1   **Doubling Time of the COVID-19 Epidemic by Chinese Province**

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22

23 **Abstract: 50 words**

24 COVID-19 epidemic doubling time by Chinese province was increasing from January 20 through

25 February 9, 2020. The harmonic mean of the arithmetic mean doubling time estimates ranged from 1.4

26 (Hunan, 95% CI, 1.2-2.0) to 3.1 (Xinjiang, 95% CI, 2.1-4.8), with an estimate of 2.5 days (95% CI, 2.4-

27 2.6) for Hubei.

28   **Main text – 791 words**

29   Our ability to estimate the basic reproduction number of emerging infectious diseases is often

30   hindered by the paucity of information about the epidemiological characteristics and transmission

31   mechanisms of new pathogens (1). Alternative metrics could synthesize real-time information about the

32   extent to which the epidemic is expanding over time. Such metrics would be particularly useful if they

33   rely on minimal and routinely collected data that capture the trajectory of an outbreak (2).

34   Epidemic doubling times characterize the sequence of intervals at which the cumulative incidence

35   doubles (3). If an epidemic is growing exponentially with a constant growth rate r, the doubling time

36   remains constant and equals to $(\ln 2)/r$. An increase in the doubling time indicates a slowdown in

37   transmission if the underlying reporting rate remains unchanged (Technical Appendix) (4).

38   Here we analyzed by province the number of times COVID-19 cumulative incidence doubled and

39   the evolution of the doubling times in mainland China (5), from January 20 (when nationwide reporting

40   began) through February 9, 2020. Province-level daily cumulative incidence data were retrieved from

41   provincial health commissions' websites. Two sensitivity analyses based on a longer and a shorter time

42   period respectively were conducted (Technical Appendix). Tibet was excluded from further analysis

43   because there had only been one case reported during the study period.

44   From January 20 through February 9, the harmonic mean of the arithmetic means of the doubling

45   times estimated from cumulative incidence ranged from 1.4 (95% CI, 1.2, 2.0) days (Hunan) to 3.1 (95%

46   CI, 2.1, 4.8) days (Xinjiang). In Hubei, it was estimated as 2.5 (95% CI, 2.4, 2.6) days. The cumulative

47   incidence doubled 6 times in Hubei. The harmonic mean of the arithmetic means of doubling times in all

48   of mainland China except Hubei was 1.8 (95% CI, 1.5, 2.3) days. Provinces with a harmonic mean of the

49   arithmetic means of doubling times <2d included Fujian, Guangxi, Hebei, Heilongjiang, Henan, Hunan,

50   Jiangxi, Shandong, Sichuan, and Zhejiang (Figures 1 and S1).

51   As the epidemic progressed, it took longer for the cumulative incidence in mainland China

52   (except Hubei) to double itself, which indicated an overall sub-exponential growth pattern outside Hubei

53   (Figures S1, S2). In Hubei, the doubling time decreased and then increased. A gradual increase in the

54   doubling time coincided with the social distancing measures and intra-and-inter-provincial travel

55   restrictions imposed across China since the implementation of quarantine of Wuhan on January 23 (6).

56   Our estimates of doubling times are shorter than prior estimates of 7.4 days (95% CI, 4.2-14) (5),

57   6.4 days (95% CrI, 5.8-7.1) (7), and 7.1 days (95% CI, 3.0-20.5) (8) respectively. Li et al. covered cases

58   reported by January 22 (5). Wu et al. statistically inferred case counts in Wuhan by internationally

59   exported cases as of January 25 (7). Volz et al. identified a common viral ancestor on December 8, 2019

60   using Bayesian phylogenetic analysis and fitted an exponential growth model to provide the epidemic

61   growth rate (8). Our estimates are based on cumulative confirmed case count by reporting date by

62   province from January 20 through February 9.

63   Our study is subject to limitations, including underreporting of cases (9). One reason for

64   underreporting is underdiagnosis, due to lack of diagnostic tests, healthcare workers, and other resources.

65   Further, underreporting is likely heterogeneous across provinces. As long as reporting remains invariant

66   over time within the same province, the calculation of doubling times remains reliable; however, this is a

67   strong assumption. Growing awareness of the epidemic and increasing availability of diagnostic tests

68   might have strengthened reporting over time, which could have artificially shortened the doubling time.

69   Nevertheless, apart from Hubei and Guangdong (first case reported on January 19), nationwide reporting

70   only began on January 20, and at this point, Chinese authorities had openly acknowledged the magnitude

71   and severity of the epidemic. Due to a lack of detailed case data describing incidence trends for imported

72   and local cases, we focused our analysis on the overall trajectory of the epidemic without adjusting for the

73   role of imported cases on the local transmission dynamics. Indeed, it is likely that the proportion of

74   imported cases was significant for provinces that only reported a few cases; their short doubling times in

75   the study period could simply reflect rapid detection of imported cases. However, with the data until

4

76   February 9, only two provinces had a cumulative case count of <40 (Table S1). It would be interesting to

77   investigate the evolution of the doubling time after accounting for case importations if more detailed data

78   becomes available.

79   To conclude, we observed an increasing trend in the epidemic doubling time of COVID-19 by

80   Chinese province from January 20 through February 9, 2020. The harmonic mean of the arithmetic means

81   of doubling times of cumulative incidence in Hubei during the study period was estimated at 2.5 (95% CI,

82   2.4, 2.6) days.

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89   This article does not represent the official positions of the Centers for Disease Control and Prevention, the

90   National Institutes of Health, or the United States Government.

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99   **References**

100   1.   Anderson RM, May RM. Infectious diseases of humans. Oxford: Oxford University
101   Press; 1991.
102   2.   Drake JM, Bakach I, Just MR, O'Regan SM, Gambhir M, Fung IC-H. Transmission
103   Models of Historical Ebola Outbreaks. Emerging Infectious Disease journal.
104   2015;21(8):1447.
105   3.   Vynnycky E, White RG. An Introduction to Infectious Disease Modelling. Oxford:
106   Oxford University Press; 2010.
107   4.   Muniz-Rodriguez K, Fung IC-H, Ferdosi SR, Ofori SK, Lee Y, Tariq A, et al.
108   Transmission potential of SARS-CoV-2 in Iran, 2020. Emerging Infectious Disease journal.
109   2020;26(8):DOI: https://doi.org/10.3201/eid2608.200536.
110   5.   Li Q, Guan X, Wu P, Wang X, Zhou L, Tong Y, et al. Early Transmission Dynamics in
111   Wuhan, China, of Novel Coronavirus-Infected Pneumonia. N Engl J Med. 2020 Mar 26
112   382(13):1199-207.
113   6.   Du Z, Wang L, Cauchemez S, Xu X, Wang X, Cowling BJ, et al. Risk for Transportation
114   of Coronavirus Disease from Wuhan to Other Cities in China. Emerging Infectious Disease
115   journal. 2020 May 17;26(5):1049-52.
116   7.   Wu JT, Leung K, Leung GM. Nowcasting and forecasting the potential domestic and
117   international spread of the 2019-nCoV outbreak originating in Wuhan, China: a modelling
118   study. Lancet. 2020 Feb 29;395(10225):689-97.
119   8.   Volz E, Baguelin M, Bhatia S, Boonyasiri A, Cori A, Cucunubá Z, et al. Report 5:
120   Phylogenetic analysis of SARS-CoV-2. 2020 [cited Apr 15, 2020]; Available from:
121   https://www.imperial.ac.uk/media/imperial-college/medicine/sph/ide/gida-
122   fellowships/Imperial-College-COVID19-phylogenetics-15-02-2020.pdf
123   9.   Fang G, Li S, Liu Y, Xin N, Ma K. People beyond the statistics: Died of "normal
124   pneumonia"? [统计数字之外的人：他们死于"普通肺炎"？]. Caijing Zachi [财经杂志]
125   (Finance and Ecomomics Magazine) 2020 [cited Feb 13, 2020]; Available from:
126   https://web.archive.org/web/20200213190623/http://www.sohu.com/a/370032279_12
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134   **Figure legend**

135   **Figure 1.** The map of the harmonic mean of the arithmetic means of doubling time estimates (Panel A)

136   and the number of times the COVID-19 epidemic cumulative incidence has doubled (Panel B) by

137   province in mainland China, from January 20 through February 9, 2020.

