

## **Supplementary Materials:**

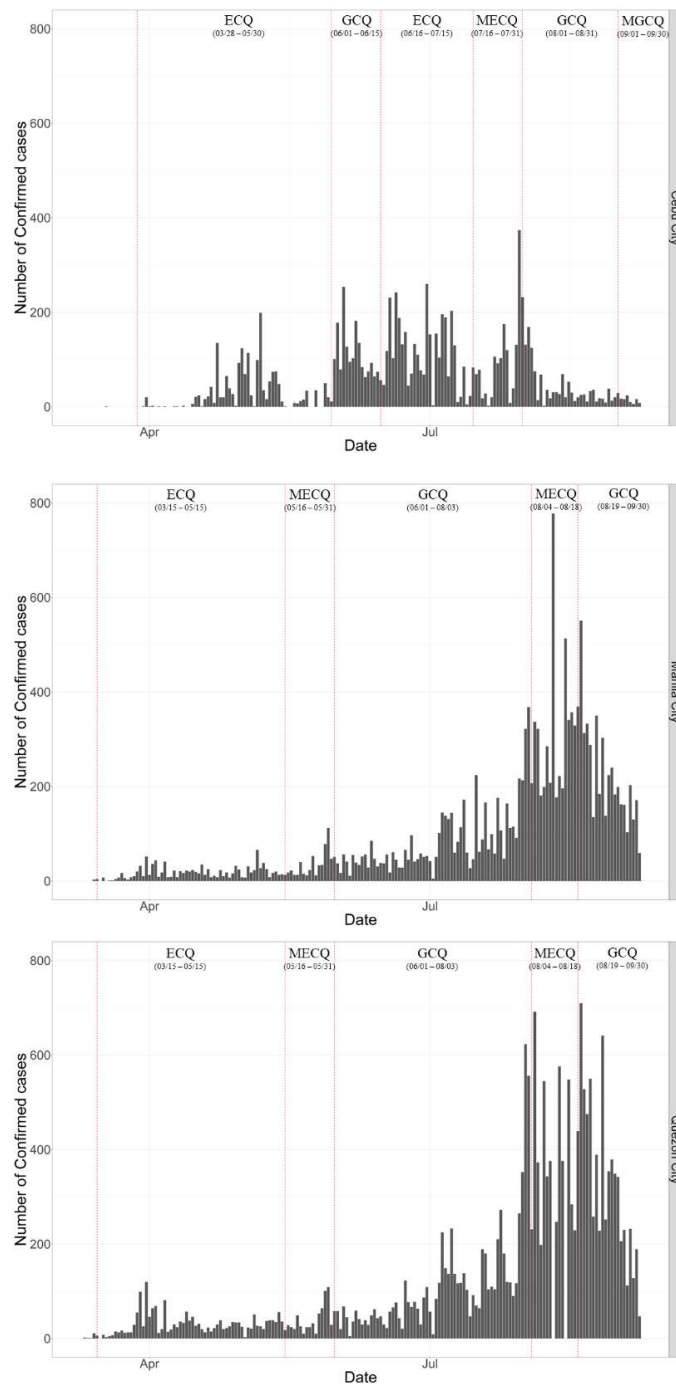
# **Immediate and Delayed Meteorological Effects on COVID-19 Time-Varying Infectiousness in Tropical Cities**

