The Impact of Government Actions and Risk Perception on the Promotion of Self-Protective Behaviors During the COVID-19 Pandemic

Javier Alvarez-Galvez (javier.alvarezgalvez@uca.es)
University of Cádiz
Andreas Anastasiou
University of Cyprus
Demetris Lamnisos
University of Cyprus
Marios Constantinou
University of Nicosia
Christiana Nicolaou
Cyprus University of Technology
Savvas Papacostas
Cyprus Institute of Neurology and Genetics
Vasilis S. Vasiliou
University of Oxford
Louise McHugh
University College Dublin
Jelena Lubenko
Riga Stradings University
Francisco J. Ruiz
European University of Madrid
Marisa Paez-Blarrina
European University of Madrid
Francisco Montesinos
European University of Madrid
Sonsoles Valdivia-Salas
University of Zaragoza
Rhonda M. Merwin
Duke University
Maria Karekla
University of Cyprus
Andrew T. Gloster

University of Basel

Angelos P. Kassianos

University College London

Research Article

Keywords: COVID-19, health behaviors, self-protective behaviors, change-point detection analysis, interrupted time series

Posted Date: March 16th, 2022

DOI: https://doi.org/10.21203/rs.3.rs-1270359/v1

Abstract

We aim to understand the factors that drive citizens of different countries adhere to recommended self-protective behaviors during the COVID-19 pandemic. Survey data obtained through the COVID Impact project was used. We combined previous evidence and change-point detection analysis to establish variations in self-protective behaviors across participating countries whose effect was then assessed by means of interrupted series analysis. A high level of compliance with health and governmental authorities' recommendations were generally observed in all countries. The level of stress decreased near the period when countries such as Cyprus, Greece or the United Kingdom relaxed their prevention behavior recommendations. However, this relaxation of behaviors did not occur in countries such as Germany, Ireland or the United States. When the daily number of recorded COVID-19 cases decreased, people relaxed their protective behaviors (Cyprus, Greece, Ireland), although the opposite trend was observed in Switzerland. COVID-19 self-protective behavior following has been heterogeneous across countries examined. Our findings show that there is probably no single winning strategy for exiting future health crises, as similar interventions, aimed to promote self-protective behaviors, may be received differently depending on the singular population groups and on the specific geographical context in which they are implemented.

Introduction

The COVID-19 pandemic has highlighted the challenges governments and health agencies have faced, to control the spread of the corona virus and protect the population during this health emergency[1]. As recent studies have shown, part of the success of certain policy actions is related to the appropriate strategies to manage the course of the disease and mitigate possible risk behaviors [2–4]. While developing pharmacological interventions for COVID-19 spread prevention and management, the mitigation of the disease depends on non-pharmacological interventions and behaviors people can follow, especially when self-protecting behaviors are known to relate with threat perceptions, social and cultural norms, stress and coping among others[5]. Perceptions of threat and severity constitute common reactions during pandemics; such reactions can be contagious among individuals[6,7]. The impact of fear on self-protection depends on individuals' perceptions among others; it can promote behavioral changes only if individuals feel capable to act upon their perceptions, yet, it can also have the opposite result, if they don't [8]. An individual's fear and behaviors exhibited that result from perceptions of threat can escalate if they perceive governmental crisis response as inconsistent, incompetent, unfair, subjective, non-empathetic and insincere[9]. Individuals' perceptions of fear can be exaggerated by evidence of contagion and mortality but how these perceptions influence self-protective behaviors is currently unknown or partly known.

The Protection Motivation Theory[10] ascertains that fear messages trigger individual appraisal of a potential threat. In cases when the threat appraisal prevails over coping appraisal then people demonstrate maladaptive responses such as denial, whereas when the coping response prevails (such as perceived self-efficacy) then people demonstrate protection motivation. A meta-analysis has demonstrated that increases in perceptions of threat severity, threat vulnerability, response efficacy, and self-efficacy facilitate adaptive behaviors [11]. If this also applies to how people react to pandemic threats such as COVID-19, then intervention programs can focus in lowering maladaptive response to potential threats and foster adaptive behaviors (i.e., protective behaviors such as mask wearing or keeping physical distancing).

Recent evidence suggests that self-protective behaviors from COVID-19 are associated with individuals' beliefs of efficacy in promoting self-protective behaviors and how much they value health [12] their perceived credibility of information provided[13,] their levels of acting with psychologically flexible way to threats, their prosociality[14], perceived threat/illness[15] and perceptions of risk[16]. Most studies however, examine fear and perceptions of threat, using only self-reported cross-sectional data, without employing more objective population health indicators such as the retrospective collection of the daily number of newly diagnosed cases or the incidences of deaths. In addition, public-health messages ought to be acceptable, credible, and trustworthy, to increase adherence to self-protective behaviors, consequently increasing the public's understanding and tackling perceptions of the threat[17]. Therefore, strong evidence highlights the importance of risk perception as a driver of self-protective behaviors in early interventions during large-scale pandemics. While there are previous works addressing this issue, most studies to date base their conclusions on the analysis of individual records from survey data (both cross-sectional and longitudinal) from which the global impact of policy interventions cannot generally be measured and nor internationally compared[12–17]. Therefore, to date, the impact of government interventions aimed to control the pandemic on people's self-protective behaviors and the role of their risk perceptions remain unclear.

In an internationally calibrated research project[18], we attempted to shed more light on how people react to COVID-19 threats. In this study, combining change point detection analysis and interrupted time series analysis, we aim to compare the impact of government actions and risk perception on the promotion of self-protective behaviors (in particular, basic protective behaviors such as hand washing, isolating, or social distancing) during the COVID-19 pandemic using data from different countries. For this research, we selected case studies according to the availability of data from the "COVID Impact" project[18], to understand how people from different countries adhere to recommended self-protective behaviors during the COVID-19 pandemic. From a dataset of 78 countries, we selected those that presented a sufficiently complete time series and a statistically relevant sample for the implementation of the analysis: Cyprus (N = 957), Germany (N = 279), Greece (N = 270), Ireland (N = 414), Latvia (N = 1285), Spain (N = 296), Switzerland (N = 550), United Kingdom (N = 100), and United States of America (N = 268).

For this aim, we hypothesized that governments' responses aiming to control the spread of the pandemic have been able to–at least partially–reduce risk behaviors (hypothesis 1), but we also hypothesize that, during health emergencies such as the COVID-19 pandemic, perceptions of threat and resulting fear may be a key coping factor in adhering to self-protective behaviors (hypothesis 2).

