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## Stay-at-home policy: is it a case of exception fallacy? An internet-based ecological study — Source link

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## Title page

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17

18 **Abstract:**

19 **Background:** Countries with strict lockdown had a spike on the number of deaths. A recent  
20 mathematical model has suggested that staying at home did not play a dominant role in reducing  
21 COVID-19 transmission. Comparison between number of deaths and social mobility is difficult  
22 due to the non-stationary nature of the COVID-19 data.

23 **Objective:** To propose a novel approach to assess the association between staying at home  
24 values and the reduction/increase in the number of deaths due to COVID-19 in several regions  
25 around the world.

26 **Methods:** In this ecological study, data from [www.google.com/covid19/mobility/](http://www.google.com/covid19/mobility/),  
27 [ourworldindata.org](http://ourworldindata.org) and [covid.saude.gov.br](http://covid.saude.gov.br) were combined. Countries with >100 deaths and with  
28 a Healthcare Access and Quality Index of  $\geq 67$  were included. Data were preprocessed and  
29 analyzed using the difference between number of deaths/million between 2 regions and the  
30 difference between the percentage of staying at home. Analysis was performed using linear  
31 regression and residual analysis

32 **Results:** After preprocessing the data, 87 regions around the world were included, yielding 3,741  
33 pairwise comparisons for linear regression analysis. Only 63 (1.6%) comparisons were  
34 significant.

35 **Discussion:** With our results, we were not able to explain if COVID-19 mortality is reduced by  
36 staying as home in ~98% of the comparisons after epidemiological weeks 9 to 34.

37

## 38 Introduction

39 By late September, 2020, approximately one million people worldwide had died from the new  
40 coronavirus (COVID-19) (Coronavirus Update (Live): 13,578,330 Cases and 583,696 Deaths  
41 from COVID-19 Virus Pandemic - Worldometer). Wearing masks, taking personal precautions,  
42 testing for COVID-19 and social distancing have been advocated for controlling the pandemic  
43 (Huang and Chen 2020; Lin et al. 2020; Wu and Qi 2020). To achieve source control and stop  
44 transmission, social distancing has been interpreted by many as staying at home. Such policies  
45 across multiple jurisdictions were suggested by some experts (Guest et al. 2020). These measures  
46 were supported by the World Health Organization (WHO Director-General's opening remarks at  
47 the media briefing on COVID-19 - 13 April 2020), local authorities (Ministry of Housing,  
48 Communities and Local Government 2020; Mucientes and Carrasco 2020; Governor Cuomo  
49 Signs the "New York State on PAUSE" Executive Order 2020), and encouraged on social media  
50 platforms (Criativo; A Movement to Stop the COVID-19 Pandemic | #StayTheFuckHome,  
51 #[stayathome] (Brazilian twitter)).

52 Some mathematical models and meta-analyses have shown a marked reduction in COVID-19  
53 cases (Ambikapathy and Krishnamurthy 2020; Espinoza et al. 2020; Ibarra-Vega 2020; Liu et al.  
54 2020; Nussbaumer-Streit et al. 2020; Sjödin et al. 2020) and deaths (Ferguson et al. 2020;  
55 Semenova et al. 2020) associated with lockdown policies. Brazilian researchers have published  
56 mathematical models of spreading patterns (Peixoto et al. 2020) and suggested implementing  
57 social distancing measures and protection policies to control virus transmission (Aquino et al.  
58 2020). By May 5th, 2020, an early report, using number of curfew days in 49 countries, found  
59 evidence that lockdown could be used to suppress the spread of COVID-19 (Atalan 2020).  
60 Measures to address the COVID-19 pandemic with Non-Pharmacological Interventions (NPIs)  
61 were adopted after Brazil enacted Law No. 13979 (Imprensa Nacional), and this was followed by  
62 many states such as Rio de Janeiro (Decreto 46970 27/03/2020), the Federal District of Brasília  
63 (Decree No. 40520, dated March 14<sup>th</sup>, 2020) (Decreto 40520 de 14/03/2020), the city of São  
64 Paulo (Decree No. 59.283, dated March 16<sup>th</sup>, 2020) (Decreto 59283 2020 de São Paulo SP), and  
65 the State of Rio Grande do Sul (Decree No. 55240/2020, dated May 10<sup>th</sup>, 2020) (Decreto 55240  
66 de 10/05/2020). It was expected that, with these actions, the number of deaths by COVID-19  
67 would be reduced. Of note, the country's most populous state, São Paulo, adopted rigorous  
68 quarantine measures and put them into effect on March 24<sup>th</sup>, 2020 (Decreto 59283 2020 de São  
69 Paulo SP). Internationally, Peru adopted the world's strictest lockdown (Tegel 2020).

70 Recently, Google LLC published datasets indicating changes in mobility (compared to an  
71 average baseline before the COVID-19 pandemic). These reports were created with aggregated,  
72 anonymized sets of daily and dynamic data at country and sub-regional levels drawn from users  
73 who had enabled the Location History setting on their cell phones. These data reflect real-world  
74 changes in social behavior and provide information on mobility trends for places like grocery  
75 stores, pharmacies, parks, public transit stations, retail and recreation locations, residences, and  
76 workplaces, when compared to the baseline period prior to the pandemic (Google LLC).  
77 Mobility in places of residence provides information about the "time spent in residences", which  
78 we will hereafter call "staying at home" and use as a surrogate for measuring adherence to stay-  
79 at-home policies.

80 Studies using Google COVID-19 Community Mobility Reports and the daily number of new  
81 COVID-19 cases have shown that over 7 weeks a strong correlation between staying at home  
82 and the reduction of COVID-19 cases in 20 counties in the United States (Badr et al. 2020);  
83 COVID-19 cases decreased by 49% after 2 weeks of staying at home (Banerjee and Nayak

84 2020); the incidence of new cases/100,000 people was also reduced (Wang et al. 2020); social  
85 distancing policies were associated with reduction in COVID-19 spread in the US (Gao et al.  
86 2020); as well as in 49 countries around the world (Atalan 2020). A recent report using Brazilian  
87 and European data has shown a correlation between NPI stringency and the spread of COVID-19  
88 (Candido et al. 2020; Islam et al. 2020); these analyses are debatable, however, due to their short  
89 time span and the type of time series behavior (Bernal et al. 2017), or for their use of Pearson's  
90 correlation in the context of non-stationary time series (Gao et al. 2020). For instance, applying  
91 the same statistical analysis to stationary and non-stationary time series is not sufficient for  
92 statistical analysis (Nason 2006), and the latter is the case with this COVID-19 data. A 2020  
93 Cochrane systematic review of this topic reported that they were not completely certain about  
94 this evidence for several reasons. The COVID-19 studies based their models on limited data and  
95 made different assumptions about the virus (Nussbaumer-Streit et al. 2020); the stay-at-home  
96 variable was analyzed as a binary indicator (Sen et al. 2020); and the number of new cases could  
97 have been substantially undocumented (Li et al. 2020); all which may have biased the results. A  
98 sophisticated mathematical model based on a high-dimensional system of partial differential  
99 equations to represent disease spread has been proposed (Zamir et al. 2020). According to this  
100 model, staying at home did not play a dominant role in disease transmission, but the combination  
101 of these, together with the use of face masks, hand washing, early-case detection (PCR test), and  
102 the use of hand sanitizers for at least 50 days could have reduced the number of new cases.  
103 Finally, after 2 months, the simulations that drove the world to lockdown have been questioned  
104 (Boretti 2020).

105 After more than 25 epidemiological weeks of this pandemic, verifying if staying at home had an  
106 impact on mortality rates is of particular interest. A PUBMED search with the terms "COVID-  
107 19" AND (Mobility) (search made on September 8th, 2020) yielded 246 articles; of these, 35  
108 were relevant to mobility measures and COVID-19, but none compared mobility reduction to  
109 mortality rates.

110 We are looking for the association between two variables: deaths/million and the percentage of  
111 people who remained in their residences. Comparison, however, is difficult due to the non-  
112 stationary nature of the data. To overcome this problem, we proposed a novel approach to assess  
113 the association between staying at home values and the reduction/increase in the number of  
114 deaths due to COVID-19 in several regions around the world. If the variation in the difference  
115 between the number of deaths/million in two countries, say A and B, and the variation in the  
116 difference of the staying at home values between A and B present similar patterns, this is due to  
117 an association between the two variables. In contrast, if these patterns are very different, this is  
118 evidence that staying at home values and the number of deaths/million are not related (unless, of  
119 course, other unaccounted for factors are at play).

## 120 **Material and methods**

121

### 122 **Study design**

123 This is an ecological study using data available on the Internet.

124

### 125 **Setting - Data collection on mobility**

126 Google COVID-19 Community Mobility Reports provided data on mobility from 138 countries  
127 and regions (Coronavirus Source Data 2020, Coronavírus Brasil) between February 15<sup>th</sup> and  
128 August 21<sup>st</sup>, 2020.(Google LLC) Data regarding the average times spent at home was generated

129 in comparison to the baseline. Baseline was considered to be the median value from between  
130 January 3<sup>rd</sup> and February 6<sup>th</sup>, 2020. Data obtained between February 15<sup>th</sup> and August 21<sup>th</sup> 2020  
131 was divided into epidemiological weeks (epi-weeks) and the mean percentage of time spent  
132 staying at home per week was obtained.