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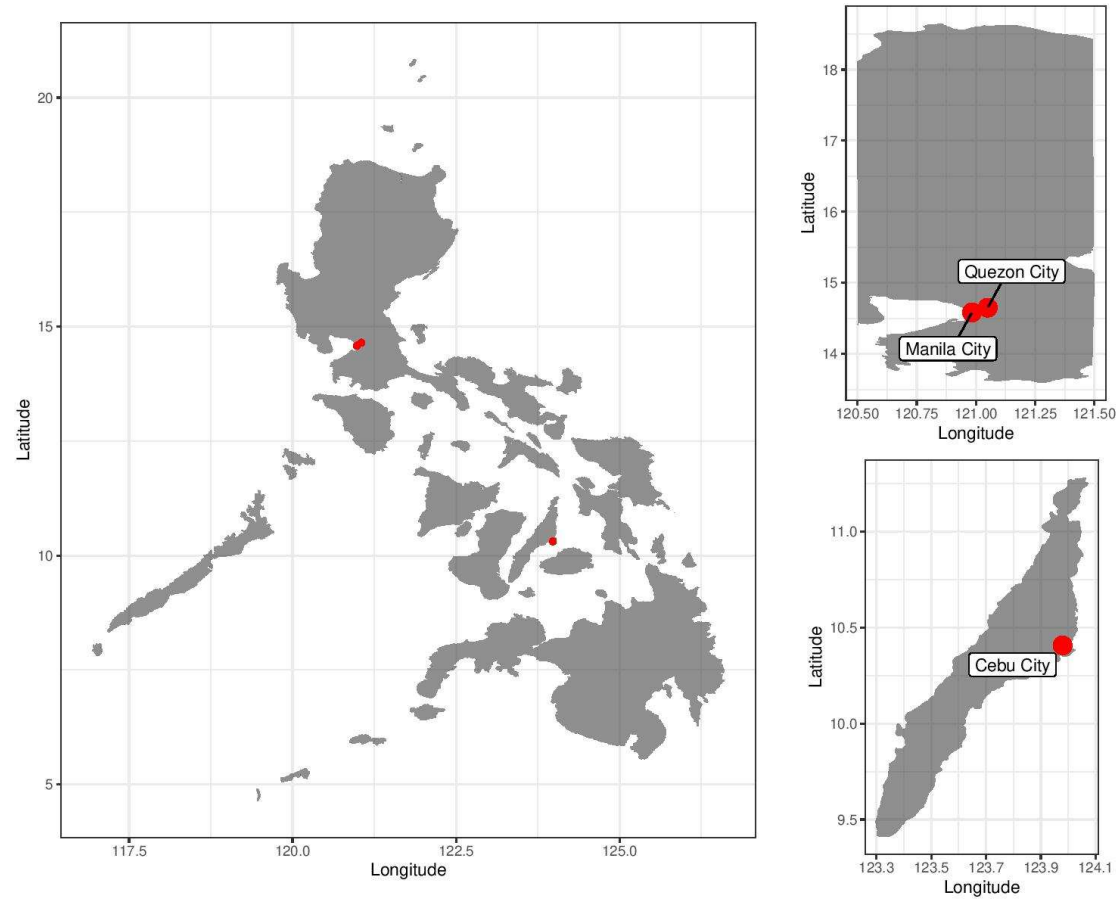
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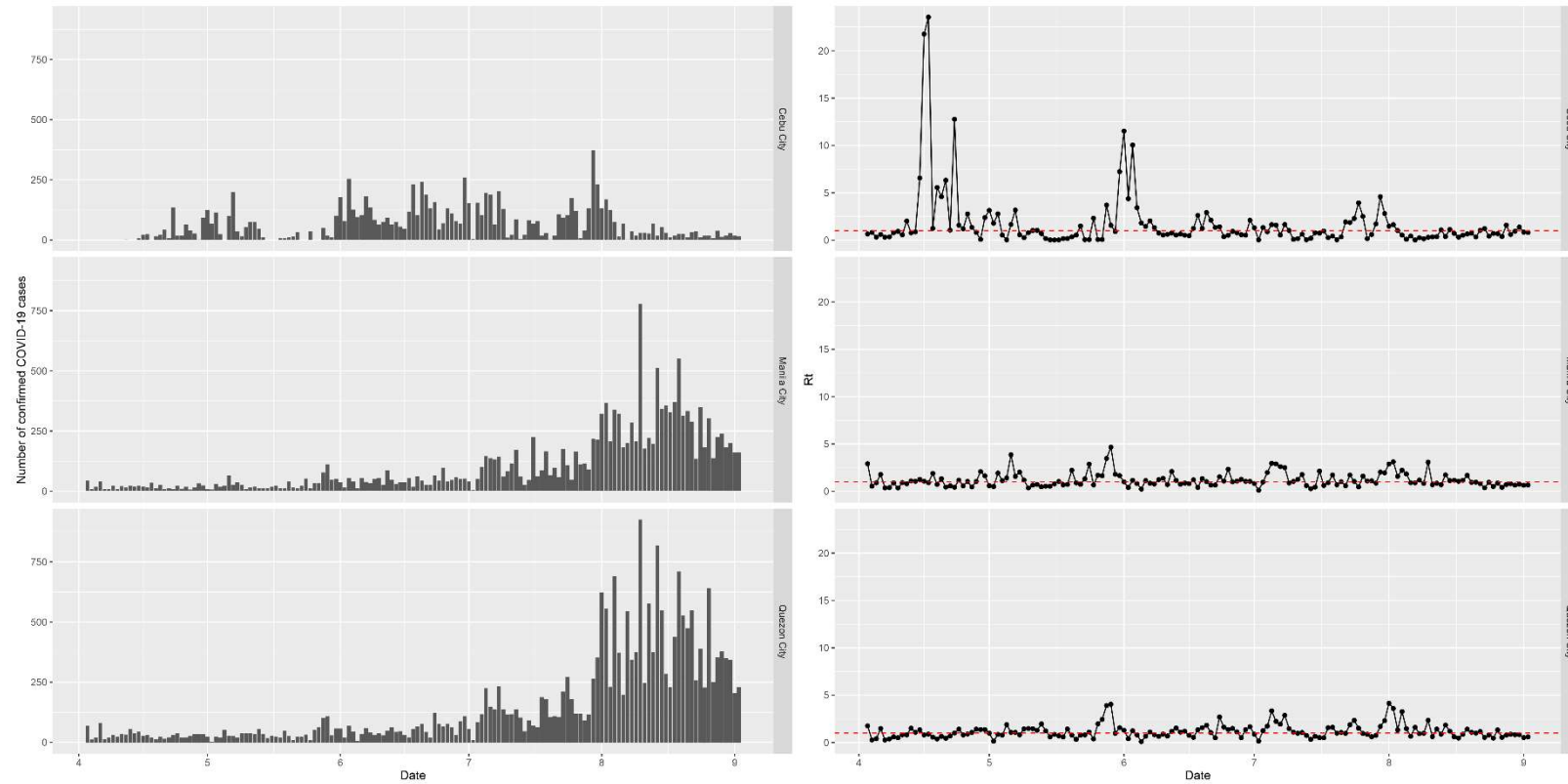
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**Figure S1.** Timeline of community quarantine measures in the three major cities of the Philippines. Red vertical dotted lines indicate the inclusive period of community quarantine implementation. ECQ is enhanced community quarantine, the most stringent community quarantine measure, followed by MECQ, modified ECQ, with slightly relaxed activities. GCQ is the general community quarantine which has lesser restrictions than MECQ, and MGCQ, a modified GCQ which is intended to be a transition towards a new normal scenario. The period of the start and end of each community quarantine is located immediately below each acronym and are enclosed in parentheses.