Results

Descriptive analysis of self-protective behaviors

A high level of adherence with the recommendations of health and governmental authorities was observed in all the countries under analysis (Fig. 1). The recommended (or, given the case, mandatory) measures of social isolation, social distancing, and hand washing were widely followed by the population (having generally mean values over 8.5 points in the 0–10 scale), and the same trend was observed for the proxy variable “adherence to COVID-19 self-protective behaviors" that we had obtained by averaging the three previous scores. The statistical significance of the differences observed between the countries was corroborated by one-way ANOVA for the four variables: social isolation ($F = 19.80$, $p < 0.001$), social distancing ($F = 16.81$, $p < 0.001$), handwashing ($F = 12.87$, $p < 0.001$), and adherence to COVID-19 self-protective behaviors ($F = 14.47$, $p < 0.001$).

Description Of Behavioral Trends According To Daily Covid-19 Cases

The time series analysis allowed us to identify a relatively stable evolution in the follow-up of the public health authorities' recommendations. However, although in general terms a high level of adherence was observed, the change-point detection analysis, using the Isolate-Detect methodology that we used previously[19,] allowed us, to identify certain points that could indicate some abrupt changes in terms of adherence with the recommended behaviors (Fig. 2).

As part of the interpretation of the detected change-points, their locations led us to consider possible factors that may have contributed to either the relaxation or the stricter adherence to self-protective behaviors of the populations living in the different countries that were affected–to a greater or lesser extent–by the COVID-19 pandemic. To this end, we ran a change-point detection analysis on the daily number of COVID-19 confirmed cases for the period of interest and for all the nine countries included in the study (Fig. 3).

With respect to Cyprus, we noticed that the prolonged period of a decrease on the daily number of cases, as shown in Fig. 3, led to a relaxation of the adherence on the self-protective behaviors, which can be seen from Fig. 2. We highlight that even though the only change-point detected for Cyprus in Fig. 3 indicates a slight decrease on the magnitude of the strong negative trend, the latter still remains negative leading to the relaxation with respect to the self-protective behaviors. In the case of Greece, it is apparent from Fig. 3, that the development of the pandemic in the country is extremely similar to the one in Cyprus. Furthermore, the last change-point for Greece in Fig. 2 shows a relaxation of the adherence to self-protective behaviors, and this is in complete agreement to the two estimated change-points for Cyprus near mid-May. In Switzerland, the significant drop on the daily number of cases (apparent from the first change-point in Fig. 3) seems to be directly connected to the first change-point (sudden drop in the self-protective behaviors) in Fig. 2, showing that people seem to relax their adherence to preventive behaviors once there is a negative trend on the daily number of confirmed cases.

Interrupted Time Series Analysis Using Stringency Of Measures And Daily Cases

In order to assess the impact of governmental measures on the self-protective behaviors of the population, we used a stringency index (i.e., extracted from the Oxford COVID-19 Government Response Tracker – OxCGRT)[1] to define the intervention dates in the interrupted times series analysis[20–23]. Specifically, what the intervention captured was the point of change in the level of stringency of the governmental measures applied to control the pandemic (Fig. 4). Thus, the aim was to analyze whether the relaxation (or tightening) of the measures applied, would actually have an effect on the control of protective behaviors. In particular, it could be observed that the level of stress decreased (i.e., there was a relaxation in the measures applied) near the period when the population of countries such as Cyprus, Greece or the United Kingdom also relaxed their self-protective behaviors. However, this relaxation of behaviors did not occur in the rest of the countries that we analyzed. In fact, we found countries such as Germany, Ireland and the United States whose populations maintained their behaviors and others where they even increased their previous levels of protection, as was the case in Spain, Latvia and Switzerland (Table 1).

Table 1
Post-interventions linear trend with (decreasing) Stringency Index

Country	Intervention	Coeff.	Std. Err.	t	P > t	[95% Conf.	Interval]
Cyprus	15/4/20	-0.008	0.020	-0.411	0.683	-0.049	0.032
Cyprus	3/5/20	-0.099***	0.022	-4.540	0.000	-0.143	-0.055
Germany	2/5/20	-0.003	0.048	-0.070	0.945	-0.100	0.093
Greece	4/5/20	-0.158**	0.071	-2.243	0.029	-0.300	-0.017
Ireland	17/5/20	-0.025	0.057	-0.432	0.668	-0.139	0.090
Latvia	11/5/20	0.088**	0.043	2.055	0.046	0.002	0.175
Spain	3/5/20	-0.025	0.024	-1.036	0.306	-0.074	0.024
Spain	18/5/20	0.176**	0.087	2.027	0.049	0.001	0.352
Switzerland	26/4/20	0.056*	0.033	1.717	0.093	-0.010	0.122
Switzerland	10/5/20	-0.010	0.030	-0.343	0.734	-0.070	0.050
United Kingdom	11/5/20	-0.127***	0.037	-3.393	0.001	-0.202	-0.052
United States	29/4/20	0.001	0.029	0.020	0.984	-0.059	0.060

Note: Statistically significant coefficients at the level of 0.1*, 0.05**, and 0.01***

Subsequently, once the variations in protective behaviors had been analyzed in relation to changes in the stringency index, the variations in these behaviors would be studied, but in this case associated with changes in the number of cases (i.e., the change-point detection analysis to define the intervention dates). Using this variant, our aim was to infer the possible impact that the number of cases in a particular context (in this case, taking the country as the unit of reference) could have on the resulting protective behaviors. Trying to assess our second hypothesis, we wanted to observe how does the perceived threat of the pandemic affected the control of protective behaviors. In other words, although we had been able to verify that the governmental measures applied to control the pandemic had not had the same impact on the population of the different countries, our intention was now to understand the possible relationship of protective behaviors with the degree of the problem (based in the number of cases) that these same countries might have experienced (Fig. 5).

As observed in the change-point detection analysis, when cases decreased, people relaxed their protective behaviors (Cyprus, Greece, Ireland), although the opposite trend was observed in one country (Switzerland). For Latvia and the United States, we were unable to detect any significant variation in the number of cases that would allow us to define the intervention point for these countries during the period analyzed (Table 2).

