## Early evaluation of the Wuhan City travel restrictions in response to the 2019 novel coronavirus outbreak

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- 37 collected and processed the Tencent's LBS data. Y.H.L., B.Y.L., B.X., Q.Q.Y., P.Y., Y.J.C., Q.Y.W.
- 38 collected the statistical data. H.Y.T. and J.C. conducted the analyses. M.K., O.B., R.F.Y., O.G.P.,
- B.G., and C.D. edited the manuscript. H.T. and Y.D.L. wrote the manuscript. All authors read andapproved the manuscript.
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## 45 One Sentence Summary-40 characters

46 The travel shutdown delayed the dispersal of 2019-nCoV infection from Wuhan to other cities in

- 47 China
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## 49 Abstract

- 50 An ongoing outbreak of a novel coronavirus (2019-nCoV) was first reported in China and has
- 51 spread worldwide. On January 23<sup>rd</sup> 2020 China shut down transit in and out of Wuhan, a major
- 52 transport hub and conurbation of 11 million inhabitants, to contain the outbreak. By combining
- 53 epidemiological and human mobility data we find that the travel ban slowed the dispersal of nCoV
- from Wuhan to other cities in China by 2.91 days (95% CI: 2.54-3.29). This delay provided time
- 55 to establish and reinforce other control measures that are essential to halt the epidemic. The
- 56 ongoing dissemination of 2019-nCoV provides an opportunity to examine how travel restrictions
- 57 impede the spatial dispersal of an emerging infectious disease.
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- 59 *Key words*: 2019 novel coronavirus; Wuhan; spatiotemporal transmission; China;
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64 At end of December 2019, less than a month before Chinese New Year (Spring Festival), a cluster 65 of pneumonia cases caused by an unknown pathogen were reported in Wuhan City, the largest transport hub in Central China. A novel coronavirus provisionally named 2019-nCoV<sup>1</sup> has since 66 67 been identified as the etiological agent. Human-to-human transmission of 2019-nCoV has been confirmed <sup>2,3</sup> and by 28<sup>th</sup> January 2020 all provinces in China except Tibet had reported 68 69 2019-nCoV infections, and the population at risk of infection sin the country stands at >1.2 billion 70 people. The increasing movement of people for Chinese New Year is expected to spread the virus 71 further throughout cities in China and elsewhere. To prevent further dissemination of nCoV from its source, Wuhan prohibited all transport in and out of the city as of 10:00 on 23<sup>rd</sup> January 2020. 72 To our knowledge, this is the largest quarantine/movement restriction in human history to prevent 73 74 infectious disease spread. By 25th January, 30 provinces in China had raised their public health 75 response level to the highest state of emergency (level-1). Here we present an analysis and 76 quantification of the consequences and importance of the Wuhan travel prohibition on the ongoing 77 spread of nCoV-2019 across China. 78 79 Assessment and measurement of the effects of large-scale interventions are crucial for the design 80 of efficient responses against this and future epidemics. To this end, we collected all city-level 81 case reports across China and noted the onset time of the first case of nCoV (arrival time) and the 82 timing of the local response. We analyse these dates together with high-resolution data on human 83 movement among cities in China, obtained from a large dataset of geolocated mobile phone 84 records, spanning 2018, from the Tencent network. This dataset describes patterns of human 85 mobility across China before nCoV was discovered. 86 87 In order to quantify the effect of the Wuhan travel shutdown on nCoV epidemic spread we 88 analyzed the arrival time of nCoV from Wuhan to each city as a function of geographic distance 89 (between city centers) and of human movement by air, train, and road (as recorded by Tencent's 90 location-based services database). Spatial spread of 2019-nCoV (Fig. 1A) was rapid, with 262 91 cities reporting cases within only 28 days (for comparison, the 2009-H1N1pdm took 132 days to 92 reach the current extent of nCoV-2019 in China). Most cities with early arrival dates were in 93 southeast China and tend to exhibit greater mobility and higher population density. The rate at 94 which cities first reported nCoV peaked on 23 January (the day of the Wuhan travel ban), with 60 95 reports, after which the spatial dissemination of nCoV slowed. 96 97 Table 1 shows that the Wuhan travel intervention significantly slowed disease spread. As expected, 98 the time it took nCoV to arrive in each city increased with distance from Wuhan City, and 99 decreased with passenger flow from Wuhan. Thus the epidemic arrived sooner in those cities that 100 had larger population and had more travelers from Wuhan. On average, the Wuhan shutdown 101 delayed the arrival time of nCoV in other cities by 2.91 days (95%CI: 2.54-3.29 days) (Fig. 1B). 102 Our results show that >130 cities, covering more than half geographic area and population of 103 China, benefited from this intervention (Fig. 1C). 104 105 Our analysis evaluates a unique intervention against an emerging infectious disease - the cessation 106 of travel from a large, well-connected city in an industrialized country (Fig. 1D). We find that this 107 intervention was effective in slowing nCoV invasion of new locations. However, other measures

108 need to be reinforced to halt the ongoing epidemic. The Wuhan travel ban provided extra time to 109 make progress on these responses. In addition to governmental responses, public awareness is 110 critical for controlling the spread of this novel coronavirus. Early detection of nCoV cases in new 111 locations in China is needed in the coming weeks and months to prevent other cities becoming 112 major exporters of nCoV. China is better equipped than in the past to meet this challenge and a 113 direct reporting system for notifiable epidemic diseases was established in the country after the 114 2003 SARS outbreak. However, the experience of nCoV in China suggests that urbanization and 115 the development of modern transport systems increase the urgency of control measures against

emerging infectious diseases, as demonstrated by the faster spatial spread of nCoV than H1N1pdm

117 in China.