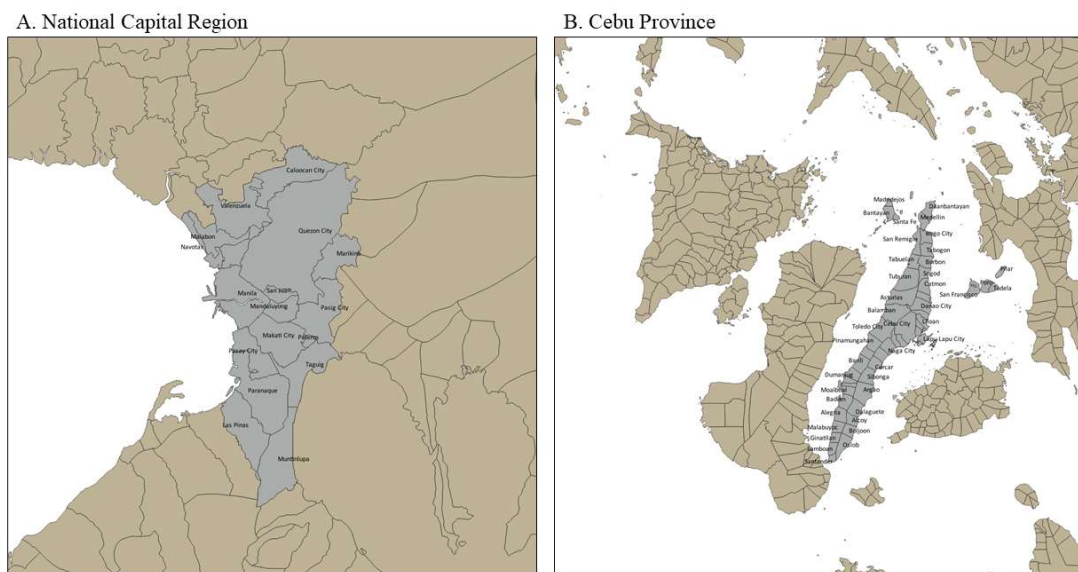


**Figure S2.** Geographical locations of the monitoring stations per city across the country (left) alongside zoomed-in locations for Manila and Quezon cities (right, upper) and Cebu city (right, lower). The cities of Manila and Quezon are located in the bigger cluster of islands, in Luzon, specifically in the National Capital Region. Whereas, Cebu city is located in the central part of the Philippines. The monitoring station of Manila city is located near the port area, whereas Quezon city is located at the heart of the city, in the Science Garden, while Cebu's monitoring station is near the Mactan Airport.