Table 2
Post-interventions linear trend with (decreasing) COVID-19 cases

Country	Intervention	Coeff.	Std. Err.	t	P > t	[95% Conf.	Interval]
Cyprus	23/4/20	-0.056***	0.015	-3.684	0.001	-0.086	-0.025
Germany	3/5/20	0.000	0.058	-0.003	0.998	-0.117	0.116
Greece	18/4/20	-0.063***	0.023	-2.704	0.009	-0.110	-0.016
Ireland	16/4/20	-0.012*	0.006	-1.944	0.057	-0.024	0.000
Spain	4/5/20	-0.003	0.030	-0.105	0.917	-0.064	0.058
Switzerland	12/4/20	0.014***	0.007	2.015	0.050	0.000	0.028
Switzerland	12/5/20	0.008	0.036	0.223	0.825	-0.065	0.082
United Kingdom	3/5/20	-0.019	0.034	-0.541	0.591	-0.088	0.050
Note: Statistically significant coefficients at the level of 0.1*, 0.05**, and 0.01***							

Discussion

This study aimed to understand the factors that drive populations to follow recommended protective behaviors during the COVID-19 pandemic (i.e., social isolating, social distancing, or hand washing). We initially assumed that government responses to control the spread of pandemic were able to reduce these behaviors (Hypothesis 1), but we also hypothesized that, during health emergencies such as the COVID-19 pandemic, perceived threat could be a key self-controlling factor in the management of protective behaviors (Hypothesis 2).

On the one hand, we found that the relaxation of governmental measures that aimed to prevent the spread of the disease also led to relaxation in population self-protective behaviors, particularly in countries such as Cyprus, Greece and the United Kingdom. In this case, the parallelism between Cyprus and Greece could be due to the fact that the governments of these two geographically adjacent countries were in close consultation with each other regarding the treatment of the pandemic. However, other countries did not follow this trend with even the opposite trend observed (e.g., Spain, Latvia and Switzerland). In addition, the change-point detection analysis carried out showed that when the number of daily confirmed cases fell, people in some countries relaxed their self-protective behaviors (specifically, in Cyprus, Greece, and Switzerland), although this behavior was not consistently observed in all countries examined in this study. Therefore, our two hypotheses were partially confirmed under certain country-specific conditions. In other words, we found that COVID-19 self-protective behaviors have been heterogeneous across different countries, as observed in previous studies[24]. Inconsistent findings between countries may be attributed to diverse socio-demographic characteristics in samples collected for this study which can differently react to governmental guidelines and therefore adherence may depend on personal circumstances as well[25]. Exploratory research can further shed light into what are the conditions that lead the population of the different countries to different reactions in the face of a shared health problem.

Pandemic fatigue could be considered as one of the different possible explanations in certain cases [26,27] but this phenomenon cannot provide a single answer for all the countries that we analyzed nor was it specifically assessed in this study. For instance, the Spanish case is interesting considering that our analysis indicates that behaviors in Spain followed a trend contrary to the one expected. That is, when the Spanish government began to relax prevention measures, self-protective behaviors increased in the country (i.e., social isolation, social distancing, and hand washing). This may mean that the population behavior is more closely related to the severity of the pandemic in that country rather than governmental responses. Moreover, when people were isolating during lockdown, they probably needed to engage less in the self-protective behaviors but when the restrictions were lifted, they needed to become more vigilant and engage in more protection. In other words, we could hypothesize the level of the health emergency and its association with the perceived risk and fear of the population might be a stronger determinant of self-protective behaviors. Indeed, as a recent study has shown, the Spanish adult population may have adapted to the new pandemic context by progressively improving their health behaviors [28]. Therefore, the increase in COVID-19 protective behaviors after the first few months of the pandemic in this country could be linked to increased hazard perception once the first wave of the disease has passed, which leads us to conclude that the perceived sense of risk at the population level may have a greater impact on collective behaviors than government-directed changes at the regulatory level.

How populations changed their behavior during the COVID-19 pandemic can also be an artifact of their response to adjustments in risk assessment since risk perceptions seem to influence COVID-19 protective behaviors similarly to how it impacts other health outcomes [29]. Monitoring how the news and information on cases and deaths at different countries are spread and presented to the public can benefit public health to prevent propensity to act in a riskless manner by reducing adherence to protective behaviors. Previous research has been limited into looking at how governmental stringency measures influence population behaviors which we have been able to demonstrate using the stringency index and estimate the enforcement's explanatory power on adherence changes over time.

From a methodological point of view, our study has several limitations that should be taken into consideration. First, our study is based on a time period that is relatively short considering the temporal breadth of the pandemic. Secondly, although the initial sample included 77 countries, for the present study we were only able to select those countries with an adequate sample size to be able to work with an aggregation of the data at a temporal level. Furthermore, because of the fact that we did not have access to direct measures of fluctuations in risk perception, we considered the trend for the daily number of confirmed COVID-19 cases as informational causes of perceived threat. Finally, and in line with the previous limitation, since our objective was to trace collective behaviors in relation to governmental protective measures and the number of confirmed COVID-19 cases, our conclusions can only be extrapolated at the aggregate level, so that we cannot draw individual conclusions on the behaviors of different profiles of individuals.

Despite the aforementioned limitations, our study presents some advances compared to previous works. To our knowledge, this the first study aimed to compare the impact of government actions and risk perception on the promotion of self-protective behaviors during the COVID-19 pandemic using data from different countries. This paper also for the first time presents how a data-driven approach can be combined with an evidence-based approach through two different time-series techniques (i.e., change point detection analysis and interrupted time series analysis). This combination of analytical approaches has allowed us to describe variations in self-protection behaviors in different geographical contexts, as well as to determine and compare the impact that governmental interventions and risk perceptions may have had on the course of the pandemic in individuals from different countries. By using these techniques, we have been able to verify that the control measures applied for the promotion of self-protective behaviors have not been equally effective in all countries, and that not all countries have responded similarly to the evolution of the pandemic.

In view of the present results, we can conclude that the promotion of self-protective behaviors should be tailored to the specific circumstances of the country in which such measures are to be applied. These findings show that there is probably no single winning strategy for exiting future health crises, as different interventions aimed to promote self-protective behaviors may be received differently depending on the singular population groups and on the specific geographical context in which they are implemented.

