Contact Tracing is Associated with Lower COVID-19 Case Fatality Rates: Evidence from 40 countries

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Abstract

The coronavirus disease (COVID-19) outbreak has killed over 725,000 people since its emergence in late 2019. As of early August 2020, there has been substantial variability in the policies and intensity of diagnostic efforts between countries. In this paper, we quantitatively evaluate the effectiveness of the national contact tracing policy in decreasing case fatality rates of COVID-19 in 40 countries. Our regression analyses indicate that countries that utilize comprehensive contact tracing have significantly lower case fatality rates. The association of contact tracing policy and case fatality rates is robust and observed in regression models using cross-sectional and panel data, even controlling for the number of tests conducted and non-pharmaceutical control measures adopted by governments. Our results suggest that comprehensive contact tracing is instrumental not only to curtailing transmission but also to reducing case fatality rates by early detection and isolation of secondary cases and ultimately diminishing the burden on the healthcare system and speeding the rate at which infected individuals receive the medical care they need to maximize their chance of recovery.

Introduction

The ongoing coronavirus disease (COVID-19) outbreak emerged in Wuhan, China, in December 2019 and has spread to 213 countries and territories, causing more than 19,000,000 cases and over 725,000 deaths as of the first week of August 2020. A considerable fraction of patients show severe pneumonia-like symptoms, and therefore, critical care is crucial for successful treatment of those patients[1].

The novel coronavirus is highly infectious with a long incubation period of up to 10-14 days[2]. In addition, a nonnegligible proportion of infected individuals is asymptomatic, which accelerates person-to-person transmission[3]. Furthermore, viral shedding is greatest during the presymptomatic phase[4]. Therefore, testing and contact tracing are both crucial to detect and isolate positive cases to mitigate the outbreak and to diminish the burden on the health care system[5].

COVID-19-related death rates vary across countries[6]. Anecdotal evidence shows that countries that have controlled the epidemic and that have relatively lower death rates have conducted ample testing and comprehensive contact tracing (e.g., South Korea, Germany)[7]. Although the importance of contact tracing has been discussed extensively in the popular press and examined in modeling studies, its effectiveness in limiting fatalities has not yet been investigated with real-time country-level data[8,9,10].

Contact tracing refers to identifying the index case's contacts and subsequent testing and quarantining these secondary cases according to national intervention guidelines. Countries vary concerning the intensity of contact tracing policy. While some countries have never implemented contact tracing throughout the pandemic (e.g., Estonia), others have been conducting comprehensive contact tracing by identifying and isolating all contacts of positive cases since the first case was seen in the country (e.g., Slovenia). Moreover, some countries have changed their policies over time. For instance, Denmark has not implemented contract tracing at all during the first two months of the outbreak (January, February), implemented contact tracing for some of the cases during the following six weeks (from March up to the third week of April), and finally adopted contact tracing for all cases since the third week of April.

A few studies have examined the role of contact tracing in reducing the transmission of COVID-19 at the country level[11,12]. Moreover, modeling studies have examined the efficacy of contact tracing interventions[13,14]. However, cross-country examination of the effectiveness of different contact tracing policies using real-time data is lacking. While modeling studies provide useful forecasts, they rely on simplified assumptions[15]. Thus, complementing modeling studies with real-time observations would enrich our understanding of the usefulness of different policies against COVID-19. In this paper, using data from the European Union (EU) and Organisation for Economic Co-operation and Development (OECD) countries, we quantitatively evaluate the effectiveness of different contact tracing policies in decreasing case fatalities from COVID-19.

Methods

Study variables and data sources. Our data come from publicly available sources. Appendix A provides detailed information on our study variables, as well as the data sources. The descriptive statistics of the variables, including the mean, standard deviation, and minimum and maximum values, are provided in Table 1. Data for our primary independent variable, contact tracing policy, were taken from the Oxford Covid-19 Government Response Tracker[16]. The Oxford Tracker provides countries' daily contact tracing policy, coded using a 3-point Likert scale (0=no contact tracing, 1=limited contact tracing, not done for all cases, 2=comprehensive contact tracing; done for all identified cases).

The measure for the intensity of non-pharmaceutical controls adopted by governments was also taken from the Covid-19 Government Response Tracker. The Tracker keeps track of the containment and closure policies implemented by governments throughout the pandemic and provides a total stringency score (a higher score indicates more stringent measures). Emergency monetary investment in healthcare made by governments was taken from the Tracker as well. In our analysis, we used emergency healthcare investment as a percentage of GDP for each country.

