

**Hospital referrals, exclusions from hospital care,
and deaths among long-term care residents in the Community of Madrid
during the March-April 2020 COVID-19 epidemic period:
A multivariate time series analysis**

Additional File 2

**François Béland
Maria Victoria Zunzunegui
Fernando J. García López
Francisco Pozo-Rodríguez**

June 18, 2024

Additional File 2

Based on the results of the unit root, volatility, and white noise tests (Additional File 1), the MGARCH(1,1) model was chosen for the multivariate analysis. Residuals of the MGARCH(1,1) models were tested for white noise with Bartlett's periodogram [33] and Portmanteau's [33] tests. Additionally, residuals were examined for unit roots with Phillips & Peron's tests [33] (Table S2).

Hospital referrals, deaths in LTCFs, and deaths in hospitals of LTCF residents were responses in the data-generating model (Figure 2). Three steps were used to examine the contribution of impulses to responses in the MGARCH(1,1). In the first step, for each equation in Table S2, the time series and break and regime impulse coefficients were tested for statistical significance (CI @ 0.95) in a GARCH(1,1) model. Second, for each equation, statistically significant coefficients on all impulses were entered simultaneously in a GARCH(1,1) model, and retained if statistically significant. Third, all significant coefficients were entered in a MGARCH(1,1) model, and retained if statistically significant.

The final results of the MGARCH(1.1) analysis are reported in Table S2.

Adjustment of estimated to observed response time series and volatility

Observed and estimated daily hospital referrals are plotted in Figure S2a. The estimated time series followed the general shape of the observed time series. Divergences were limited to small day-to-day variations. Hospital referrals were well predicted by daily deaths in the population aged 65 and over.

Arch and *garch* terms for volatility were not statistically significant for daily hospital referrals in the MGARCH(1,1) model. The null hypothesis of white noise in the residuals was not rejected (Table S2, Equation 1, Section D)). Phillips & Perron's test [1] rejected the null hypothesis of a unit root in the residuals (Table S2, Equation 1, Section E).

Observed and predicted values of daily deaths in LTCFs are plotted in Figure S2b. The two distributions showed few discrepancies, while daily variations were small. Volatilities for daily death in LTCFs were statistically significant (Table S2, Equation 2, section C). They were flat in the pre and post-COVID-19 periods, while peaked during the COVID-19 epidemic (Figure 6a), indicating uncertainties and disturbances in daily deaths in LTCFs.

Daily deaths in hospitals of LTCF residents were reproduced by the model (Figure S2c). More estimated, than observed, in-hospital deaths were obtained in the first week of the COVID-19 epidemic. Volatilities were statistically significant for daily deaths in hospitals of LTCF residents (Table S2, Equation 3, Section C). Small increases of volatility in the pre and post-COVID-19 periods were obtained suggesting a seasonal pattern not associated with the COVID-19 epidemic. In the COVID-19 period, volatilities occurred as surges on specific days. White-Noise and unit root tests behaved as expected (Table S2, Equation 3, Sections D, E).

**Table S2. MGARCH multivariate model
for hospital referrals, deaths within residences, and in hospitals**

	Coefficients	Standard Errors	P-levels	95% C.I.
<i>Equation 1: Daily hospital referrals</i>				
A) Response: Previous daily hospital referrals				
Lag(7)	0.432	0.063	0.000	0.309 0.554
Lag(12)	-0.239	0.053	0.000	-0.343 -0.136
B) Impulse: Daily deaths in the population 65+ in the CoM				
1. Time series coefficients				
Lag(5)	0.088	0.041	0.031	0.008 0.167
Lag(8)	-0.079	0.044	0.068	-0.165 0.006
Lag(10)	0.130	0.043	0.003	0.046 0.215
Lag(14)	0.125	0.041	0.002	0.045 0.206
Lag(16)	-0.105	0.035	0.003	-0.173 -0.036
2. Breaks and regime				
Shift:				
Mar27-2021	36.268	16.499	0.028	3.931 68.605
Pulses:				
Jan5/Feb29-2020	22.514	3.887	0.000	14.895 30.133
Mar01/Mar26-2020	33.561	6.672	0.000	20.483 46.638
Mar27/Apr26-2020	-85.436	22.599	0.000	-129.729 -41.143
Ramps:				
Mar01/Mar26-2020	-3.973	0.556	0.000	-5.062 -2.884
Mar27/Apr26-2020	2.998	0.802	0.000	1.426 4.571
3. Constant	1.481	3.182	0.642	-4.755 7.718
C) Volatility				
Constant	182.725	20.616	0.000	142.317 223.132
D) White-Noise tests				
Bartlett's B	0.680		0.740	
Portmanteau's Q	47.950		0.182	
E) Unit Root P&P test				
			> 0.000	