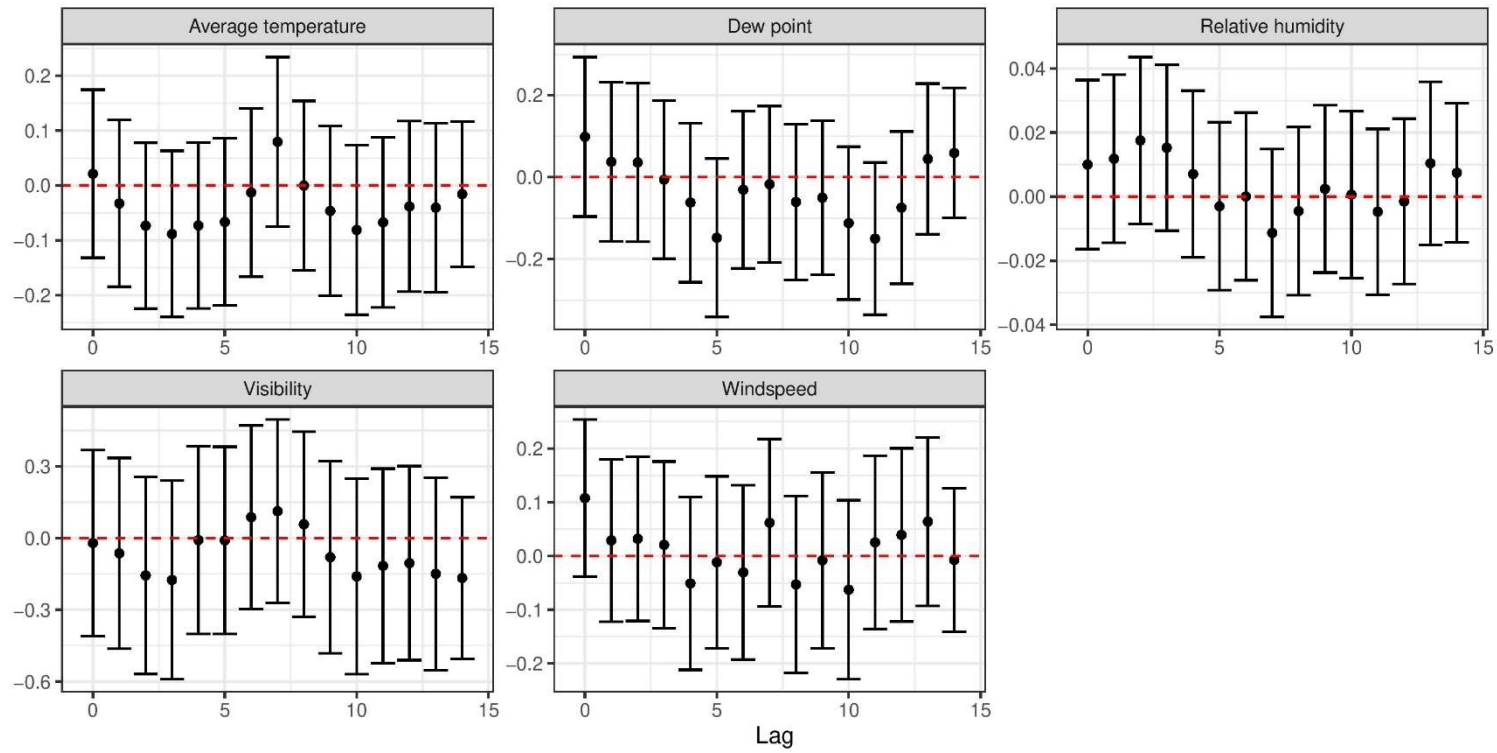
**Figure S3.** Time-varying  $R_t$  and daily number of COVID-19 cases in Cebu city (upper panel), Manila city (middle panel) and C) Quezon city (lower panel). Red horizontal dotted line for  $R_t$  panels (right panels, top to bottom) are drawn across when  $R_t$  is equal to 1. Daily number of COVID-19 case are located in the top to bottom right panels.

Daily number of RT-PCR tests were aggregated per health facility across the country. While some facilities have complete address, down to the city-level information, several health facilities did not have this information. In order to harmonize and identify the exact location of the health facilities, the raw/inputted address data of the health facilities were geocoded using the “*ggmap*” package in R statistical programming. The exact latitude and longitude of the facilities were extracted. Locations beyond the Philippine latitude and longitude specifications have been re-examined and re-geocoded. Instead of using the city-level number of tests for each city, given the complex nature of health facility referral system and the lack of clear geographical boundaries of health facility referrals, we assumed that the trend of regional/provincial RT-PCRs would reflect the same trend at the city-level. For Manila and Quezon cities, we used the trend of the National Capital Region (NCR), whereas for Cebu city, we utilized the trend from Cebu Province; geographical boundaries of the respective locations are depicted in Figure S4.