We compiled COVID-19-related data on the number of tests, cases, and deaths as well as country-specific characteristics (population density, the percentage of the population over 70 years old, public health expenditure as a percent of GDP, the percentage of smokers as well as people with diabetes in the overall population) from ourworldindata.org[17]. Data on countries' pre-pandemic healthcare capabilities were taken from the World Development Indicators[18] and national websites. Data on the fiscal stimulus packages introduced by governments during the pandemic to revive economies were taken from the COVID-19 Economic Stimulus Index[19].

COVID-19-related data (the number of tests, cases, deaths, and contact tracing policy) for each country were taken from the day the first case was recorded in a country to August 3 for all countries. All data used in this study are aggregated in one dataset and are available upon request.

Multiple Regression Analysis. We ran negative binomial regression models to investigate the relationship between contact tracing policy and death rates since the dependent variable in our model, the case fatality rate, is over-dispersed[20,21]. We operationalized the case fatality rate as the number of deaths in closed cases (closed case refers to those who have recovered or died). We used closed cases instead of total cases because taking the total case as the denominator may result in an underestimation of the death rate..\..\AppData\Local\slack\app-4.8.0\resources\app.asar\dist\notifications-2018.html[22]. In the cross-sectional analysis, we used the cumulative number of tests for countries. For the contact tracing policy, we used the mean of the contact tracing policy score observed on all days for a country. Similarly, for the stringency score, we used the mean of stringency scores recorded on all days for each country.

For the panel data analysis, we ran fixed-effect regression models, as dictated by the Hausman specification test. The panel data estimation is particularly useful in analyzing the dynamic lagged effects of different contact tracing policies on case fatality rates. Specifically, panel data analysis allows us to analyze whether the number of tests and contact tracing policies on a given day are associated with the case fatality rate 14 days later. For example, we associated the testing and contact tracing data from March 15 with the case fatality rate from March 29 for countries with available data. We used the 14-day interval in our analysis because previous research reported that the median number of days from the first symptom to death is 14 days[23]. In regression models, we use the fixed effects estimator, as indicated by the F and Hausman tests. Limited by the availability of the data, our cross-country and daily panel data span 38 countries with 4,248 observations in total.

Results

Cross-sectional data analysis. In our study, the primary dependent variable is case fatality rates of COVID-19, operationalized as the number of deaths in closed cases. In our cross-sectional analysis, we regressed case fatality rates on four sets of predictors: testing policy variables (the number of tests and contact tracing policy), healthcare system capabilities (the number of hospital beds, ICU beds, doctors, and nurses), country characteristics (population density, the percentage of the population over 70 years old, health expenditure, GDP per capita, the percentage of smokers and people with diabetes in the population), economic measures against COVID-19 (fiscal stimulus, emergency investment in healthcare) and stringency score (non-pharmaceutical public health control measures adopted by countries).

Tables 2a and 2b present the results from cross-sectional data using negative binomial regression models. Table 2a shows that contact tracing policy is significantly and negatively associated with case fatality rates controlling for a host of variables. Among the country-related factors, on average, a 1-unit increase in contact tracing policy was associated with a 13% (0.07/-0.55) reduction in the case fatality rate on average (RR = -0.56; 95% CI -1.08 to 0.02, P = 0.04)

Our regression analysis with cross-sectional data also shows that the number of hospital beds is significantly associated with case fatality rates, indicating that countries with a higher number of hospital beds have lower rates of case fatalities. In addition, countries with higher population density have higher rates of case fatalities.

To improve the robustness of our findings from the cross-sectional analysis, we ran the same regression model using the mortality rate (the number of deaths per million) as a dependent variable. Table 2b shows that the contact tracing policy is significantly and negatively associated with the mortality rate, controlling for a host of variables. The results from cross-sectional analyses suggest that countries that have utilized more comprehensive contact tracing have lower deaths from COVID-19, controlling for the number of tests conducted, country-specific characteristics, and other public health measures.

Figures 1 and 2 show scatterplots of the association between contact tracing policy and case fatality and mortality rates, respectively. The figures illustrate the plain correlation between the variables, particularly that countries that implement more comprehensive contact tracing policy have lower death rates.

Panel Data Analysis. In a second set of analyses, we use panel data and examine the effect of the contact tracing policy on a given day (T1-14) on case fatality rates after 14 days (T1). Panel data regression models with country fixed effects allow us to control unobserved heterogeneity across countries.