### 133 **Data collection on mortality**

134 Numbers of daily deaths from selected regions were obtained from open databases (Coronavirus  
135 Source Data 2020, Coronavírus Brasil) on August 27<sup>st</sup>, 2020.

### 136 **Inclusion criteria for analysis**

137 Only regions with mobility data and with more than 100 deaths, by August 26th, 2020, were  
138 included in this study. For data quality, only countries with Healthcare Access and Quality  
139 Index (HAQI) of  $\geq 67$  were included.(Barber et al. 2017) By choosing a HAQI of  $\geq 67$ , we  
140 assumed that data from these countries were reliable and healthcare was of high quality. For  
141 Brazilian regions, a HAQI was substituted for the Human Development Index (HDI), and those  
142 with  $<0.549$  (low) were excluded.

143 Three major cities with  $>100$  deaths and well-established results (Tokyo, Japan; Berlin,  
144 Germany, and New York, USA) were selected as controlled areas.

### 145 **Dataset of COVID-19 cases and associated data**

146 After inclusion of the countries/regions, further data were obtained to reduce comparison bias,  
147 including population density (population/km<sup>2</sup>), percentage of the urban population, HDI, and the  
148 total area of the region in square kilometers. All data were obtained from open databases.(2019  
149 Human Development Index Ranking, [Cities and States Statistics], Population by Country (2020  
150 - Worldometer)

### 151 **Classification of areas with COVID-19**

152 Regions were classified as controlled for cases of COVID-19 if they present at least two out of  
153 the three following conditions: **a**) type of transmission classified as “clusters of cases”, **b**) a  
154 downward curve of newly reported deaths in the last seven days, and **c**) a flat curve in the  
155 cumulative total number of deaths in the last seven days (variation of 5%) according to the  
156 World Health Organization.(WHO Coronavirus Disease (COVID-19) Dashboard) An example is  
157 shown in Figure S3 (supplement).

158 Data from the cities (Tokyo, Berlin, New York, Fortaleza, Belo Horizonte, Manaus, Rio de  
159 Janeiro, São Paulo, and Porto Alegre) were obtained from official government sites.(Population  
160 of Tokyo - Tokyo Metropolitan Government, Berlin, COVID-19:Data, Planning-Population-  
161 Census 2010-DCP) Tokyo, Berlin and New York were chosen for having controlled the COVID-  
162 19 dissemination, for representing three different continents, and for similarity to major Brazilian  
163 cities (Fortaleza, Belo Horizonte, Manaus, Rio de Janeiro, São Paulo, and Porto Alegre).

### 164 **Merged database**

165 Different databases from the sites mentioned above were merged using Microsoft Excel Power  
166 Query (Microsoft Office 2010 for Windows Version 14.0.7232.5000) and manually inspected for  
167 consistency.

### 168 **Processing the data - cleaning**

169 Data collected from multiple regions were processed using Python 3.7.3 in the Jupyter Notebook  
170 environment through the use of the Python Data Analysis Library in Google Colab Research.

171 Details of preprocessing are described in Python script (Supplemental material). Briefly, after  
172 taking the sum of deaths/million per epi-week, and the average of the variable “staying at home”  
173 per epi-week, non-stationary patterns were mitigated by subtracting  $week_t$  by  $week_{t-1}$ .

#### 174 **Time series data setup and variables**

175 Details regarding the pre-processing and methodological details were presented on the *approach*  
176 *for analyzing the time series data*. Our variables were the difference in the variation of deaths  
177 between locations A and B (dependent variable - outcome), and the difference in the variation of  
178 staying at home values between the same location (independent variable).

#### 179 **Comparison between areas**

180 Direct comparison, between regions with and without controlled COVID-19 cases, was  
181 considered in two scenarios: 1) Restrictive if, at least three out of four of the following  
182 conditions were similar: a) population density, b) percentage of the urban population, c) HDI and  
183 d) total area of the region. Similarity was considered adequate when a variation in conditions a),  
184 b), and c) was within 30%, while, for condition d), a variation of 50% was considered adequate.  
185 2) Global: all regions and countries were compared to each other.

#### 186 **Statistical analysis**

##### 187 *Rationale*

188 Time series on COVID-19 mortality (deaths/millions) display a non-stationary pattern. The daily  
189 data present a very distinct seasonal behavior on the weekends, with valleys on Saturdays and  
190 Sundays followed by peaks on Mondays (Figure S1)

191 To make it stationary, one may introduce dummy variables for Saturdays, Sundays, and  
192 Mondays, regress the number of deaths in these dummy variables, and then analyze the residuals.  
193 However, in most cases, the residuals are still non-stationary time series, and special treatment  
194 would be required in each case. Although this approach may be feasible for a few series, we are  
195 interested in analyzing hundreds of time series from different countries and regions. Hence, we  
196 need a more efficient way to deal with this amount of data. The covariates present another issue  
197 in regressing the daily time series of deaths/staying at home. The covariates are typically  
198 correlated with error terms due to public policies adopted by regions/countries. Mechanisms  
199 controlling social isolation are intrinsically related to the number of deaths/cases in each  
200 location. An increase in the death rate may cause more stringent policies to be adopted, which  
201 increases the percentage of people staying at home. This change causes an imbalance between  
202 the observed number of deaths and staying at home levels. In a regression model, this  
203 discrepancy is accounted for in the error term. Hence, the error term will change in accordance  
204 with staying at home levels.

##### 205 *Approach for analyzing the time series data*

206 Data aggregation by epidemiological week is a plausible alternative (Figure S2). In this way,  
207 artificial seasonality, imposed by work scheduled during weekends and the effect of  
208 governmental control over social interaction, in a regression framework, are mitigated. The  
209 drawback is that the sample size is significantly reduced from 187 days (Figure S1) to 26  
210 epidemiological weeks (Figure S2).

211 Aggregation by epidemiological week, however, still yields non-stationary time series in most  
212 cases. To overcome this problem, we differentiated each time series. Recall that if  $Z_t$  denotes the  
213 number of deaths in the  $t$ -th epidemiological week, we define the first difference of  $Z_t$  as



214

$$\Delta Z_t = Z_t - Z_{t-1}.$$

215 Intuitively,  $\Delta Z_t$  denotes the variation of deaths between weeks  $t$  and  $t-1$ , also known as the flux  
216 of deaths. The same is valid for the staying at home time series. This simple operation yielded, in  
217 most cases, stationary time series, and verified with the so-called Phillips-Perron stationarity test  
218 (Perron 1988). In the few cases where the resulting time series did not reject the null hypothesis  
219 of non-stationarity (technically, the existence of a unitary root, in the time series characteristic),  
220 this was due to the presence of one or two outliers combined with the small sample size. These  
221 outliers were usually related to the very low incidence of COVID-19 deaths by the 9<sup>th</sup>  
222 epidemiological week when paired with countries with a significant number of deaths in that  
223 same week, thus resulting in an outlier which cannot be accounted for by linear  
224 regression.(Perron 1988)

225 To investigate pairwise behavior, we propose a method to assess the relationship between deaths  
226 and staying at home data between various countries and regions. For two countries/regions, say  
227 A and B, let  $Y_t^A$  and  $Y_t^B$  denote the number of deaths per million at epidemiological week  $t$  for  
228 country A and B respectively, while  $X_t^A$  and  $X_t^B$  denote the staying at home at epidemiological  
229 week  $t$  for A and B, respectively. The idea is to regress the difference  $\Delta Y_t^A - \Delta Y_t^B = \Delta(Y_t^A -$   
230  $Y_t^B)$  on  $\Delta X_t^A - \Delta X_t^B = \Delta(X_t^A - X_t^B)$ . Formally, we perform the regression

$$\Delta(Y_t^A - Y_t^B) = \beta_0 + \beta_1 \Delta(X_t^A - X_t^B) + \varepsilon_t,$$

231 where  $\beta_0$  and  $\beta_1$  are unknown coefficients and  $\varepsilon_t$  denotes an error term. Estimation of  $\beta_0$  and  $\beta_1$  is  
232 carried out through ordinary least squares. The interpretation of the model is important. We are  
233 regressing the difference in the variation of deaths between locations A and B into the difference  
234 in the variation of staying at home values between the same location.

235 If the number of deaths in locations A and B have a similar functional behavior over time, then  
236  $Y_t^A - Y_t^B$  tends to be near-constant, and  $\Delta(Y_t^A - Y_t^B)$  tends to oscillate around zero. If the same  
237 applies to  $\Delta(X_t^A - X_t^B)$ , then we expect  $\beta_1 \neq 0$ ; consequently, we conclude that the behavior,  
238 between A and B, is similar and the number of deaths and the percentage of staying at home are  
239 associated in these regions. The other non-spurious situation implying  $\beta_1 \neq 0$  occurs when the  
240 variation in the number of deaths in locations A and B increases/decreases over time following a  
241 certain pattern, while the variation in the percentage of “staying at home” values also  
242 increases/decreases following the same pattern (apart from the direction). In this situation, we  
243 found different epidemiological patterns as in the variation in the number of deaths, and in the  
244 staying at home values, in locations A and B were on opposite trends. However, if these patterns  
245 were similar (proportional), this would be captured in the difference and, as a consequence, in  
246 the regression. This means that the different trends were near proportional and, hence, the  
247 variation in staying at home is associated with the variation in deaths.

