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Combating the COVID-19 pandemic: The role of the SARS imprint

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Abstract

This paper documents a strong delayed response to COVID-19, which is caused by the SARS-CoV-2 virus in countries that did not encounter the SARS disease in 2003. The SARS outbreak was caused by a similar virus, SARS-CoV-1. Individuals in countries that developed SARS infections in 2003 search more intensively for COVID-19-related information on Google during the first outbreak of COVID-19 in Wuhan, China, in late January 2020. Governments in countries that have not experienced SARS respond significantly slower in implementing containment measures to combat COVID-19 than countries that have experienced SARS. Furthermore, the timely responses of individuals and governments are more pronounced in countries that reported deaths caused by SARS, which left deeper imprints. Consequently, COVID-19 case numbers and mortalities have been substantially higher in countries that did not experience SARS deaths. Our findings suggest that the imprint of the early experience of similar viruses is a fundamental mechanism underlying timely responses to COVID-19.

Keywords: COVID-19, imprint, early experience, delayed response

JEL Classification: D83, E70, H12, I10

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1 Introduction

The global pandemic of the coronavirus disease 2019 (COVID-19) is one of the biggest social and economic crises in human history, one that is projected to lead to a 4.6% drop in global GDP in 2020.[1] The first known outbreak was in China in January 2020. Subsequently, the disease spread across the globe, causing a massive number of infections and deaths in more than 200 countries and territories. Despite its severity, countries respond differently in implementing containment measures and economic policies (e.g., Huang et al., 2020; Ding, Fan, and Lin, 2020).

This paper studies how the imprint of earlier similar virus outbreaks experience affects countries' responses to COVID-19. In particular, we explore the heterogeneous attention and responses to the first known outbreak of COVID-19 in Wuhan, China, between countries that were severely affected by Severe Acute Respiratory Syndrome (SARS) in 2003 and other countries, given the similarity between the viruses that cause SARS and COVID-19.[2] The first SARS patient was identified in Guangdong province, China, in November 2002, after which the disease spread to 29 countries/territories and resulted in more than 8,000 cases and 774 deaths. We find that countries that experienced outbreaks of SARS previously are more concerned about COVID-19 and respond in a more timely and proactive manner.

More specifically, we first directly examine whether the imprint of the SARS experience in 2003 exists in Google search data.[3] We study individuals' attention to the first known outbreak of COVID-19 in China from January 20 to 31, which covers the initial government responses and first extensive media coverage of COVID-19 in China and abroad.[4] We find that searches for SARS in Google are twice as high in the 28 countries/territories with SARS cases than in the other 150 countries/territories in this two-week window. People in countries without SARS experience start to pay more attention to COVID-19 when the disease spread rapidly outside of China at the beginning of March. Furthermore, Google searches for SARS are five times higher in the 10 countries/territories with SARS deaths than others. This suggests that the 2003 SARS experience is indeed imprinted in people's memory, and the imprint is stronger when the disease causes fatalities. These imprinted individuals also search significantly more for COVID-19 information, given that SARS and COVID-19 are closely related. In summary, people with SARS experience pay more attention to the initial COVID-19 outbreak than people without such experience.

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[1] See a special report from Fitch Ratings, https://www.fitchratings.com/research/sovereigns/global-economic-outlook-crisis-update-may-2020-coronavirus-shock-broadens-26-05-2020

[2] SARS-CoV-1 and SARS-CoV-2 are similar viruses, which cause SARS and COVID-19, respectively. See detailed discussions in Section 2.2.

[3] We download Google search indexes for the keywords "SARS" and "coronavirus". See detailed data descriptions in Section 3.

[4] See detailed discussions on the development of COVID-19 in Section 2.1.

Besides imprint theory, several alternative stories might explain these different responses. First, the countries that recorded deaths in the 2003 SARS outbreak might be more vulnerable to COVID-19 as well, given the similarity between the two viruses, which are both discovered in mainland China. To mitigate this concern, we exclude mainland China in the analyses to estimate other countries' responses before COVID-19 spread globally. In addition, we control for several country-level characteristics, especially for contemporaneous COVID-19 confirmed case numbers, which illustrate the severity of the domestic COVID-19 situation. Most countries had zero cases of COVID-19 from January 20 to 31. Second, we control for trade intensity between China and other countries and continent fixed effects to mitigate the concern that geographic and economic proximity to mainland China could explain higher attention to COVID-19. Furthermore, we restrict our sample to non-Asian countries, such as Europe and North America, and still find the same pattern of neglect in countries without SARS experience.

Next, we obtain data with detailed information on government responses to COVID-19 across the globe from the University of Oxford (Hale et al., 2020) and explore heterogeneous reactions to contain COVID-19 outbreaks between countries with and without SARS experience. Specifically, we perform a duration analysis of various containment measures on the interactions between COVID-19 case numbers and the SARS experience dummy across 142 countries. We find that contemporaneous COVID-19 case numbers are positively associated with the timeliness of government containment measures, and this effect is significantly more pronounced for countries with SARS cases. Again, such patterns are stronger for countries that recorded SARS deaths. On average, the associations between COVID-19 case numbers and decisions relating to school closures, workplace closures, cancellation of public events, restrictions on public gatherings, restrictions on domestic movements, and international travel controls are 114.51%, 195.19%, 65.07%, 118.63%, 125.89%, and 142.51% higher, respectively, in countries with SARS deaths than others. Besides, governments in non-Asian countries reveal the same pattern. In short, governments that were hit hard by the 2003 SARS epidemic respond more quickly to domestic COVID-19 outbreaks than governments that weren't.

Lastly, we provide suggestive evidence on significant potential consequences of slower responses to COVID-19 in countries without SARS experience. The severity of COVID-19 in countries with SARS might be higher in some countries than others for various reasons (e.g., geographic proximity to mainland China, population genetics and race, and healthcare systems). Yet, we find the opposite in the data. WHO declared COVID-19 a global pandemic on March 11, when it had infected over 100 countries. Since then, COVID-19 case numbers per capita and mortality rates have been, on average, 59.2% and 24.6% higher, respectively, in countries without SARS deaths than those that had recorded SARS deaths. This is consistent with the slower responses of governments in countries without SARS experience.

Our findings contribute to the literature examining the impact of prior experience on subsequent economic and social activities. After the seminal work by Stinchcombe (1965), imprint theory has been studied widely.[5] A number of studies show that early experience in life could leave imprints on individuals during their careers (e.g., Elder, 1986, 1998; Gibbons and Waldman, 2006; Kahn, 2010), and impact risk aversion (e.g., Malmendier and Nagel, 2011; Guiso, Sapienza, and Zingales, 2015; Bernile, Bhagwat, and Rau, 2017), investments (e.g., Kaustia and Knüpfer, 2008; Knüpfer, Rantapuska, and Sarvimäki, 2017; Huang, 2019), and corporate management (e.g., Graham and Narasimhan, 2004; Bayus and Agarwal, 2007; Billett and Qian, 2008; Malmendier, Tate, and Yan, 2011; Kaplan, Klebanov, and Sorensen, 2012; Benmelech and Frydman, 2015; Schoar and Zuo, 2017; He et al., 2018).[6] In particular, inexperienced investors tend to neglect risks until they experience severe and adverse investment outcomes (e.g., Gennaioli, Shleifer, and Vishny, 2012; Chernenko, Hanson, and Sunderam, 2016). This paper documents for the first time a crucial fundamental mechanism underlying the different responses to COVID-19 across the globe: the early experience of similar viruses.[7] This has important policy implications for economic aid programs and containment measures across the globe. Early response to COVID-19 can mean the difference between life and death.