To improve the robustness of our analysis, we ran five sets of regression models with the panel data. The results of all models are presented in Table 3. In our baseline model, we ran a country fixed effect regression. In this model, we regressed case fatality rates (T1) on the daily number of tests, contact tracing policy, and stringency score 14 days earlier (T1-14). The results show that a higher number of daily tests and more comprehensive contact tracing on a given day reduces case fatalities significantly 14 days later within a country, controlling for the stringency score. Among the country-related factors, on average, a 1-unit increase in contact tracing policy was associated with a 3.1% (0.2048/-6.5071) reduction in the case fatality rate.

For robustness checks, we ran four additional models (see Table 3). In the second model, we ran a Poisson regression model. In the third model, we controlled for an indicator variable we generated to represent the negative binomial trend. In the fourth model, we controlled for the daily new cases. Finally, in the fifth model, we added time fixed effects. All regression models with panel data show that contact tracing policy and the number of daily tests on a given day are significantly associated with case fatality rates 14 days later within a country. Particularly, when countries utilize comprehensive contact tracing and increase the number of daily tests, their case fatality rates significantly decrease, controlling for non-pharmaceutical public health measures.

Discussion

The primary goal of this study was to explore the effect of different contact tracing policy choices adopted by countries on decreasing COVID-19-related deaths. Our analyses with the EU and OECD countries showed that comprehensive contact tracing is a significant factor that contributes to reducing deaths from COVID-19. We provide empirical evidence that controls for pre-pandemic health capabilities, non-pharmaceutical public health controls, economic measures, and country-specific characteristics, countries that utilized contact tracing more intensely have lower rates of case fatalities. Thus, our evidence with real-time country-level data confirms the anecdotal evidence on the effectiveness of contact tracing in suppressing the epidemic and limiting fatalities.

Our study has important policy implications. Effective national health systems and adequate government spending for public health are necessary to improve healthcare quality and decrease mortality rates under normal conditions[24]. However, in the case of a nationwide epidemic, additional interventions are needed to curtail the transmission of the virus and to diminish fatalities. Specifically, in the case of COVID-19 with high contagiousness, rapid and targeted responses are crucial. Thus, laboratory infrastructure for developing and producing diagnostic tests, flexible regulatory arrangements that allow rapid approval, strong decentralized systems to conduct and process tests, and widespread employment of epidemiologists to identify secondary cases are essential factors to consider for effective pandemic management. Since a vaccine is not available for COVID-19, early detection of index cases and identification and isolation of secondary cases through contact tracing are key to suppressing the epidemic.

Several limitations of our study need to be mentioned. First, our paper contributed to the understanding of what reduces deaths from COVID-19; however, the pandemic still persists. Therefore, future research is very much needed to see the full picture of the predictors of case fatality rates when the pandemic ends. Second, due to data availability and reliability, we focused only on EU and OECD countries in our analyses. Third, our analyses do not take the economic costs of different policies into account since country-level data on the costs of contact tracing are not available. Finally, the timing of the identification of secondary cases is vital for an effective contact tracing policy; however, we were not able to examine cross-country variation in timing due to data unavailability.

In this study, we investigated the effect of overall contact tracing policies of countries on case fatality rates. Our results suggest that comprehensive contract tracing is an effective policy, along with mass testing, for diminishing the burden on the healthcare system and speeding the rate at which infected individuals receive the medical care they need to maximize their chance of recovery.