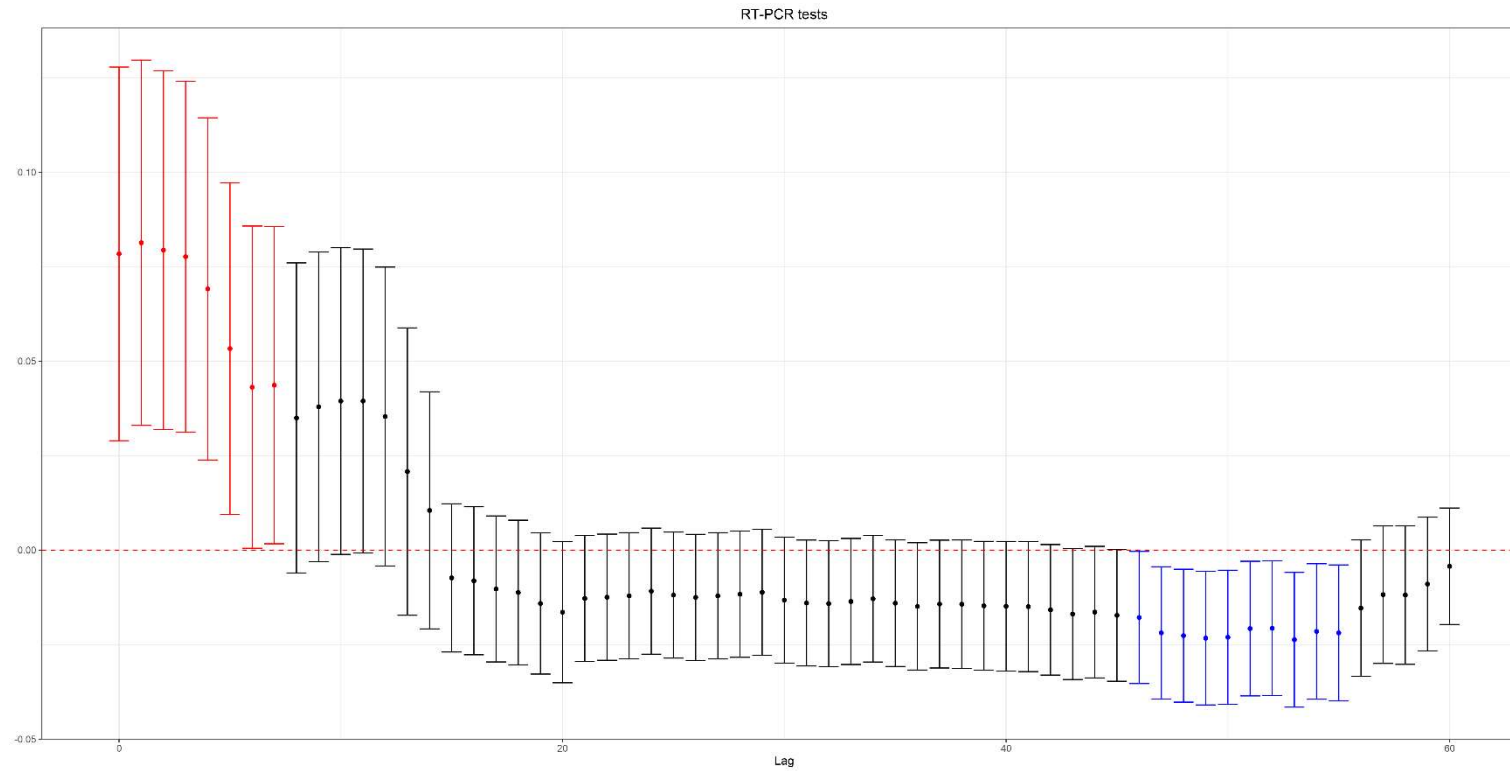


**Figure S4.** Geographical location and administrative boundaries of the National Capital Region (left) and Cebu Island (right).

The grey colored location is the area coverage for the National Capital Region (NCR) and Cebu Island. Overlayed in the colored regions are the administrative boundaries of the included cities and municipalities.



**Figure S5.** Lag-specific association of  $R_t$  and average temperature (leftmost, upper panel), dewpoint (middle, upper panel), relative humidity (rightmost, upper panel), visibility (leftmost, lower panel) and windspeed (middle, lower panel). The coefficients, in black, represent the statistically non-significant association with  $R_t$ , which cross the red horizontal dotted line (representing the null association).



**Figure S6.** Extended lagged association of RT-PCR tests and  $R_t$ . Set at a 2-month (60 days) maximum lag, positive and statistically significant effects estimates are shown in red, whereas statistically negative associations are in blue. Red horizontal dotted line represents the null association.

**Table S1.** Characteristics of Top 5 cities in the Philippines with the most COVID-19 cases from 03 April 2020 to 02 September 2020.

City	Cumulative COVID-19 Cases	2015 Population <sup>a</sup>	Availability of Weather Monitoring Station <sup>b</sup>	COVID-19 Cumulative Incidence (per 1,000 Population)
Quezon city	23,708	2,936,116	+	8
Manila city	16,722	1,780,148	+	9
Cebu city	9,804	922,611	+	11
Caloocan city	8,949	1,583,978	-	6
Makati city	8,176	582,602	-	14

<sup>a</sup>2015 Census of Population<sup>b</sup>National Oceanic and Atmospheric Administration (NOAA) weather monitoring station [presence (+)/ absence (-)]**Table S2.** Definition of community quarantine classifications.

Community quarantine classification	CQ Level	Definition <sup>1</sup>
<b>Enhanced Community Quarantine (ECQ)</b>	4	<i>“refers to the implementation of temporary measures imposing <u>stringent limitations</u> on movement and transportation of people, strict regulation of operating industries, provision of food and essential services, and heightened presence of uniformed personnel to enforce community quarantine protocols”</i>
<b>Modified Enhanced Community Quarantine (MECQ)</b>	3	<i>“refers to the <u>transition phase between ECQ and GCQ</u>, when the following <u>temporary measures are relaxed</u> and become less necessary: stringent limits on movement and transportation of people, strict regulation of operating industries, provision of food and essential services, and heightened presence of uniformed personnel to enforce community quarantine protocols”</i>
<b>General Community Quarantine (GCQ)</b>	2	<i>“refers to the implementation of <u>temporary measures limiting movement and transportation</u>, regulation of operating industries, and presence of uniformed personnel to enforce community quarantine protocols”</i>
<b>Modified General Community Quarantine (MGCQ)</b>	1	<i>“refers to <u>the transition phase between GCQ and the New Normal</u>, when the following temporary measures are relaxed and become less necessary: limiting movement and transportation, the regulation of operating industries, and the presence of uniformed personnel to enforce community quarantine protocols”</i>

<sup>1</sup>OMNIBUS GUIDELINES ON THE IMPLEMENTATION OF COMMUNITY QUARANTINE IN THE PHILIPPINES with Amendments as of 08 October 2020