248 The proposed approach presents a way to evaluate staying at home and the number of deaths  
249 between two countries/regions. In the section below “Definition of areas with and without  
250 controlled cases of COVID-19”, each country/region was classified into a binary class: either  
251 controlled or not controlled areas for COVID-19. The proposed method allows for insights  
252 regarding the association of the number of deaths and staying at home levels between  
253 countries/regions with similar/different degrees of COVID-19 control.

254 Estimation of  $\beta_0$  and  $\beta_1$  is carried out through ordinary least squares. Assumptions related to  
255 consistency, efficiency, and asymptotic normality of the ordinary least squares, in the context of  
256 time series regression, can be found in Greene, 2012 (Greene 2012). Since we are comparing  
257 many time series, to avoid any problem with spurious regression, we performed a cointegration



258 test between the response and covariates. In this context, this is equivalent to testing the  
259 stationarity of  $\varepsilon_t$ , which was done by performing the Phillips-Perron test. Residual analysis is of  
260 utmost importance in linear regression, especially in the context of small samples. The steps and  
261 tests performed in the residual analysis are described in the statistical analysis section.

262 After data preprocessing, the association between the number of deaths and staying at home was  
263 verified using a linear regression approach. Data were analyzed using the Python model  
264 statsmodels.api v0.12.0 (statsmodels.regression.linear\_model.OLS; statsmodels.org), and  
265 double-checked using R version 3.6.1. False Discovery Rate proposed by Benjamini-Hochberg  
266 (FDR-BH) was used for multiple testing.

267 We checked the residuals for heteroskedasticity using White's test; for the presence of  
268 autocorrelation using the Lagrange Multiplier test; for normality using the Shapiro-Wilk's  
269 normality test; and for functional specification using the Ramsey's RESET test. All tests were  
270 performed with a 0.05 significance level and the analysis was performed with R version 3.6.1.

271 Data from 30 restrictive comparisons were manually inspected and checked a third time using  
272 Microsoft Excel (Microsoft). A heat map was designed using GraphPad Prism version 8.4.3 for  
273 Mac (GraphPad Software, San Diego, California, USA). Graphs plotting the number of  
274 deaths/million and staying at home over epidemiological weeks were obtained from Google  
275 Sheets.

## 276 **Results**

277 A flowchart of the data manipulation is depicted in Figure 1. Briefly, Google COVID-19  
278 Community Mobility Report data between February 16<sup>th</sup> and August 21<sup>st</sup>, 2020, yielded 138  
279 separate countries and their regions. The website Our World in Data provided data on 212  
280 countries (between December 31<sup>st</sup>, 2019, and August 26<sup>th</sup>, 2020), and the Brazilian Health  
281 Ministry website provided data on all states (n=27) and cities (n=5,570) in Brazil (February 25<sup>th</sup>  
282 to August 26<sup>th</sup>, 2020).

283 After data compilation, a total of 87 regions and countries were selected: 51 countries, 27 States  
284 in Brazil, six major Brazilian State capitals [Manaus, Amazonas (AM), Fortaleza, Ceará (CE),  
285 Belo Horizonte, Minas Gerais (MG), Rio de Janeiro, Rio de Janeiro (RJ), São Paulo, São Paulo  
286 (SP) and Porto Alegre, Rio Grande do Sul (RS)], and three major cities throughout the world  
287 (Tokyo, Berlin and New York) (Figure 1).

288 Characteristics of these 87 regions are presented in Table 1 (further details are in [Supplemental](#)  
289 [Material - Characteristics of Regions](#)).

290

## 291 **Comparisons**

292 The restrictive analysis between controlled and not controlled areas yielded 33 appropriate  
293 comparisons, as shown in Table 2. Only one comparison out of 33 (3%) - state of Roraima  
294 (Brazil) versus state of Rondonia (Brazil) - was significant (p-value = 0.04). After correction for  
295 residual analysis, it did not pass the autocorrelation test (Lagrange Multiplier test=0.04). (Further  
296 details are in [Supplemental Material - Restrictive Analysis](#)).

297 The global comparison yielded 3,741 combinations; from these, 184 (4.9%) had a p-value <  
298 0.05, after correcting for False Discovery Rate (Table S3). After performing the residual  
299 analysis, by testing for cointegration between response and covariate, normality of the residuals,  
300 presence of residual autocorrelation, homoscedasticity, and functional specification, only 63  
301 (1.6%) of models passed all tests (Table S4). Closer inspection of several cases where the model

302 did not pass all the tests revealed a common factor: the presence of outliers, mostly due to  
303 differences in the epidemiological week in which deaths started to be reported. A heat map  
304 showing the comparison between the 87 regions is presented in Figure 2.

## 305 **Discussion**

306 We were not able to explain the variation of deaths/million in different regions in the world by  
307 social isolation, herein analyzed as differences in staying at home, compared to baseline. In the  
308 restrictive and global comparisons, only 3% and 1.6% of the comparisons were significantly  
309 different, respectively. These findings are in accordance with those found by Klein et al. (Klein  
310 et al.). These authors explain why lockdown was the least probable cause for Sweden's high  
311 death rate from COVID-19 (Klein et al.). Likewise, Chaudry et al. made a country-level  
312 exploratory analysis, using a variety of socioeconomic and health-related characteristics, similar  
313 to what we have done here, and reported that full lockdowns and wide-spread testing were not  
314 associated with COVID-19 mortality per million people (Chaudhry et al. 2020). Different from  
315 Chaudry et al., in our dataset, after 25 epidemiological weeks, (counting from the 9<sup>th</sup>  
316 epidemiological week onwards in 2020) we included regions and countries with a "plateau" and  
317 a downslope phase in their epidemiological curves. Our findings are in accordance with the  
318 dataset of daily confirmed COVID-19 deaths/million in the UK. Pubs, restaurants, and  
319 barbershops were open in Ireland on June 29<sup>th</sup> and masks were not mandatory (Therese 2020);  
320 after more than 2 months, no spike was observed; indeed, death rates kept falling (Daily  
321 confirmed COVID-19 deaths per million, rolling 7-day average). Peru has been considered to be  
322 the most strict lockdown country in the world (Tegel 2020), nevertheless, by September 20<sup>th</sup>, it  
323 had the highest number of deaths/million (Coronavirus Update (Live): 31,036,957 Cases and  
324 962,339 Deaths from COVID-19 Virus Pandemic - Worldometer). Of note, differences were  
325 also observed between regions that were considered to be COVID-19 controlled, e.g., Sweden  
326 versus Macedonia. Possible explanations for these significant differences may be related to the  
327 magnitude of deaths in these countries.

328 Our results are different from those published by Flaxman et al. These authors calculated that  
329 NPIs would prevent 3.1 million deaths across 11 European countries (Flaxman et al. 2020). The  
330 discrepant results can be explained by different approaches to the data. While Flaxman et al.  
331 assumed a constant reproduction number ( $R_t$ ) to calculate the total number of deaths, which  
332 eventually did not occur, we calculated the difference between the actual number of deaths  
333 between 2 countries/regions. The same explanation for the discrepancy can be applied to other  
334 publications where mathematical models were created to predict outcomes (Ambikapathy and  
335 Krishnamurthy 2020; Ibarra-Vega 2020; Liu et al. 2020; Nussbaumer-Streit et al. 2020; Sjödin et  
336 al. 2020). Most of these studies dealt with COVID-19 cases (Banerjee and Nayak 2020; Wang et  
337 al. 2020) and not observed deaths. Despite its limitations, reported deaths are likely to be more  
338 reliable than new case data. Further explanations for different results in the literature, besides  
339 methodological aspects, could be explained by the complexity of the virus dynamic and its  
340 interaction with the environment. It is unwise to try to explain a complex and multifactorial  
341 condition, with the inherent constant changes, using a single variable. An initial approach would  
342 employ a linear regression to verify the influence of one factor over an outcome. Herein we were  
343 not able to identify this association.

344 This study has limitations. Different from the established paradigm of randomized clinical trial,  
345 this is an ecological study. An ecological study observes findings at the population level and  
346 generates hypotheses (Pearce 2000). Population-level studies play an essential part in defining  
347 the most important public health problems to be tackled (Pearce 2000), which is the case here.

348 Another limitation was the use of Google Community Mobility Reports as a surrogate marker for  
349 staying at home. This may underestimate the real value: for instance, if a user's cell phone is  
350 switched off while at home, the observation will be absent from the database. Furthermore, the  
351 sample does not represent 100% of the population. This tool, nevertheless, has been used by  
352 other authors to demonstrate the efficacy in reducing the number of new cases after NPI (Delen  
353 et al. 2020; Vokó and Pitter 2020). Using different methodologies for measuring mobility may  
354 introduce bias and would prevent comparisons between different countries. The number of  
355 deaths may be another issue. Death figures may be underestimated, however, reported deaths  
356 may be more relevant than new case data. The arbitrary criteria used for including countries and  
357 regions, the restrictive comparisons, and our definition of an area as COVID-19 controlled are  
358 open for criticism. Nonetheless, these arbitrary criteria were created a priori to the selection of  
359 the countries. With these criteria, we expected to obtain representative regions of the world,  
360 compare similar regions, and obtain accurate data. By using a HAQI of  $\geq 67$ , we assumed that  
361 data from these countries would be accurate, reliable, and health conditions were generally good.  
362 Nevertheless, the global analysis of the regions ( $n = 3741$  comparisons) overcame any issue of  
363 the restrictive comparison. Indeed, the global comparison confirmed the results found in the  
364 restrictive one; only 1.6% of the death rates could be explained by staying at home. Also, our  
365 effective sample size in all studies is only 25 epidemiological weeks, which is a very small  
366 sample size for a time series regression. The small sample size and the non-stationary nature of  
367 COVID-19 data are challenges for statistical models, but our analysis, with 25 epidemiological  
368 weeks, is relatively larger than previous publications which used only 7 weeks (Ghosal et al.  
369 2020). The effects of small samples in this case are related to possible large type II errors and  
370 also affect the consistency of the ordinary least square estimates. Nevertheless, given the  
371 importance of social isolation promoted by world authorities (COVID-19 advice - Physical  
372 distancing), we expected a higher incidence of significant comparisons, even though it could be  
373 an ecological fallacy. The low number of significant associations between regions for mortality  
374 rate and the percentage of staying at home may be a case of exception fallacy, which is a  
375 generalization of individual characteristics applied at the group-level characteristics (Miller and  
376 Brewer 2003).