2 Background

2.1 COVID-19 (caused by SARS-CoV-2)

According to WHO, severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) causes COVID-19. The first known outbreak of COVID-19 was in Wuhan, China, with the earliest known patient of COVID-19 recorded on December 15, 2019. One doctor, Wenliang Li, detected positive coronavirus in the SARS tests in the Central Hospital of Wuhan and sent out a warning to his fellow doctors on December 30, 2019. Subsequently, there were 27 COVID-19 cases recorded as of December 31, 2019. On January 9, 2020, a 61-year-old man who was infected by COVID-19 and had

[5] See, for example, the survey paper by Marquis and Tilcsik (2013) and a book by Higgins (2005).

[6] Fungáčová, Kerola, and Weill (2019) show that the experience of banking crises affects trust in banks. See Oyer (2006, 2008); McEvily, Jaffee, and Tortoriello (2012); Oreopouplos, von Wachter, and Heisz (2012); Shu et al. (2012) on the early experience of workers.

[7] A number of contemporaneous works have studied the economic consequences of COVID-19 outbreaks in China and beyond as well as policy responses to the virus. E.g., Atkeson (2020); Barrot, Grassi, and Sauvagnat (2020); Chen, Qian, and Wen (2020); Ding, Fan, and Lin (2020); Duan, Wang, and Yang (2020); Eichenbaum, Rebelo, and Trabandt (2020); Fahlenbrach, Rageth, and Stulz (2020); Gormsen and Koijen (2020); Hassan, et al. (2020); Iverson et al. (2020); Ramelli and Wagner (2020); Stock (2020).

an underlying heart condition became the first known person to die of COVID-19. Subsequently, the virus spread rapidly across cities in China, and by March 15, 2020, there were 80,860 officially confirmed cases, as shown in Figure A1.[8]

The media and public in China started to pay attention to COVID-19 in late January. In particular, Dr. Zhong Nanshan, a Chinese epidemiologist who discovered SARS in 2003, addressed the nation on China Central Television (CCTV) and, for the first time, confirmed the human-to-human transmission of COVID-19 on January 20. After that, the Chinese government initiated several strong containment measures. For example, at 2:30 am on January 23 (GMT+8), the Chinese government announced a complete lockdown of Wuhan and several other nearby cities in Hubei province after a total of 444 cases had been confirmed. This lockdown is the first major move in China to contain the outbreak, and the size of the lockdown, which affected approximately 57 million people, is unprecedented in public health history. On January 25, the first day of the Chinese Lunar New Year, the Standing Committee of the Politburo of the CPC, the highest authority of the CPC and the Chinese government, held an emergency meeting to combat COVID-19. It is unprecedented for the Standing Committee of the Politburo to have a meeting on the Chinese New Year holiday, and this event sent a strong signal of the severity of the COVID-19 situation in China to the rest of the world.

Outside of China, the first confirmed case, according to the WHO, was reported in Thailand on January 13, followed by a few confirmed cases in other countries. Figure A1 shows that the total number of confirmed cases outside of mainland China was under 150 until January 31. Figure A2 summarizes the important events and dates along the timeline and shows the milestones for COVID-19 development across the globe from the first known case in December 2019 to March 2020, when it became a global pandemic on March 11.

2.2 SARS (caused by SARS-CoV-1)

There are many similarities between SARS-CoV-1 and SARS-CoV-2, which cause SARS disease and COVID-19 disease, respectively. Specifically, SARS-CoV-2 is most closely related to SARS-CoV-1, according to the article by the National Institutes of Health titled "SARS-CoV-2 stability similar to original SARS virus." SARS-CoV-2 is recognized as a SARS family virus with similar symptoms and forms of transmission. For example, Chan et al. (2020) investigated the familial cluster of pneumonia associated with SARS-CoV-2 and conducted a phylogenetic analysis showing it is closest to the bat SARS-related coronavirus found in Chinese horseshoe bats. Van Doremalen et

[8] See Huang, Wang, Li, et al. (2020) on the development of coronavirus in Wuhan, China.

al. (2020) found the stability of SARS-CoV-2 in aerosols and on various surfaces is similar to that of SARS-CoV-1. In summary, COVID-19 is similar to SARS in many respects but quite different from other known pathogens, such as MERS and the influenza virus (see Appendix 3 for details). Hence, in this paper, we select SARS outbreaks to measure adverse early experiences.

3 Data and summary statistics

3.1 Data for SARS and COVID-19

We collect SARS case numbers in each country/territory from the WHO website (See Table A2 for details). SARS was first reported in mainland China and then spread to 28 other countries/territories. As of December 31, 2003, the WHO reported 8,096 probable SARS cases worldwide, with a fatality rate of 9.6%. Eleven countries/territories on three continents reported SARS fatalities. We obtain data on daily COVID-19 cases for each country from the Coronavirus Resource Center at John Hopkins University, which cover daily COVID-19 confirmed cases and deaths in 187 countries and territories from January 22, 2020. We supplement the earlier data on COVID-19 cases from WHO.

3.2 Data for Google search

We focus on Google searches for two keywords: “SARS” and “coronavirus.” Google provides search intensity measures ranging from 0 to 100, which represent search interests relative to the highest point for a given region and time. A value of 100 is the peak popularity for the keyword, and a score of 0 means there was not enough data (no search) on the keyword. To make Google search interests comparable across different regions, we obtain cross-sectional data from the "Interest by region" section over the period from January 20 to January 31 in Google Trends (trends.google.com). A higher value means a higher proportion of all queries, not a higher absolute query count. Therefore, we can compare these search intensities among different regions. For countries/territories with low search volumes, we fill up the missing search intensity by 0.

3.3 Data for government responses

We collect the cross-country containment policies from the Oxford COVID-19 Government Response Tracker (OxCGRT). Specifically, we obtain information on government policies to combat COVID-19 in the following six categories: school closure, workplace closure, public events cancellation, gathering restrictions, restrictions on internal movement between cities/regions, and international travel controls (Hale et al., 2020). In each category, we construct a dummy variable that equals

1 if the most stringent policy comes into effect in this category, and 0 otherwise. For example, OxCGRT provides the ordinal-scaled variable on school-closing policies, with 0 representing no measurement, 1 representing recommended closing, 2 representing required closing for some types of schools, and 3 representing required closing for all schools. We code the school-closing policy variable into a dummy variable that equals 1 if the government required all schools to be closed, and 0 otherwise.

3.4 Summary statistics

Panel A of Table 1 shows the summary statistics for cross-sectional data. Google Search intensity covers the period around the initial COVID-19 outbreak in Wuhan, China, from January 20 to January 31, 2020. We exclude mainland China in our sample to mitigate the concern that the results might be driven mainly by the concurrent severe COVID-19 situation in China, and Google is banned in mainland China. The average Google search intensity for the keywords "SARS" and "coronavirus" are 2.640 and 9.205, respectively. The average COVID-19 case number is 0.254 across 178 countries/territories, suggesting that most countries/territories were not affected by COVID-19 during its initial outbreak in mainland China. The average trade intensity is 0.102, indicating that, on average, trade with China accounts for 10.2% of the countries'/territories' total trade.

Panel B of Table 1 is for panel data on countries' containment measures and the local development of the COVID-19 pandemic at the country-date level. Closing schools and cancelling public events are the most frequent policies carried out by governments, while closing workplaces is the least frequent policy. 134 out of 142 countries/territories implemented the school closure at all levels. 99 countries/territories implemented workplace closure for all non-essential industries. 98 countries/territories implemented restrictions on gatherings of 10 people or more.