Methods

Data and countries

This study, utilized data from the COVID Impact project survey, a population based cross-sectional study. This dataset includes information from adult participants (≥ 18 years of age) from 78 countries, with an ability to read one of the 18 languages (English, Greek, German, French, Spanish, Turkish, Dutch, Latvian, Italian, Portuguese, Finnish, Slovenian, Polish, Romanian, Hong Kong, Hungarian, Montenegrin, & Persian). People from any country were eligible to participate in this study. Data was collected for two months between the 7th of April and the 7th of June 2020. At the time of data collection, the majority of participating countries had declared a state of emergency for COVID-19 and were on lockdown. Additional information on the project can be found in Gloster et al[18].

In order to facilitate the comparison between the different units of analysis, we selected countries that presented a sufficiently complete time series (at least 30 days per country) and a statistically relevant sample for the implementation of the analysis. The countries selected that met these criteria as case studies were the following: Cyprus (N = 957), Germany (N = 279), Greece (N = 270), Ireland (N = 414), Latvia (N = 1285), Spain (N = 296), Switzerland (N = 550), United Kingdom (N = 100), and United States of America (N = 268).

Ethics Approval

For this study, ethics approval was acquired from the Cyprus National Bioethics Committee (ref.: ΕΕΒΚ ΕΠ 2020.01.60) followed by site approvals from different research groups involved in data collection. All respondents provided informed consent prior to completing the survey and all methods were performed in accordance with the relevant guidelines and European regulations on data protection.

Variables Of Study

For the present study we focused on three main variables that captured COVID-19 self-protective behaviors: hand washing, isolation, and social distancing. Participants were asked to respond on a 10-point Likert scale ranging from never (0) to all the time (10) whether they followed these self-protective behavior recommendations. Using these three indicators, a new outcome variable measuring overall adherence to (recommended) COVID-19 self-protective behaviors was constructed. The response variable was obtained as a mean score of the aforementioned three indicators, having values between 0 and 10, where 0 = minimum adherence and 10 = maximum adherence to the COVID-19 self-protective behaviors. The reason for choosing to pool the three behaviors was due to the need to reduce possible variations due to sample size at different time points, while at the same time obtaining an overall measure of compliance with internationally established behavioral recommendations during the COVID-19 pandemic.

To capture variations in adherence to protective behaviors measures during the COVID-19 pandemic along the different countries under study, we used a governmental measures' stringency index that was extracted through the Oxford COVID-19 Government Response Tracker (OxCGRT), which is a continuously updated dataset that addresses the need for comparable information on policy measures during the pandemic[1]. This dataset contains information about government policies related to closure and containment, health and economic policy for more than 180 countries from the 1st of January 2020. The stringency index is a composite measure based on nine response indicators: (1) school closures, (2) workplace closures, (3) cancellation of public events, (4) restriction on gatherings, (5) public transport closures, (6) stay at home requirements, (7) restriction on internal movements, (8) international travel controls, and (9) public information campaigns. These indicators are rescaled to a value from 0 to 100 (where 100 = strictest).

Additionally, for our second study hypothesis, we considered the time points at which the numbers of diagnosed cases of COVID-19 peaked during the analysis period. In this way, we aimed to analyze the impact of the course of the pandemic on possible variations in health behaviors and, indirectly, on general adherence to health and national authorities' norms.

Statistical analysis

Interrupted time series analysis:

To study the factors that lead citizens of different countries to follow the rules during the COVID-19 pandemic, we used interrupted time series analysis (ITSA)[20–23]. This technique was used to examine the impact of governmental actions on the control of COVID self-protective behaviors during the COVID-19 pandemic. As an advantage, in contrast to other statistical techniques, ITSA allows to work with data sequences that present comparability problems due to missing information or methodological problems in data collection (i.e., data sequence gaps along the trend), but also explore the impact of contextual events which might explain changes in data trends (in our case, the subsequent effect of governmental actions and/or the effect of disease waves/picks on people's protective behaviors).

The standard interrupted time series regression model [20–23] can be described as:

$$Y_t = \beta_0 + \beta_1 T_t + \beta_2 X_t + \beta_3 X_t T_t + \epsilon_t$$

In this model, Y_t represents the outcome variable measured at each equally spaced t (time), T_t is the time elapsed from the initiation of the study, X_t is a binary variable representing the intervention time we are interested in (i.e., a change or interruption in the time series), and finally, an interaction term which is represented by $X_t T_t$. In this standard model, β_0 is the constant (or intercept) of the response variable, β_1 represents the slope of the outcome variable prior to the inclusion of the intervention, β_2 represents the change in the level of the response variable that occurs in the period immediately following the intervention, and β_3 is the difference between pre- and post-intervention slopes of the outcome variable. Thus, the fundamental objective of the ITSA is to look for significant *p-values* in either β_2 to identify any subsequent intervention (i.e., change in governmental action) over people's behaviors, or in β_3 to identify a treatment effect along the time of study[22,23].

Change-point detection analysis:

In terms of data acquisition, change-point detection is split into two main categories; *a-posteriori* detection where the data are already obtained prior to the analysis, and *online* detection where the observations arrive sequentially at present. In our study, the focus is on a-posteriori change-point detection being applied to two main pillars of our data; firstly, on the daily number of new COVID-19 cases and deaths, and secondly, on the COVID-19 self-protective behavior variables as described in the Methods section. The model that we work on is

$$X_t = f_t + \sigma \epsilon_t, \ t = 1, 2, \ldots, T$$

(1)

where T is the length of the given data sequence, X_t are the observed data, while f_t is a one-dimensional, piecewise-constant signal with abrupt changes in the mean. The number, N, of the change-points as well as their locations $r_1, r_2, \ldots, r_N$ are unknown and our aim is to estimate them. The random variables ϵ_t have mean zero and variance one, while $\sigma > 0$.

Detecting changes in the mean or the slope of the data sequence X_t as expressed in Eq. (1) allows us to separate the given data sequence into homogeneous segments, which leads to more flexible models. In addition, the advantages of such change detections are split into two main categories; interpretation and forecasting. Interpretation comes naturally since the detected changes are often connected with life events that took place near the estimated change-point location. Associating the results with such real-life phenomena can easily lead to a better understanding of the behavior of the data at hand. When it comes to forecasting, the role of the final homogeneous segment (the data after the last change-point) is very important because it allows for a more accurate prediction of the future values of the data sequence at hand.