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119 While emerging data from mainland China on nCoV epidemiology and virus genomics have

120 generated important insights into the origin, transmissibility, and severity of this unfolding

121 epidemic <sup>1,4</sup>, many uncertainties remain <sup>5</sup> and important questions remain unanswered. For

122 example the role of mobility network structure on disease diffusion is unknown, and the degree to

123 which the delay in spatial spread (due to the Wuhan travel ban) will impact on the final size of the

124 epidemic is unclear. Our analysis is only a preliminary step and further analyses and models are

125 urgently required to evaluate the impact of quarantine and other intervention.

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128 Fig.1 Spatial diffusion of 2019-nCoV in China. (A) Cumulative number of cities reporting disease. 129 Arrival days, defined as the time interval (days) from the date of the first case in the first infected 130 city to the date of the first case in each newly infected city, to characterize the inter-city 131 transmission rate of 2019-nCoV and 2009-H1N1pdm, respectively. Dashed line shows the date of 132 Wuhan shutdown. (B) Before (blue) and after (red) the intervention. The plotted line reports the 133 fitted values from a regression of predicted arrival time (solid line, with shutdown of Wuhan in red 134 and without in blue). Each observation (point) represents one city. Error bars give  $\pm 2$  standard 135 deviations. Dashed line shows the date of Wuhan shutdown. (C) Map of arrival time delayed by 136 the shutdown of Wuhan. Colors represent the change in arrival time (days) after 23 January, 2020. 137 The arrival time is estimated using the data before the shutdown of Wuhan. (D) Human movement 138 outflows from Wuhan city to other cities in 2018. The warmer and thick lines denote higher 139 volume of outflows (high-connectivity) while the cool and thin lines denote a lower volume of 140 outflows (low-connectivity).

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142 Table 1. Estimating the impact of the Wuhan travel ban on 2019-nCoV dissemination

(Intercept) $25.95$ $(23.43, 28.48)$ $<0.001$ Longitude $-0.03$ $(-0.05, -0.01)$ $0.003$ Latitude $0.03$ $(0.01, 0.06)$ $0.014$ log10.Population $-0.70$ $(-1.12, -0.28)$ $0.001$ log10.Total flow $-0.12$ $(-0.22, -0.02)$ $0.024$ Shutdown intervention (days) $2.91$ $(2.54, 3.29)$ $<0.001$	Covariates	Coefficient	95% CI	Р
Longitude-0.03(-0.05, -0.01)0.003Latitude0.03(0.01, 0.06)0.014log10.Population-0.70(-1.12, -0.28)0.001log10.Total flow-0.12(-0.22, -0.02)0.024Shutdown intervention (days)2.91(2.54, 3.29)<0.001	(Intercept)	25.95	(23.43, 28.48)	< 0.001
Latitude0.03(0.01, 0.06)0.014log10.Population-0.70(-1.12, -0.28)0.001log10.Total flow-0.12(-0.22, -0.02)0.024Shutdown intervention (days)2.91(2.54, 3.29)<0.001	Longitude	-0.03	(-0.05, -0.01)	0.003
log10.Population         -0.70         (-1.12, -0.28)         0.001           log10.Total flow         -0.12         (-0.22, -0.02)         0.024           Shutdown intervention (days)         2.91         (2.54, 3.29)         <0.001	Latitude	0.03	(0.01, 0.06)	0.014
log10.Total flow -0.12 (-0.22, -0.02) 0.024 Shutdown intervention (days) 2.91 (2.54, 3.29) <0.001	log10.Population	-0.70	(-1.12, -0.28)	0.001
Shutdown intervention (days) 2.91 (2.54, 3.29) <0.001	log10.Total flow	-0.12	(-0.22, -0.02)	0.024
	Shutdown intervention (days)	2.91	(2.54, 3.29)	< 0.001

143  $R^2/R^2$  adjusted, 0.59 /0.58

Epidemiological and demographic dataWe collected raw data from the daily official reports of the health commission of 34provincial-level administrative units and 341 city-level units. Only laboratory-confirmed caseswere used. We constructed a real-time database recording the date of the first reported case in allnewly-infected cities with daily updates from 31 December 2019 to 28 January 2020. Populationsizes for each city were collected from the China City Statistical Yearbook(http://olap.epsnet.com.cn/). The population sizes recorded for 2018 were used. We calculated thedistance between Wuhan and each city reporting 2019-nCoV cases. The location of each city isgeocoded by the latitude and longitude coordinates of the city center and the Euclidean distancebetween the two cities we calculated.Human movement can be observed directly from mobile phone data, through the location-basedservices (LBS) employed by popular Tencent applications, such as WeChat and QQ. Averagemovement outflows from Wuhan City to other cities, by air, train, and road, were calculated fromthe migration flows database (https://heat.qq.com/) over the entire 2018.fillthe sociation between distance, human movement, interventions and epidemic timing of2019-nCoV was assessed with a regression analysis using a General Linear Model frameworkfillfillfillwhere TotalFlow; represents the average passenger volume from Wuhan City to city j by airplane, train, and road. <i>Pop</i> is the population in city j. Lai, and Lon , represent latitude and longitude ofcity j. The dumb variable shutdown j is used to identify whether the arrival time of the mellyin	144 145	Materials and Methods
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