Table 1 Summary statistics

Panel A: Cross-sectional data							
Variables	Observations	Mean	SD.	P10	P25	P75	P90
SARS	178	2.640	9.116	0	0	1	6
Coronavirus	178	9.205	16.432	0	0	13	39
SARSDeath	178	0.056	0.231	0	0	0	0
SARSCase	178	0.157	0.365	0	0	0	1
Log(GDP)	178	24.593	2.111	21.807	23.243	26.225	27.371
Log(Popu)	178	15.831	1.953	13.153	14.839	17.209	18.220
AvgCOV19	178	0.254	0.920	0	0	0	0.4
TradeIntensity	178	0.102	0.131	0	0	0.149	0.263
Panel B: Country - date panel							
Variables	Observations	Mean	SD.	P10	P25	P75	P90
School	17831	0.393	0.488	0	0	1	1
WorkPlace	17748	0.198	0.399	0	0	0	1
PublicEvent	17714	0.402	0.490	0	0	1	1
Gathering	16640	0.226	0.419	0	0	0	1
InternalMovement	17695	0.272	0.445	0	0	1	1
Travel	17621	0.243	0.429	0	0	0	1
COV19 Cases	18599	5492.714	43998.940	0	0	368	4534
COV19 Deaths	18599	375.907	3056.165	0	0	6	107

This table presents the summary statistics of our sample data. Panel A is for the cross-sectional data, including Google Search intensity, SARS experience, macro-economic conditions, and trade linkage with mainland China at the country/territory level. Panel B is for the country-date panel data on the countries' policy responses and local development of COVID-19 pandemic, which covers 142 countries from January 1 to May 10, 2020. Countries /territories without GDP or population information from the World Bank, or not covered by Coronavirus Resource Center at John Hopkins University, are excluded. Mainland China is excluded in both panels. *COV19 Cases* and *COV19 Deaths* are the reported COVID-19 confirmed cases and deaths, respectively. See Table A1 for variable definitions.

4 Empirical analyses and results

4.1 The imprint of the 2003 SARS epidemic

We begin the analysis by estimating whether the imprint of the SARS experience in 2003 exists during the initial COVID-19 outbreak in Wuhan. Specifically, we perform an OLS regression of Google search indexes for SARS during the two-week window from January 20 to January 31 on the country's SARS experience. This two-week window covers the entire first government response in China and broad media coverage of COVID-19, as described in Section 2.1. Formally, the regression can be expressed as follows:

$$GoogleSearchIntensity_i = \alpha + \beta \times SARSCase_i + Controls_i + Continent\ FE + \varepsilon_i, \quad (1)$$

where $GoogleSearchIntensity_i$ indicates the two Google search intensity measures on the keywords "SARS" or "coronavirus," respectively, in country i during the initial outbreak in Wuhan; $SARSCase_i$ is an indicator variable denoting that country i has recorded domestic SARS cases. Panel A of Table 2 shows the results. In column (1), the coefficient on $SARSCase$ is 5.792 at the 1% significance level, suggesting that people in countries with confirmed SARS cases search for SARS-related information about twice (5.792/2.640=219.39%) more intensively than people without SARS experience.

Furthermore, we use $SARSDeath_i$, which is an indicator variable denoting that country i has recorded domestic SARS deaths, and repeat the regressions. In column (3), the coefficient on $SARSDeath$ is 14.407 at the 10% significance level, suggesting that people in countries with SARS fatalities search five times (14.407/2.640=545.72%) more than people in countries that did not experience SARS deaths. These results indicate that the 2003 SARS experience made an imprint in the memories of people who started to search for SARS information at the very beginning of the COVID-19 outbreak in China and that deaths resulting from SARS leave a stronger imprint.[9]

Besides the imprint theory, there might be several alternative mechanisms that could potentially explain the higher search activities for SARS. For example, 14 of 29 countries/territories that suffered from SARS in 2003 are in Asia and are particularly close to mainland China geographically. Those countries/territories are probably affected by COVID-19 more heavily as well, given that the known outbreaks of both SARS and COVID-19 are from mainland China. We control for country-level characteristics such as GDP and population. More importantly, we also control for the contemporaneous number of confirmed COVID-19 cases. Only 25 out of the 178 countries/territories reported confirmed COVID-19 cases as of January 31, while only 5 of the 25 have more than 10 confirmed cases (e.g., the maximum number of cases was 19). This means the 178 countries in our sample were mostly unaffected by COVID-19 in our two-week window (see Figure A1 for outbreaks within and outside mainland China). In addition, we control for economic proximity to China by adding the trade intensities between China and country i in regressions, which is the ratio between total imports and exports to China over total trade in this country.

In columns (2) and (4), we further control the continent fixed effects to tease out the variation across continents and find consistent results. For example, in column (4), the coefficient on *SARSDeath* is 14.408 at the 5% level, which scarcely differs from that in column (3). Moreover, in columns (5) and (6), we exclude Asian countries and restrict our sample to the other four continents, mainly for countries in Europe and North America. The coefficients on *SARSCase* and *SARSDeath*

[9] Figure A3 shows that people in countries with SARS deaths search more intensively for SARS and COVID-19-related information on Google following the Wuhan outbreak at the end of January. Such patterns are much weaker in countries without SARS deaths until the beginning of March when COVID-19 spread widely outside of China.

are both significantly positive. These findings serve as strong evidence that even in non-Asian countries such as Europe, the people in countries affected by SARS in 2003 pay significantly more attention to the COVID-19 outbreak in Wuhan, when there were zero (or near zero) domestic cases.

Table 2 Imprint of SARS (Google search indexes)

	All countries/territories				Exclude Asia	
Panel A: SARS search						
Variables	(1) *SARS*	(2) *SARS*	(3) *SARS*	(4) *SARS*	(5) *SARS*	(6) *SARS*
SARSCase	5.792***	6.152***			5.124*	
	(2.62)	(2.65)			(1.68)	
SARSDeath			14.407*	14.408**		14.516**
			(1.97)	(1.99)		(1.99)
Log(GDP)	0.275	0.800	0.802***	1.321**	0.910***	1.159***
	(0.89)	(1.59)	(2.61)	(2.55)	(3.75)	(4.29)
Log(Popu)	–0.744**	–1.317**	–1.037***	–1.574***	–0.546***	–0.619***
	(–2.33)	(–2.42)	(–2.99)	(–2.68)	(–2.62)	(–3.17)
Log(AvgCOV19)	12.384**	11.699**	9.136	8.535	–2.078	–3.669
	(2.34)	(2.23)	(1.60)	(1.49)	(–0.67)	(–1.03)
TradeIntensity	1.519	–0.289	2.301	0.690	1.818	2.057
	(0.53)	(–0.10)	(0.77)	(0.24)	(0.88)	(1.17)
Continent FE	NO	YES	NO	YES	YES	YES
Observations	178	178	178	178	136	136
R-squared	0.456	0.472	0.507	0.520	0.389	0.569
Panel B: Coronavirus search						
Variables	(1) *Coronavirus*	(2) *Coronavirus*	(3) *Coronavirus*	(4) *Coronavirus*	(5) *Coronavirus*	(6) *Coronavirus*
SARSCase	11.035**	13.457***			17.329***	
	(2.25)	(2.93)			(3.85)	
SARSDeath			17.137**	19.341**		15.340**
			(2.08)	(2.57)		(2.36)
Log(GDP)	4.418***	3.840***	5.374***	4.939***	4.442***	5.785***
	(6.64)	(4.32)	(8.28)	(5.81)	(4.64)	(6.06)
Log(Popu)	–1.643***	–1.003	–2.098***	–1.458*	–1.535**	–2.058**
	(–2.94)	(–1.30)	(–3.71)	(–1.94)	(–2.01)	(–2.55)
Log(AvgCOV19)	0.461	2.012	–1.785	–0.267	2.676	6.844
	(0.09)	(0.42)	(–0.33)	(–0.06)	(0.40)	(1.01)
TradeIntensity	–4.204	–5.378	–1.907	–2.092	–3.317	–1.990
	(–0.74)	(–0.96)	(–0.34)	(–0.38)	(–0.50)	(–0.26)
Continent FE	NO	YES	NO	YES	YES	YES
Observations	178	178	178	178	136	136
R-squared	0.379	0.533	0.382	0.530	0.663	0.622

This table presents the results of the cross-sectional OLS regressions of Google search indexes on SARS experience during the initial COVID-19 outbreak in Wuhan. In Panel A (B), the dependent variable *SARS* (*Coronavirus*) is Google Search intensity on keyword "SARS" ("coronavirus") between January 20 and January 31, 2020. Mainland China is excluded. See Table A1 for variable definitions. Robust standard errors are used, and *t*-statistics are reported in parentheses. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

Besides paying attention to SARS, we also look at the Google search for COVID-19-related information. Because the WHO officially named the pandemic COVID-19 on February 11, 2020, we choose the keyword "coronavirus," which was the term the public used in late January. We download the Google search index for "coronavirus" and repeat the regressions in equation (1). In columns (1) to (6) of Panel B, the coefficients on *SARSCase* and *SARSDeath* are all significantly positive. For example, in column (4), the coefficient estimate is 19.341 at the 5% significance level, suggesting that people in countries with SARS deaths search for COVID-19 related information about 2.1 times (19.341/9.205=210.11%) more intensively than people in countries without such experiences. We also perform the ordered probit regressions by classifying Google search intensity into five levels, and the results are consistent with Table 2. See Table A3 for detailed regression results.