Equation 2: In-LTCF daily deaths

A) Response: Previous in-LTCF daily deaths

Lag(1)	0.151	0.069	0.029	0.016	0.286
Lag(2)	0.146	0.073	0.045	0.003	0.288
Lag(6)	0.152	0.063	0.016	0.028	0.276
Lag(9)	0.13	0.056	0.021	0.020	0.24
Lag(10)	-0.209	0.048	0.000	-0.303	-0.115

B) Impulses:

1. Daily deaths in the population 65+ in the CoM living in the community

a. Time series coefficients

Lag(0)	0.071	0.024	0.003	0.024	0.116
Lag(1)	0.064	0.023	0.004	0.02	0.110
Lag(3)	0.114	0.027	0.000	0.062	0.167
Lag(6)	0.080	0.027	0.003	0.027	0.133
Lag(8)	0.078	0.027	0.004	0.025	0.130
Lag(11)	0.060	0.026	0.020	0.009	0.110
Lag(12)	0.069	0.028	0.014	0.014	0.124

b. Breaks and regime

Pulse:

Jan05/Feb29-2020	-10.141	4.002	0.011	-17.984	-2.299
Apr27/May30-2020	-3.522	1.653	0.033	-6.762	-0.281

Ramps:

Jan05/Feb29-2020	0.168	0.073	0.013	0.025	0.31
------------------	-------	-------	-------	-------	------

2. Hospital referrals

a. Time series coefficients

Lag(3)	-0.056	0.027	0.035	-0.109	-0.004
Lag(4)	0.058	0.026	0.026	0.007	0.110
Lag(6)	-0.062	0.024	0.009	-0.109	-0.015

b. Breaks and regime

Ramp:

Apr01/27Jun-2020	-0.130	0.049	0.008	-0.269	-0.034
------------------	--------	-------	-------	--------	--------

3. Constant

	1.814	0.964	0.060	-0.074	3.702
--	-------	-------	-------	--------	-------

C) Volatility

Constant	1.555	1.151	0.177	-0.701	3.812
Arch(1)	0.233	0.079	0.003	0.077	0.388
Garch(1)	0.729	0.082	0.000	0.567	0.890