377 There are strengths to highlight. Inclusion criteria and the Healthcare Access and Quality Index  
378 were incorporated. We obtained representative regions throughout the world, including major  
379 cities from 4 different continents. Special attention was given to compiling and analyzing the  
380 dataset. We also devised a tailored approach to deal with challenges presented by the data. To  
381 our knowledge, our modeling approach is unique in pooling information from multiple countries  
382 all at once using up-to-date data. Some criteria, such as population density, percentage of urban  
383 population, HDI, and HAQI, were established to compare similar regions. Finally, we gave  
384 special attention to the residual analysis in the linear regression, an absolutely essential aspect of  
385 studies using small samples.

386 In conclusion, using this methodology and current data, in ~98% of the comparisons using 87  
387 different regions of the world we found no evidence that the number of deaths/million is reduced  
388 by staying at home. Regional differences in treatment methods and the natural course of the virus  
389 may also be major factors in this pandemic, and further studies are necessary to better understand  
390 it.

### 391 **Supplemental Material:**

392 The Python and R scripts are available at  
393 <https://gist.github.com/rsavaris66/eccfc6caf4c9578d676c134fac74d3fe>

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More supplemental material , including raw data, is available at this  
<https://drive.google.com/drive/folders/1239llmxz9YenWweWXA1wgdF07WFYDrYG>

## 398 **References**

- 399 [2019 Human Development Index Ranking. Available: http://hdr.undp.org/en/content/2019-](http://hdr.undp.org/en/content/2019-human-development-index-ranking)  
400 [human-development-index-ranking](http://hdr.undp.org/en/content/2019-human-development-index-ranking) [accessed 19 August 2020].
- 401 Ambikapathy B, Krishnamurthy K. 2020. Mathematical Modelling to Assess the Impact of  
402 Lockdown on COVID-19 Transmission in India: Model Development and Validation. *JMIR*  
403 *Public Health Surveill* 6: e19368.
- 404 A Movement to Stop the COVID-19 Pandemic | #StayTheFuckHome. #StayTheFuckHome.  
405 Available: <https://staythefuckhome.com/> [accessed 15 July 2020].
- 406 Aquino EML, Silveira IH, Pescarini JM, Aquino R, Souza-Filho JA de, Rocha A dos S, et al.  
407 2020. Social distancing measures to control the COVID-19 pandemic: potential impacts and  
408 challenges in Brazil. *Cien Saude Colet* 25: 2423–2446.
- 409 Atalan A. 2020. Is the lockdown important to prevent the COVID-9 pandemic? Effects on  
410 psychology, environment and economy-perspective. *Ann Med Surg (Lond)* 56: 38–42.
- 411 Badr HS, Du H, Marshall M, Dong E, Squire MM, Gardner LM. 2020. Association between  
412 mobility patterns and COVID-19 transmission in the USA: a mathematical modelling study.  
413 *Lancet Infect Dis*; doi:10.1016/S1473-3099(20)30553-3.
- 414 Banerjee T, Nayak A. 2020. U.S. county level analysis to determine If social distancing slowed  
415 the spread of COVID-19. *Rev Panam Salud Publica* 44: e90.
- 416 Barber RM, Fullman N, Sorensen RJD, Bollyky T, McKee M, Nolte E, et al. 2017. Healthcare  
417 Access and Quality Index based on mortality from causes amenable to personal health care  
418 in 195 countries and territories, 1990–2015: a novel analysis from the Global Burden of  
419 Disease Study 2015. *Lancet* 390: 231–266.
- 420 Berlin. Available: [https://www.citypopulation.de/en/germany/berlin/berlin/11000000\\_\\_berlin/](https://www.citypopulation.de/en/germany/berlin/berlin/11000000__berlin/)  
421 [accessed 26 August 2020].
- 422 Bernal JL, Cummins S, Gasparrini A. 2017. Interrupted time series regression for the evaluation  
423 of public health interventions: a tutorial. *Int J Epidemiol* 46: 348–355.
- 424 Boretti A. 2020. After Less Than 2 Months, the Simulations That Drove the World to Strict  
425 Lockdown Appear to be Wrong, the Same of the Policies They Generated. *Health Serv Res*  
426 *Manag Epidemiol* 7: 2333392820932324.
- 427 Candido DS, Claro IM, de Jesus JG, Souza WM, Moreira FRR, Dellicour S, et al. 2020.  
428 Evolution and epidemic spread of SARS-CoV-2 in Brazil. *Science*;  
429 doi:10.1126/science.abd2161.
- 430 Chaudhry R, Dranitsaris G, Mubashir T, Bartoszko J, Riazi S. 2020. A country level analysis

- 431 measuring the impact of government actions, country preparedness and socioeconomic  
432 factors on COVID-19 mortality and related health outcomes. *EClinicalMedicine* 25: 100464.
- 433 [Cities and States Statistics]. Instituto Brasileiro de Geografia e Estatística. Available:  
434 <https://www.ibge.gov.br/cidades-e-estados> [accessed 24 August 2020].
- 435 Coronavírus Brasil. Available: <https://covid.saude.gov.br/> [accessed 15 July 2020].
- 436 Coronavirus Source Data. 2020. Our World in Data. Available:  
437 <https://ourworldindata.org/coronavirus-source-data> [accessed 17 September 2020].
- 438 Coronavirus Update (Live): 13,578,330 Cases and 583,696 Deaths from COVID-19 Virus  
439 Pandemic - Worldometer. Worldometers. Available:  
440 <https://www.worldometers.info/coronavirus/#countries> [accessed 15 July 2020].
- 441 Coronavirus Update (Live): 31,036,957 Cases and 962,339 Deaths from COVID-19 Virus  
442 Pandemic - Worldometer. Available: <https://www.worldometers.info/coronavirus/#countries>  
443 [accessed 20 September 2020].
- 444 COVID-19 advice - Physical distancing. Available:  
445 <https://www.who.int/westernpacific/emergencies/covid-19/information/physical-distancing>  
446 [accessed 20 September 2020].
- 447 COVID-19:Data. nychealth/coronavirus-data. Available:  
448 <https://github.com/nychealth/coronavirus-data> [accessed 26 August 2020].
- 449 Criativo A. #stayathome. #stayathome. Available: <https://www.stayathome.world/> [accessed 15  
450 July 2020].
- 451 Daily confirmed COVID-19 deaths per million, rolling 7-day average. Available:  
452 <https://ourworldindata.org/grapher/daily-covid-deaths-per-million-7-day-average> [accessed  
453 10 September 2020].
- 454 Decreto 40520 de 14/03/2020. Available:  
455 [http://www.sinj.df.gov.br/sinj/Norma/ed3d931f353d4503bd35b9b34fe747f2/Decreto\\_40520\\_14\\_03\\_2020.html](http://www.sinj.df.gov.br/sinj/Norma/ed3d931f353d4503bd35b9b34fe747f2/Decreto_40520_14_03_2020.html) [accessed 8 September 2020].
- 457 Decreto 46970 27/03/2020. [www.fazenda.rj.gov.br](http://www.fazenda.rj.gov.br). Available:  
458 [http://www.fazenda.rj.gov.br/sefaz/content/conn/UCMServer/path/Contribution%20Folders/site\\_fazenda/Subportais/PortalGestaoPessoas/Legisla%C3%A7%C3%B5es%20SILEP/Legisla%C3%A7%C3%B5es/2020/Decretos/DECRETO%20N%C2%BA%2046.970%20DE%2013%20DE%20MAR%C3%87O%20DE%202020\\_MEDIDAS%20TEMPOR%C3%81RIAS%20PREVEN%C3%87%C3%83O%20CORONAV%C3%8DRUS.pdf?lve](http://www.fazenda.rj.gov.br/sefaz/content/conn/UCMServer/path/Contribution%20Folders/site_fazenda/Subportais/PortalGestaoPessoas/Legisla%C3%A7%C3%B5es%20SILEP/Legisla%C3%A7%C3%B5es/2020/Decretos/DECRETO%20N%C2%BA%2046.970%20DE%2013%20DE%20MAR%C3%87O%20DE%202020_MEDIDAS%20TEMPOR%C3%81RIAS%20PREVEN%C3%87%C3%83O%20CORONAV%C3%8DRUS.pdf?lve) [accessed 26  
462 March 2020].
- 464 Decreto 55240 de 10/05/2020. Available:  
465 <https://www.pge.rs.gov.br/upload/arquivos/202009/02110103-decreto-55240.pdf> [accessed  
466 8 September 2020].
- 467 Decreto 59283 2020 de São Paulo SP. Available: <https://leismunicipais.com.br/a/sp/s/sao-paulo/decreto/2020/5929/59283/decreto-n-59283-2020-declara-situacao-de-emergencia-no->  
468