Taken together, the results in Table 2 suggest that people in countries with SARS experience pay more attention to COVID-19-related information than people in other countries during the first known outbreak in Wuhan in late January 2020, which is due mainly to the imprint of the early experience of the SARS epidemic in 2003, especially for countries with SARS deaths.

4.2 Government actions to combat COVID-19 outbreaks

In this section, we aim to understand the impact of the SARS imprint on government actions to combat domestic COVID-19 outbreaks. One of the major criticisms against government containment measures is the slow response to COVID-19. We employ the Cox proportional hazard model to study the association between the probability of implementing various containment measures (e.g., lockdowns) and the SARS imprint. Formally, the regression can be expressed as follows:

$$h(t) = h_0(t)\, exp\big(\beta_1 \times Log(COV19Cases)_{i,t} + \beta_2 \times Log(COV19Cases)_{i,t} \times SARSDeath_i + \beta_3 \times SARSDeath_i + Controls_i + Continent\ FE\big), \quad (2)$$

where $Log(COV19Cases)_{i,t}$ is the natural logarithm of one plus the total number of confirmed COVID-19 cases in country i at date t; $Controls_i$ includes GDP, population, and trade intensity with China. We also control for continent fixed effects. Each country enters the hazard regression at the date of its first confirmed domestic COVID-19 case and exits after the respective policy comes into effect.

We focus on the sample of 142 countries worldwide where we have data on government actions and estimate the hazard probabilities for six different containment measures in Table 3. Panel A uses the SARS death dummy to proxy for SARS imprint, and Panel B uses the SARS case dummy. In columns (1) to (6) of Panel A, the coefficients of *Log(COV19Cases)* are 0.602, 0.331, 0.734, 0.157, 0.397, and 0.205, respectively, which are all statistically significant. This suggests that the likelihood of enforcing these containment measures is significantly higher when there are more contemporaneous confirmed COVID-19 cases. Moreover, in columns (1) to (6), the coefficients of *Log(COV19Cases)× SARSDeath* are all significantly positive. On average, the association between COVID-19 case numbers and the decisions to close schools and workplaces, cancel public events, restrict public gathering and domestic movements, and control international travel are 114.51%, 195.19%, 65.07%, 118.63%, 125.89%, and 142.51% higher, respectively, in countries with SARS deaths before than the others.[10] In Panel B, we find similar patterns that are relatively weaker than the results in Panel A. This is consistent with Table 2, which shows that the imprint of SARS experiences, especially SARS deaths, plays an important role in dealing with similar crises subsequently.[11] In Table A4, we restrict the sample to non-Asian countries and find consistent results for all six containment measures.

In summary, the results in Table 3 suggest that governments in countries with SARS imprints respond significantly more quickly to domestic increases in the spread of COVID-19, while countries without such imprints are slower in their decisions to close schools and workplaces, cancel public events, ban public gatherings, and restrict travel.

[10] These percentage increases are based on the hazard ratios on *Log(COV19Cases)* in columns (1) to (6), which are 1.826, 1.392, 2.084, 1.170, 1.487, and 1.228, respectively, and the hazard ratios on *Log(COV19Cases)×SARSDeath* in columns (1) to (6), which are 2.091, 2.717, 1.356, 1.388, 1.872, and 1.750, respectively. For example, in column (1), the association between COVID-19 case numbers and decisions to close schools is 114.51% higher for SARS countries (2.091/1.826).

[11] For example, David Naylor, a leading Canadian expert on pandemic control, said that Canada's response to coronavirus benefited vastly from the 2003 SARS epidemic that killed 44 Canadians (Webster, 2020). In contrast, the US has recorded SARS cases but no deaths and has about twice as many confirmed COVID-19 cases as Canada and about 30 percent more deaths.

Table 3 Policy responses to combat COVID-19

Panel A: SARS Death						
Variables	(1) *School*	(2) *Workplace*	(3) *Public event*	(4) *Gathering*	(5) *Internal movement*	(6) *Travel*
Log(COV19Cases)	0.602***	0.331***	0.734***	0.157**	0.397***	0.205***
	(6.64)	(4.64)	(7.67)	(2.39)	(6.03)	(2.95)
Log(COV19Cases) × SARSDeath	0.738***	1.000***	0.304**	0.328***	0.627***	0.560***
	(3.12)	(5.66)	(2.30)	(3.08)	(3.29)	(3.36)
Controls	YES	YES	YES	YES	YES	YES
Continent FE	YES	YES	YES	YES	YES	YES
Observations	2,249	5,446	2,280	5,590	4,297	5,138
Pseudo R^2	0.105	0.078	0.098	0.036	0.081	0.051
Panel B: SARS Case						
Variables	(1) *School*	(2) *Workplace*	(3) *Public event*	(4) *Gathering*	(5) *Internal movement*	(6) *Travel*
Log(COV19Cases)	0.526***	0.218***	0.697***	0.074	0.327***	0.131*
	(5.68)	(2.89)	(7.05)	(1.09)	(4.54)	(1.78)
Log(COV19Cases) × SARSCase	0.483***	0.500***	0.146	0.473***	0.179	0.240***
	(4.11)	(4.94)	(0.99)	(5.58)	(1.62)	(2.73)
Controls	YES	YES	YES	YES	YES	YES
Continent FE	YES	YES	YES	YES	YES	YES
Observations	2,249	5,446	2,280	5,590	4,297	5,138
Pseudo R^2	0.110	0.081	0.097	0.058	0.073	0.049

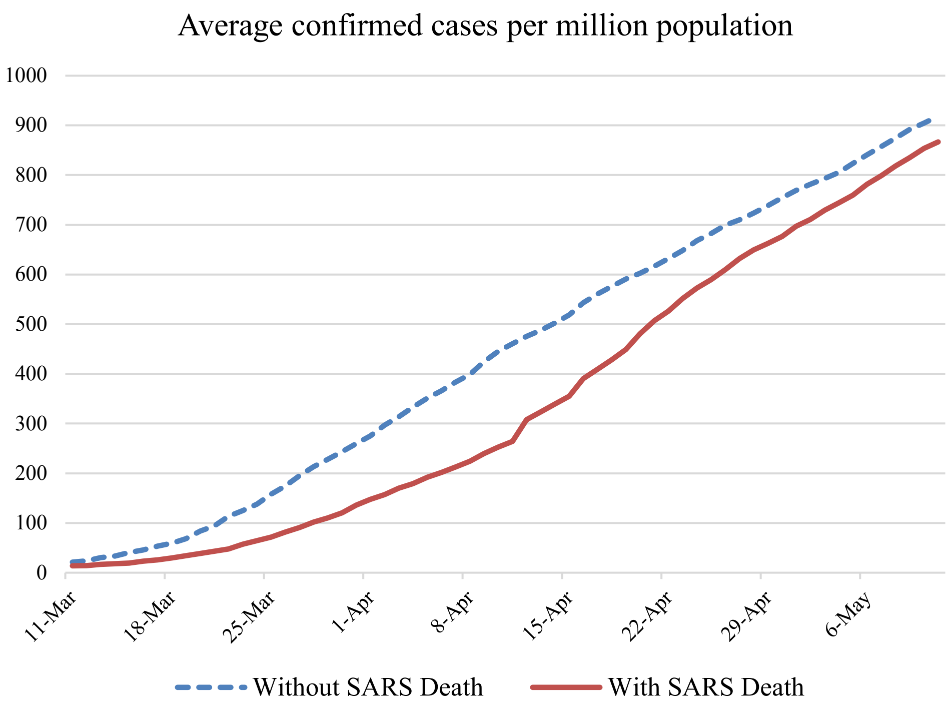
This table presents duration analysis results for policy responses on COVID-19 across different countries. The origin date is the date when the country/territory reported its first COVID-19 confirmed case. The failure date is the date when the respective policy came into effect. Observations before the original date or after the failure date are dropped. *SARSDeath (SARSCase)*, *TradeIntensity*, *Log(GDP)*, and *Log(Popu)* are controlled in each column. Mainland China is excluded. See Table A1 for variable definitions. Standard errors are clustered at the country level, and *t*-statistics are reported in parentheses. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