**Table S3.** Stepwise regression via backward elimination results.

Model	Covariate	$\beta$	SE	p-value
Model 1 (Initial Full Model)	Air Pressure - Lag 0	2.36247	1.21806	0.05244
	Air Pressure - Lag 1	0.53617	1.77271	0.76230
	Air Pressure - Lag 2	−0.08887	1.83028	0.96127
	Air Pressure - Lag 3	1.10942	1.83642	0.54576
	Air Pressure - Lag 4	−0.46479	1.83515	0.80006
	Air Pressure - Lag 5	0.16214	1.87781	0.93119
	Air Pressure - Lag 6	0.49013	1.89564	0.79598
	Air Pressure - Lag 7	1.70331	1.83031	0.35205
	Air Pressure - Lag 8	0.38506	1.28620	0.76465
	RT-PCR tests - Lag 0	0.08072	0.06767	0.23289
	RT-PCR tests - Lag 1	0.05413	0.07885	0.49242
	RT-PCR tests - Lag 2	−0.00681	0.08124	0.93318
	RT-PCR tests - Lag 3	0.02874	0.08103	0.72284
	RT-PCR tests - Lag 4	0.05667	0.08033	0.48054
	RT-PCR tests - Lag 5	−0.00403	0.08034	0.95995
	RT-PCR tests - Lag 6	−0.01234	0.07939	0.87651
	RT-PCR tests - Lag 7	−0.02977	0.06452	0.64450
	CQ 1:Time	−0.01324	0.00855	0.12142
	CQ 2:Time	−0.01679	0.00464	0.00030
	CQ 3:Time	−0.01262	0.00543	0.02010
	CQ 4:Time	−0.02768	0.00662	0.00003
Model 2	Air Pressure - Lag 0	2.32075	1.16636	0.04662
	Air Pressure - Lag 1	0.41952	1.30015	0.74694
	Air Pressure - Lag 3	1.17031	1.35561	0.38797
	Air Pressure - Lag 4	−0.43311	1.80647	0.81052
	Air Pressure - Lag 5	−0.01124	1.83777	0.99512
	Air Pressure - Lag 6	0.73016	1.81692	0.68778
	Air Pressure - Lag 7	1.31687	1.74540	0.45056
	Air Pressure - Lag 8	0.60224	1.25705	0.63187
	RT-PCR tests - Lag 0	0.08127	0.06677	0.22357
	RT-PCR tests - Lag 1	0.05600	0.07735	0.46907
	RT-PCR tests - Lag 2	−0.01107	0.08059	0.89078
	RT-PCR tests - Lag 3	0.03168	0.08072	0.69466
	RT-PCR tests - Lag 4	0.05614	0.08004	0.48303
	RT-PCR tests - Lag 5	−0.00554	0.08002	0.94484
	RT-PCR tests - Lag 6	−0.01245	0.07864	0.87415
	RT-PCR tests - Lag 7	−0.02908	0.06368	0.64789
	CQ 1:Time	−0.01330	0.00851	0.11811

Model 3	CQ 2:Time	−0.01667	0.00461	0.00030
	CQ 3:Time	−0.01260	0.00539	0.01937
	CQ 4:Time	−0.02765	0.00659	0.00003
	Air Pressure - Lag 0	2.32891	1.15451	0.04367
	Air Pressure - Lag 1	0.45021	1.27429	0.72386
	Air Pressure - Lag 3	1.13070	1.28696	0.37963
	Air Pressure - Lag 4	−0.42426	1.32540	0.74889
	Air Pressure - Lag 6	0.61649	1.36192	0.65079
	Air Pressure - Lag 7	1.34959	1.70606	0.42891
	Air Pressure - Lag 8	0.55720	1.24572	0.65466
	RT-PCR tests - Lag 0	0.08709	0.06591	0.18638
	RT-PCR tests - Lag 1	0.05011	0.07646	0.51225
	RT-PCR tests - Lag 2	−0.00720	0.07948	0.92778
	RT-PCR tests - Lag 3	0.02963	0.07926	0.70852
	RT-PCR tests - Lag 4	0.04991	0.07899	0.52747
	RT-PCR tests - Lag 5	−0.00325	0.07934	0.96733
	RT-PCR tests - Lag 6	−0.01088	0.07792	0.88891
	RT-PCR tests - Lag 7	−0.03001	0.06328	0.63536
	CQ 1:Time	−0.01353	0.00847	0.11003
	CQ 2:Time	−0.01684	0.00456	0.00022
Model 4	CQ 3:Time	−0.01317	0.00531	0.01312
	CQ 4:Time	−0.02799	0.00655	0.00002
	Air Pressure - Lag 0	2.33371	1.14701	0.04189
	Air Pressure - Lag 1	0.44596	1.26834	0.72513
	Air Pressure - Lag 3	1.12854	1.28414	0.37949
	Air Pressure - Lag 4	−0.42129	1.32162	0.74990
	Air Pressure - Lag 6	0.61450	1.35921	0.65120
	Air Pressure - Lag 7	1.36210	1.67623	0.41645
	Air Pressure - Lag 8	0.54658	1.21681	0.65329
	RT-PCR tests - Lag 0	0.08686	0.06558	0.18535
	RT-PCR tests - Lag 1	0.05017	0.07634	0.51101
	RT-PCR tests - Lag 2	−0.00686	0.07893	0.93071
	RT-PCR tests - Lag 3	0.02895	0.07741	0.70839
	RT-PCR tests - Lag 4	0.04883	0.07431	0.51115
	RT-PCR tests - Lag 6	−0.01199	0.07300	0.86954
	RT-PCR tests - Lag 7	−0.03058	0.06162	0.61968
	CQ 1:Time	−0.01352	0.00845	0.10966
	CQ 2:Time	−0.01683	0.00455	0.00022
	CQ 3:Time	−0.01317	0.00530	0.01299
	CQ 4:Time	−0.02799	0.00654	0.00002