- 469 município-de-sao-paulo-e-definiroutras-medidas-para-o-enfrentamento-da-pandemia-  
470 decorrente-do-coronavirus [accessed 8 September 2020].
- 471 Delen D, Eryarsoy E, Davazdahemami B. 2020. No Place Like Home: Cross-National Data  
472 Analysis of the Efficacy of Social Distancing During the COVID-19 Pandemic. *JMIR*  
473 *Public Health Surveill* 6: e19862.
- 474 Espinoza B, Castillo-Chavez C, Perrings C. 2020. Mobility restrictions for the control of  
475 epidemics: When do they work? *PLoS One* 15: e0235731.
- 476 Ferguson N, Nedjati Gilani G, Laydon D. 2020. COVID-19 CovidSim microsimulation model.  
477 [www.imperial.ac.uk](http://www.imperial.ac.uk). Available: <https://spiral.imperial.ac.uk/handle/10044/1/79647>  
478 [accessed 20 September 2020].
- 479 Flaxman S, Mishra S, Gandy A, Unwin HJT, Mellan TA, Coupland H, et al. 2020. Estimating  
480 the effects of non-pharmaceutical interventions on COVID-19 in Europe. *Nature* 584: 257–  
481 261.
- 482 Gao S, Rao J, Kang Y, Liang Y, Kruse J, Dopfer D, et al. 2020. Association of Mobile Phone  
483 Location Data Indications of Travel and Stay-at-Home Mandates With COVID-19 Infection  
484 Rates in the US. *JAMA Netw Open* 3: e2020485.
- 485 Ghosal S, Bhattacharyya R, Majumder M. 2020. Impact of complete lockdown on total infection  
486 and death rates: A hierarchical cluster analysis. *Diabetes Metab Syndr* 14: 707–711.
- 487 Google LLC. Google COVID-19 Community Mobility Reports.
- 488 Governor Cuomo Signs the “New York State on PAUSE” Executive Order. 2020. Governor  
489 Andrew M Cuomo. Available: [https://www.governor.ny.gov/news/governor-cuomo-signs-  
490 new-york-state-pause-executive-order](https://www.governor.ny.gov/news/governor-cuomo-signs-new-york-state-pause-executive-order) [accessed 15 July 2020].
- 491 Greene WH. 2012. *Econometric Analysis*.
- 492 Guest JL, Del Rio C, Sanchez T. 2020. The Three Steps Needed to End the COVID-19  
493 Pandemic: Bold Public Health Leadership, Rapid Innovations, and Courageous Political  
494 Will. *JMIR Public Health Surveill* 6: e19043.
- 495 Huang W-T, Chen Y-Y. 2020. [The War Against the Coronavirus Disease (COVID-2019): Keys  
496 to Successfully Defending Taiwan]. *Hu Li Za Zhi* 67: 75–83.
- 497 Ibarra-Vega D. 2020. Lockdown, one, two, none, or smart. Modeling containing covid-19  
498 infection. *A conceptual model. Sci Total Environ* 730: 138917.
- 499 Imprensa Nacional. LEI N° 13.979, DE 6 DE FEVEREIRO DE 2020 - LEI N° 13.979, DE 6 DE  
500 FEVEREIRO DE 2020 - DOU - Imprensa Nacional. Available:  
501 <https://www.in.gov.br/en/web/dou/-/lei-n-13.979-de-6-de-fevereiro-de-2020-242078735>  
502 [accessed 8 September 2020].
- 503 Islam N, Sharp SJ, Chowell G, Shabnam S, Kawachi I, Lacey B, et al. 2020. Physical distancing  
504 interventions and incidence of coronavirus disease 2019: natural experiment in 149  
505 countries. *BMJ* 370; doi:10.1136/bmj.m2743.



- 506 Klein DB, Book J, Bjørnskov C. 16 Possible Factors for Sweden's High COVID Death Rate  
507 among the Nordics. SSRN Electronic Journal; doi:10.2139/ssrn.3674138.
- 508 Lin C, Braund WE, Auerbach J, Chou J-H, Teng J-H, Tu P, et al. 2020. Policy Decisions and  
509 Use of Information Technology to Fight COVID-19, Taiwan. *Emerg Infect Dis* 26: 1506–  
510 1512.
- 511 Li R, Pei S, Chen B, Song Y, Zhang T, Yang W, et al. 2020. Substantial undocumented infection  
512 facilitates the rapid dissemination of novel coronavirus (COVID-19). medRxiv;  
513 doi:10.1101/2020.02.14.20023127.
- 514 Liu Z, Huang S, Lu W, Su Z, Yin X, Liang H, et al. 2020. Modeling the trend of coronavirus  
515 disease 2019 and restoration of operational capability of metropolitan medical service in  
516 China: a machine learning and mathematical model-based analysis. *Glob Health Res Policy*  
517 5: 20.
- 518 Miller RL, Brewer JD. 2003. *The A-Z of Social Research: A Dictionary of Key Social Science*  
519 *Research Concepts*. SAGE.
- 520 Ministry of Housing, Communities, Local Government. 2020. Government advice on home  
521 moving during the coronavirus (COVID-19) outbreak.
- 522 Mucientes E, Carrasco A. 2020. Covid-19 | Un juez de Lleida avala ahora las medidas de  
523 confinamiento en Segrià. ELMUNDO. Available: [https://www.elmundo.es/ciencia-y-](https://www.elmundo.es/ciencia-y-salud/salud/2020/07/14/5f0d542cfdddf7d0a8b460c.html)  
524 [salud/salud/2020/07/14/5f0d542cfdddf7d0a8b460c.html](https://www.elmundo.es/ciencia-y-salud/salud/2020/07/14/5f0d542cfdddf7d0a8b460c.html) [accessed 15 July 2020].
- 525 Nason GP. 2006. Stationary and non-stationary time series. In: *Statistics in Volcanology* (H.M.  
526 Mader, S.G. Coles, C.B. Connor, and L.J. Connor, eds). The Geological Society of London  
527 on behalf of The International Association of Volcanology and Chemistry of the Earth's  
528 Interior. 129–142.
- 529 Nussbaumer-Streit B, Mayr V, Dobrescu AI, Chapman A, Persad E, Klerings I, et al. 2020.  
530 Quarantine alone or in combination with other public health measures to control COVID-19:  
531 a rapid review. *Cochrane Database Syst Rev* 4: CD013574.
- 532 Pearce N. 2000. The ecological fallacy strikes back. *J Epidemiol Community Health* 54: 326–  
533 327.
- 534 Peixoto PS, Marcondes D, Peixoto C, Oliva SM. 2020. Modeling future spread of infections via  
535 mobile geolocation data and population dynamics. An application to COVID-19 in Brazil.  
536 *PLoS One* 15: e0235732.
- 537 Perron P. 1988. Trends and random walks in macroeconomic time series. *Journal of Economic*  
538 *Dynamics and Control* 12:297–332; doi:10.1016/0165-1889(88)90043-7.
- 539 Planning-Population-Census 2010-DCP. Available:  
540 <https://www1.nyc.gov/site/planning/planning-level/nyc-population/census-2010.page>  
541 [accessed 26 August 2020].
- 542 Population by Country (2020) - Worldometer. Available: [https://www.worldometers.info/world-](https://www.worldometers.info/world-population/population-by-country/)  
543 [population/population-by-country/](https://www.worldometers.info/world-population/population-by-country/) [accessed 24 August 2020].