Declarations

Conflicts of interest/Competing interests: None

Availability of data: Available at Springer Nature Research Data

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Tables

Table 1. Descriptive Statistics of Study Variables

Country	Code	Total Tests (per million)	Contact Tracing	Fiscal	Stringency Score	Age over 70	Smokers
Australia	AU	172.04	1.35	12.41	68.06	10.13	14.75
Austria	AT	101.79	1.29	17.30	31.48	13.75	29.65
Belgium	BE	146.89	0.81	19.70	42.59	12.85	28.25
Bulgaria	BG	39.81	1.30	4.58	36.11	13.27	37.25
Canada	CA	110.70	1.00	15.00	67.13	10.80	14.30
Chile	CL	88.80	1.66	12.34	89.35	6.94	37.85
Croatia	HR	29.74	1.67	11.39	26.85	13.05	37.10
Cyprus	CY	173.84	1.74	10.86	52.78	8.56	36.15
Czech	CZ	65.96	1.41	7.30	34.72	11.58	34.40
Denmark	DK	273.97	1.20	13.36	60.19	12.32	19.05
Estonia	EE	91.21	0.00	11.30	22.22	13.49	31.90
Finland	FI	66.37	0.73	16.18	43.52	13.26	20.45
France	FR	45.68	1.12	10.44	31.48	13.08	32.85
Germany	DE	95.53	1.16	17.71	37.50	15.96	30.65
Greece	GR	54.19	0.59	14.00	57.41	14.52	43.65
Hungary	HU	35.92	2.00	3.59	52.78	11.98	30.80
Iceland	IS	416.53	1.37	9.90	33.33	9.21	14.75
Ireland	IE	128.69	1.00	14.49	38.89	8.68	24.35
Israel	IL	195.15	1.16	11.35	68.52	7.36	25.40
Italy	IT	68.33	1.71	10.80	58.33	16.24	23.80
Japan	JP	6.72	0.93	42.20	24.07	18.49	22.45
Latvia	LV	107.09	1.29	16.30	46.30	14.14	38.30
Lithuania	LT	195.25	1.07	17.90	35.19	13.78	29.65
Luxembourg	LU	951.28	1.43	22.00	11.11	9.84	23.45
Mexico	MX	7.79	0.73	1.20	70.83	4.32	14.15
Netherlands	NL	56.19	1.10	12.80	39.81	11.88	25.85
New Zealand	NZ	98.25	1.44	10.81	22.22	9.72	16.00
Norway	NO	83.88	0.85	5.50	34.26	10.81	20.15
Poland	PL	52.33	0.83	9.60	39.81	10.20	28.20
Portugal	PT	159.21	1.05	15.30	71.76	14.92	23.15
Romania	RO	65.96	0.58	4.30	39.81	11.69	30.00
Slovakia	SK	48.68	2.00	6.10	37.96	9.17	30.40
Slovenia	SI	63.78	2.00	19.71	33.33	12.93	22.55
South Korea	KR	30.47	1.67	3.39	48.61	8.62	23.55
Spain	ES	142.83	0.97	7.80	58.80	13.80	29.40
Sweden	SE	80.19	1.10	16.00	38.89	13.43	18.85
Switzerland	CH	93.36	0.79	10.40	36.57	12.64	25.75
Turkey	TR	58.36	1.74	3.78	63.89	5.06	27.60
UK	GB	246.14	0.94	5.00	64.35	12.53	22.35
US	US	173.85	0.91	13.92	68.98	9.73	21.85
Mean		128.07	1.19	12.20	45.99	11.62	26.53
Median		90.01	1.14	11.37	39.81	12.15	25.80
Std.Dev		155.48	0.43	7.06	17.10	2.95	7.35
Max		951.28	2.00	42.20	89.35	18.49	43.65
Min		6.72	0.00	1.20	11.11	4.32	14.15
95% CI		78.35-177.79	1.05-1.33	9.94-14.46	40.52-51.46	10.68-12.56	24.18-28.88

Country	Code	Diabetes	Nurse (per 1000)	Hospital Beds (per 1000)	ICU Beds (per 100000)	Physicians (per1000)	Population Density
Australia	AU	5.07	12.00	3.80	9.00	3.68	3.20
Austria	AT	6.35	7.00	7.60	22.00	5.17	106.75
Belgium	BE	4.29	11.00	6.20	16.00	3.07	375.56
Bulgaria	BG	5.81	4.00	6.80	12.00	4.03	65.18
Canada	CA	7.37	10.00	2.70	13.00	2.61	4.04
Chile	CL	8.46	3.00	2.20		2.59	24.28
Croatia	HR	5.59	7.00	5.60	15.00	3.00	73.73
Cyprus	CY	9.24	5.00	3.40	11.00	1.95	127.66
Czech	CZ	6.82	8.00	6.50	12.00	4.12	137.18
Denmark	DK	6.41	10.00	2.50	7.00	4.01	136.52
Estonia	EE	4.02	6.00	5.00	15.00	4.48	31.03
Finland	FI	5.76	14.00	4.40	6.00	3.81	18.14
France	FR	4.77	11.00	6.50	12.00	3.27	122.58
Germany	DE	8.31	13.00	8.30	29.00	4.25	237.02
Greece	GR	4.55	3.00	4.30	6.00	5.48	83.48
Hungary	HU	7.55	7.00	7.00	14.00	3.41	108.04
Iceland	IS	5.31	15.00	3.20	9.00	4.08	3.40
Ireland	IE	3.28	12.00	2.80	7.00	3.31	69.87
Israel	IL	6.74	5.00	3.10		4.62	402.61
Italy	IT	4.78	7.00	3.40	13.00	3.98	205.86
Japan	JP	5.72	11.00	13.40	7.00	2.41	347.78
Latvia	LV	4.91	5.00	5.80	10.00	3.19	31.21
Lithuania	LT	3.67	8.00	7.30	16.00	6.35	45.13
Luxembourg	LU	4.42	12.00	4.80	15.00	3.01	231.45
Mexico	MX	13.06	3.00	1.50	1.00	2.38	66.44
Netherlands	NL	5.29	11.00	4.70	6.00	3.61	508.54
New Zealand	NZ	8.08	10.00	2.80	6.00	3.59	18.21
Norway	NO	5.31	18.00	3.90	8.00	2.92	14.46
Poland	PL	5.91	5.00	6.50	7.00	2.38	124.03
Portugal	PT	9.85	8.00	3.40	4.00	5.12	112.37
Romania	RO	9.74	6.00	6.30	21.00	2.98	85.13
Slovakia	SK	7.29	6.00	5.80	9.00	3.42	113.13
Slovenia	SI	7.25	10.00	4.60	6.00	3.09	102.62
South Korea	KR	6.80	7.00	11.50	11.00	2.36	527.97
Spain	ES	7.17	6.00	3.00	10.00	3.87	93.11
Sweden	SE	4.79	11.00	2.60	6.00	3.98	24.72
Switzerland	CH	5.59	17.00	4.70	11.00	4.30	214.24
Turkey	TR	12.13	2.00	2.70	46.00	1.85	104.91
UK	GB	4.28	8.00	2.80	7.00	2.81	272.90
US	US	10.79	12.00	2.90	35.00	2.61	35.61
Mean		6.56	8.65	4.91	12.37	3.53	135.25
Median		5.91	8.00	4.60	11.00	3.41	104.91
Std.Dev		2.31	3.92	2.49	8.77	0.97	136.23
Max		13.06	18.00	13.40	46.00	6.35	527.97
Min		3.28	2.00	1.50	1.00	1.85	3.40
95% CI		5.82—7.30	7.40-9.90	4.11-5.71	9.57-15.17	3.22-3.84	91.68-178.82