4.3 Potential consequences of delayed action against COVID-19

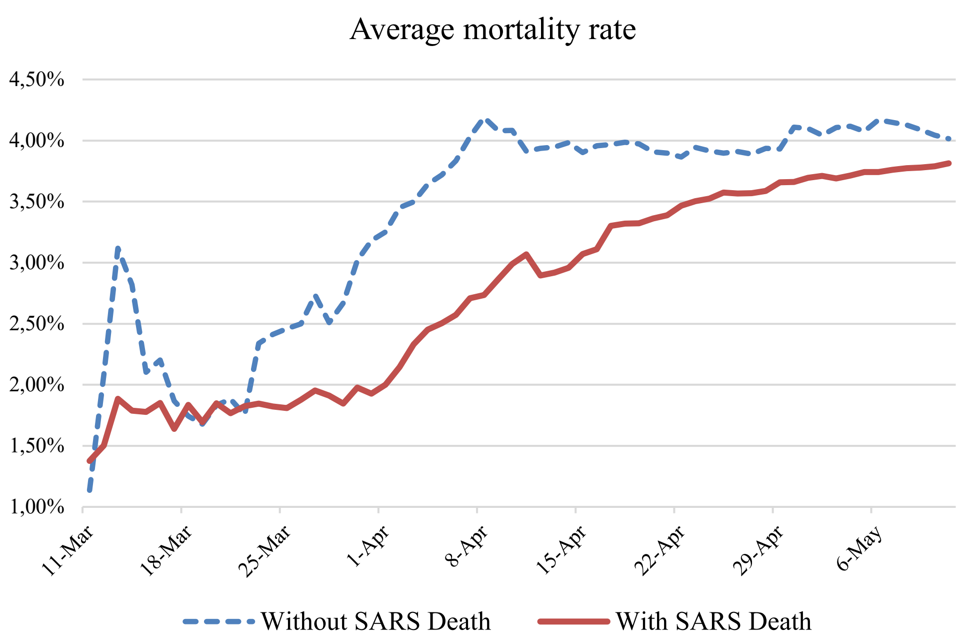
Lastly, we show some suggestive evidence on the consequences of delayed action in implementing containment measures for countries without SARS experience, as shown in Section 4.2. In particular, we compare the severity of COVID-19 between countries with and without SARS deaths. In Figure 1, we plot the time trends of total confirmed COVID-19 cases normalized by population and the mortality rates in countries with and without SARS deaths, starting on March 11, 2020, when the WHO declared COVID-19 a global pandemic.

Figure 1 COVID-19 infections and mortality

Panel A



Panel B



This figure shows the time trends of average infections and mortality for two groups of countries/territories from March 11 to May 11, 2020. Panel A presents average confirmed COVID-19 cases per million population, while Panel B shows the average mortality rate. The mortality rate is the ratio between the total number of deaths and the total number of cases. The dashed blue line represents the countries without SARS deaths, and the solid orange line represents the countries with SARS deaths. See Table A2 for the list of countries/territories with SARS infections.

Over time, COVID-19 case numbers and mortality rates have been substantially lower in countries with SARS deaths. On average, the case numbers and mortality rates are 59.2% and 24.6% lower, respectively, in countries with SARS deaths than in the other countries. Given the similarities between SARS and COVID-19, countries that were badly impacted by SARS might be more vulnerable to COVID-19. For example, the countries that lost lives in the 2003 SARS outbreak might have less robust healthcare systems and are closer to mainland China, the first known epicenter of both COVID-19 and SARS. These countries might also have populations that are more vulnerable to coronavirus genetically. Yet, our data shows that the opposite is the case.

In summary, although the final mortality count for COVID-19 is still inconclusive, the cost in terms of human lives is lower in countries with SARS deaths so far, which is consistent with the timely responses of the governments in those countries.

5 Conclusion

The current COVID-19 pandemic might be a once-in-a-lifetime global crisis. Although many countries have been hard at work combating this disease, it has nevertheless developed dramatically in many parts of the world, and its impacts are detrimental to human life and wellbeing. One perceived wisdom is that public healthcare systems should respond to these pandemics as early and as intensively as possible. This paper, for the first time, shows the different reactions to COVID-19 across countries with different experiences of the 2003 SARS outbreak. We document that countries with prior experiences of SARS respond in a more proactive, timely manner, and policymakers should be aware of such delayed responses to the COVID-19 pandemic.

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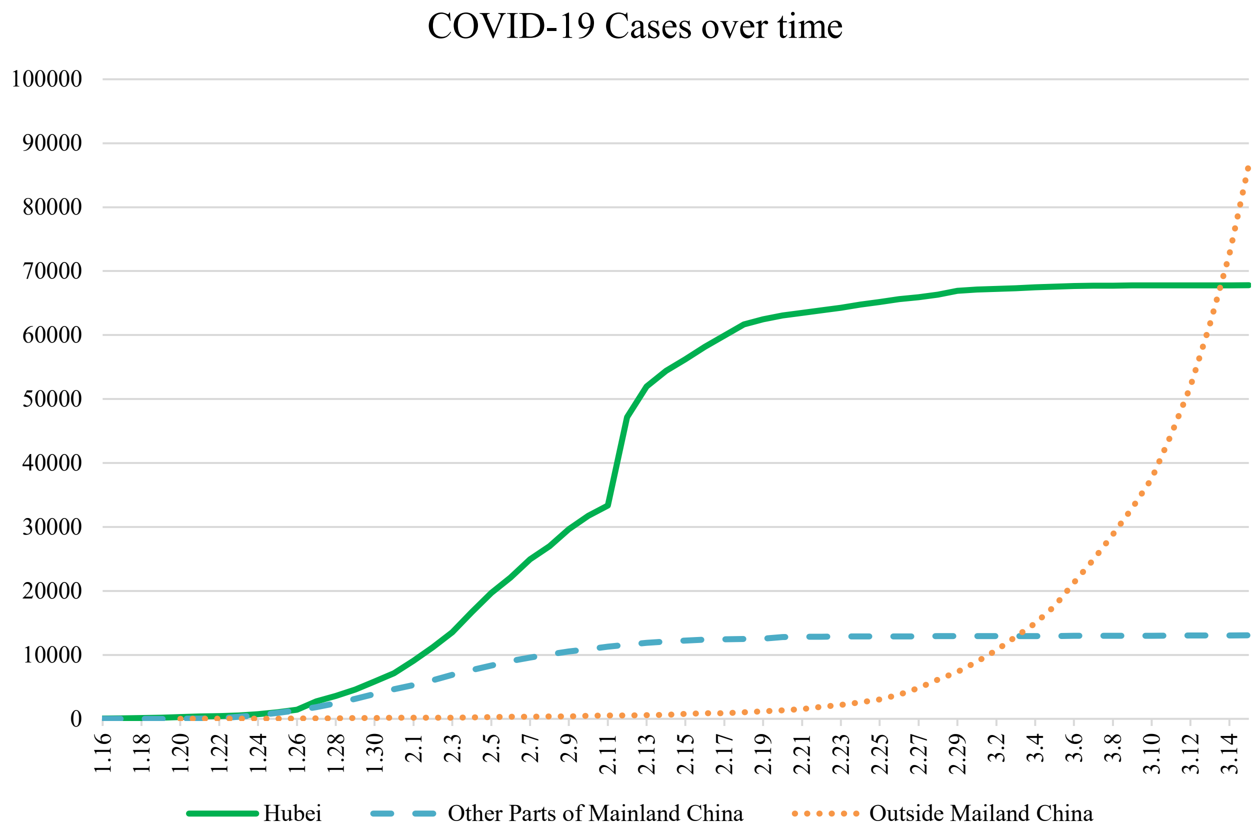
Internet appendix for combating the COVID-19 pandemic: The role of the SARS imprint

