	Population Density			0.5***	[0.5 - 0.6]	0.5***	[0.5 - 0.6]
	Reduction in Metro Traffic			1.0***	[1.0 - 1.0]	1.0*	[1.0 - 1.0]
	Business Activity			1.0	[1.0 - 1.0]	1.0	[1.0 - 1.0]
	Income Inequality			1.0	[1.0 - 1.0]	1.0	[1.0 - 1.0]
	Governor's Gender			0.7***	[0.6 - 0.8]	0.7***	[0.6 - 0.8]
	Social Learning X Disease Penetration					1.0***	[1.0 - 1.0]
	Information Cascades X Disease Penetration					1.0***	[1.0 - 1.0]

^ HR (Coefficient * $p \leq .05$; ** $p \leq .01$; *** $p \leq .001$):

Web Appendix B Table W3b: Hazard Model to Test Why Governors Ordered *School Closure NPI*

Independent Variables		Model 1		Model 2		Model 3	
		Hazard Ratio^	Confidence Interval	Hazard Ratio^	Confidence Interval	Hazard Ratio^	Confidence Interval
Theoretical Variables	Disease Penetration	1.0***	[1.0 - 1.0]	1.0***	[1.0 - 1.0]	1.0***	[1.0 - 1.0]
	Political Polarization#	0.9**	[0.8 - 1.0]	1.0	[1.0 - 1.1]	1.1*	[1.0 - 1.2]
	Information Cascades	1.0***	[1.0 - 1.0]	1.0***	[1.0 - 1.0]	1.0***	[1.0 - 1.0]
	Social Learning	1.1***	[1.1 - 1.1]	1.1***	[1.1 - 1.1]	1.1***	[1.1 - 1.1]
Control Variables / Interactions	Population Density			1.0	[0.9 - 1.1]	1.0	[0.9 - 1.0]
	Reduction in Metro Traffic			1.0***	[1.0 - 1.0]	1.0***	[1.0 - 1.0]
	Business Activity			1.0***	[1.0 - 1.0]	1.0***	[1.0 - 1.0]
	Income Inequality			0.9***	[0.8 - 0.9]	0.9***	[0.9 - 0.9]
	Governor's Gender			1.1*	[1.0 - 1.2]	1.1	[1.0 - 1.2]
	Social Learning X Disease Penetration					1.0	[1.0 - 1.0]
	Information Cascades X Disease Penetration					1.0***	[1.0 - 1.0]

^ HR (Coefficient * $p \leq .05$; ** $p \leq .01$; *** $p \leq .001$)

Web Appendix B Table W3c: Hazard Model to Test Why Governors Ordered *Business Close NPI*

Independent Variables		Model 1		Model 2		Model 3	
		Hazard Ratio^	Confidence Interval	Hazard Ratio^	Confidence Interval	Hazard Ratio^	Confidence Interval
Theoretical Variables	Disease Penetration	1.0***	[1.0 - 1.0]	1.0***	[1.0 - 1.0]	1.0	[1.0 - 1.0]
	Political Polarization#	1.6***	[1.5 - 1.7]	1.4***	[1.3 - 1.5]	1.4***	[1.3 - 1.5]
	Information Cascades	1.1***	[1.1 - 1.1]	1.1***	[1.1 - 1.2]	1.1***	[1.1 - 1.1]
	Social Learning	1.1***	[1.1 - 1.1]	1.1***	[1.1 - 1.1]	1.1***	[1.1 - 1.1]
Control Variables / Interactions	Population Density			1.9***	[1.8 - 2.0]	2.0***	[1.9 - 2.1]
	Reduction in Metro Traffic			1.0**	[1.0 - 1.0]	1.0*	[1.0 - 1.0]
	Business Activity			1.0***	[1.0 - 1.0]	1.0***	[1.0 - 1.0]
	Income Inequality			1.0	[1.0 - 1.0]	1.0	[1.0 - 1.0]
	Governor's Gender			1.0	[0.9 - 1.2]	1.0	[0.9 - 1.2]
	Social Learning X Disease Penetration					1.0	[1.0 - 1.0]
	Information Cascades X Disease Penetration					1.0***	[1.0 - 1.0]