Country	Code	Case Fatality Rate	Mortality Rate	GDP per capita	Emergency Investment in Healthcare	Gov. Health Exp. (% of current health exp.)
Australia	AU	0.02	8.16	44648.71	0.16	0.69
Austria	AT	0.04	79.72	45436.69	0.00	0.72
Belgium	BE	0.36	849.90	42658.57	0.34	0.77
Bulgaria	BG	0.06	55.84	18563.31	0.18	0.52
Canada	CA	0.08	237.00	44017.59	0.04	0.74
Chile	CL	0.03	502.61	22767.04	0.41	0.50
Croatia	HR	0.03	36.29	22669.80	1.38	0.83
Cyprus	CY	0.02	21.69	32415.13	0.28	0.42
Czech	CZ	0.03	35.76	32605.91	0.04	0.82
Denmark	DK	0.05	106.18	46682.52	0.04	0.84
Estonia	EE	0.03	47.49	29481.25	0.00	0.75
Finland	FI	0.05	59.38	40585.72	0.05	0.77
France	FR	0.27	463.66	38605.67	0.17	0.77
Germany	DE	0.05	109.19	45229.25	1.76	0.78
Greece	GR	0.13	19.96	24574.38	0.00	0.60
Hungary	HU	0.15	61.80	26777.56	0.27	0.69
Iceland	IS	0.01	29.30	46482.96	0.00	0.82
Ireland	IE	0.07	357.04	67335.30	0.51	0.73
Israel	IL	0.01	61.93	33132.32	1.39	0.64
Italy	IT	0.15	581.42	35220.09	0.35	0.74
Japan	JP	0.04	7.99	39002.22	0.35	0.84
Latvia	LV	0.03	16.97	25063.85	0.02	0.57
Lithuania	LT	0.05	29.39	29524.27	0.67	0.65
Luxembourg	LU	0.02	186.91	94277.97	0.06	0.85
Mexico	MX	0.14	370.32	17336.47	0.34	0.52
Netherlands	NL		358.33	48472.55	0.00	0.64
New Zealand	NZ	0.01	4.56	36085.84	0.17	0.75
Norway	NO	0.03	47.04	64800.06	0.01	0.85
Poland	PL	0.05	45.74	27216.45	0.03	0.69
Portugal	PT	0.04	170.45	27936.90	0.00	0.66
Romania	RO	0.08	125.43	23313.20	0.01	0.79
Slovakia	SK	0.02	5.31	30155.15	0.04	0.79
Slovenia	SI	0.06	56.28	31400.84	0.00	0.72
South Korea	KR	0.02	5.87	35938.38	0.20	0.57
Spain	ES		608.96	34272.36	0.26	0.71
Sweden	SE		568.66	46949.28	0.14	0.84
Switzerland	CH	0.06	197.01	57410.16	0.17	0.30
Turkey	TR	0.03	67.92	25129.34	0.00	0.78
UK	GB		680.57	39753.24	0.39	0.79
US	US	0.06	467.85	54225.45	2.30	0.70
Mean		0.07	193.65	38203.84	0.31	0.70
Median		0.05	73.82	35579.23	0.16	0.74
Std.Dev		0.07	228.48	14892.42	0.51	0.12
Max		0.36	849.90	94277.97	2.30	0.85
Min		0.01	4.56	17336.47	0	0.30
95% CI		0.03-0.07	120.58-266.72	33441.01-42966.67	0.15-0.47	0.66-0.74