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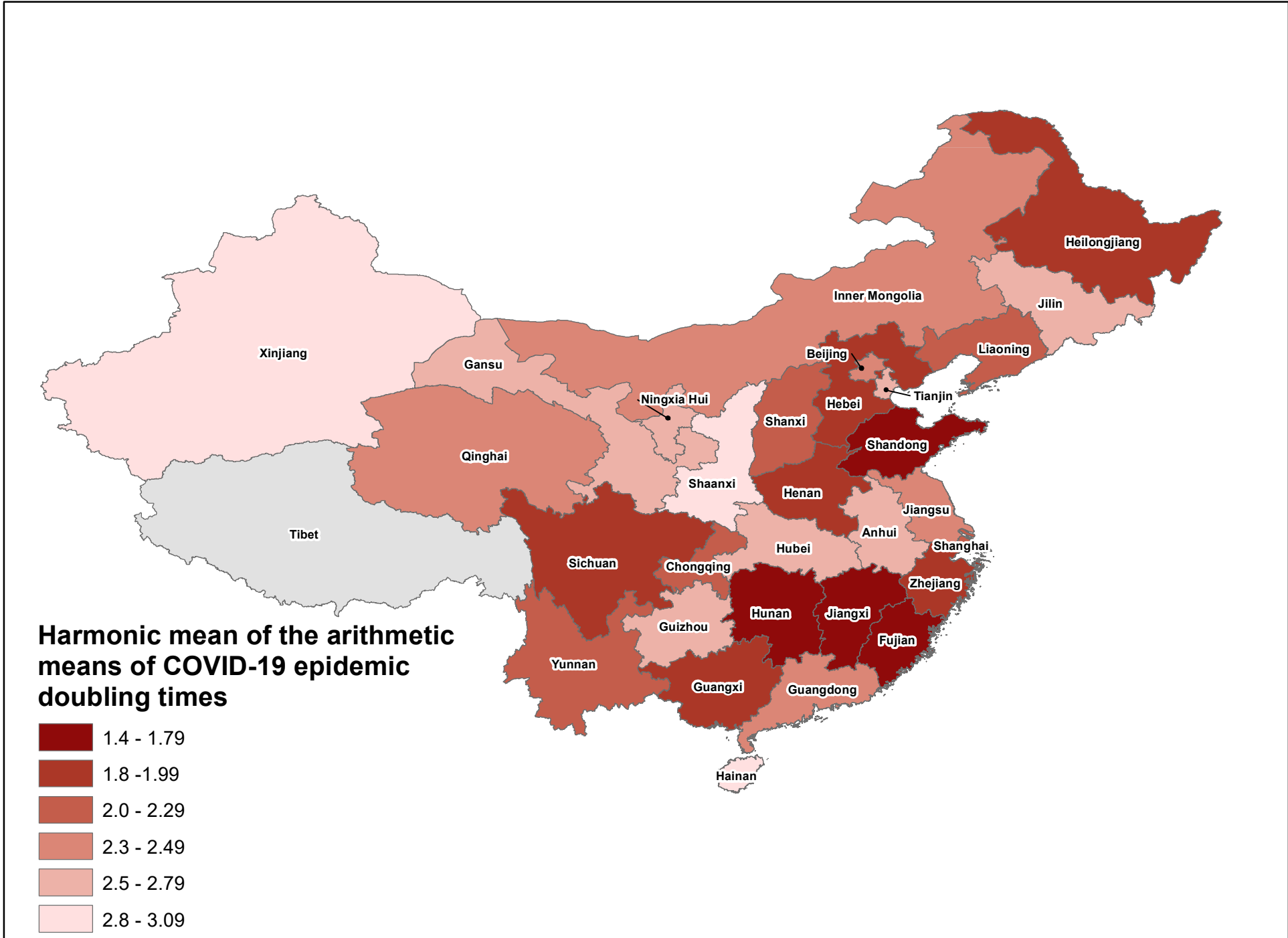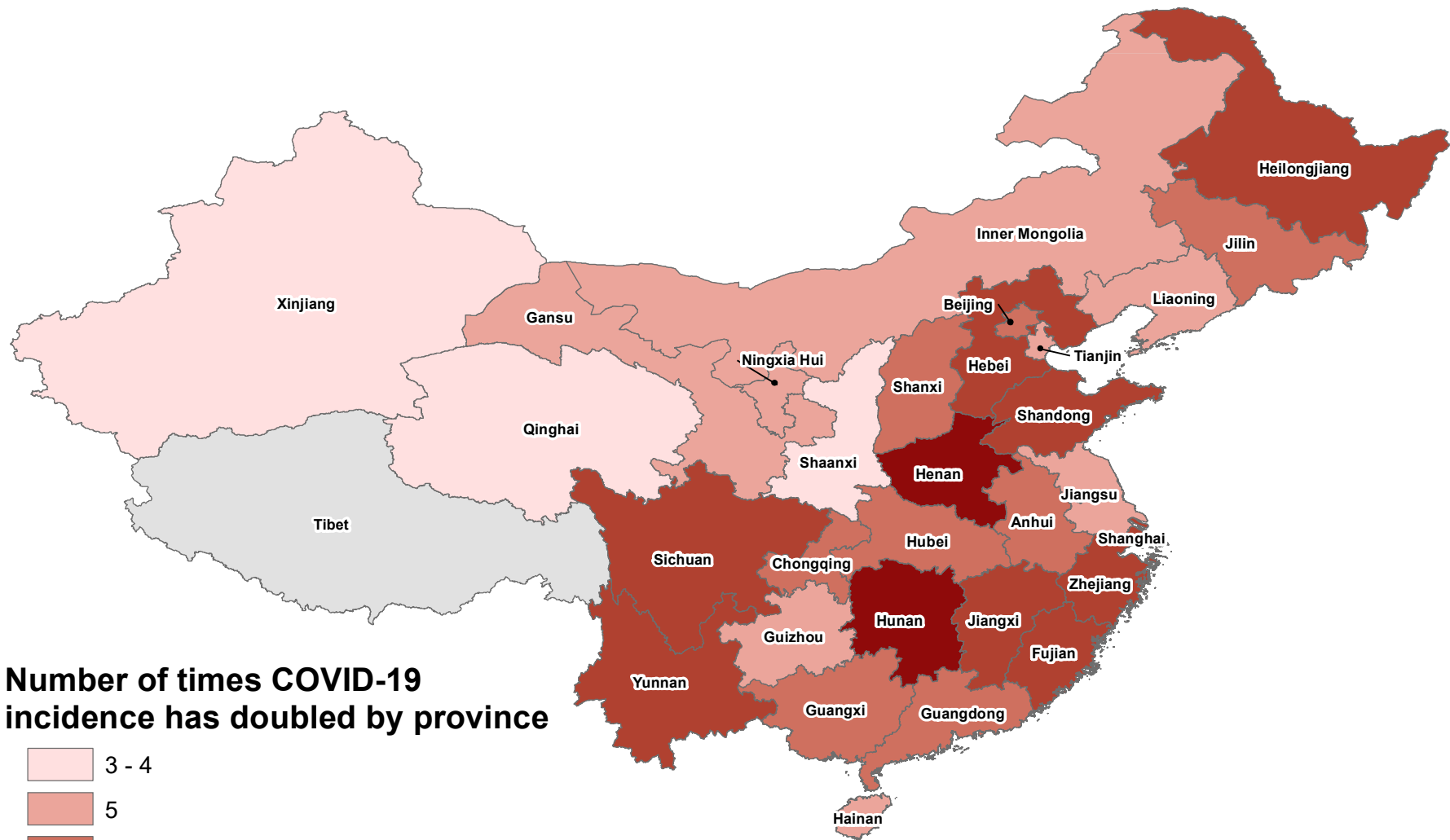
Harmonic mean of the arithmetic
means of COVID-19 epidemic
doubling times

	1.4 - 1.79
	1.8 -1.99
	2.0 - 2.29
	2.3 - 2.49
	2.5 - 2.79
	2.8 - 3.09

Map labels:
Xinjiang, Gansu, Ningxia Hui, Inner Mongolia, Jilin, Heilongjiang, Beijing, Liaoning, Hebei, Tianjin, Shanxi, Shandong, Qinghai, Shaanxi, Henan, Jiangsu, Tibet, Hubei, Anhui, Shanghai, Sichuan, Chongqing, Zhejiang, Hunan, Jiangxi, Guizhou, Fujian, Yunnan, Guangxi, Guangdong, Hainan

Number of times COVID-19 incidence has doubled by province

- 3 - 4
- 5
- 6
- 7 - 8
- 9 - 10

Doubling Time of the COVID-19 Epidemic by Chinese Province

Technical Appendix

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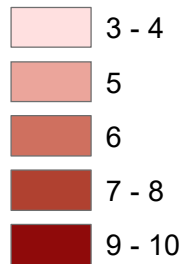## Technical appendix

Additional information on our motivation, scope and methods

Motivation. R_0 is a widely used indicator of transmission potential in a totally susceptible population and is driven by the average contact rate and the mean infectious period of the disease (1). Yet, it only characterizes transmission potential at the onset of the epidemic and varies geographically for a given infectious disease according to local healthcare provision, outbreak response, as well as socioeconomic and cultural factors. Furthermore, estimating R_0 requires information about the natural history of the infectious disease. Thus, our ability to estimate reproduction numbers for novel infectious diseases is hindered by the paucity of information about their epidemiological characteristics and transmission mechanisms. More informative metrics could synthesize real-time information about the extent to which the epidemic is expanding over time. Such metrics would be particularly useful if they rely on minimal data on the outbreak's trajectory (2).

Scope and definition. Our analysis is restricted to mainland China in this paper. A 'province' herein encompasses three different types of political sub-divisions of mainland China, namely, a province, a centrally (literally, 'directly') administered municipality (Beijing, Chongqing, Shanghai, and Tianjin) and an 'ethnic minority' autonomous region (Guangxi, Inner Mongolia, Ningxia, Tibet, and Xinjiang). Our analysis does not include the Hong Kong Special Administrative Region and the Macau Special Administrative Region, which are under the effective rule of the People's Republic of China through the so-called 'One Country, Two Systems' political arrangements. Likewise, our analysis does not include Taiwan, which is *de facto* governed by a different government (the Republic of China).

Data sources. Daily cumulative incidence data were retrieved from provincial health commissions' websites (Table S8). Data were double-checked against the cumulative national total published by the National Health Commission (3), data compiled by the Centre for Health Protection, Hong Kong, when

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available (4) and by John Hopkins University Center for Systems Science and Engineering (5). Whenever

discrepancies arose, provincial government sources were deemed authoritative.

Doubling time calculation and its relationship with growth rate of an epidemic

As the epidemic grows, the times at which cumulative incidence doubles are given by t_{d_i} such that

$$2C(t_{d_i}) = C(t_{d_{i+1}}) \text{ where } t_{d_o} = 0, \ C(t_{d_o}) = C_0,$$ and $i = 0,1,2,3, \ldots, n_d$ where n_d is the total number of

times cumulative incidence doubles. The actual sequence of "doubling times" are defined as follows:

$$d_j = \Delta t_{d_j} = t_{d_j} - t_{d_{j-1}} \text{ where } j = 1,2,3, \ldots, n_d.$$

To quantify parameter uncertainty, we used parametric bootstrapping with a Poisson error structure

around the harmonic mean of doubling times d_j to obtain the 95% confidence interval. See references (6-

8) for further details.

If we assume homogeneous mixing (equal probability of acquiring infection through contacts) and

exponential growth, then, $C(t_2) = C(t_1)\exp(rt)$, and therefore, $\ln(C(t_2)/C(t_1)) = rt$. When $C(t_2)/C(t_1) = 2$ and

thus t is the doubling time, i.e. $t = t_d$, $\ln2 = rt_d$. Therefore, the doubling time, t_d, equals to $(\ln2)/r$. See

Vynnycky and White (9), panel 4.1, p.74 for further explanation.

Additional details on methods. Doubling time calculation was conducted using MATLAB R2019b

(Mathworks, Natick, MA). Figures were created either using R version 3.6.2 (R Core Team) or MATLAB

2019b. Significance level in this manuscript was a priori decided to be $\alpha = 0.05$.