Model 5	Air Pressure - Lag 0	2.32717	1.14301	0.04175
	Air Pressure - Lag 1	0.44968	1.26592	0.72242
	Air Pressure - Lag 3	1.12723	1.28233	0.37938
	Air Pressure - Lag 4	−0.40806	1.31108	0.75562
	Air Pressure - Lag 6	0.60196	1.34973	0.65561
	Air Pressure - Lag 7	1.37012	1.67145	0.41238
	Air Pressure - Lag 8	0.54070	1.21330	0.65586
	RT-PCR tests - Lag 0	0.08571	0.06413	0.18142
	RT-PCR tests - Lag 1	0.04788	0.07153	0.50325
	RT-PCR tests - Lag 3	0.02671	0.07290	0.71404
	RT-PCR tests - Lag 4	0.04770	0.07307	0.51391
	RT-PCR tests - Lag 6	−0.01173	0.07285	0.87204
	RT-PCR tests - Lag 7	−0.03085	0.06146	0.61563
	CQ 1:Time	−0.01353	0.00844	0.10884
	CQ 2:Time	−0.01684	0.00455	0.00021
	CQ 3:Time	−0.01318	0.00530	0.01286
	CQ 4:Time	−0.02799	0.00653	0.00002
Model 6	Air Pressure - Lag 0	2.31756	1.13996	0.04205
	Air Pressure - Lag 1	0.47345	1.25564	0.70613
	Air Pressure - Lag 3	1.11381	1.27795	0.38345
	Air Pressure - Lag 4	−0.40810	1.30936	0.75529
	Air Pressure - Lag 6	0.60736	1.34755	0.65219
	Air Pressure - Lag 7	1.37765	1.66861	0.40901
	Air Pressure - Lag 8	0.54866	1.21071	0.65043
	RT-PCR tests - Lag 0	0.08565	0.06405	0.18114
	RT-PCR tests - Lag 1	0.04735	0.07136	0.50698
	RT-PCR tests - Lag 3	0.02722	0.07274	0.70827
	RT-PCR tests - Lag 4	0.04294	0.06674	0.51999
	RT-PCR tests - Lag 7	−0.03757	0.04509	0.40465
	CQ 1:Time	−0.01350	0.00843	0.10911
	CQ 2:Time	−0.01680	0.00453	0.00021
	CQ 3:Time	−0.01311	0.00528	0.01293
	CQ 4:Time	−0.02793	0.00651	0.00002
Model 7	Air Pressure - Lag 0	2.30294	1.11874	0.03954
	Air Pressure - Lag 1	0.54885	1.22464	0.65403
	Air Pressure - Lag 3	0.76194	0.84537	0.36742
	Air Pressure - Lag 6	0.43203	1.20598	0.72017
	Air Pressure - Lag 7	1.33290	1.58552	0.40053
	Air Pressure - Lag 8	0.57776	1.16970	0.62135
	RT-PCR tests - Lag 0	0.08288	0.06358	0.19240

Model 8	RT-PCR tests - Lag 1	0.04950	0.07040	0.48199
	RT-PCR tests - Lag 3	0.02368	0.07162	0.74091
	RT-PCR tests - Lag 4	0.04681	0.06613	0.47907
	RT-PCR tests - Lag 7	−0.03927	0.04484	0.38107
	CQ 1:Time	−0.01369	0.00838	0.10238
	CQ 2:Time	−0.01681	0.00449	0.00018
	CQ 3:Time	−0.01351	0.00523	0.00979
	CQ 4:Time	−0.02809	0.00648	0.00001
	Air Pressure - Lag 0	2.31481	1.11685	0.03821
	Air Pressure - Lag 1	0.55475	1.22308	0.65014
	Air Pressure - Lag 3	0.72427	0.83668	0.38668
	Air Pressure - Lag 6	0.44804	1.20361	0.70971
	Air Pressure - Lag 7	1.34172	1.58344	0.39680
	Air Pressure - Lag 8	0.58023	1.16831	0.61944
	RT-PCR tests - Lag 0	0.08303	0.06350	0.19101
	RT-PCR tests - Lag 1	0.05765	0.06587	0.38145
	RT-PCR tests - Lag 4	0.06004	0.05255	0.25324
	RT-PCR tests - Lag 7	−0.03752	0.04447	0.39880
	CQ 1:Time	−0.01363	0.00837	0.10331
	CQ 2:Time	−0.01674	0.00448	0.00019
Model 9	CQ 3:Time	−0.01344	0.00522	0.01003
	CQ 4:Time	−0.02800	0.00646	0.00001
	Air Pressure - Lag 0	2.27428	1.10505	0.03958
	Air Pressure - Lag 1	0.63062	1.20939	0.60206
	Air Pressure - Lag 3	0.76069	0.82586	0.35700
	Air Pressure - Lag 7	1.72937	1.10755	0.11842
	Air Pressure - Lag 8	0.46861	1.13141	0.67874
	RT-PCR tests - Lag 0	0.08378	0.06254	0.18041
	RT-PCR tests - Lag 1	0.06137	0.06472	0.34299
	RT-PCR tests - Lag 4	0.05463	0.05074	0.28164
Model 10	RT-PCR tests - Lag 7	−0.03649	0.04414	0.40838
	CQ 1:Time	−0.01375	0.00832	0.09824
	CQ 2:Time	−0.01691	0.00443	0.00014
	CQ 3:Time	−0.01361	0.00518	0.00855
	CQ 4:Time	−0.02819	0.00642	0.00001
	Air Pressure - Lag 0	2.12447	1.09720	0.05283
	Air Pressure - Lag 1	0.39821	1.19078	0.73807
	Air Pressure - Lag 3	0.99154	0.81799	0.22545
	Air Pressure - Lag 7	1.91031	0.71436	0.00749
	RT-PCR tests - Lag 0	0.07317	0.06231	0.24026