The Isolate-Detect (ID) methodology [19] is employed in order to detect changes based on the model given in Eq. (1). Our focus is on the detection of changes in the mean or the trend of the unknown signal f_t. In the former case of changes in the mean, the signal is assumed to be piecewise-constant (see Fig. 2 for more details), while in the latter case, where we seek changes in the trend, f_t is assumed to be continuous and piecewise-linear (Fig. 3).

Declarations

Data availability

The dataset used and analyzed during the current study is available from thecorresponding author on reasonable request.

References

1 Hale T, Angrist N, Goldszmidt R, *et al.* A global panel database of pandemic policies (Oxford COVID-19 Government Response Tracker). *Nat Hum Behav* 2021; **5**: 529–38.

2 Hsiang S, Allen D, Annan-Phan S, *et al.* The effect of large-scale anti-contagion policies on the COVID-19 pandemic. *Nature* 2020; **584**: 262–7.

3 Chernozhukov V, Kasahara H, Schrimpf P. Causal impact of masks, policies, behavior on early covid-19 pandemic in the US. *J Econom* 2021; **220**: 23–62.

4 Betsch C, Korn L, Sprengholz P, *et al.* Social and behavioral consequences of mask policies during the COVID-19 pandemic. *Proc Natl Acad Sci* 2020; **117**: 21851–3.

5 Van Bavel JJ, Boggio P, Capraro V, *et al.* Using social and behavioural science to support COVID-19 pandemic response. 2020.

6 Mobbs D, Hagan CC, Dalgleish T, Silston B, Prévost C. The ecology of human fear: survival optimization and the nervous system. *Front Neurosci* 2015; **9**: 55.

7 Kramer AD, Guillory JE, Hancock JT. Experimental evidence of massive-scale emotional contagion through social networks. *Proc Natl Acad Sci* 2014; **111**: 8788–90.

8 Witte K, Allen M. A meta-analysis of fear appeals: Implications for effective public health campaigns. *Health Educ Behav* 2000; **27**: 591–615.

9 Europe WHO. Vaccination and trust—How concerns arise and the role of communication in mitigating crises. *World Health Organ* 2017.

10 Rogers RW, Prentice-Dunn S. Protection motivation theory. 1997.

11 Floyd DL, Prentice-Dunn S, Rogers RW. A meta-analysis of research on protection motivation theory. *J Appl Soc Psychol* 2000; **30**: 407–29.

12 Clark C, Davila A, Regis M, Kraus S. Predictors of COVID-19 voluntary compliance behaviors: An international investigation. *Glob Transit* 2020; **2**: 76–82.

13 Lep Ž, Babnik K, Hacin Beyazoglu K. Emotional Responses and Self-Protective Behavior Within Days of the COVID-19 Outbreak: The Promoting Role of Information Credibility. *Front Psychol* 2020; **11**: 1846.

14 Chong YY, Chien WT, Cheng HY, Kassianos AP, Gloster AT, Karekla M. Can psychological flexibility and prosociality mitigate illness perceptions toward COVID-19 on mental health? A cross-sectional study among Hong Kong adults. *Glob Health* 2021; **17**: 1–13.

15 Chong YY, Chien WT, Cheng HY, *et al.* The role of illness perceptions, coping, and self-efficacy on adherence to precautionary measures for COVID-19. *Int J Environ Res Public Health* 2020; **17**: 6540.

16 Betsch C, Wieler LH, Habersaat K. Monitoring behavioural insights related to COVID-19. *The Lancet* 2020; **395**: 1255–6.

17 Ghio D, Lawes-Wickwar S, Tang MY, *et al.* What influences people's responses to public health messages for managing risks and preventing infectious diseases? A rapid systematic review of the evidence and recommendations. 2020; published online July 13. DOI:10.31234/osf.io/nz7tr.

18 Gloster AT, Lamnisos D, Lubenko J, *et al.* Impact of COVID-19 pandemic on mental health: An international study. *PloS One* 2020; **15**: e0244809.

19 Anastasiou A, Fryzlewicz P. Detecting multiple generalized change-points by isolating single ones. *Metrika* 2021; : 1–34.

20 Huitema BE, Mckean JW. Design specification issues in time-series intervention models. *Educ Psychol Meas* 2000; **60**: 38–58.

21 Linden A, Adams JL. Applying a propensity score-based weighting model to interrupted time series data: improving causal inference in programme evaluation. *J Eval Clin Pract* 2011; **17**: 1231–8.

22 Bernal JL, Cummins S, Gasparrini A. Interrupted time series regression for the evaluation of public health interventions: a tutorial. *Int J Epidemiol* 2017; **46**: 348–55.

23 Linden A. Conducting interrupted time-series analysis for single-and multiple-group comparisons. *Stata J* 2015; **15**: 480–500.

24 Petherick A, Goldszmidt R, Andrade EB, *et al.* A worldwide assessment of changes in adherence to COVID-19 protective behaviours and hypothesized pandemic fatigue. *Nat Hum Behav* 2021; **5**: 1145–60.

25 Krpan D, Makki F, Saleh N, Brink SI, Klauznicer HV. When behavioural science can make a difference in times of COVID-19. *Behav Public Policy* 2021; **5**: 153–79.

26 Petherick ES, Fairley L, Parslow RC, *et al.* Ethnic differences in the clustering and outcomes of health behaviours during pregnancy: results from the Born in Bradford cohort. *J Public Health* 2016; **39**: 514–22.

27 Reicher S, Drury J. Pandemic fatigue? How adherence to covid-19 regulations has been misrepresented and why it matters. *bmj* 2021; **372**.

28 López-Bueno R, Calatayud J, Casaña J, *et al.* COVID-19 confinement and health risk behaviors in Spain. *Front Psychol* 2020; **11**: 1426.

29 Brewer NT, Chapman GB, Gibbons FX, Gerrard M, McCaul KD, Weinstein ND. Meta-analysis of the relationship between risk perception and health behavior: the example of vaccination. *Health Psychol* 2007; **26**: 136.