Table 2a. Negative Binomial Regression Models for Case Fatality (N=34)

Predictors	RR	SE	P>|z|	95% CI
Total Tests (per million)	-0.0019	0.0021	0.371	-0.0059-0.002201
Contact Tracing Policy	-0.5552**	0.2700	0.04	-1.08426-0.02606
Stringency Score	0.0211	0.0133	0.113	-0.00501-0.047295
Age over 70	0.0415	0.0608	0.494	-0.07759-0.160661
Percentage of Smokers	0.0410	0.0272	0.132	-0.01235-0.094337
Diabetes (% of population aged 20 to 79)	-0.1066	0.0716	0.137	-0.24695-0.033784
# of Nurses (per 1000)	0.0938	0.0805	0.244	-0.06387-0.25149
# of Hospital Beds (per 1000)	-0.1862**	0.0928	0.045	-0.36807--0.00436
# of ICU beds (per 100,000)	-0.0033	0.0174	0.851	-0.03739-0.03086
# of Physicians (per1000)	-0.2431	0.1809	0.179	-0.59775-0.111534
Population Density	0.0043***	0.0012	<0.001	0.001904-0.006758
GDP per capita	-0.0258	0.0215	0.23	-0.06798-0.016371
Emergency Investment in Healthcare	10.5488	26.7634	0.693	-41.9064-63.0041
Government Health Expenditure	1.3007	0.7913	0.1	-0.25016-2.851561
Fiscal Stimulus	-0.0142	0.0234	0.544	-0.06004-0.031635
Constant	-3.0554	1.9982	0.126	-6.97183-0.860959

Robust standard errors in parentheses. *** p<0.01, ** p<0.05. A total of 34 countries were included in the regression analysis. RR: relative risk. SE: standard errors

Table 2b. Negative Binomial Regression Models for Mortality Rates (N=38)

	RR	SE	P>|z|	95% CI
Total Tests (per million)	-0.0016	0.0009	0.08	-0.00336-0.00019
Contact Tracing Policy	-1.0342**	0.4348	0.017	-1.88632--0.18206
Stringency Score	-0.0054	0.0252	0.83	-0.05482-0.044015
Age over 70	0.2393***	0.0827	0.004	0.077328-0.401324
Percentage of Smokers	-0.0072	0.0556	0.897	-0.11619-0.101813
Diabetes (% of population aged 20 to 79)	0.0188	0.0866	0.828	-0.15098-0.188553
# of Nurses (per 1000)	-0.0686	0.0721	0.341	-0.20999-0.07275
# of Hospital Beds (per 1000)	-0.4109***	0.1420	0.004	-0.68925--0.13263
# of ICU beds (per 100,000)	0.0150	0.0218	0.491	-0.02772-0.057713
# of Physicians (per1000)	-0.1975	0.1670	0.237	-0.52479-0.129826
Population Density	0.0043**	0.0017	0.014	0.000857-0.007652
GDP per capita	0.0365**	0.0176	0.038	0.001983-0.071012
Emergency Investment in Healthcare	36.0044	31.5551	0.254	-25.8425-97.8513
Government Health Expenditure	1.0340	1.2334	0.402	-1.3835-3.451408
Fiscal Stimulus	-0.0535	0.0387	0.167	-0.12929-0.022365
Constant	4.6971	2.9694	0.114	-1.12285-10.51696

Robust standard errors in parentheses. *** p<0.01, ** p<0.05. A total of 34 countries were included in the regression analysis. RR: relative risk. SE: standard errors.