- 544 Population of Tokyo - Tokyo Metropolitan Government. Available:  
545 [https://www.metro.tokyo.lg.jp/ENGLISH/ABOUT/HISTORY/history03.htm#:~:text=With](https://www.metro.tokyo.lg.jp/ENGLISH/ABOUT/HISTORY/history03.htm#:~:text=With%20a%20population%20density%20of,average%201.94%20persons%20per%20household.)  
546 [%20a%20population%20density%20of,average%201.94%20persons%20per%20household.](https://www.metro.tokyo.lg.jp/ENGLISH/ABOUT/HISTORY/history03.htm#:~:text=With%20a%20population%20density%20of,average%201.94%20persons%20per%20household.)  
547 [accessed 26 August 2020].
- 548 Semenova Y, Glushkova N, Pivina L, Khismetova Z, Zhunussov Y, Sandybaev M, et al. 2020.  
549 Epidemiological Characteristics and Forecast of COVID-19 Outbreak in the Republic of  
550 Kazakhstan. *J Korean Med Sci* 35: e227.
- 551 Sen BP, Padalabalanarayanan S, Hanumanthu VS. 2020. Stay-at-Home Orders, African  
552 American Population, Poverty and State-level Covid-19 Infections: Are there associations?;  
553 doi:10.1101/2020.06.17.20133355. Available: <https://doi.org/10.1101/2020.06.17.20133355>  
554 [accessed 31 August 2020].
- 555 Sjödin H, Wilder-Smith A, Osman S, Farooq Z, Rocklöv J. 2020. Only strict quarantine  
556 measures can curb the coronavirus disease (COVID-19) outbreak in Italy, 2020. *Euro*  
557 *Surveill* 25; doi:10.2807/1560-7917.ES.2020.25.13.2000280.
- 558 #[stayathome] (Brazilian twitter). Twitter. Available: <https://twitter.com/hashtag/ficaemcasa>  
559 [accessed 15 July 2020].
- 560 Tegel S. 2020. The country with the world's strictest lockdown is now the worst for excess  
561 deaths. *The Telegraph*. Available: [https://www.telegraph.co.uk/travel/destinations/south-](https://www.telegraph.co.uk/travel/destinations/south-america/peru/articles/peru-strict-lockdown-excess-deaths/)  
562 [america/peru/articles/peru-strict-lockdown-excess-deaths/](https://www.telegraph.co.uk/travel/destinations/south-america/peru/articles/peru-strict-lockdown-excess-deaths/) [accessed 20 September 2020].
- 563 Therese MM. 2020. Government confirms that it is safe to proceed to Phase 3 of the Roadmap  
564 for Reopening Business and Society.
- 565 Vokó Z, Pitter JG. 2020. The effect of social distance measures on COVID-19 epidemics in  
566 Europe: an interrupted time series analysis. *Geroscience* 42: 1075–1082.
- 567 Wang Y, Liu Y, Struthers J, Lian M. 2020. Spatiotemporal Characteristics of COVID-19  
568 Epidemic in the United States. *Clin Infect Dis*; doi:10.1093/cid/ciaa934.
- 569 WHO Coronavirus Disease (COVID-19) Dashboard. World Health Organization. Available:  
570 <https://covid19.who.int/table> [accessed 19 August 2020].
- 571 WHO Director-General's opening remarks at the media briefing on COVID-19 - 13 April 2020.  
572 Available: [https://www.who.int/dg/speeches/detail/who-director-general-s-opening-remarks-](https://www.who.int/dg/speeches/detail/who-director-general-s-opening-remarks-at-the-media-briefing-on-covid-19--13-april-2020)  
573 [at-the-media-briefing-on-covid-19--13-april-2020](https://www.who.int/dg/speeches/detail/who-director-general-s-opening-remarks-at-the-media-briefing-on-covid-19--13-april-2020) [accessed 15 July 2020].
- 574 Wu E, Qi D. 2020. Masks and thermometers: Paramount measures to stop the rapid spread of  
575 SARS-CoV-2 in the United States. *Genes Dis*; doi:10.1016/j.gendis.2020.04.011.
- 576 Zamir M, Shah Z, Nadeem F, Memood A, Alrabaiah H, Kumam P. 2020. Non Pharmaceutical  
577 Interventions for Optimal Control of COVID-19. *Comput Methods Programs Biomed* 196:  
578 105642.

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**Table 1. Characteristics of the 87 regions and countries used for comparison in the study. HDI = Human Development Index (the higher, the better).**

Region/Country	Density people/km <sup>2</sup>	Urban Pop (%)	HDI	Population	Land area (km <sup>2</sup> )
<b>Controlled areas</b>					
Austria	109	57	0.914	9,014,380	82,409
Bahrain	2,239	89	0.838	1,709,919	760
Belgium	383	98	0.919	11,597,489	30,280
Berlin	4,118	100	0.950	3,669,491	891
Canada	4	81	0.922	37,793,085	9,093,510
Czech Republic	139	74	0.891	10,712,102	78,866
Denmark	137	88	0.930	5,795,391	42,430
Finland	18	86	0.925	5,542,073	303,890
city of Fortaleza, Ceará, Brazil	7,786	100	0.754	2,686,612	312
France	119	82	0.891	65,296,176	547,557
Germany	240	76	0.939	83,825,861	348,560
Greece	81	85	0.870	10,414,904	128,900
Hungary	107	72	0.845	9,656,450	90,530
Ireland	72	63	0.942	4,946,213	68,890
Italy	206	69	0.883	60,447,728	294,140
Japan	347	92	0.915	126,414,795	364,555
Kuwait	240	100	0.808	4,280,111	17,820
Macedonia	83	59	0.759	2,083,360	25,220
city of Manaus, Amazonas, Brazil	158	100	0.737	2,219,580	11,401
Netherlands	508	92	0.934	17,140,821	33,720
New York City	10,194	100	0.941	8,336,817	784
Norway	15	83	0.954	5,427,784	365,268
Portugal	111	66	0.850	10,191,976	91,590
city of Rio de Janeiro, RJ, Brazil	5,266	100	0.799	6,747,815	1,200
Russia	9	74	0.824	145,944,331	16,376,870
Slovenia	103	55	0.902	2,078,983	20,140

South Korea	527	82	0.906	51,276,136	97,230
Spain	94	80	0.893	46,757,635	498,800
State of Acre	4	73	0.663	894,470	164,124
State of Amazonas	2	79	0.674	4,207,714	1,559,169
State of Pará	6	68	0.646	8,602,865	1,245,871
State of Roraima	2	76	0.707	631,181	223,645
Sweden	25	88	0.937	10,109,031	410,340
Switzerland	219	74	0.946	8,664,406	39,516
Tokyo, Japan	6,158	100	0.941	13,491,000	2,191
United Kingdom	279	83	0.920	67,886,011	241,930
<b>Not Controlled areas</b>					
Argentina	17	93	0.83	45,259,525	2,736,690
Australia	3	86	0.938	25,545,026	7,682,300
Belarus	47	79	0.817	9,448,832	202,910
city of Belo Horizonte, MG, Brazil	7167	100	0.81	2,521,564	331
Bosnia and Herzegovina	64	52	0.769	3,277,541	51,000
Bulgaria	64	76	0.861	6,940,012	108,560
Chile	26	85	0.847	19,141,470	743,532
Colombia	46	80	0.761	50,965,881	1,109,500
Costa Rica	100	80	0.794	5,101,269	51,060
Croatia	73	58	0.837	4,101,200	55,960
Brasília, FD Brazil	444.66	96.62	0.824	3,055,149	5,761
Israel	400	93	0.906	9,197,590	21,640
Lebanon	667	78	0.73	6,820,558	10,230
Libya	4	78	0.708	6,885,460	1,759,540
Luxembourg	242	88	0.909	627,509	2,590
Moldova	105	43	0.711	4,032,473	32,850
Oman	16	87	0.834	5,125,566	309,500
Peru	26	79	0.759	33,041,424	1,280,000
Poland	124	60	0.872	37,840,045	306,230
city of Porto Alegre, RS, Brazil	2837.53	100	0.805	1,488,252	495

Qatar	248	96	0.848	2,807,805	11,610
Romania	84	55	0.816	19,217,049	230,170
city of São Paulo, SP, Brazil	7398.26	100	0.805	12,325,232	1,521
Saudi Arabia	16	84	0.857	34,895,566	2,149,690
Serbia	100	56	0.799	8,731,751	87,460
state of Alagoas	112.23	73.64	0.631	3,351,543	27,843
state of Amapá	4.69	89.81	0.708	861,773	142,471
state of Bahia	24.82	72.07	0.66	14,930,634	564,760
state of Ceará	56.76	75.09	0.682	9,187,103	148,894
state of Espírito Santo	76.25	85.29	0.74	4,064,052	46,074
state of Goiás	17.65	90.29	0.735	7,113,540	340,203
state of Maranhão	19.81	63.07	0.639	7,114,598	329,642
state of Mato Grosso	3.36	81.9	0.725	3,526,220	903,207
state of Mato Grosso do Sul	6.86	85.64	0.729	2,809,394	357,146
state of Minas Gerais	33.41	83.38	0.731	21,292,666	586,521
state of Paraíba	66.7	75.37	0.658	4,039,277	56,467
state of Paraná	52.4	85.31	0.749	11,516,840	199,299
state of Pernambuco	89.63	80.15	0.673	9,616,621	98,068
state of Piauí	12.4	65.77	0.646	3,281,480	251,757
state of Rio de Janeiro	365.23	96.71	0.761	17,264,943	43,750
state of Rio Grande do Norte	59.99	77.82	0.684	3,534,165	52,810
state of Rio Grande do Sul	37.96	85.1	0.746	11,422,973	281,707
state of Rondônia	6.58	73.22	0.69	1,796,460	237,765
state of Santa Catarina	65.27	83.99	0.774	7,252,502	95,731
state of São Paulo	166.23	95.88	0.783	46,289,333	248,219
state of Sergipe	94.35	73.51	0.665	2,318,822	21,925
state of Tocantins	4.98	78.81	0.699	1,590,248	277,467
Turkey	110	76	0.807	84,477,895	769,630
Ukraine	75	69	0.75	43,691,576	579,320
United Arab Emirates	118	86	0.866	9,908,607	83,600
United States of America	36	82	0.92	331,303,997	9,834,000

582 **Table 2.** Comparisons using the 4-point criteria. Comparability was considered if at least 3 out  
 583 of 4 of the following conditions were similar: a) population density, b) percentage of the urban  
 584 population, c) Human Development Index and d) total area of the region. Similarity was  
 585 considered adequate when a variation in conditions a), b) and c) was within 30%, while, for  
 586 condition d), a variation of 50% was considered adequate (Further details are in [Data sharing - 4](#)  
 587 [point criteria](#)) .