D) White-Noise tests

Bartlett's B	0.95	0.322
Portmanteau's Q	50.484	0.124

E) Unit Root P&P test

> 0.000

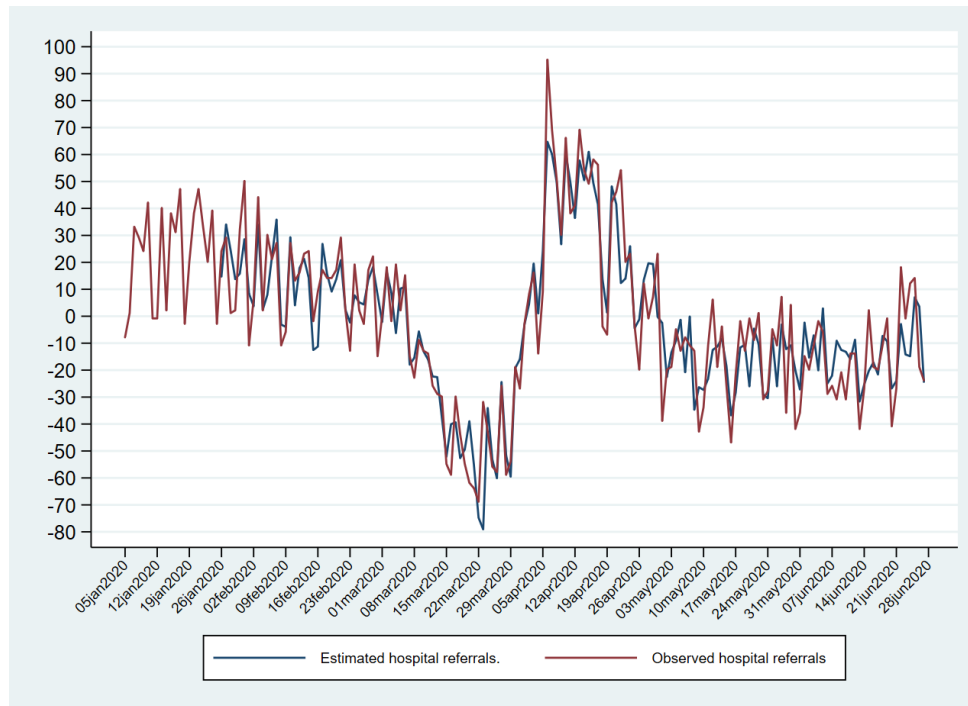
Equation 3: In-hospital daily deaths

A) Response: Previous in-hospital deaths	n.s.	n.s.	n.s.	n.s.	n.s.
B) Impulses:					
1. Daily deaths in the population 65+ in the CoM					
a. Lagged time series coefficients					
Lag(2)	0.146	0.017	0.000	0.113	0.180
Lag(15)	0.091	0.021	0.000	0.049	0.133
2. Hospital referrals					
a. Time series coefficients					
Lag(4)	-0.109	0.023	0.000	-0.154	-0.064
Lag(7)	0.054	0.027	0.045	0.001	0.107
Lag(14)	0.044	0.021	0.034	0.003	0.085
b. Breaks and regime					
Ramp :					
Mar05/Mar31-2020	-1.099	0.186	0.000	-1.463	-0.734
3. In-LTCF daily deaths					
a. Time series coefficients					
Lag(3)	-0.094	0.023	0.000	-0.140	-0.048
Lag(12)	0.141	0.021	0.000	0.100	0.183
b. Breaks and regime					
Pulse :					
Apr01/28-2020	-14.461	5.030	0.004	-24.319	-4.603
Ramp :					
Apr01/28-2020	0.792	0.228	0.001	0.344	1.239
4. Constant	1.688	0.794	0.033	0.133	3.244
C) Volatility					
Constant	0.802	0.226	0.000	0.359	1.246
Arch(1)	0.802	0.226	0.000	0.359	1.246
D) White-Noise tests					
Bartlett's B	0.750		0.620		
Portmanteau's Q	49.134		0.153		
E) Unit Root P&P test			> 0.000		

Correlations between predicted time series

Equations 1 and 2	0.245	0.079	0.002	0.090	0.400
Equations 1 and 3	0.015	0.087	0.861	-0.155	0.185
Equations 2 and 3	-0.091	0.082	0.266	-0.252	0.070

- **Figure S2.1 Adjustment of estimated response time series to observed time series**