Additional information on our results and discussion

Cumulative incidence over time. From Figure S7 to Figure S10, we provided plots of cumulative

incidence over time (left panel) and semi-log plots with $\log_{10}$-transformed cumulative incidence over time

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(right panel) for a total of 8 provinces with a relatively high number of cases, namely, the epicenter Hubei, followed by (in alphabetical order) Fujian, Guangdong, Heilongjiang, Henan, Hubei, Hunan, Jiangxi and Shandong. If the epidemic is growing exponentially, the log_{10}-transformed cumulative incidence over time will be a linear curve. If social distancing would have an impact, the slope of the semi-log plot would decrease, indicating a decreasing epidemic growth rate.

Harmonic mean of the harmonic mean. In this study, we also presented the harmonic mean of the harmonic means of the estimates of the epidemic doubling times. The harmonic means of the epidemic doubling times are shorter than their arithmetic means. From January 20 through February 9, the harmonic mean of the harmonic means of the doubling times estimated ranged from 0.5 (95% CI, 0.2, 1.3) days for Guangxi, to 2.3 (95% CI, 2.3, 2.4) days for Hubei. The harmonic mean of the harmonic means of doubling times in mainland China except Hubei were 1.2 (95% CI, 1.0, 1.4) days.

Further discussion. The slowing-down of the epidemic as represented in increasing epidemic doubling times in our study is also consistent with a study by Benjamin F. Maier and Dirk Brockmann, "Effective containment explains sub-exponential growth in confirmed cases of recent COVID-19 outbreak in Mainland China" (pre-print available at arXiv. 2020:2002.07572). They also identified sub-exponential growth of the outbreak across provinces, as mass quarantine and restriction of travels across mainland China began since January 23, 2020.

Sensitivity analysis #1. We performed a sensitivity analysis by expanding our data analysis to the data since December 31, 2019, when Hubei first reported a cluster of pneumonia cases with unexplained etiology that turned out to be COVID-19. The only difference between the sensitivity analysis and the main analysis is the inclusion of Hubei and Guangdong data from December 31, 2019, through January 19, 2020, because nationwide reporting started on January 20, 2020. The only differences in results were found for Hubei and Guangdong. For Hubei, the harmonic mean of the arithmetic mean of the doubling

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times was 4.06 (95% CI, 3.85-4.33); the harmonic mean of the harmonic means of the doubling times for

Hubei was 2.28 (95% CI, 2.08-2.56); and the cumulative incidence in Hubei doubled nine times from

December 31, 2019, through February 9, 2020 (Table S5, Figures S3, S4, S12, S13, S14). The first

doubling time of Hubei (Figure S3) was high, reflecting that real-time data was unavailable before mid-

January. It was only by January 17, 2020, onwards when data reporting become increasingly transparent

and timely.

Sensitivity analysis #2. We also performed a sensitivity analysis by restricting our data analysis to the data

from January 23, 2020 through February 9, 2020, to allow for the time that all the other provinces to ramp

up their testing. January 23 was also the day when the Chinese authorities to put the city of Wuhan on

'lockdown' and major inter-provincial travel restrictions were put in place. When we changed the start

date of our study period from January 20 (main analysis) to January 23, 2020 (sensitivity analysis #2), the

epidemic doubling time of the aggregate cumulative incidence of mainland China (except Hubei)

increased from 1.79 (95% CI, 1.52, 2.25) to 2.90 (95% CI, 2.62, 3.24) (harmonic mean of the arithmetic

means), and from 1.18 (95% CI, 0.96, 1.42) to 1.98 (95% CI, 1.82, 2.17) (harmonic mean of the harmonic

means) (Table S7, Figure S5, S6). Apart from the epidemic doubling time of the aggregate cumulative

incidence of mainland China (except Hubei), we did not observe significant differences by province

between results in the main analysis and sensitivity analysis #2. Therefore, our results should be robust

for the purpose of this study.

Table S1. Confirmed cases of COVID-19 (December 31, 2019 to January 19, 2020) by province in mainland China extracted from official government sources used for the sensitivity analysis.

Locations[1]	Dec 31	January 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Mainland China (Excluding Hubei) (Sum of provincial reports)	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	1
Mainland China (Including Hubei) (Sum of provincial reports)	27	NR	NR	44	NR	59	NR	NR	NR	NR	41	41	41	41	41	41	45	62	121	199
Mainland China (Including Hubei) (Sum by NCH)[2]	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Hubei	27	NR	NR	44	NR	59	NR	NR	NR	NR	41	41	41	41	41	41	45	62	121	198
Guangdong	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	1

Note. NA, not applicable. NR, not reported. [1]Observations were collected directly from government official sites from each province in mainland China. If a press release included data reported at midnight and early morning, they were considered to belong to the previous day the data was reported. [2]Official national tally of cumulative case count of confirmed cases was first published by the National Health Commission of China on January 21, 2020 for January 20, 2020 (3).

Table S2. Confirmed cases of COVID-19 (January 20 to 31, 2020) by province in mainland China extracted from official government sources used for the main analysis and sensitivity analysis.

Locations[1]	January											
	20	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**
Mainland China (Excluding Hubei) (Sum of provincial reports)	26	71	145	291	585	923	1321	1802	2386	3126	3885	4637
Mainland China (Including Hubei) (Sum of provincial reports)	296	446	589	840	1314	1975	2744	4516	5940	7712	9691	11790
Mainland China (Including Hubei) (Sum by NCH)[2]	291	440	571	830	1287	1975	2744	4515	5974	7711	9692	11791
Hubei	270	375	444	549	729	1052	1423	2714	3554	4586	5806	7153
Anhui	0	1	9	15	39	60	70	106	152	200	237	297
Beijing	5	10	14	26	36	49	68	80	91	111	132	156
Chongqing	0	5	9	27	57	75	110	132	147	165	206	238
Fujian	0	0	1	5	10	18	35	59	82	101	120	144
Gansu	0	0	0	2	4	7	14	19	24	26	29	35
Guangdong	14	26	32	53	78	98	146	188	241	311	393	520
Guangxi	0	0	2	13	23	33	46	51	58	78	87	100
Guizhou	0	0	0	3	5	5	7	9	9	12	15	29
Hainan	0	0	4	8	11	20	27	33	40	46	49	57
Hebei	0	0	1	2	8	13	18	33	48	65	82	96
Heilongjiang	0	0	1	4	9	15	21	30	37	43	59	80
Henan	0	1	5	9	32	83	128	168	206	278	352	422
Hunan	0	1	4	9	43	69	100	143	221	277	332	389
Inner Mongolia	0	0	0	1	2	7	11	13	16	18	20	23
Jiangsu	0	0	1	9	18	31	47	70	99	129	168	202
Jiangxi	0	2	3	7	18	36	48	72	109	162	240	286
Jilin	0	0	1	3	4	4	6	8	9	14	14	17
Liaoning	0	0	2	4	12	19	22	30	36	41	45	60
Ningxia	0	0	1	2	3	4	7	11	12	17	21	26
Qinghai	0	0	0	0	0	1	4	6	6	6	8	9
Shaanxi	0	0	0	0	7	15	22	46	56	63	87	101
Shandong	0	1	1	1	21	39	63	87	87	145	178	202
Shanghai	2	9	16	20	33	40	53	66	80	101	128	153
Shanxi	0	0	1	1	6	9	13	20	27	35	39	47
Sichuan	0	2	5	15	28	44	69	90	108	142	177	207
Tianjin	0	2	4	5	8	10	14	23	25	27	32	32
Tibet	0	0	0	0	0	0	0	0	0	1	1	1
Xinjiang	0	0	0	2	3	4	5	10	13	14	17	18
Yunnan	0	1	1	2	5	11	19	26	51	70	80	91
Zhejiang	5	10	27	43	62	104	128	173	296	428	537	599

Note. [1]Observations were collected directly from government official sites from each province in mainland China. If a press release included data reported at midnight and early morning, they were considered to belong to the previous day the data was reported. [2]Data was collected of press releases of the National Health Commission of China (3).

Table S3. Confirmed cases of COVID-19 (February 1 to 9, 2020) by province in mainland China extracted from official government sources used for the main analysis and sensitivity analysis.

	February								
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Locations[1]									
Mainland China (Excluding Hubei) (Sum of provincial reports)	5396	6031	6910	7646	8352	9049	9614	10098	10507
Mainland China (Including Hubei) (Sum of provincial reports)	14381	17208	20432	24324	28017	31161	34567	37198	40138
Mainland China (Including Hubei) (Sum by NCH)[2]	14380	17205	20438	24324	28018	31161	34546	37198	40171
Hubei	9074	11177	13522	16678	19665	22112	24953	27100	29631
Anhui	340	408	480	530	591	665	733	779	830
Beijing	183	212	228	253	274	297	315	326	337
Chongqing	262	300	337	366	389	411	426	446	468
Fujian	159	179	194	205	215	224	239	250	261
Gansu	40	51	55	57	62	67	71	79	83
Guangdong	604	683	797	870	944	1018	1075	1120	1131
Guangxi	111	127	139	150	168	172	183	195	210
Guizhou	38	46	56	64	69	77	89	96	99
Hainan	63	70	79	89	100	111	122	128	136
Hebei	104	113	126	135	157	171	195	206	218
Heilongjiang	95	118	155	190	227	277	295	307	331
Henan	493	566	675	764	851	914	981	1033	1073
Hunan	463	521	593	661	711	772	803	838	879
Inner Mongolia	27	34	35	42	46	50	52	54	58
Jiangsu	236	271	308	341	373	408	439	468	492
Jiangxi	333	391	476	548	600	661	698	740	771
Jilin	23	31	42	54	59	65	69	78	80
Liaoning	64	73	74	81	89	94	99	105	108
Ningxia	28	31	34	34	40	43	45	45	49
Qinghai	9	13	15	17	18	18	18	18	18
Shaanxi	116	128	142	165	173	184	195	208	213
Shandong	225	246	270	298	343	379	407	435	466
Shanghai	177	193	208	233	254	269	281	292	295
Shanxi	56	66	74	81	90	96	104	115	119
Sichuan	231	254	282	301	321	344	363	386	405
Tianjin	45	48	60	67	69	81	88	90	94
Tibet	1	1	1	1	1	1	1	1	1
Xinjiang	21	24	29	32	36	39	42	45	49
Yunnan	99	109	117	122	128	135	138	140	141
Zhejiang	661	724	829	895	954	1006	1048	1075	1092

Note. [1]Observations were collected directly from government official sites from each province in mainland China. If a press release included data reported at midnight and early morning, they were considered to belong to the previous day the data was reported. [2]Data was collected of press releases of the National Health Commission of China (3).