Region/Country (controlled)	Region/Country (not controlled)	Comparability <sup>a</sup>	p-value <sup>b</sup>
Austria	Serbia	4	0.055
Bahrain	city of Porto Alegre, RS, Brazil	4	0.911
Belgium	Israel	4	0.114
Canada	Australia	4	0.965
Czech Republic	State of Alagoas	3	0.3501
Denmark	Turkey	3	0.911
Finland	State of Goiás	4	0.268
city of Fortaleza, CE, Brazil	city of Belo Horizonte, MG, Brazil	4	0.301
France	Ukraine	3	0.623
Germany	Qatar	3	0.892
Greece	Bulgaria	4	0.275
Ireland	Croatia	4	0.711
Italy	State of São Paulo	3	0.928
Japan	Israel	3	0.102
Kuwait	Luxembourg	3	0.060
city of Manaus, AM, Brazil	Qatar	3	0.524
Macedonia	Romania	3	0.6169
Netherlands	city of Brasília, Brazil	3	0.459
New York City	city of São Paulo, SP, Brazil	3	0.645
Norway	Saudi Arabia	3	0.379
Portugal	United Arab Emirates	3	0.248
Russia	United States of America	3	0.557
Slovenia	Poland	4	0.875
South Korea	Lebanon	3	0.645
Spain	State of Minas Gerais	3	0.853



State of Acre	State of Amapá	4	0.803
State of Amazonas	Colombia	3	0.638
State of Pará	Libya	3	0.681
State of Roraima	State of Rondônia	3	0.042
Sweden	State of Bahia	4	0.131
Switzerland	State of Espírito Santo	3	0.745
Tokyo, Japan	city of São Paulo, SP, Brazil	4	0.731
United Kingdom	State of Rio Grande do Sul	3	0.084

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588 <sup>a</sup> From four-point criteria, how many criteria were present

589 <sup>b</sup> Linear regression

590 **Figure caption**

591

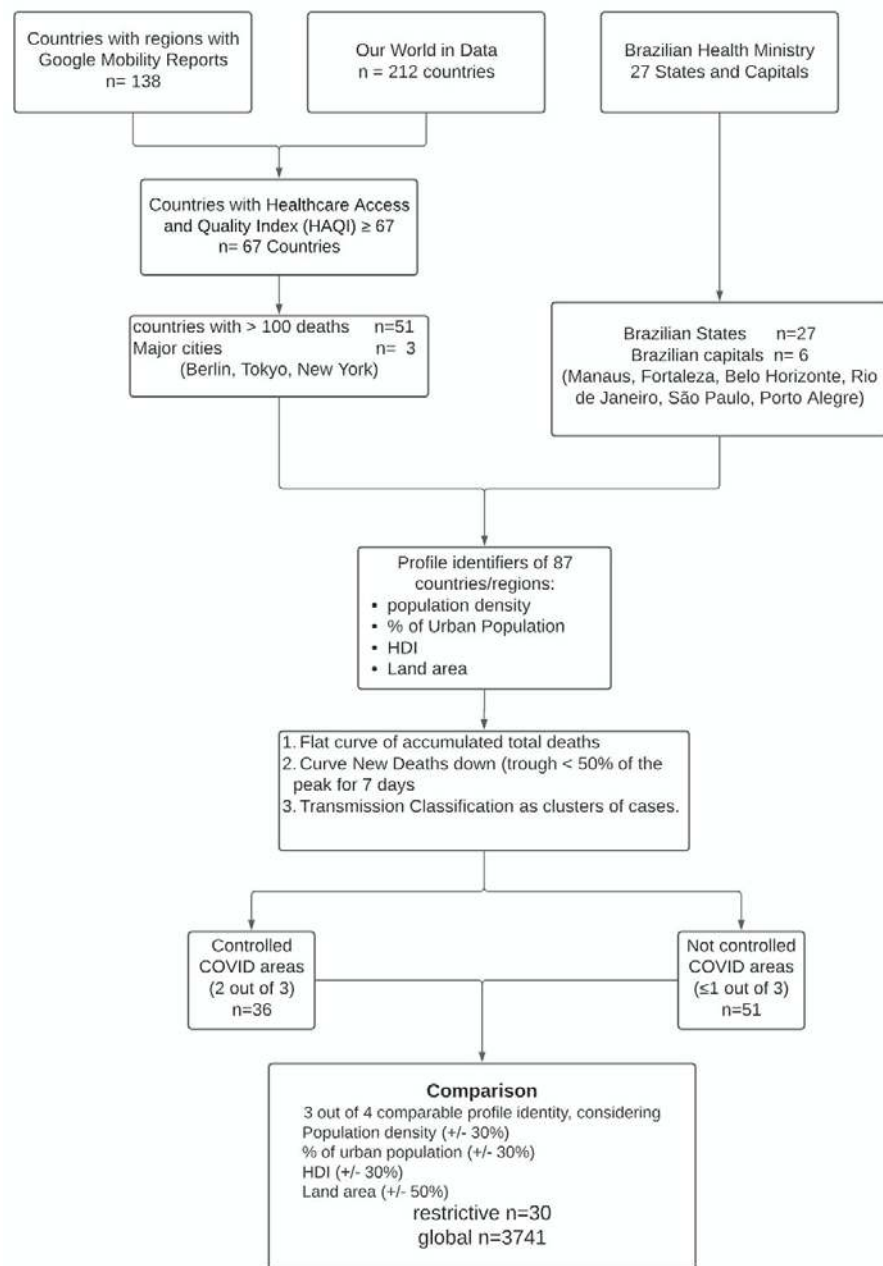
592 Figure 1. Flow chart of the data setup (Further details are in [Supplemental Material - Flow](#)  
593 [chart](#)).

594

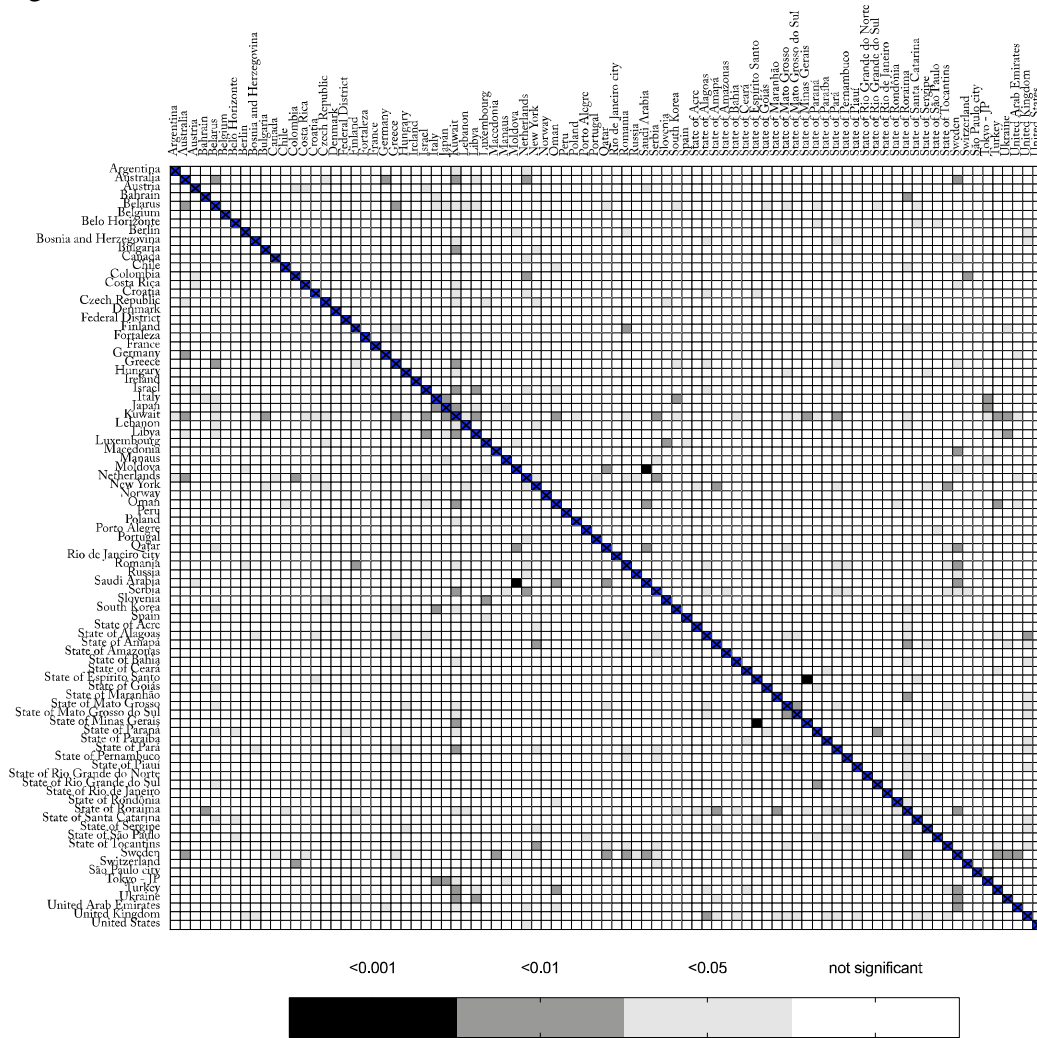
595 Figure 2. Heat map comparing different regions with COVID-19. The bar below represents p-  
596 values for the linear regression.

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598 Figure 1.