Table 3. Panel Data Regression Models for Case Fatality Rates on Time 1 [T1]

	(1)	(2)	(3)	(4)	(5)
# of Daily Tests [T1-14 days]	-0.0557***	-0.0026***	-0.0557***	-0.0598***	-0.0560***
	(0.0045)	(0.0001)	(0.0045)	(0.0131)	(0.0045)
Contact Tracing [T1-14 days]	-6.5071**	-0.2544***	-6.5072**	-6.6346**	-6.5446**
	(3.2585)	(0.0073)	(3.2588)	(3.3248)	(3.2998)
Stringency Score [T1-14 days]	0.0013	-0.0008***	0.0013	0.0048	0.0032
	(0.0579)	(0.0002)	(0.0579)	(0.0601)	(0.0583)
Simulated Negative Binomial			0.0272		
			(0.0934)		
# of New Cases [T1-14 days]				0.0001	
				(0.0002)	
Country Fixed Effect	+	+	+	+	+
Time Fixed Effect					+
Constant	27.8703***		27.7957***	27.8022***	27.3235***
	(5.7952)		(5.8760)	(5.7700)	(5.5167)
Observations	4,248	4,248	4,248	4,206	4,248
Number of id	36	36	36	36	36

Robust standard errors in parentheses. Model (2) is a Poisson model. *** p<0.01, ** p<0.05. When a specific fixed effect is included in the panel regression, we denote it by the sign +.