Table S4. Main analysis: Doubling times of COVID-19 cumulative incidence and their harmonic mean of the arithmetic means of the doubling times and harmonic mean of the harmonic means of the doubling times (95% Confidence interval) by province in mainland China from January 20 through February 9, 2020.

	Mainland China (Except Hubei)	Hubei	Anhui	Beijing	Chongqing	Fujian	Gansu	Guangdong	Guangxi	Guizhou	Hainan
Harmonic mean of arithmetic means	1.79 (1.52-2.25)	2.54 (2.44-2.64)	2.56 (2.16-3.11)	2.49 (1.89-3.38)	2.22 (1.53-3.22)	1.71 (1.15-2.52)	2.56 (2.00-3.78)	2.47 (1.97-3.20)	1.92 (1.45-3.09)	2.71 (1.90-3.90)	2.91 (1.91-3.89)
Harmonic mean of harmonic means	1.18 (0.96-1.42)	2.34 (2.27-2.41)	1.72 (1.13-2.67)	1.48 (0.63-2.70)	1.23 (0.67-1.96)	0.82 (0.46-1.41)	1.36 (0.76-2.86)	2.01 (1.53-2.54)	0.48 (0.22-1.34)	1.88 (0.81-3.28)	1.52 (0.65-2.99)
Times doubled 1	0.59	2.91	2.12	1.00	2.05	0.25	1	1.33	0.18	2.5	1.00
2	0.86	2.16	0.75	1.5	0.56	0.5	1.14	1.79	0.36	3.5	1.55
3	0.98	1.5	2.18	1.8	0.82	0.85	1.26	2.17	0.76	1.64	2.28
4	1	2.17	1.77	2.7	1.71	1.15	4.1	2.38	1.6	2.56	5.31
5	1.3	3.03	4.03	4.14	3.58	1.07	5.9	2.76	3.4	5.8	6.86
6	1.98	3.43	4.9	7.31	4.82	1.39		4.92	4.78		
7	2.55					3.12					
8	4.53					9.21					

	Hebei	Heilongjiang	Henan	Hunan	Inner Mongolia	Jiangsu	Jiangxi	Jilin	Liaoning	Ningxia	Qinghai
Harmonic mean of arithmetic means	1.88 (1.57-2.72)	1.93 (1.76-2.36)	1.81 (1.35-2.05)	1.42 (1.24-2.04)	2.37 (1.80-3.67)	2.43 (1.77-3.26)	1.68 (1.45-2.33)	2.64 (2.13-3.50)	2.10 (1.45-3.30)	2.54 (1.76-4.33)	2.50 (1.50-5.00)
Harmonic mean doubling time	1.04 (0.67-1.93)	1.08 (0.62-1.98)	0.81 (0.56-1.12)	0.71 (0.47-1.13)	1.17 (0.67-2.67)	1.93 (1.35-2.63)	1.13 (0.71-1.71)	1.48 (0.66-3.03)	1.05 (0.54-1.94)	1.59 (0.73-3.07)	1.00 (0.38-3.87)
Times doubled 1	1	0.33	0.25	0.33	1	2	1.25	0.5	1	1	0.33
2	0.33	0.67	0.5	0.67	0.4	1.31	0.84	2.5	0.5	2	0.67
3	0.67	0.8	1	0.8	0.85	1.75	0.72	2	1.07	1.25	4
4	1.6	1.36	0.55	0.4	2.75	2.32	0.96	3.66	2.76	2.55	4.5
5	1.33	2.12	0.7	0.47	4.71	4.07	1.89	2.43	4.67	4.53	
6	2.01	2.95	0.62	1.13			1.69	3.74			
7	5.28	3.04	1.38	1.85			1.99				
8		3.31	2.69	1.97			4.16				
9			3.57	4.22							
10			6.56								

	Shaanxi	Shandong	Shanghai	Shanxi	Sichuan	Tianjin	Tibet	Xinjiang	Yunnan	Zhejiang	
Harmonic mean of the arithmetic means	2.82 (2.12-9.97)	1.68 (1.42-2.39)	2.19 (1.88-2.68)	2.31 (1.67-3.25)	1.83 (1.39-2.70)	2.78 (2.07-4.06)	Not applied	3.05 (2.06-4.75)	2.05 (1.34-2.72)	1.91 (1.60-2.51)	
Harmonic mean doubling time	2.04 (1.28-3.01)	0.48 (0.28-1.15)	0.77 (0.34-1.73)	1.22 (0.68-2.51)	0.96 (0.51-1.75)	1.69 (0.80-3.55)	Not applied	1.91 (0.83-4.46)	1.25 (0.89-1.81)	1.20 (0.74-1.70)	
Times doubled 1	1.33	2.05	0.28	1.2	0.66	1		2	2	1	
2	2.24	0.1	0.57	0.4	0.64	2		1.6	0.66	0.58	
3	3.76	0.19	1.15	1.06	0.77	2.22		3.06	0.84	1.23	
4		0.41	1.92	1.76	1.18	4.78		5.34	1.12	1.61	
5		0.86	2.92	2.2	1.55	3.57			1.61	2.29	
6		1.43	3.16	4.18	2.78				1.45	1.47	
7		2.66	6.13		4.49				7.32	3.48	
8		4.71									

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Table S5. Sensitivity analysis #1 (1 of 2 tables): Doubling times of COVID-19 cumulative incidence and their harmonic mean of the arithmetic means of the doubling times and harmonic mean of the harmonic means of the doubling times (95% Confidence interval) by province in mainland China from December 31, 2019 through February 9, 2020: Mainland China (Except Hubei), Hubei, and from Anhui to Qinghai.

		Mainland China (Except Hubei)	Hubei	Anhui	Beijing	Chongqing	Fujian	Gansu	Guangdong	Guangxi	Guizhou	Hainan
Harmonic mean of arithmetic means		1.34 (1.28-1.52)	4.06 (3.85-4.33)	2.57 (2.12-3.00)	2.51 (1.99-3.26)	2.22 (1.60-3.23)	1.82 (1.18-2.55)	2.55 (1.83-3.79)	1.88 (1.74-2.19)	1.93 (1.47-2.96)	2.78 (2.00-3.97)	2.92 (1.97-4.25)
Harmonic mean of harmonic means		0.29 (0.15-0.59)	2.28 (2.08-2.56)	1.76 (1.21-2.40)	1.60 (0.93-2.70)	1.23 (0.74-1.88)	0.83 (0.47-1.42)	1.33 (0.70-2.62)	0.44 (0.25-1.13)	0.49 (0.22-1.29)	1.98 (1.09-3.53)	1.55 (0.60-3.29)
Times doubled	1	0.04	17.33	2.12	1.00	2.05	0.25	1.00	0.07	0.18	2.50	1.00
	2	0.08	1.22	0.75	1.5	0.56	0.5	1.14	0.16	0.36	3.5	1.55
	3	0.15	2	2.18	1.8	0.82	0.85	1.26	0.3	0.76	1.64	2.28
	4	0.33	3.04	1.77	2.7	1.71	1.15	4.1	0.63	1.6	2.56	5.31
	5	0.53	2.11	4.03	4.14	3.58	1.07	5.9	1.84	3.4	5.8	6.86
	6	0.73	1.23	4.9	7.31	4.82	1.39		1.44	4.78		
	7	0.92	2.61				3.12		2.18			
	8	0.98	3.13				9.21		2.59			
	9	1.01	3.87						2.72			
	10	1.48							6.17			
	11	2.17										
	12	2.88										
	13	5.55										

		Hebei	Heilongjiang	Henan	Hunan	Inner Mongolia	Jiangsu	Jiangxi	Jilin	Liaoning	Ningxia	Qinghai
Harmonic mean of arithmetic means		1.89 (1.55-2.74)	1.96 (1.76-2.26)	1.80 (1.31-2.10)	1.41 (1.26-1.99)	2.37 (1.82-3.57)	2.45 (1.75-3.31)	1.72 (1.44-2.36)	2.67 (2.13-3.50)	2.16 (1.49-3.53)	2.58 (1.72-4.43)	2.64 (1.79-5.00)
Harmonic mean of harmonic means		1.07 (0.66-1.90)	1.12 (0.66-1.97)	0.77 (0.48-1.14)	0.73 (0.48-1.15)	1.15 (0.65-2.71)	1.92 (1.31-2.68)	1.17 (0.81-1.74)	1.60 (0.70-3.11)	1.06 (0.50-2.45)	1.67 (0.87-3.65)	0.96 (0.39-3.69)
Times doubled	1	1.00	0.33	0.25	0.33	1.00	2.00	1.25	0.50	1.00	1.00	0.33
	2	0.33	0.67	0.5	0.67	0.4	1.31	0.84	2.5	0.5	2	0.67
	3	0.67	0.8	1	0.8	0.85	1.75	0.72	2	1.07	1.25	4
	4	1.6	1.36	0.55	0.4	2.75	2.32	0.96	3.66	2.76	2.55	4.5
	5	1.33	2.12	0.7	0.47	4.71	4.07	1.89	2.43	4.67	4.53	
	6	2.01	2.95	0.62	1.13			1.69	3.74			
	7	5.28	3.04	1.38	1.85			1.99				
	8		3.31	2.69	1.97			4.16				
	9			3.57	4.22							
	10			6.56								

Table S6. Sensitivity analysis #1 (2 of 2 tables): Doubling times of COVID-19 cumulative incidence and their harmonic mean of the arithmetic means of the doubling times and harmonic mean of the harmonic means of the doubling times (95% Confidence interval) by province in mainland China from December 31, 2019 through February 9, 2020: from Shaanxi to Zhejiang.

		Shaanxi	Shandong	Shanghai	Shanxi	Sichuan	Tianjin	Tibet	Xinjiang	Yunnan	Zhejiang
Harmonic mean of arithmetic means		2.77 (2.06-3.93)	1.68 (1.41-2.36)	2.21 (1.91-2.78)	2.12 (1.67-3.00)	1.79 (1.40-2.65)	2.75 (2.10-3.89)	Not applied	3.09 (2.12-4.89)	2.10 (1.42-2.78)	1.90 (1.59-2.55)
Harmonic mean of harmonic means		2.03 (1.27-2.93)	0.48 (0.30-1.11)	0.82 (0.40-1.83)	1.26 (0.68-2.60)	0.96 (0.62-1.73)	1.67 (0.78-3.38)	Not applied	1.98 (0.80-4.69)	1.28 (0.80-1.93)	1.23 (0.77-1.72)
Times doubled	1	1.33	2.05	0.28	1.20	0.66	1.00		2.00	2	1.00
	2	2.24	0.1	0.57	0.4	0.64	2		1.6	0.66	0.58
	3	3.76	0.19	1.15	1.06	0.77	2.22		3.06	0.84	1.23
	4		0.41	1.92	1.76	1.18	4.78		5.34	1.12	1.61
	5		0.86	2.92	2.2	1.55	3.57			1.61	2.29
	6		1.43	3.16	4.18	2.78				1.45	1.47
	7		2.66	6.13		4.49				7.32	3.48
	8		4.71								

Table S7. Sensitivity analysis #2: Doubling times of COVID-19 cumulative incidence and their harmonic mean of the arithmetic means of the doubling times and harmonic mean of the harmonic means of the doubling times (95% Confidence interval) by province in mainland China from January 23, 2020 through February 9, 2020.