^ HR (Coefficient * $p \leq .05$; ** $p \leq .01$; *** $p \leq .001$)

Web Appendix B Table W3d: Hazard Model to Test Why Governors Ordered *Restaurants Closure NPI*

Independent Variables		Model 1		Model 2		Model 3	
		Hazard Ratio^	Confidence Interval	Hazard Ratio^	Confidence Interval	Hazard Ratio^	Confidence Interval
Theoretical Variables	Disease Penetration	1.0***	[1.0 - 1.0]	1.0*	[1.0 - 1.0]	1.0***	[1.0 - 1.0]
	Political Polarization[#]	1.9***	[1.8 - 2.0]	3.0***	[2.7 - 3.2]	3.1***	[2.8 - 3.3]
	Information Cascades	1.1***	[1.1 - 1.1]	1.1***	[1.1 - 1.1]	1.1***	[1.1 - 1.1]
	Social Learning	1.1***	[1.0 - 1.1]	1.1***	[1.1 - 1.1]	1.1***	[1.1 - 1.1]
Control Variables / Interactions	Population Density			1.5***	[1.4 - 1.6]	1.5***	[1.4 - 1.5]
	Reduction in Metro Traffic			1.0**	[1.0 - 1.0]	1.0*	[1.0 - 1.0]
	Business Activity			1.0*	[1.0 - 1.0]	1.0**	[1.0 - 1.0]
	Income Inequality			1.0***	[0.9 - 1.0]	1.0***	[0.9 - 1.0]
	Governor's Gender			0.2***	[0.2 - 0.3]	0.2***	[0.2 - 0.3]
	Social Learning X Disease Penetration					1.0***	[1.0 - 1.0]
	Information Cascades X Disease Penetration					1.0	[1.0 - 1.0]

^ HR (Coefficient * $p \leq .05$; ** $p \leq .01$; *** $p \leq .001$)

Web Appendix B Table W3e: Hazard Model to Test Why Governors Ordered *Gathering Restriction NPI*

Independent Variables		Model 1		Model 2		Model 3	
		Hazard Ratio^	Confidence Interval	Hazard Ratio^	Confidence Interval	Hazard Ratio^	Confidence Interval
Theoretical Variables	Disease Penetration	1.0***	[1.0 - 1.0]	1.0***	[1.0 - 1.0]	1.0***	[1.0 - 1.0]
	Political Polarization#	1.3***	[1.2 - 1.5]	1.4***	[1.3 - 1.6]	1.4***	[1.3 - 1.5]
	Information Cascades	1.1***	[1.1 - 1.1]	1.1***	[1.1 - 1.1]	1.1***	[1.1 - 1.1]
	Social Learning	1.0***	[1.0 - 1.0]	1.0***	[1.0 - 1.0]	1.0***	[1.0 - 1.0]
Control Variables / Interactions	Population Density			1.1***	[1.1 - 1.2]	1.3***	[1.2 - 1.3]
	Reduction in Metro Traffic			1.0***	[1.0 - 1.0]	1.0***	[1.0 - 1.0]
	Business Activity			1.0***	[1.0 - 1.0]	1.0***	[1.0 - 1.0]
	Income Inequality			1.0**	[0.9 - 1.0]	1.0***	[0.9 - 1.0]
	Governor's Gender			1.1	[1.0 - 1.2]	1.1	[1.0 - 1.2]
	Social Learning X Disease Penetration					1.0***	[1.0 - 1.0]
	Information Cascades X Disease Penetration					1.0***	[1.0 - 1.0]

^ HR (Coefficient * $p \leq .05$; ** $p \leq .01$; *** $p \leq .001$)