- **FIG S2a. Observed and estimated number of daily hospital referrals**

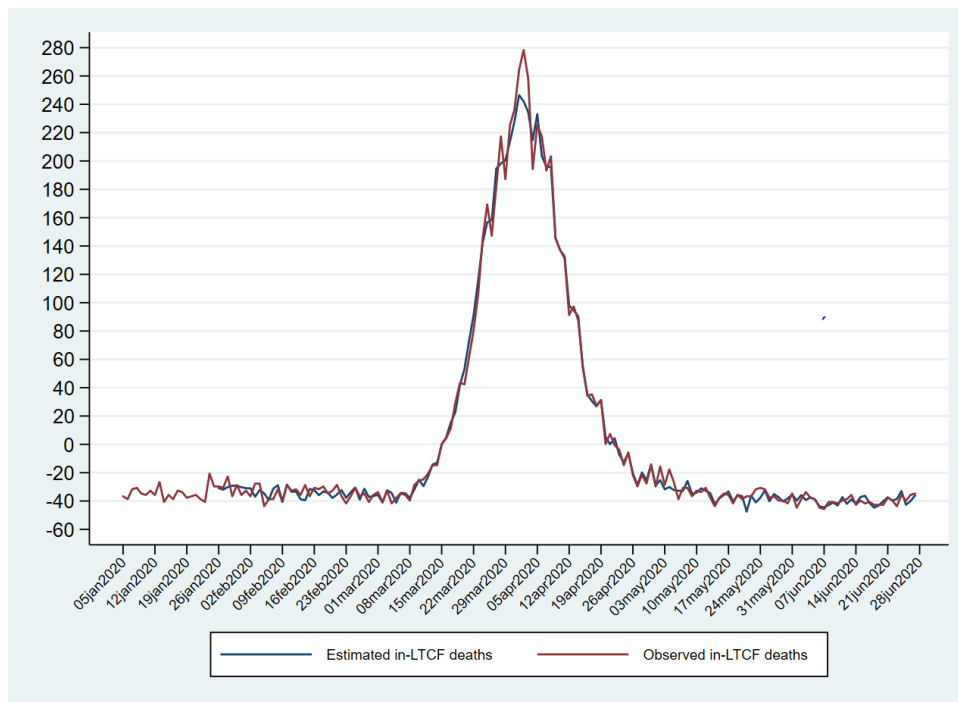


FIG S2b. Observed and estimated number of in-LTCF daily deaths

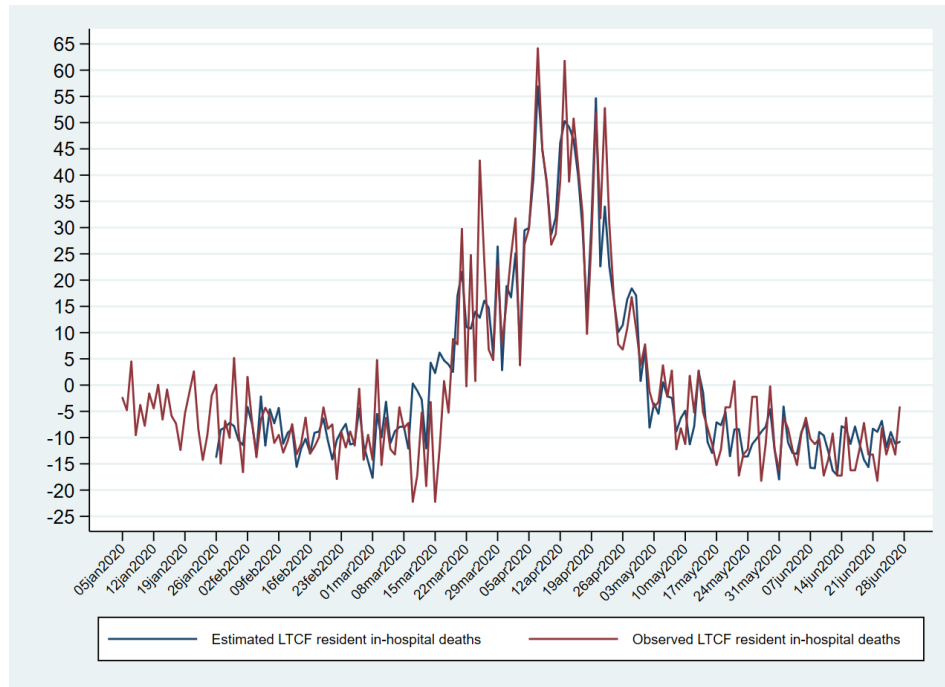


FIG S2c Observed and estimated numbers of LTCF residents' in-hospital daily deaths

Reference

1. Phillips P.C.B., Perron P., Unit root in time series_Cowles_1988. Biometrika. 1988;75:335–46.
2. Stata. Stata Press. 2017.