		Mainland China (Except Hubei)	Hubei	Anhui	Beijing	Chongqing	Fujian	Gansu	Guangdong	Guangxi	Guizhou	Hainan
Harmonic mean of arithmetic means		2.9 (2.62-3.24)	2.46 (2.37-2.55)	2.54 (2.12-2.99)	3.46 (2.77-4.57)	3.11 (2.38-4.17)	2.03 (1.29-3.10)	2.54 (1.80-3.89)	2.91 (2.40-3.61)	3.26 (2.37-4.22)	2.67 (1.85-3.92)	3.43 (2.57-4.62)
Harmonic mean of harmonic means		1.98 (1.82-2.17)	2.25 (2.18-2.33)	1.47 (0.90-2.29)	3.03 (2.23-3.99)	1.87 (1.28-2.80)	1.26 (0.69-2.01)	1.27 (0.66-2.84)	2.65 (2.14-3.10)	2.23 (1.33-3.29)	1.73 (0.67-3.40)	2.31 (1.40-3.71)
Times doubled	1	1.01	2.12	0.62	2.15	0.90	1.00	1.00	2.16	1.30	2.50	1.55
	2	1.59	1.47	1.38	3.50	2.04	1.11	1.14	2.29	2.84	3.50	2.28
	3	2.30	2.22	2.30	4.21	4.37	1.09	1.26	2.79	4.22	1.64	5.31
	4	3.21	3.03	3.74		7.99	1.71	4.10	4.45	8.50	2.56	6.86
	5	6.41	3.45	3.96			4.13	5.90			5.80	

		Hebei	Heilongjiang	Henan	Hunan	Inner Mongolia	Jiangsu	Jiangxi	Jilin	Liaoning	Ningxia	Qinghai
Harmonic mean of arithmetic means		1.91 (1.42-2.83)	2.21 (1.74-2.81)	1.87 (1.50-2.40)	1.89 (1.48-2.77)	2.39 (1.84-4.00)	2.31 (1.80-3.10)	1.89 (1.44-2.52)	3.01 (2.14-4.06)	2.44 (1.49-4.00)	2.68 (1.70-4.50)	3.21 (2.25-5.67)
Harmonic mean of harmonic means		0.81 (0.39-1.78)	1.47 (0.77-2.51)	0.85 (0.48-1.37)	0.75 (0.41-1.27)	1.16 (0.66-3.02)	1.60 (1.06-2.36)	1.18 (0.62-1.86)	2.44 (1.29-3.73)	0.99 (0.37-2.46)	1.88 (0.94-3.96)	1.8 (0.80-5.08)
Times doubled	1	0.33	0.80	0.39	0.26	1.00	1.00	0.63	3.00	0.50	2.00	2.33
	2	0.67	1.36	0.68	0.53	0.40	1.31	0.92	2.59	1.07	1.25	0.67
	3	1.60	2.12	0.71	1.30	0.85	1.75	1.78	3.53	2.76	2.55	4.00
	4	1.33	2.95	1.62	1.92	2.75	2.32	1.72	2.38	4.67	4.53	4.50
	5	2.01	3.04	2.73	2.19	4.71	4.07	1.74				
	6	5.28	3.31	3.96	4.56			3.88				

		Shaanxi	Shandong	Shanghai	Shanxi	Sichuan	Tianjin	Tibet	Xinjiang	Yunnan	Zhejiang
Harmonic mean of arithmetic means		3.44 (2.76-4.40)	1.43 (1.18-2.14)	3.08 (2.52-4.07)	1.93 (1.50-3.09)	2.61 (1.89-3.60)	3.17 (2.16-4.59)	Not applied	3.05 (2.10-4.67)	1.82 (1.20-2.87)	2.37 (1.87-3.14)
Harmonic mean of harmonic means		2.84 (1.82-4.05)	0.24 (0.14-0.60)	2.61 (1.72-3.59)	0.71 (0.32-1.88)	1.82 (1.28-2.57)	2.12 (0.79-4.34)	Not applied	1.86 (0.83-4.40)	1.03 (0.56-1.77)	1.98 (1.73-2.41)
Times doubled	1	3.33	0.05	2.00	0.20	1.12	2.00		2.00	0.66	1.57
	2	2.24	0.10	3.00	0.40	1.51	1.66		1.60	0.84	2.4
	3	3.76	0.20	3.29	1.06	2.72	4.95		3.06	1.12	1.39
	4		0.40		1.76	4.04	5.30		5.34	1.61	4.06
	5		0.86		2.20					1.45	
	6		1.43		4.18					7.32	
	7		2.66								
	8		4.71								

Table S8. Websites of national and provincial health commissions in mainland China

Health commission	URL	Notes
National Health Commission of the People's Republic of China	http://www.nhc.gov.cn	
Provincial health commissions		
Anhui	http://wjw.ah.gov.cn/	
Beijing	http://wjw.beijing.gov.cn/	
Chongqing	http://wsjkw.cq.gov.cn/	
Fujian	http://fjwsjk.fjsen.com/	
Gansu	http://wsjk.gansu.gov.cn/	
Guangdong	http://wsjkw.gd.gov.cn/	
Guangxi	http://wsjkw.gxzf.gov.cn/	
Guizhou	http://www.gzhfpc.gov.cn/	
Hainan	http://wst.hainan.gov.cn/	
Hebei	http://www.hebwst.gov.cn/	Our team members found it often inaccessible from Statesboro, GA, USA.
Heilongjiang	http://wsjkw.hlj.gov.cn/	
Henan	http://www.hnwsjsw.gov.cn/	
Hubei	http://wjw.hubei.gov.cn/	
Hunan	http://wjw.hunan.gov.cn/	
Inner Mongolia	http://wjw.nmg.gov.cn/	
Jiangsu	http://wjw.jiangsu.gov.cn/	
Jiangxi	http://hc.jiangxi.gov.cn/	
Jilin	http://www.jl.gov.cn/	
Liaoning	http://www.shenyang.gov.cn/	
Ningxia	http://wsjkw.nx.gov.cn/index.htm	
Qinghai	https://wsjkw.qinghai.gov.cn/	
Shaanxi	http://sxwjw.shaanxi.gov.cn/	
Shandong	http://wsjkw.shandong.gov.cn	Our team members found it persistently inaccessible from Statesboro, GA, USA.
Shanghai	http://www.shanghai.gov.cn/	
Shanxi	http://wjw.shanxi.gov.cn/	
Sichuan	http://wsjkw.sc.gov.cn/	
Tianjin	http://www.tj.gov.cn/	
Tibet	http://wjw.xizang.gov.cn/	
Xinjiang	http://www.xjhfpc.gov.cn/	
Yunnan	http://ynswsjkw.yn.gov.cn/	
Zhejiang	https://www.zjwjw.gov.cn	

Notes: If our team was unable to directly retrieve the press release from a provincial health commissions, we will use mainland Chinese media reports that directly reported on the provincial health commissions' announcements. Please note that mainland Chinese media are controlled by the Chinese Communist Party and they could not deviate from the government's announcements.

Figure S1. Main analysis: The harmonic mean of the arithmetic means of COVID-19 epidemic doubling times (red circle) with 95% confidence interval (red bar) of the doubling times (days), and their values (black diamond) by the number of times the reported cumulative incidence doubles by province within mainland China from January 20, 2020 through February 9, 2020. Each panel represents a province except the panel representing "Mainland China (except Hubei)" that is the aggregate of all other provinces in mainland China, except Hubei. Doubling time for Tibet is not available, because there had only been 1 confirmed case in Tibet as of February 9, 2020.

Figure S2. Main analysis: The harmonic mean of the harmonic means of COVID-19 epidemic doubling times (red circle) with 95% confidence interval (red bar) of the doubling times (days), and their values (black diamond) by the number of times the reported cumulative incidence doubles by province within mainland China from January 20, 2020 through February 9, 2020. Each panel represents a province except the panel representing "Mainland China (except Hubei)" that is the aggregate of all other provinces in mainland China, except Hubei. Doubling time for Tibet is not available, because there had only been 1 confirmed case in Tibet as of February 9, 2020.

Figure S3. Sensitivity analysis #1: The harmonic mean of the arithmetic means of COVID-19 doubling times (red circle) with 95% confidence interval (red bar) of the doubling times (days), and their values (black diamond) by the number of times the reported cumulative incidence doubles by province within mainland China from December 31, 2019 through February 9, 2020. Each panel represents a province except the panel representing "Mainland China (except Hubei)" that is the aggregate of all other provinces in mainland China, except Hubei. Doubling time for Tibet is not available, because there had only been 1 confirmed case in Tibet as of February 9, 2020.

Figure S4. Sensitivity analysis #1: The harmonic mean of the harmonic means of COVID-19 doubling times (red circle) with 95% confidence interval (red bar) of the doubling times (days), and their values (black diamond) by the number of times the reported cumulative incidence doubles by province within mainland China from December 31, 2019 through February 9, 2020. Each panel represents a province except the panel representing "Mainland China (except Hubei)" that is the aggregate of all other provinces in mainland China, except Hubei. Doubling time for Tibet is not available, because there had only been 1 confirmed case in Tibet as of February 9, 2020.

Figure S5. Sensitivity analysis #2: The harmonic mean of the arithmetic means of COVID-19 doubling times (red circle) with 95% confidence interval (red bar) of the doubling times (days), and their values (black diamond) by the number of times the reported cumulative incidence doubles by province within mainland China from January 23, 2020 through February 9, 2020. Each panel represents a province except the panel representing "Mainland China (except Hubei)" that is the aggregate of all other provinces in mainland China, except Hubei. Doubling time for Tibet is not available, because there had only been 1 confirmed case in Tibet as of February 9, 2020.