Web Appendix C: Analysis of Model Fit

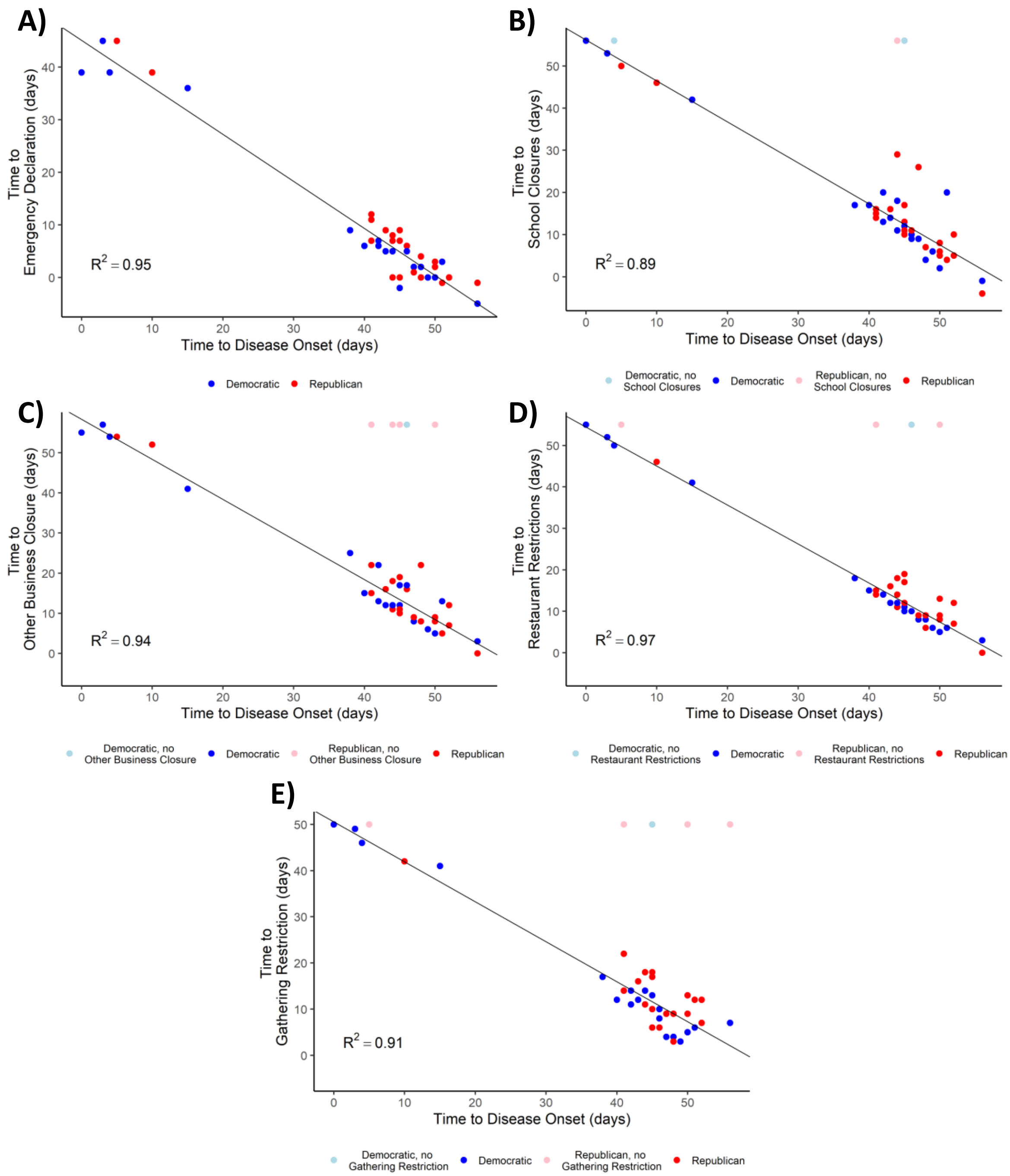
Web Appendix Table W4a: Model Performance in Hit Rates

		Predicted Outcome	
		NPI	**No *NPI***
Actual Outcome	***NPI***	True Positive = 0.97	False Negative = 0.72
	No *NPI*	False Positive = 0.03	True Negative = 0.27