Contents

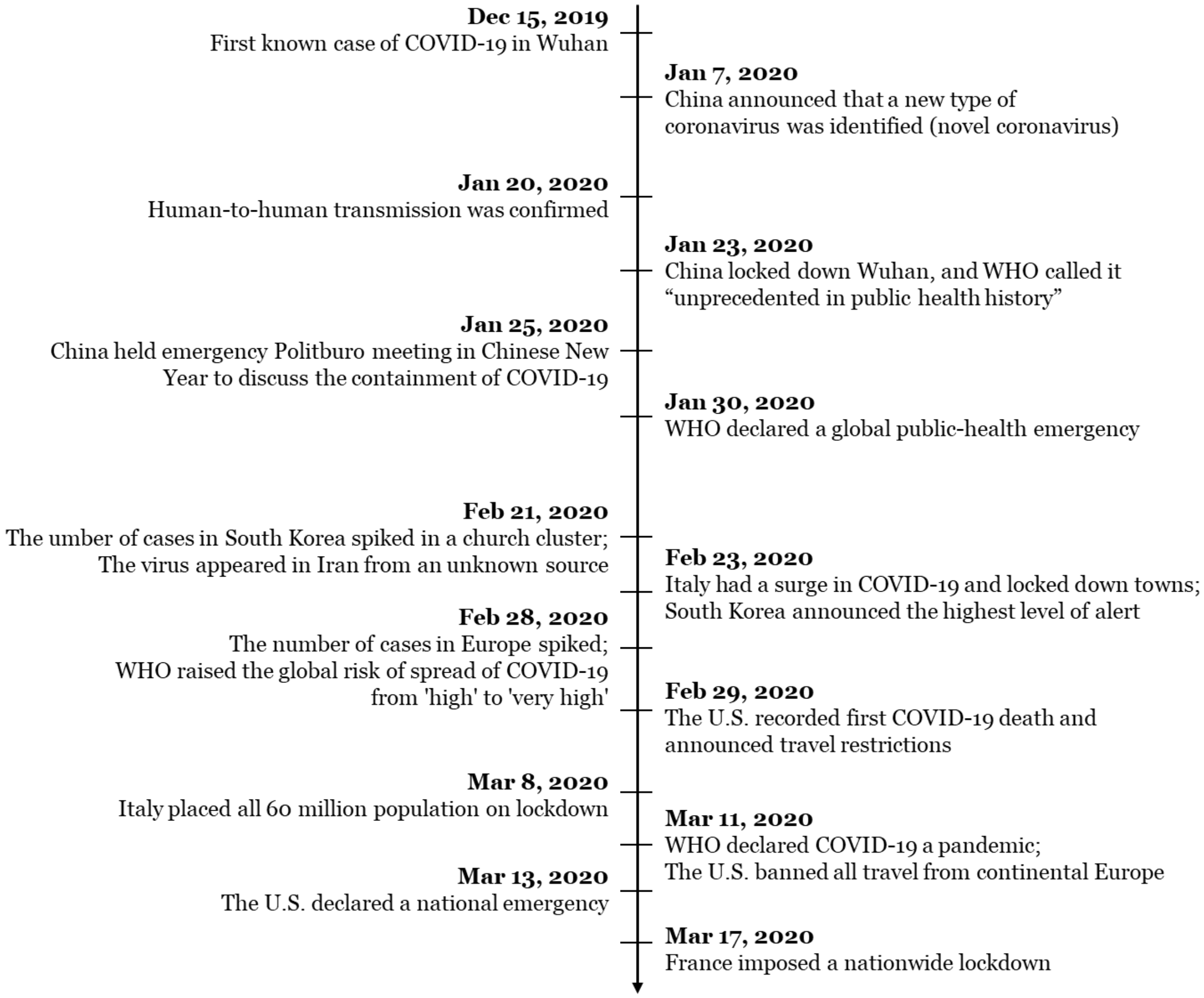
Appendix 1 Figures

Figure A1 Time trend of COVID-19 outbreak



This figure displays the COVID-19 cumulative case numbers across the globe from January 15 to March 15, 2020. The solid green line represents the number of cumulative cases in Hubei province of China. The blue dashed line represents the number of cumulative cases in other parts of mainland China. The yellow dotted line represents the number of cumulative cases outside mainland China. Starting from February 12, 2020, Hubei province includes clinically diagnosed cases into total confirmed cases, which causes a sharp increase, while in other places, only lab-confirmed cases are included from WHO data.