Figures

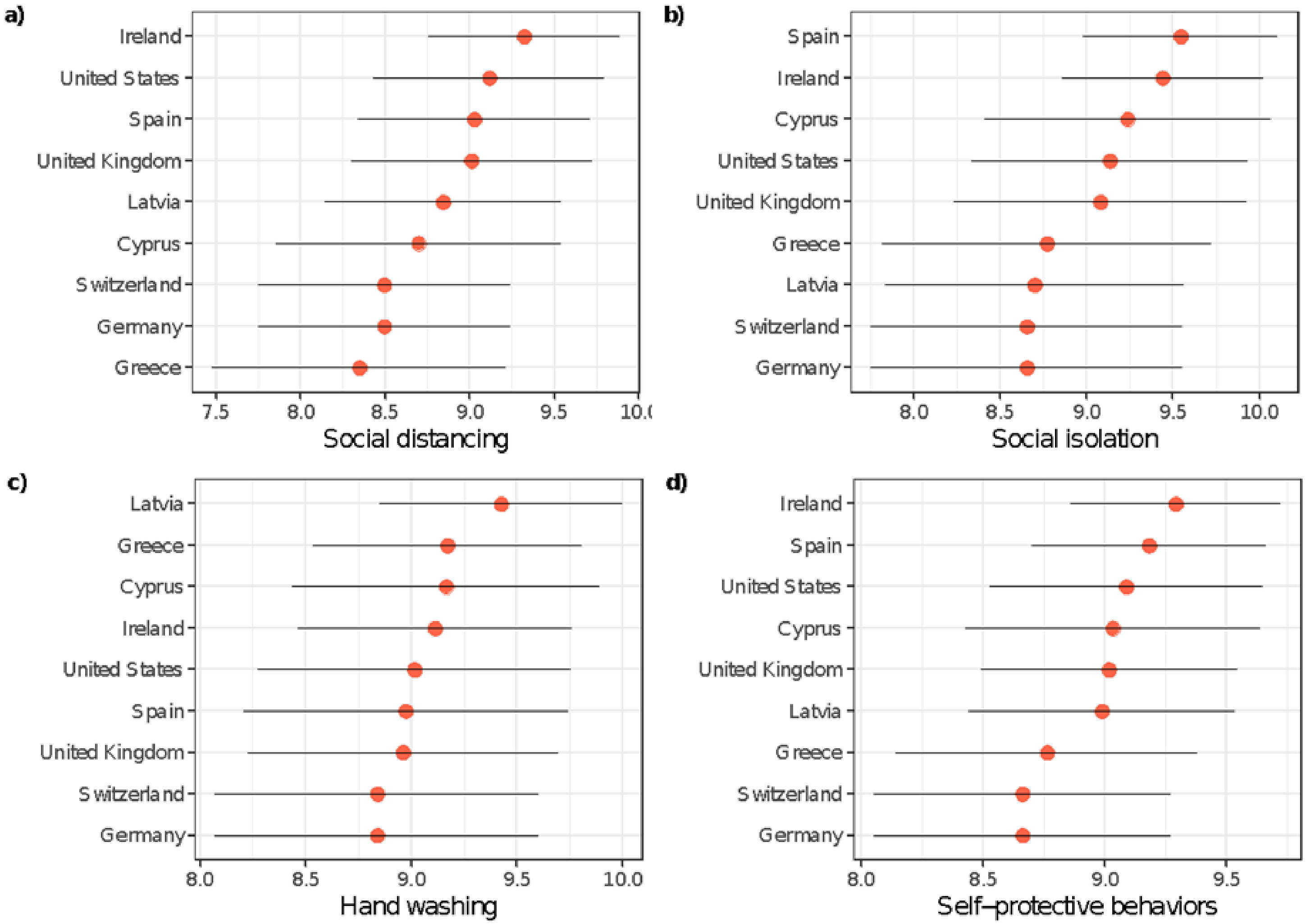

Figure 1

Mean and standard deviations for the variables a) social distancing, b) social isolation, c) hand washing, and d) protective behaviors in nine countries: Cyprus (N=957), Germany (N=279), Greece (N=270), Ireland (N=414), Latvia (N=1285), Spain (N=296), Switzerland (N=550), United Kingdom (N=100), and United States of America (N=268).