Figures

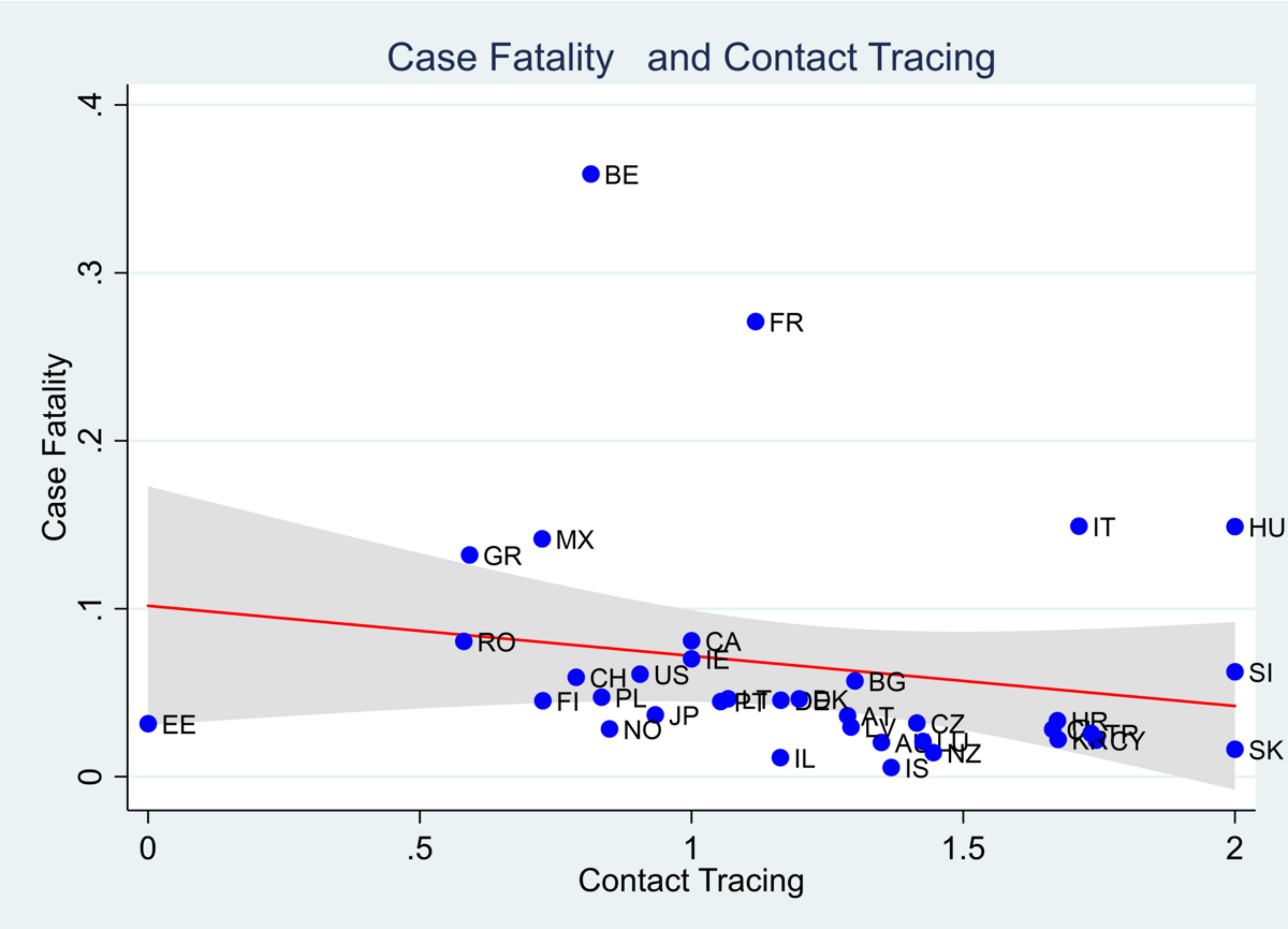

Figure 1

The association between contact tracing policy and case fatality rate

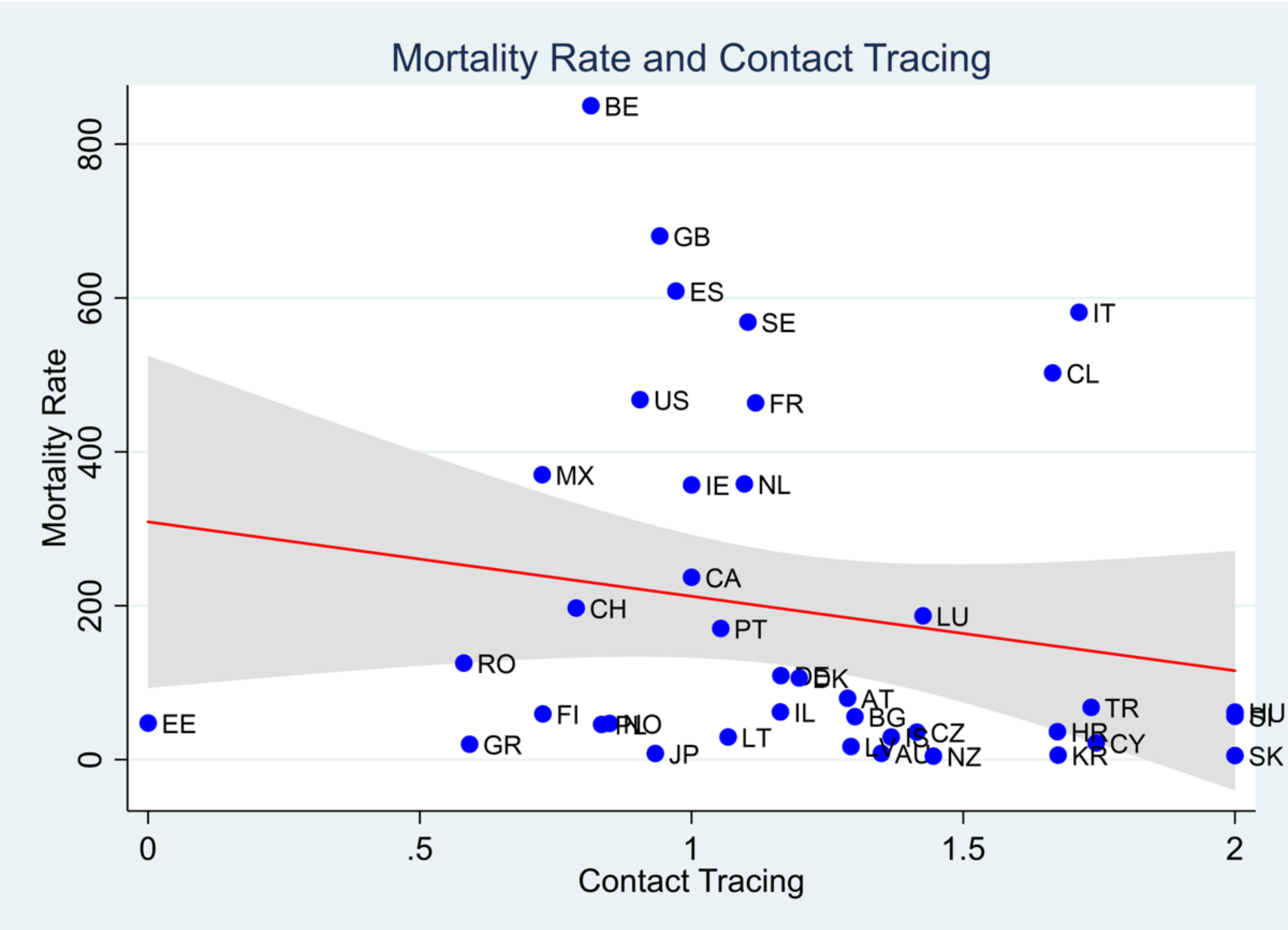

Figure 2

The association between contact tracing policy and mortality rates

Supplementary Files

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- Appendix.png