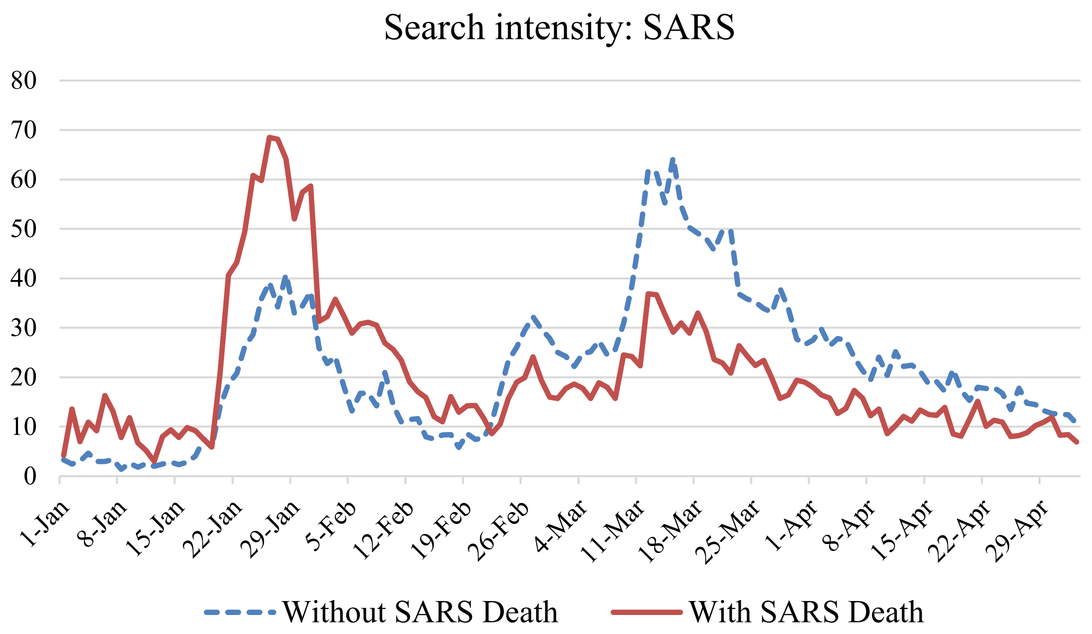
Figure A2 Timeline of COVID-19 outbreak



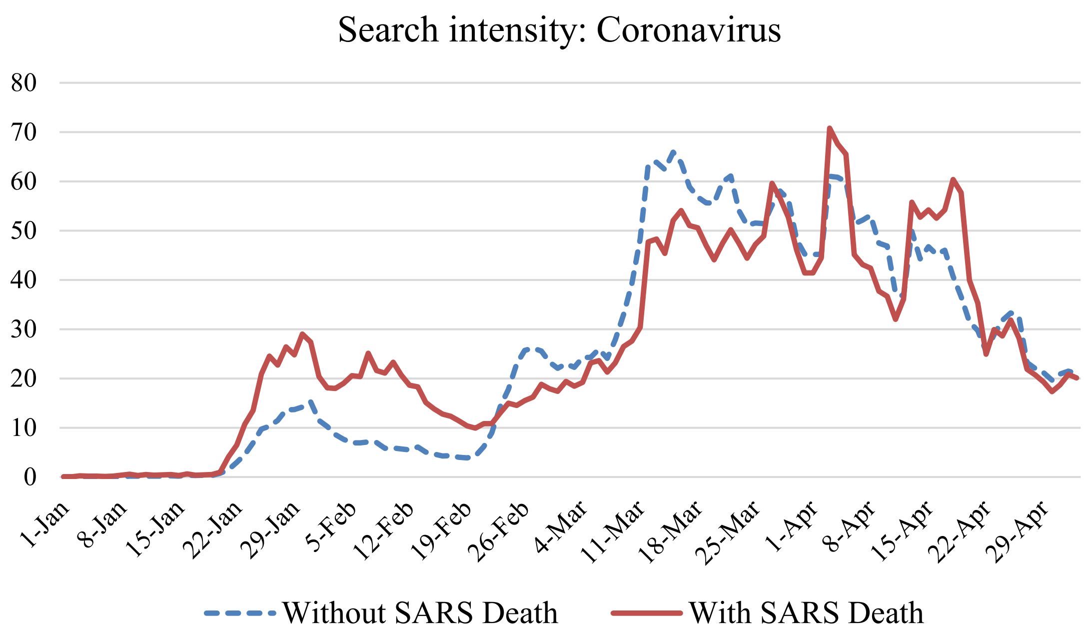
This figure displays the milestones for COVID-19 development dynamics across the globe from the first known case in December 2019 to March 2020, when it became the global pandemic. We summarize these events with the dates accordingly along the timeline.

Figure A3 Google search intensity over time

Panel A: SARS search



Panel B: Coronavirus search



This figure displays the average Google search intensity for two groups of countries/territories from January 1 to May 3, 2020. Panel A displays the average search intensity of keyword "SARS", and Panel B displays the average search intensity of keyword "coronavirus". The dashed blue line represents the countries/territories without SARS deaths, and the solid orange line represents the countries/territories with SARS deaths. Google search intensity of mainland China is excluded.

Appendix 2 Tables

Table A1 Variable definitions

Variable names	Variable definitions
SARSCase	A dummy variable that equals 1 if the country/territory had SARS cases and 0 otherwise.
SARSDeath	A dummy variable that equals 1 if the country/territory had SARS deaths and 0 otherwise.
SARS	Google Search intensity for keyword “SARS” over the period from January 20 to January 31, 2020. For regions with low search volume, we fill up the missing *SARS* by 0.
Coronavirus	Google Search intensity for keyword "coronavirus" over the period from January 20 to January 31, 2020. For regions with low search volume, we fill up the missing *Coronavirus* by 0.
Log(GDP)	Natural logarithm of GDP in each country/territory.
Log(Popu)	Natural logarithm of the total population in each country/territory.
Log(AvgCOV19)	Natural logarithm of one plus average cumulative confirmed cases of COVID-19 over the period from January 20 to January 31, 2020.
Log(COV19Cases)	Natural logarithm of one plus the concurrent cumulative COVID-19 confirmed cases.
TradeIntensity	The ratio between total import and export to mainland China over total trade.
School	A dummy variable that equals 1 after the school closure is required at all levels in this country/territory. Observations after the policy comes into effect are dropped in the duration analysis.
Workplace	A dummy variable that equals 1 after working from home is required for all-but-essential workplaces in this country/territory. Observations after the policy comes into effect are dropped in the duration analysis.
PublicEvent	A dummy variable that equals 1 after public events are required to be canceled in this country/territory. Observations after the policy comes into effect are dropped in the duration analysis.
Gathering	A dummy variable that equals 1 after the government restricts on gathering of 10 people or more in this country/territory. Observations after the policy comes into effect are dropped in the duration analysis.
InternalMovement	A dummy variable that equals 1 after internal movement between cities/regions is restricted in this country/territory. Observations after the policy comes into effect are dropped in the duration analysis.
Travel	A dummy variable that equals 1 after the international travel is banned in all regions or a complete border closure policy came into effect in this country/territory. Observations after the policy comes into effect are dropped in the duration analysis.
SARS_0-4	Ordinal Google Search intensity for keyword "SARS" where 1,2,3,4 denote the first, second, third, and fourth quantile of the raw Google Search intensity, respectively. For regions with low search volume, we fill up the missing *SARS_0-4* by 0.
Coronavirus_0-4	Ordinal Google Search intensity for keyword "coronavirus” where 1,2,3,4 denote the first, second, third, and fourth quantile of the raw Google Search intensity, respectively. For regions with low search volume, we fill up the missing *Coronavirus_0-4* by 0.

Table A2 Reported SARS cases around the world

Country/territory	Female	Male	Total	Number of deaths	Case fatality ratio
Australia	4	2	6	0	0
Canada	151	100	251	43	17
France	1	6	7	1	14
Germany	4	5	9	0	0
Hong Kong SAR	977	778	1755	299	17
India	0	3	3	0	0
Indonesia	0	2	2	0	0
Italy	1	3	4	0	0
Kuwait	1	0	1	0	0
Macao SAR	0	1	1	0	0
Mainland China	2674	2607	5327	349	7
Malaysia	1	4	5	2	40
Mongolia	8	1	9	0	0
New Zealand	1	0	1	0	0
Philippines	8	6	14	2	14
Ireland	0	1	1	0	0
South Korea	0	3	3	0	0
Romania	0	1	1	0	0
Russia	0	1	1	0	0
Singapore	161	77	238	33	14
South Africa	0	1	1	1	100
Spain	0	1	1	0	0
Sweden	3	2	5	0	0
Switzerland	0	1	1	0	0
Taiwan	218	128	346	37	11
Thailand	5	4	9	2	22
United Kingdom	2	2	4	0	0
United States	13	14	27	0	0
Vietnam	39	24	63	5	8
Total			8096	774	9.6

This table presents information about SARS spread. The list contains all countries/territories with confirmed SARS cases. We report the total number of confirmed SARS cases (female vs. male), the number of deaths, and the fatality ratio. Data are obtained from the WHO website. Note that US CDC reports 27 probable cases where 8 of them were confirmed by laboratory testing. The data can be found in the last update of the WHO summary of the cumulative SARS report, which is available on the following website: https://www.who.int/csr/sars/country/table2004_04_21/en/. WHO reported probable cases because the United States has reported probable cases of SARS with onsets of illness after July 5, 2003, due to differences in definitions of case. In the United States, the CDC stated that eight SARS infections were documented by laboratory testing, and an additional 19 probable SARS infections were reported, which is available at https://www.cdc.gov/about/history/sars/timeline.htm.