601 Figure 2



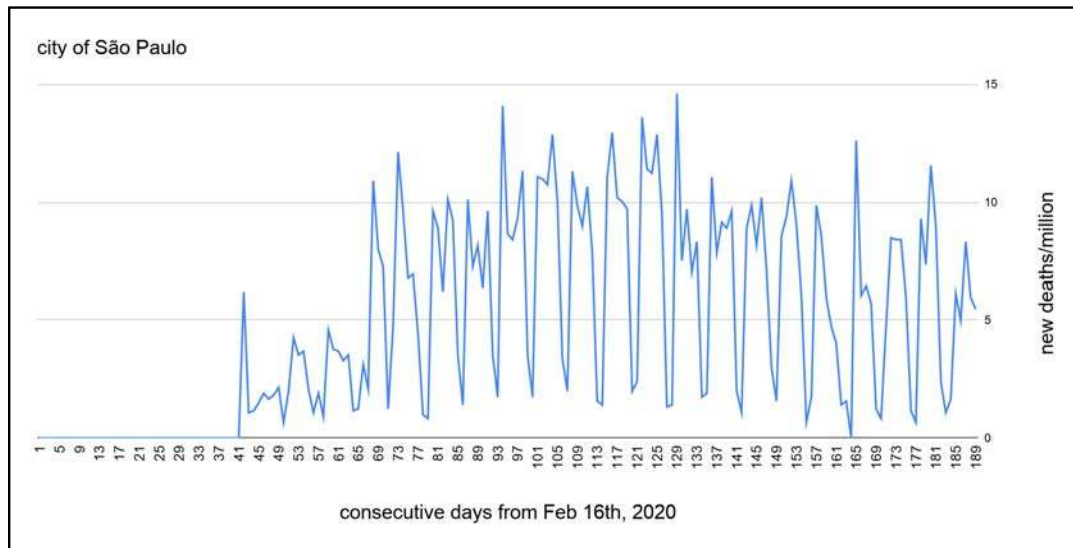
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604 **SUPPLEMENTAL MATERIAL**

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606 **Approach for analyzing the time series data**

607 Time series on COVID-19 mortality (deaths/millions) display a non-stationary pattern. The daily  
608 data present a very distinct seasonal behavior on the weekends, with valleys on Saturdays and  
609 Sundays followed by peaks on Mondays (Figure S1).

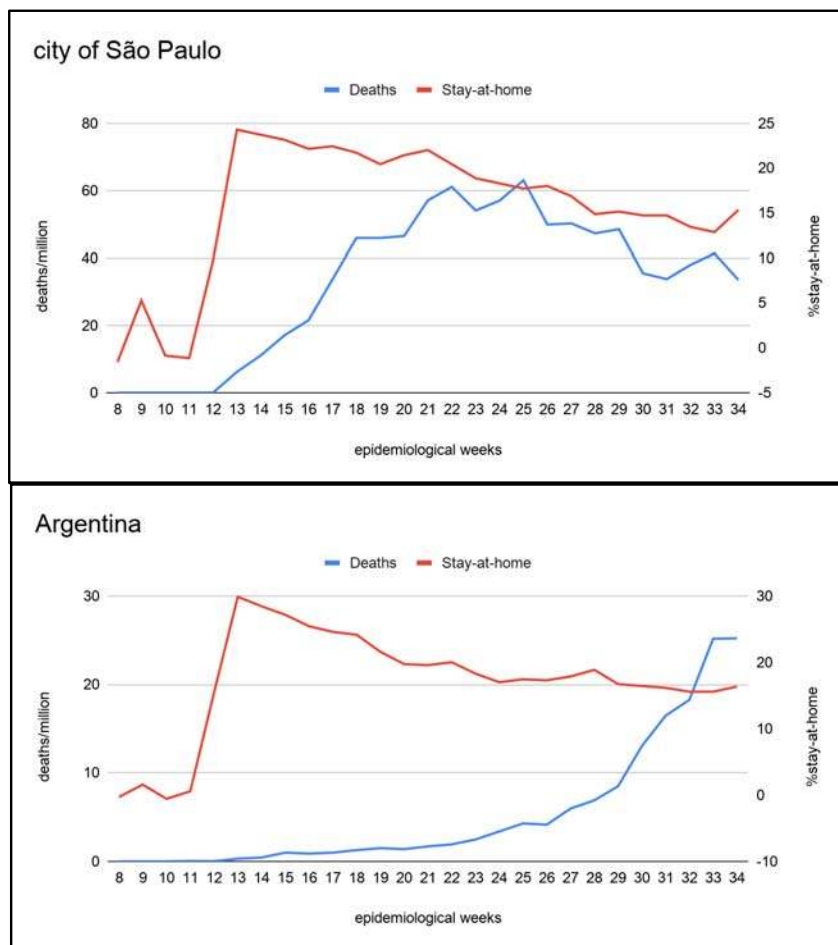


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612 **Figure S1.** Characteristics of the time series data on new daily deaths/million in the city of São  
613 Paulo over 187 days. Note the non-stationary time series pattern.

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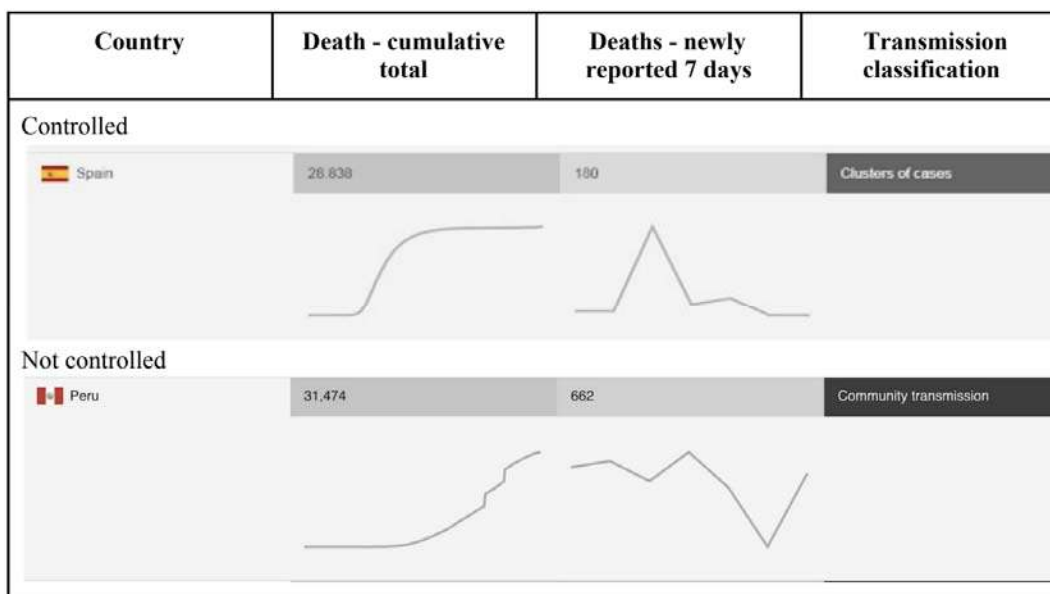
645 **Figure S2.** Data aggregation of the number of deaths/million in the city of São Paulo and in  
646 Argentina over several epidemiological weeks, compared to the percentage of staying at home.  
647 Data aggregation by epidemiological week is a plausible alternative. In this way, artificial  
648 seasonality, imposed by work scheduled during weekends and the effect of governmental control  
649 over social interaction, in a regression framework, are mitigated. The drawback is that the  
650 sample size is significantly reduced from 187 days (Figure S1) to 26 epidemiological weeks.

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### 652 **Definition of areas with and without controlled cases of COVID-19**

653 Regions were classified as controlled for cases of COVID-19 if they present at least 2 out of the  
654 3 following conditions: a) type of transmission classified as “clusters of cases”, b) a downward  
655 curve of newly reported deaths in the last 7 days, and c) a flat curve in the cumulative total  
656 number of deaths in the last 7 days (variation of 5%) according to the World Health  
657 Organization (WHO Coronavirus Disease (COVID-19) Dashboard). An example is shown in  
658 Figure S3.





659

660 **Figure S3.** Example of areas with and without control of COVID-19

661

662 **Table S3).** Comparison between 184 countries and regions displaying a significant association  
 663 between the variation of number of deaths/million and the variation of the percentage of staying  
 664 at home, after False Discovery Rate (FDR B-H) analysis. Intercept and coef\_isolation are  $\beta_0$  and  
 665  $\beta_1$  from the linear regression formula; Shapiro is the test for normality; White is the test for  
 666 heteroskedasticity; LM is the Lagrange Multiplier test for autocorrelation, Reset is the Ramsey's  
 667 RESET test for functional specification (all should have a p-value  $\geq 0.05$  for a valid comparison),  
 668 CoInt= the p-value of the Phillips-Perron test applied to the residual of the regression (for a valid  
 669 comparison, p-value  $< 0.05$ )

670 **Table S4)** Comparison between 63 countries and regions displaying a significant association  
 671 between the variation of number of deaths/million and the variation of the percentage of staying  
 672 at home, after False Discovery Rate analysis and after residual analysis. Intercept and  
 673 coef\_isolation are  $\beta_0$  and  $\beta_1$  from the linear regression formula; Shapiro is the test for  
 674 normality; White is the test for heteroskedasticity; LM is the Lagrange Multiplier test for  
 675 autocorrelation, Reset is the Ramsey's RESET test for functional specification (all should have a  
 676 p-value  $\geq 0.05$  for a valid comparison), CoInt= the p-value of the Phillips-Perron test applied to  
 677 the residual of the regression (for a valid comparison, p-value  $< 0.05$ ).