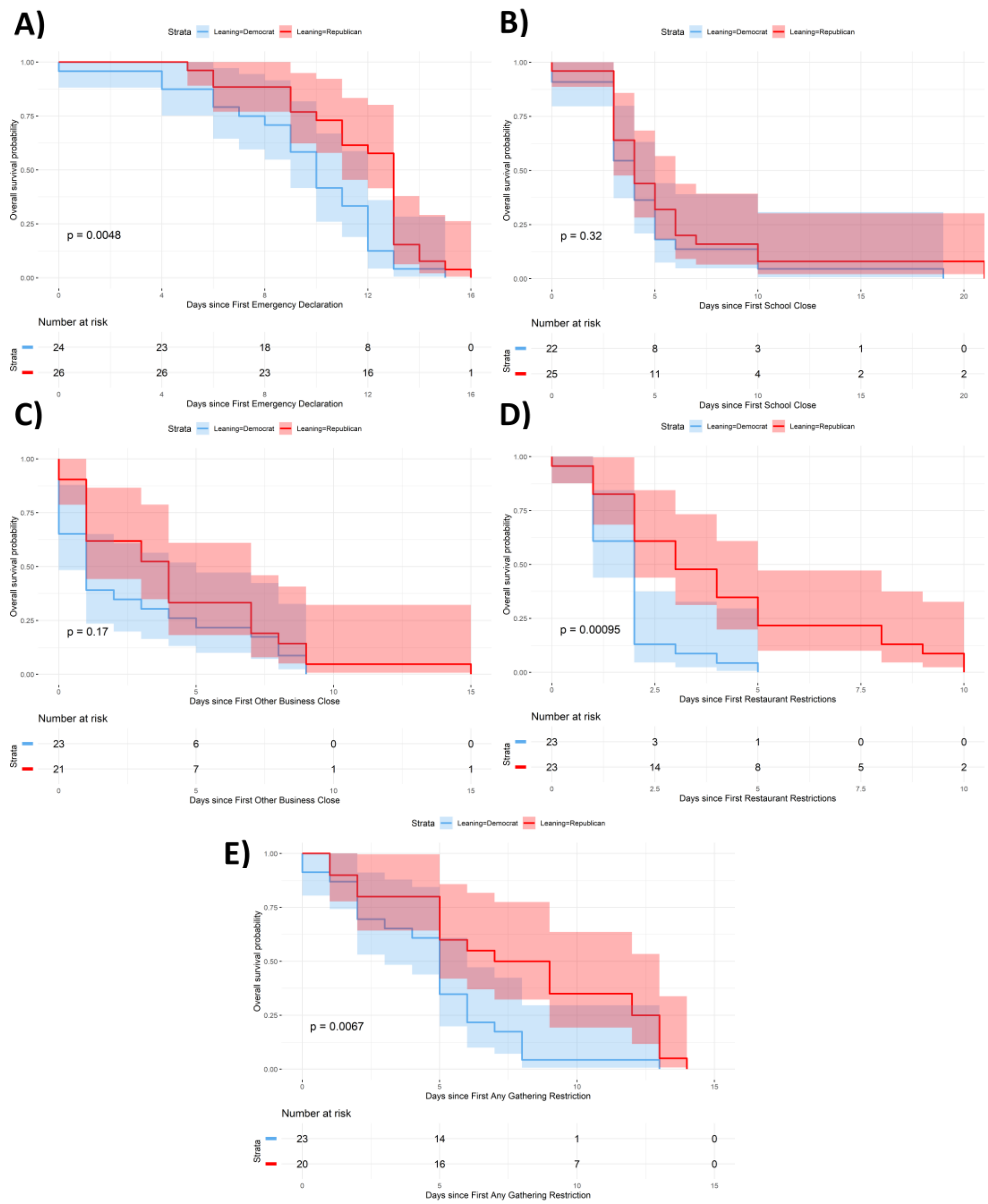
Web Appendix Table W4b: Concordance Statistics

Harrell's Concordance Statistic					
Source	**Estimate**	**Comparable Pairs**			
		Concordance	**Discordance**	**Tied in Predictor**	**Tied in Time**
Model	0.92	30416	3402	9	22

Web Appendix Figure W1: Robustness Analysis of Learning Effect.



Web Appendix Figure W2: Kaplan-Meier Plots.



Note: Plot of fraction of states not declaring various NPIs demonstrates the impact of political polarization on the decision making by governors.

Web Appendix Figure W3: Model Fit. (A) ROC and (B) AOC Curves