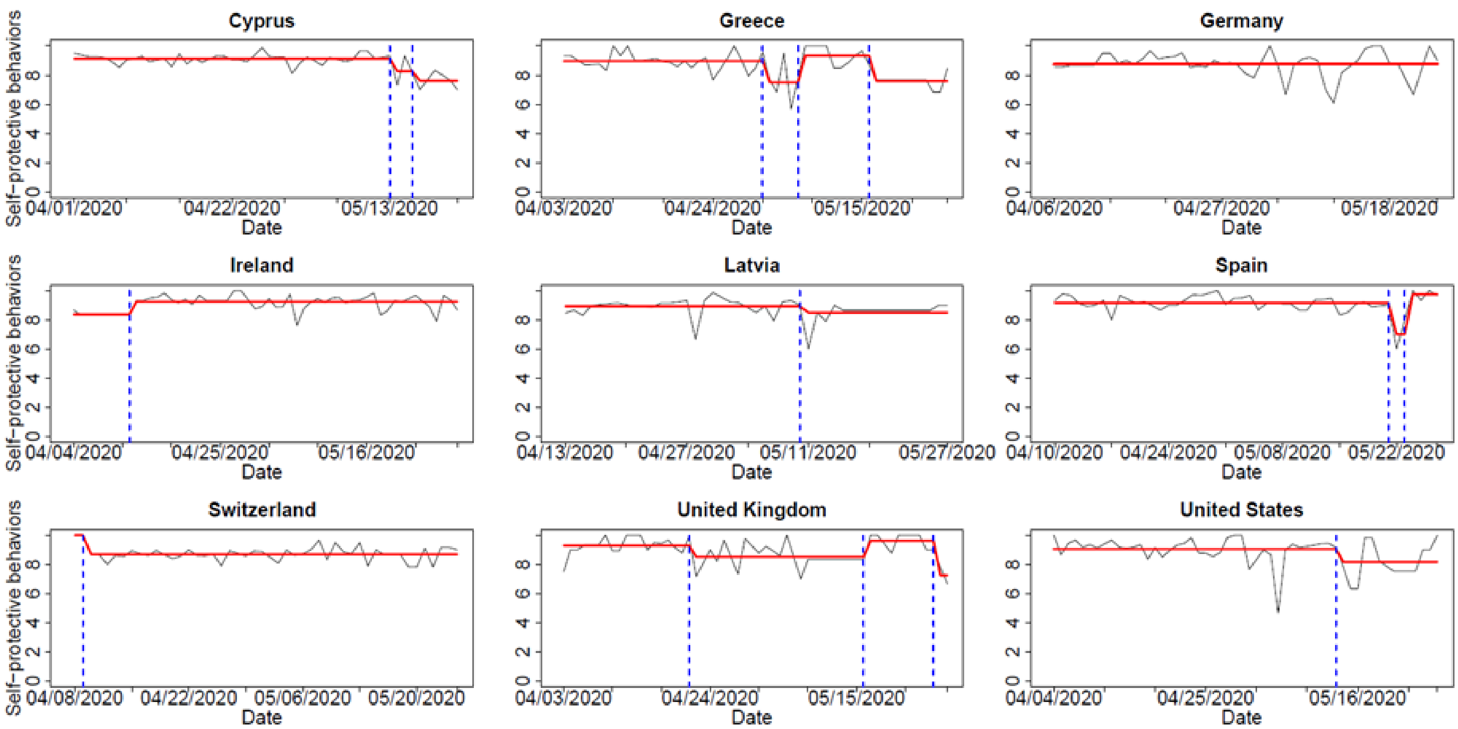

Figure 2

Results of change-point detection analysis for the self-protective behaviors variable in nine countries. The real data are given with black colored line, while the estimated piecewise-constant signal is the red colored line. The change-point locations are given with dotted, blue vertical lines.

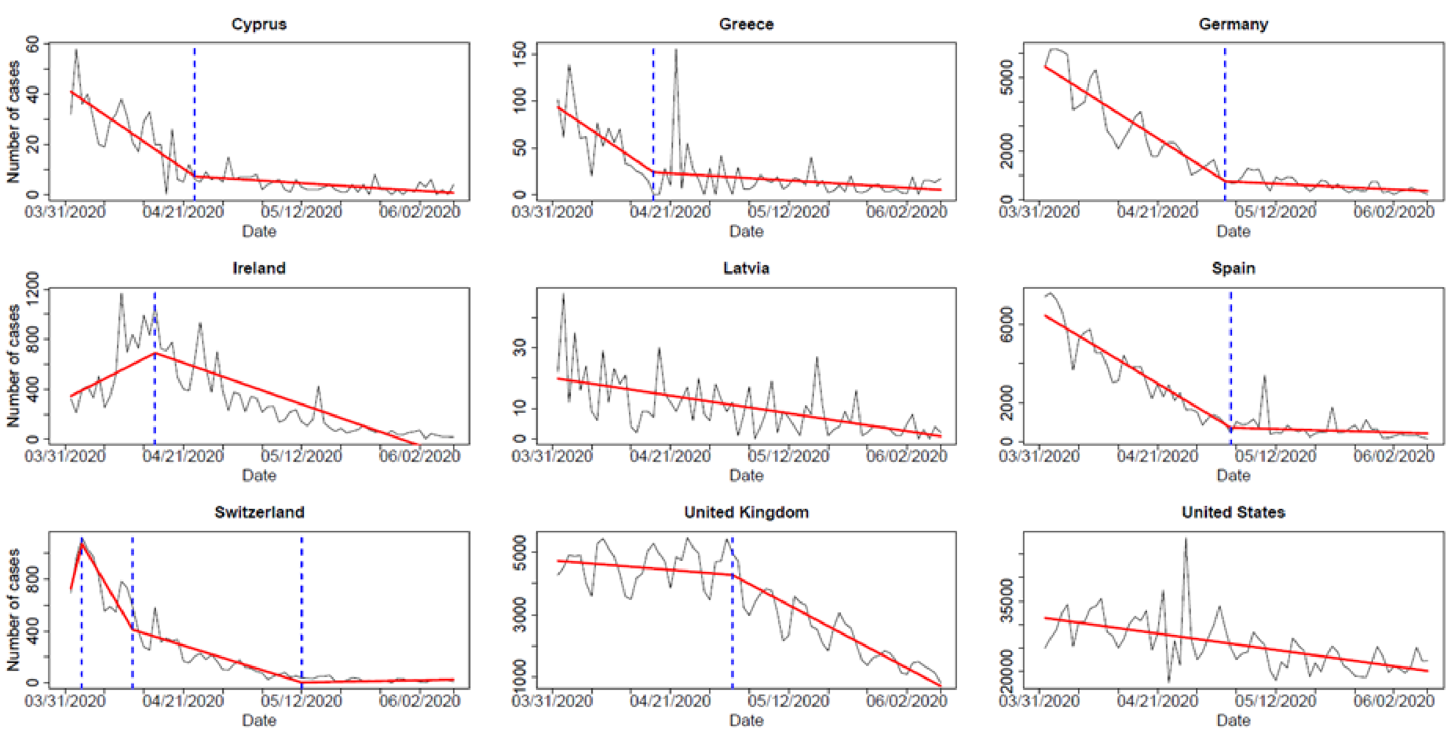

Figure 3

The real data (black colored line) and the estimated continuous, piecewise-linear signal (red colored line) for the daily number of COVID-19 confirmed cases in nine countries. The change-point locations are given with dotted, blue vertical lines.