Model 11	RT-PCR tests - Lag 1	0.06790	0.06448	0.29229
	RT-PCR tests - Lag 4	0.05400	0.05010	0.28111
	RT-PCR tests - Lag 7	−0.03965	0.04320	0.35865
	CQ 1:Time	−0.01304	0.00831	0.11634
	CQ 2:Time	−0.01651	0.00434	0.00014
	CQ 3:Time	−0.01329	0.00504	0.00836
	CQ 4:Time	−0.02731	0.00632	0.00002
	Air Pressure - Lag 0	2.35975	0.71899	0.00103
	Air Pressure - Lag 3	1.04757	0.74405	0.15916
	Air Pressure - Lag 7	1.95802	0.70912	0.00576
	RT-PCR tests - Lag 0	0.07458	0.06166	0.22648
	RT-PCR tests - Lag 1	0.06465	0.06374	0.31052
	RT-PCR tests - Lag 4	0.05626	0.04964	0.25708
	RT-PCR tests - Lag 7	−0.03960	0.04292	0.35616
	CQ 1:Time	−0.01326	0.00826	0.10876
	CQ 2:Time	−0.01667	0.00430	0.00011
Model 12	CQ 3:Time	−0.01349	0.00499	0.00690
	CQ 4:Time	−0.02737	0.00629	0.00001
	Air Pressure - Lag 0	2.30540	0.71644	0.00129
	Air Pressure - Lag 3	1.00801	0.74269	0.17470
	Air Pressure - Lag 7	2.16579	0.67231	0.00128
	RT-PCR tests - Lag 0	0.06968	0.06142	0.25661
	RT-PCR tests - Lag 1	0.05852	0.06339	0.35593
	RT-PCR tests - Lag 4	0.03084	0.04129	0.45509
	CQ 1:Time	−0.01298	0.00826	0.11610
	CQ 2:Time	−0.01620	0.00427	0.00015
	CQ 3:Time	−0.01303	0.00497	0.00872
	CQ 4:Time	−0.02664	0.00624	0.00002
	Air Pressure - Lag 0	2.33492	0.71499	0.00109
	Air Pressure - Lag 3	0.93678	0.73620	0.20321
	Air Pressure - Lag 7	2.08578	0.66329	0.00166
Model 13	RT-PCR tests - Lag 0	0.07788	0.06036	0.19697
	RT-PCR tests - Lag 1	0.07644	0.05859	0.19199
	CQ 1:Time	−0.01335	0.00824	0.10506
	CQ 2:Time	−0.01624	0.00427	0.00014
	CQ 3:Time	−0.01317	0.00496	0.00791
	CQ 4:Time	−0.02685	0.00622	0.00002
Model 14	Air Pressure - Lag 0	2.58824	0.68417	0.00015
	Air Pressure - Lag 7	2.29139	0.63572	0.00031
	RT-PCR tests - Lag 0	0.09497	0.05891	0.10692

Model 15 (Final Model)	RT-PCR tests - Lag 1	0.05698	0.05673	0.31520
	CQ 1:Time	−0.01535	0.00808	0.05729
	CQ 2:Time	−0.01713	0.00419	0.00004
	CQ 3:Time	−0.01433	0.00488	0.00332
	CQ 4:Time	−0.02783	0.00617	0.00001
	Air Pressure - Lag 0	2.59425	0.68426	0.00015
	Air Pressure - Lag 7	2.25998	0.63500	0.00037
	RT-PCR tests - Lag 0	0.14491	0.03068	0.00000
	CQ 1:Time	−0.01496	0.00807	0.06366
	CQ 2:Time	−0.01671	0.00417	0.00006
	CQ 3:Time	−0.01385	0.00486	0.00437
	CQ 4:Time	−0.02743	0.00616	0.00001

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RT-PCR = reverse transcriptase polymerase chain reaction; CQ = community quarantine; CQ:Time = interaction of CQ with time; ;CQ = 1 (Modified General Community Quarantine); CQ = 2 (General Community Quarantine); CQ = 3 (Modified Enhanced Community Quarantine); CQ = 4 (Enhanced Community Quarantine);  $\beta$ = beta coefficient; SE = standard error