Figure S6. Sensitivity analysis #2: The harmonic mean of the harmonic means of COVID-19 doubling times (red circle) with 95% confidence interval (red bar) of the doubling times (days), and their values (black diamond) by the number of times the reported cumulative incidence doubles by province within mainland China from January 23, 2020 through February 9, 2020. Each panel represents a province except the panel representing "Mainland China (except Hubei)" that is the aggregate of all other provinces in mainland China, except Hubei. Doubling time for Tibet is not available, because there had only been 1 confirmed case in Tibet as of February 9, 2020.

Figure S7. Cumulative incidence and log$_{10}$ cumulative incidence over time (date) for Hubei (upper panel) and Fujian (lower panel).

Figure S8. Cumulative incidence and log$_{10}$ cumulative incidence over time (date) for Guangdong (upper panel) and Heilongjiang (lower panel).

Figure S9. Cumulative incidence and log$_{10}$ cumulative incidence over time (date) for Henan (upper panel) and Hunan (lower panel).

Figure S10. Cumulative incidence and log$_{10}$ cumulative incidence over time (date) for Jiangxi (upper panel) and Shandong (lower panel).

Figure S11. Main analysis: The map of the harmonic mean of the harmonic means of COVID-19 by province in mainland China, from January 20, 2020 through February 9, 2020.

Figure S12. Sensitivity analysis #1: The map of the harmonic mean of the arithmetic means of COVID-19 by province in mainland China, from December 31, 2019 through February 9, 2020.

Figure S13. Sensitivity Analysis #1: The map of the harmonic mean of the harmonic means of COVID-19 by province in mainland China, from December 31, 2019 through February 9, 2020.

Figure S14. Sensitivity analysis #1: The map of the number of times the COVID-19 outbreak has doubled by province in mainland China, from December 31, 2019 through February 9, 2020.

Authors' contributions

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Manuscript writing: Dr. Isaac Chun-Hai Fung and Dr. Gerardo Chowell

Manuscript editing and data interpretation: Ms. Kamalich Muniz-Rodriguez, Dr. Gerardo Chowell, Dr. Isaac Chun-Hai Fung, Dr. Lone Simonsen, and Dr. Cecile Viboud

MATLAB code and methods of doubling time estimation: Dr. Gerardo Chowell

Doubling time calculation using MATLAB and presentation of results: Ms. Kamalich Muniz-Rodriguez, Dr. Gerardo Chowell and Dr. Isaac Chun-Hai Fung

Statistical analysis in R: Dr. Isaac Chun-Hai Fung, Ms. Kamalich Muniz-Rodriguez

Data management and quality check of epidemic data entry: Ms. Kamalich Muniz-Rodriguez, Dr. Isaac Chun-Hai Fung

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Curation of epidemic data for provinces in mainland China: Ms. Manyun Liu (from the early reports, up to Jan 24, 2020 data), Ms. Po-Ying Lai (since Jan 25, 2020 data to today), Mr. Chi-Hin Cheung (since Jan 27, 2020 data to today), and Ms. Kamalich Muniz-Rodriguez and Dr. Isaac Chun-Hai Fung (whenever there is a back-log).

Retrieval of epidemic data from official websites (downloading and archiving of China's national and provincial authorities' press releases): Ms. Manyun Liu and Dr. Dongyu Jia (at the very beginning of our project)

Retrieval of statistical data from the official website of National Bureau of Statistics of the People's Republic of China: Mr. Chi-Hin Cheung

Retrieval of publicly available statistical data from various sources: Ms. Yiseul Lee, Dr. Isaac Chun-Hai Fung