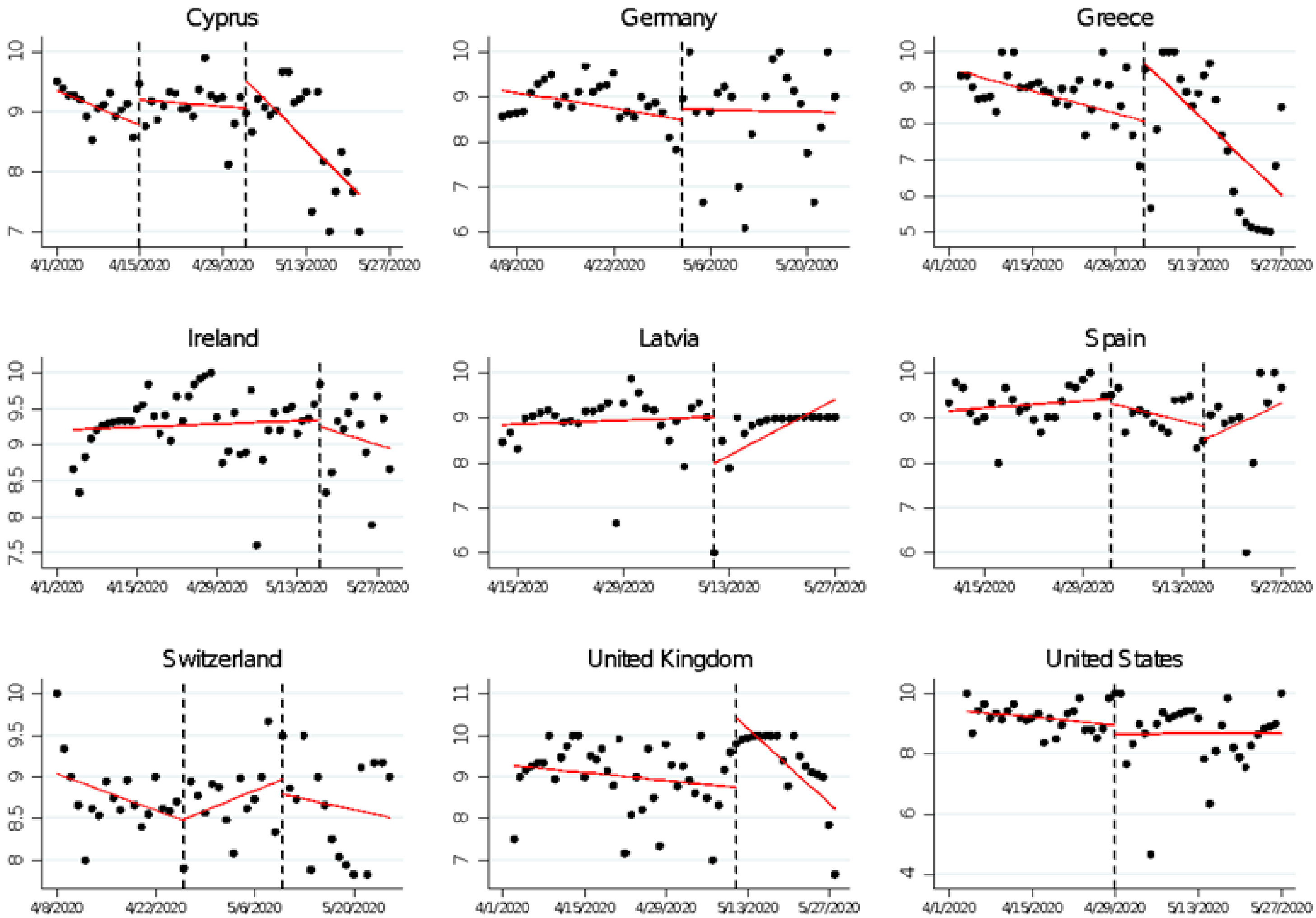

Figure 4

Interrupted time series analysis using stringency index

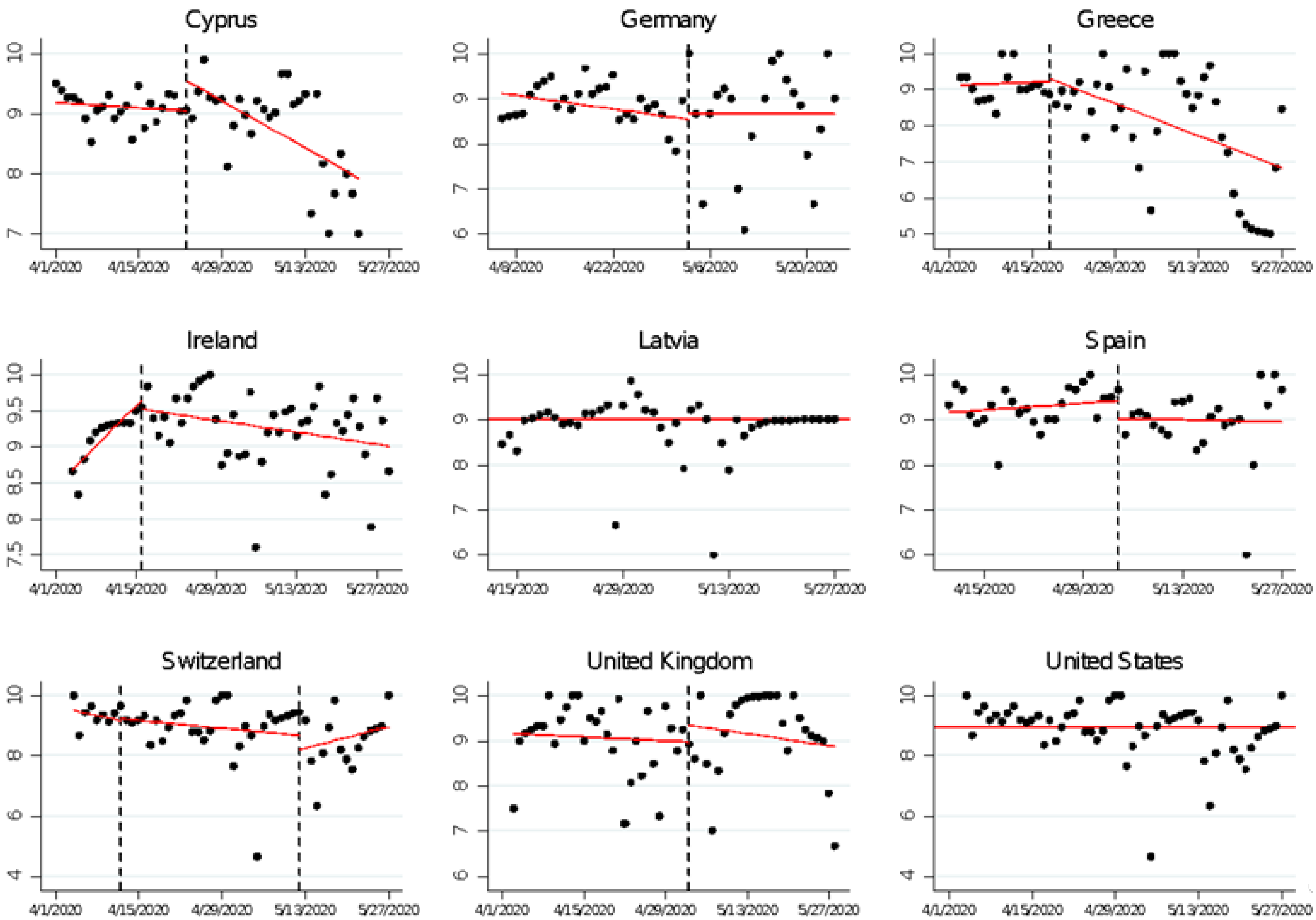

Figure 5

Interrupted time series analysis using COVID-19 cases.