Table A3 Google search intensity (robustness checks)

	All countries/territories		Exclude Asia
Panel A: SARS search			
Dependent variable	(1) *SARS_0-4*	(2) *SARS_0-4*	(3) *SARS_0-4*
SARSDeath	2.120**	2.184**	2.006*
	(2.55)	(2.51)	(1.79)
Log(GDP)	0.942***	0.846***	1.229***
	(7.58)	(5.96)	(5.56)
Log(Popu)	–0.431***	–0.306**	–0.445**
	(–4.17)	(–2.50)	(–2.37)
Log(AvgCOV19)	–0.279	–0.118	–1.833***
	(–0.62)	(–0.23)	(–2.71)
TradeIntensity	1.729*	1.708*	0.571
	(1.80)	(1.93)	(0.33)
Continent FE	NO	YES	YES
Observations	178	178	136
Pseudo R-squared	0.405	0.435	0.487
Panel B: Coronavirus search			
Dependent variable	(1) *Coronavirus_0-4*	(2) *Coronavirus_0-4*	(3) *Coronavirus_0-4*
SARSDeath	1.133***	1.854***	1.631***
	(2.63)	(3.29)	(3.38)
Log(GDP)	0.692***	0.774***	1.141***
	(6.90)	(4.76)	(4.56)
Log(Popu)	–0.227***	–0.204	–0.450**
	(–2.85)	(–1.58)	(–2.32)
Log(AvgCOV19)	–0.413	–0.513	–1.168*
	(–1.41)	(–1.49)	(–1.95)
TradeIntensity	0.046	–1.363	–3.355
	(0.05)	(–0.85)	(–1.20)
Continent FE	NO	YES	YES
Observations	178	178	136
Pseudo R-squaredz	0.271	0.378	0.449

This table presents the results of the cross-sectional ordered probit regressions of Google search intensity on SARS experience during the initial COVID-19 outbreak in Wuhan. In Panel A, the dependent variable *SARS_0-4* is ordered Google Search intensity on keyword "SARS" from January 20 to January 31, 2020. In Panel B, the dependent variable *Coronavirus_0-4* is ordered Google Search intensity on keyword "Coronavirus" over the same period as for *SARS_0-4*. The main independent variable is *SARSDeath* that takes the value of 1 if the country had SARS deaths and 0 otherwise. See Table A1 in the Internet Appendix for detailed variable definitions. Robust standard errors are used in all regressions, and *t*-statistics are reported in parentheses. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

Table A4 Policy responses to combat COVID-19 (exclude Asia)

Panel A: SARS death						
Variables	(1) *School*	(2) *Workplace*	(3) *Public event*	(4) *Gathering*	(5) *Internal movement*	(6) *Travel*
Log(COV19Cases)	0.838***	0.395***	0.783***	0.222***	0.367***	0.343***
	(7.51)	(3.88)	(7.34)	(2.67)	(4.48)	(3.88)
Log(COV19Cases) × SARSDeath	2.405***	1.110***	0.380***	0.415**	0.693***	0.936***
	(3.61)	(3.10)	(2.81)	(2.07)	(3.64)	(2.77)
Controls	YES	YES	YES	YES	YES	YES
Continent FE	YES	YES	YES	YES	YES	YES
Observations	1,580	3,746	1,460	3,968	2,808	3,439
Pseudo R^2	0.142	0.078	0.110	0.039	0.064	0.079
Panel B: SARS Case						
Variables	(1) *School*	(2) *Workplace*	(3) *Public event*	(4) *Gathering*	(5) *Internal movement*	(6) *Travel*
Log(COV19Cases)	0.714***	0.267**	0.692***	0.138	0.295***	0.248***
	(5.83)	(2.57)	(5.97)	(1.60)	(3.34)	(2.70)
Log(COV19Cases) × SARSCase	0.480***	0.734***	0.314*	0.494***	0.196	0.370**
	(3.40)	(3.99)	(1.68)	(4.65)	(1.34)	(2.53)
Controls	YES	YES	YES	YES	YES	YES
Continent FE	YES	YES	YES	YES	YES	YES
Observations	1,580	3,746	1,460	3,968	2,808	3,439
Pseudo R^2	0.137	0.098	0.112	0.067	0.060	0.072

This table presents duration analysis results for policy responses on COVID-19 across non-Asian countries. We set up the duration analysis specification as follows. The origin date is the date when the country/territory reported its first COVID-19 confirmed case. The failure date is the date when the respective policy came into effect. Observations before the original date or after the failure date are dropped. *Log(COV19Cases)* is the natural logarithm of one plus the number of concurrent cumulative confirmed cases. *SARSDeath (SARSCase)* is a dummy variable that takes a value of 1 if the country had SARS cases (deaths) and 0 otherwise. *SARSDeath (SARSCase)*, *TradeIntensity*, *Log(GDP)*, and *Log(Popu)* are controlled in each column. See Table A1 in the Internet Appendix for detailed variable definitions. Standard errors clustered at the country level are used in all regressions, and *t*-statistics are reported in parentheses. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

Appendix 3 Additional background of COVID-19

Bill Gates, the co-chairman and co-founder of the Bill & Melinda Gates Foundation that heavily invested in global healthcare systems, said the COVID-19 is starting to behave like the "once-in-a-century pathogen we've been worried about." By the time of completing this paper (May 18), WHO reported that there are 4,618,821 confirmed cases in over 200 countries, areas, or territories with 4,452 recorded deaths related to COVID-19.

The United States, the hot zone of COVID-19, acted slowly with the Center for Disease Control (CDC)'s testing kits found to have manufacturing defects and the Food and Drug Administration (FDA) not allowing the use of any test kits from institutions other than CDC until February 29.[12] As of May 18, 1,508,957 COVID-19 cases with 90,369 deaths have been reported in the US, and New York state is the most heavily impacted state with 351,371 cases and 28,339 deaths according to Coronavirus Resource Center at John Hopkins University. The estimated deaths in the US alone range from 100,000 to 240,000 under the best scenario, according to the White House press conference.

As a part of the urgent plan to respond to COVID-19, leaders of G20 major economies held a virtual talk on March 31, 2020, claiming to inject a package of US$ 5 trillion fiscal stimulus. Kristalina Georgieva, Managing Director of IMF, stated that nearly 80 countries are already requesting IMF to help battle coronavirus, and IMF is ready to deploy US$1 trillion lending capacity. See, also, "Coronavirus: A visual guide to the economic impact.", *BBC*, March 28, 2020; "Understanding the economic shock of coronavirus", *Harvard Business Review*, March 27, 2020.

The new coronavirus is recognized as the SARS family virus. See, for example, "'Sars-family' virus claims the second victim in China", *BBC*, January 16, 2020. Chan et al. (2020), published online on January 24, 2020, studied the familial cluster of pneumonia associated with the novel coronavirus and conducting phylogenetic analysis showing it is closest to the bat SARS related coronavirus found in Chinese horseshoe bats. Dr. Wenliang Li shared a message to fellow doctors warning about a possible outbreak of an illness which resembled severe acute respiratory syndrome in Wuhan (*The Lancet,* February 18, 2020).

Besides SARS, there are several other epidemics in the past 20 years, such as Middle East respiratory syndrome coronavirus (MERS) and swine influenza caused by H1N1. However, they are quite different from COVID-19. In particular, the MERS outbreak started in Saudi Arabia in 2012 and have been resulted in 2,494 laboratory-confirmed cases with a total of 858 deaths (34%

[12] Kelly Wroblewski, director of infectious disease at the Association of Public Health Laboratories, stated that the key problem with CDC's testing kits is on the negative control. The declaration of public health emergencies, unintentionally, limited the diagnostic capacity. See detailed description in a Science news article: https://www.sciencemag.org/news/2020/02/united-states-badly-bungled-coronavirus-testing-things-may-soon-improve#

fatality rate) at the end of November 2019.[13] The fatality rates and the speeds of transmission are very different between COVID-19 and MERS. Moreover, WHO particularly pointed out the key differences between influenza and COVID-19. For example, influenza has a much shorter incubation period and spreads faster than COVID-19. More importantly, the fatality of influenza is below 0.1% (e.g., 0.02% for H1N1, according to the CDC), while the crude fatality rate of COVID-19 is between 3% – 4% according to WHO.[14]

[13] https://www.who.int/emergencies/mers-cov/en/
[14] https://www.who.int/news-room/q-a-detail/q-a-similarities-and-differences-covid-19-and-influenza

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