Table S8: Ms. Manyun Liu, Dr. Isaac Chun-Hai Fung

Map creation: Ms. Kimberlyn M. Roosa

Assistance provided to Dr. Fung and Ms. Muniz-Rodriguez: Ms. Sylvia K. Ofori

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References

1.   Anderson RM, May RM. Infectious diseases of humans. Oxford: Oxford University Press; 1991.
2.   Drake JM, Bakach I, Just MR, O'Regan SM, Gambhir M, Fung IC-H. Transmission Models of Historical Ebola Outbreaks. Emerging Infectious Disease journal. 2015 Aug;21(8):1447-50.
3.   National Health Commission of the People's Republic of China. 2020 [cited Feb 2, 2020]; Available from: http://www.nhc.gov.cn/
4.   Centre for Health Protection, Department of Health, The Government for the Hong Kong Special Administrative Region. 2020 [cited Feb 2, 2020]; Available from: https://www.chp.gov.hk/en/index.html
5.   John Hopkins University Center for Systems Science and Engineering. 2019 Novel Coronavirus COVID-19 (2019-nCoV) Data Repository by Johns Hopkins CSSE. 2020 [cited Feb 13, 2020]; Available from: https://github.com/CSSEGISandData/COVID-19
6.   Banks HT, Hu S, Thompson WC. Modeling and inverse problems in the presence of uncertainty: CRC Press; 2014.
7.   Chowell G, Ammon CE, Hengartner NW, Hyman JM. Transmission dynamics of the great influenza pandemic of 1918 in Geneva, Switzerland: Assessing the effects of hypothetical interventions. J Theor Biol. 2006 Jul 21;241(2):193-204.
8.   Chowell G, Shim E, Brauer F, Diaz-Duenas P, Hyman JM, Castillo-Chavez C. Modelling the transmission dynamics of acute haemorrhagic conjunctivitis: application to the 2003 outbreak in Mexico. Stat Med. 2006 Jun 15;25(11):1840-57.
9.   Vynnycky E, White RG. An Introduction to Infectious Disease Modelling. Oxford: Oxford University Press; 2010.
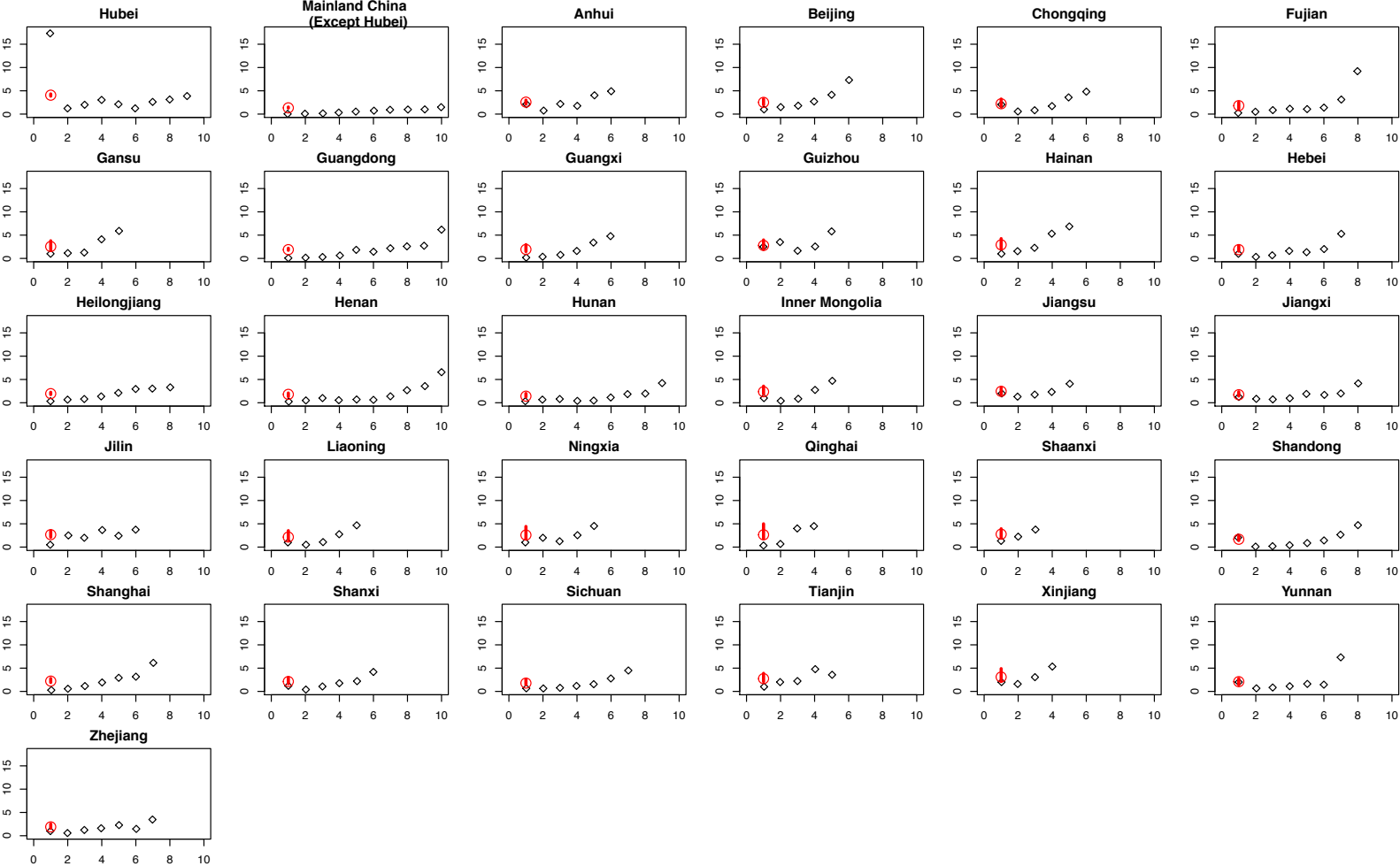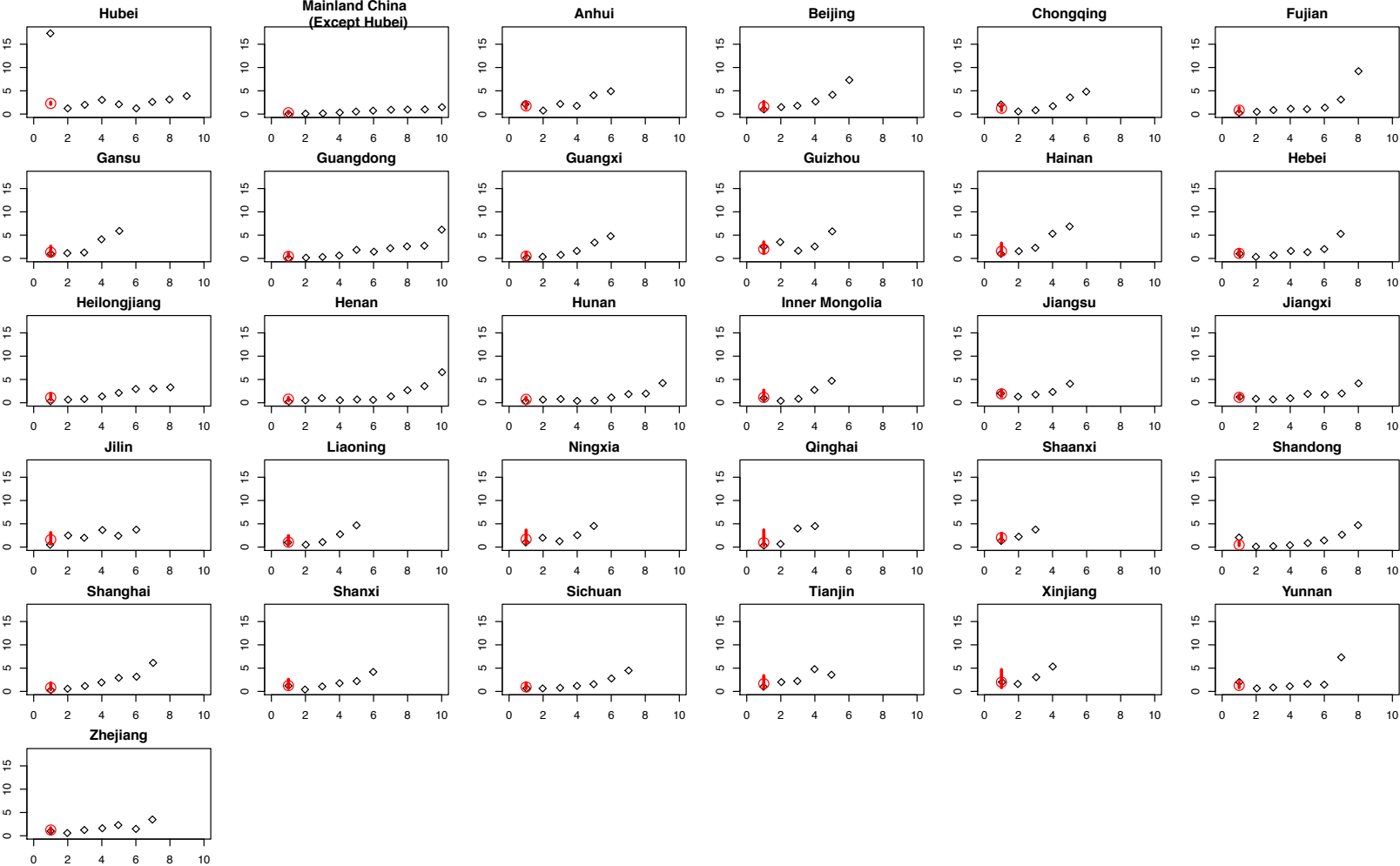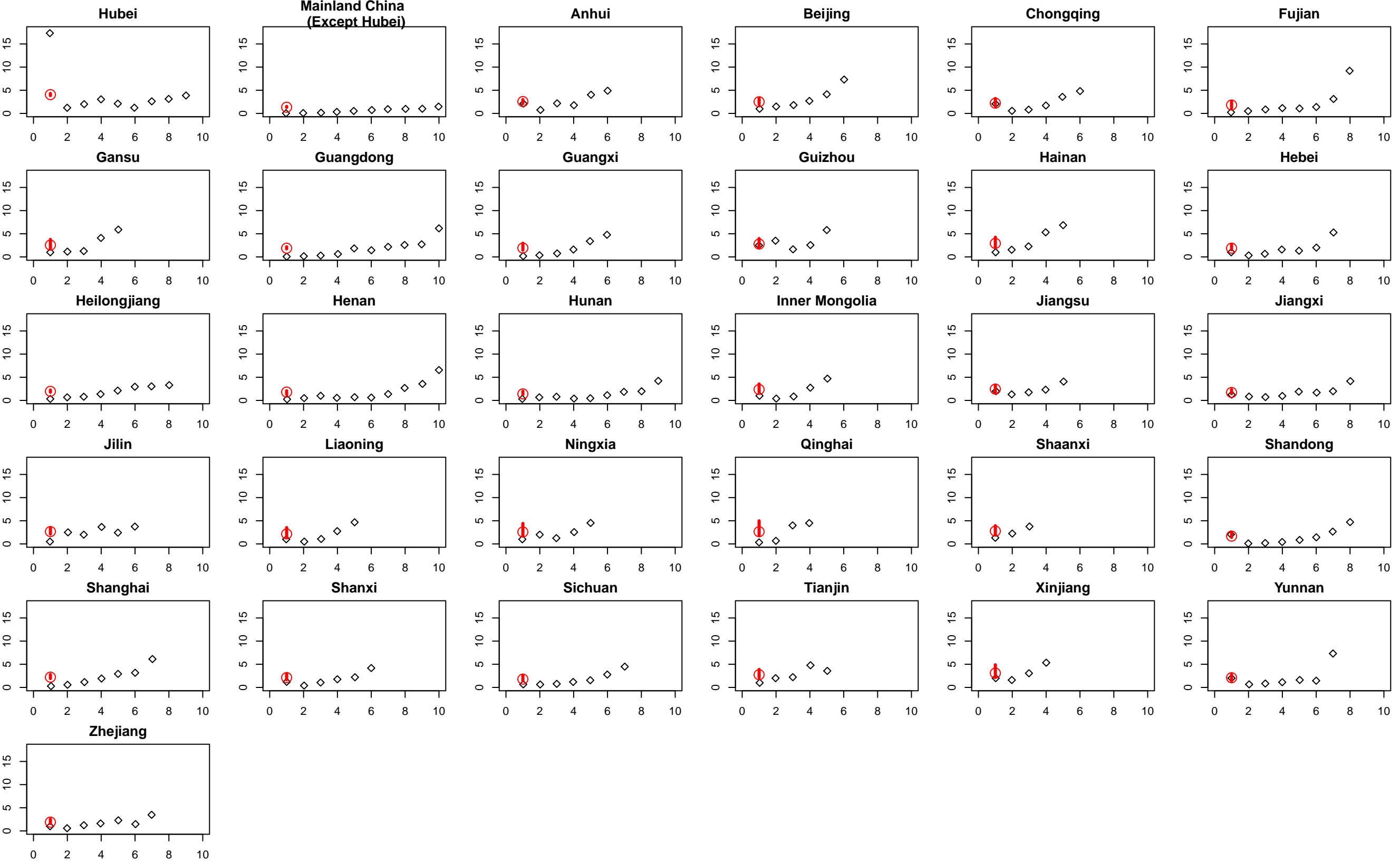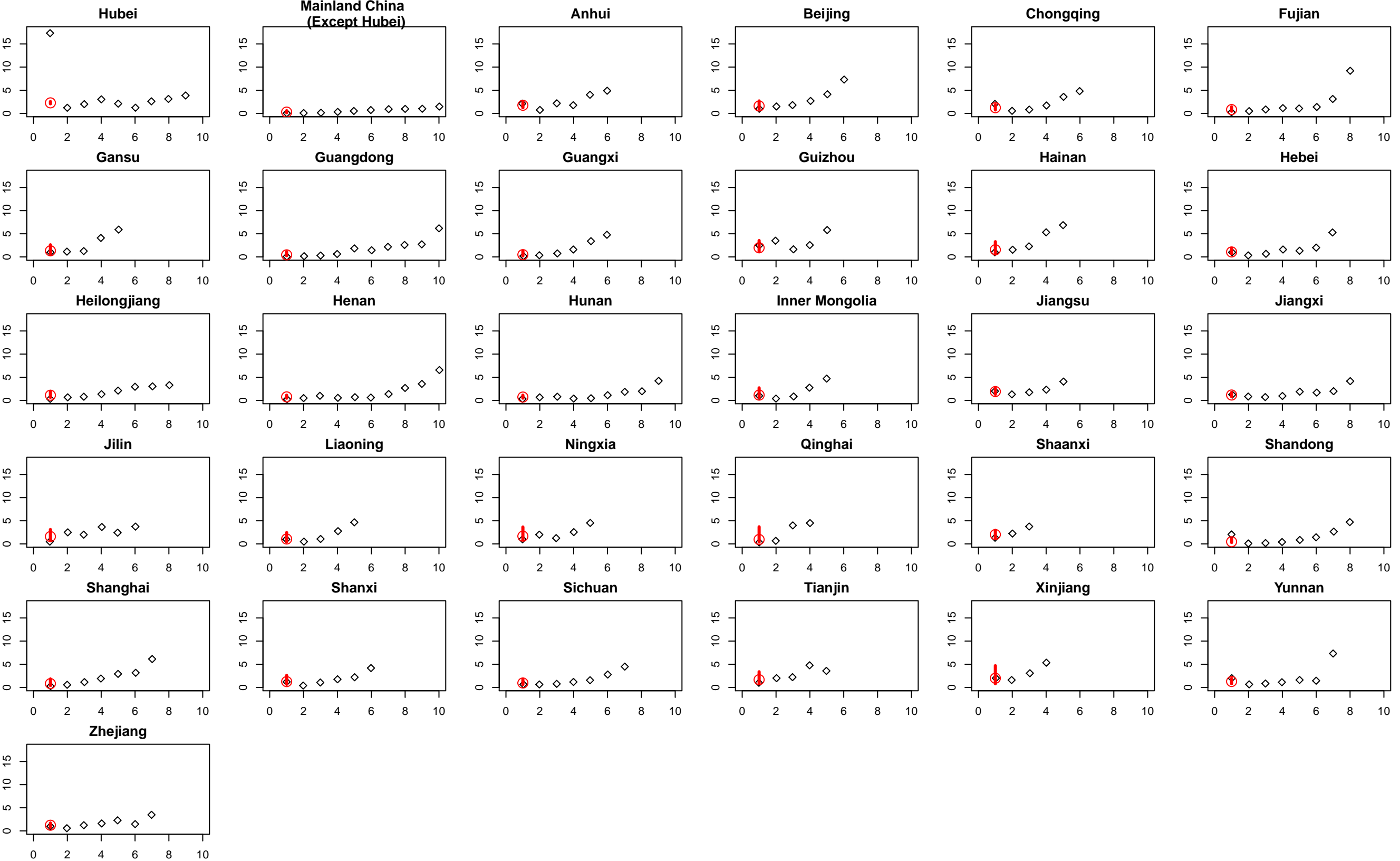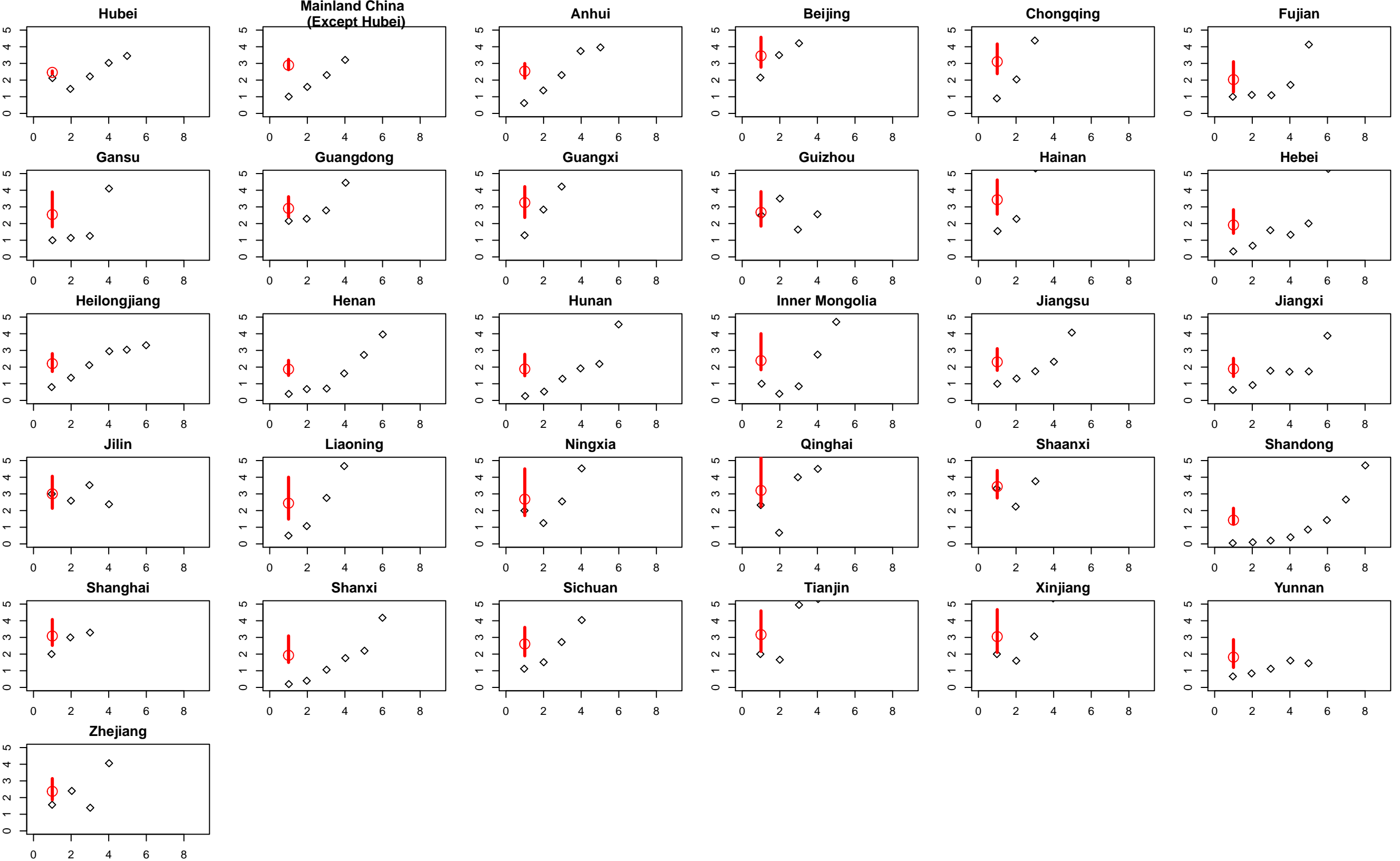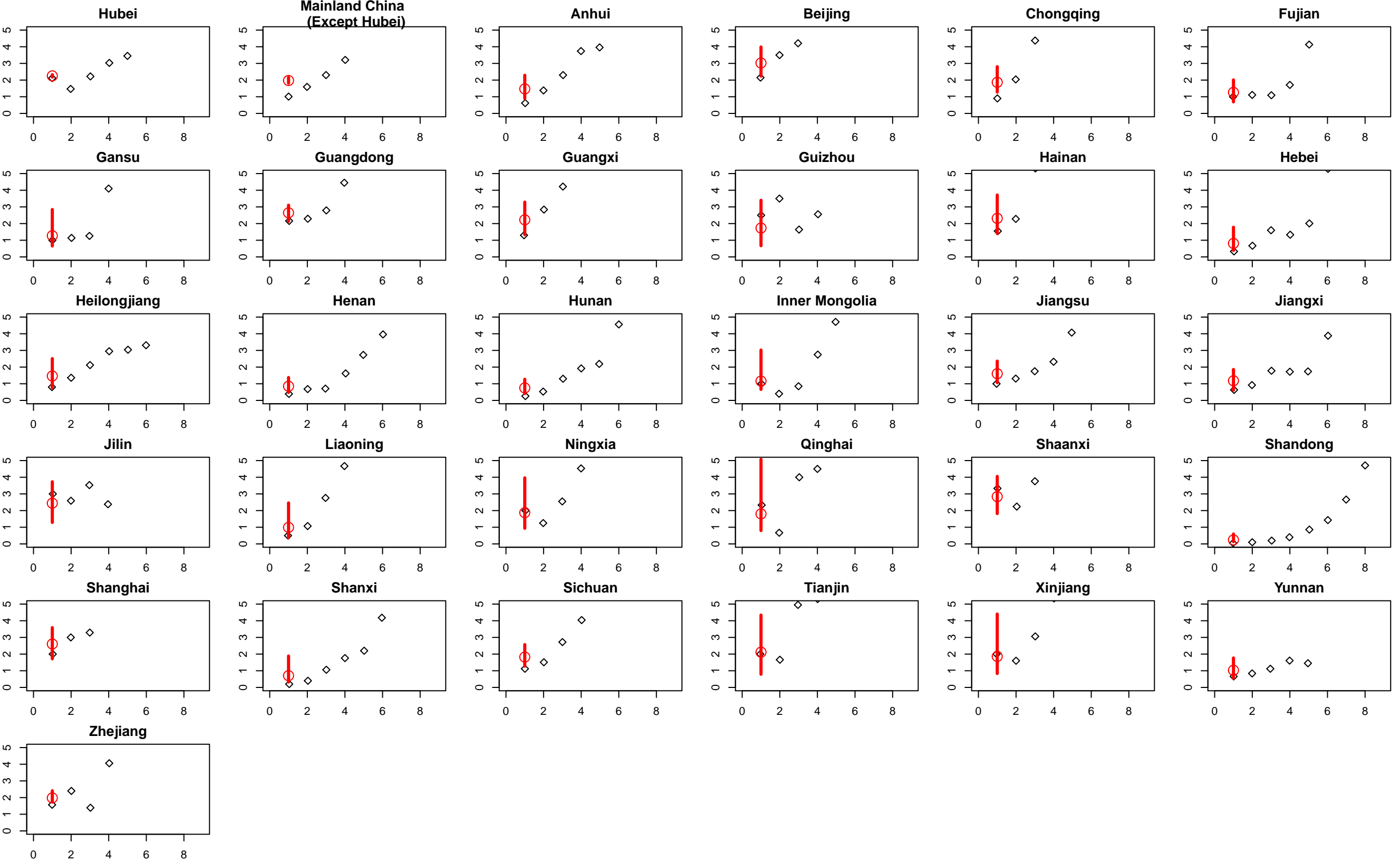
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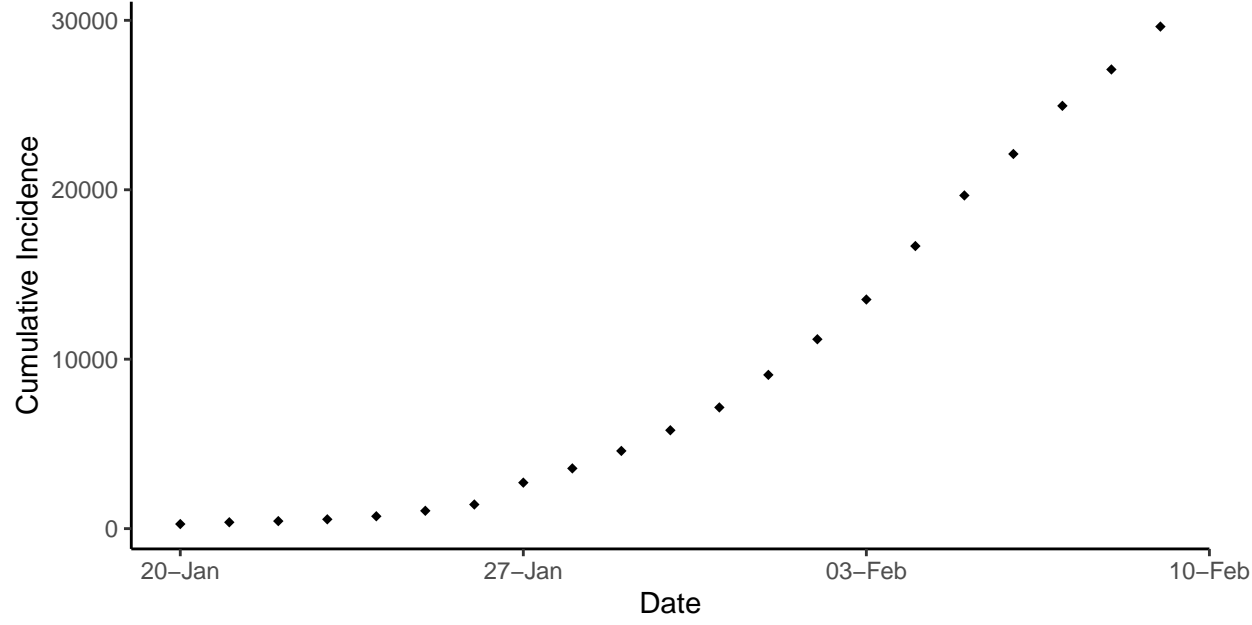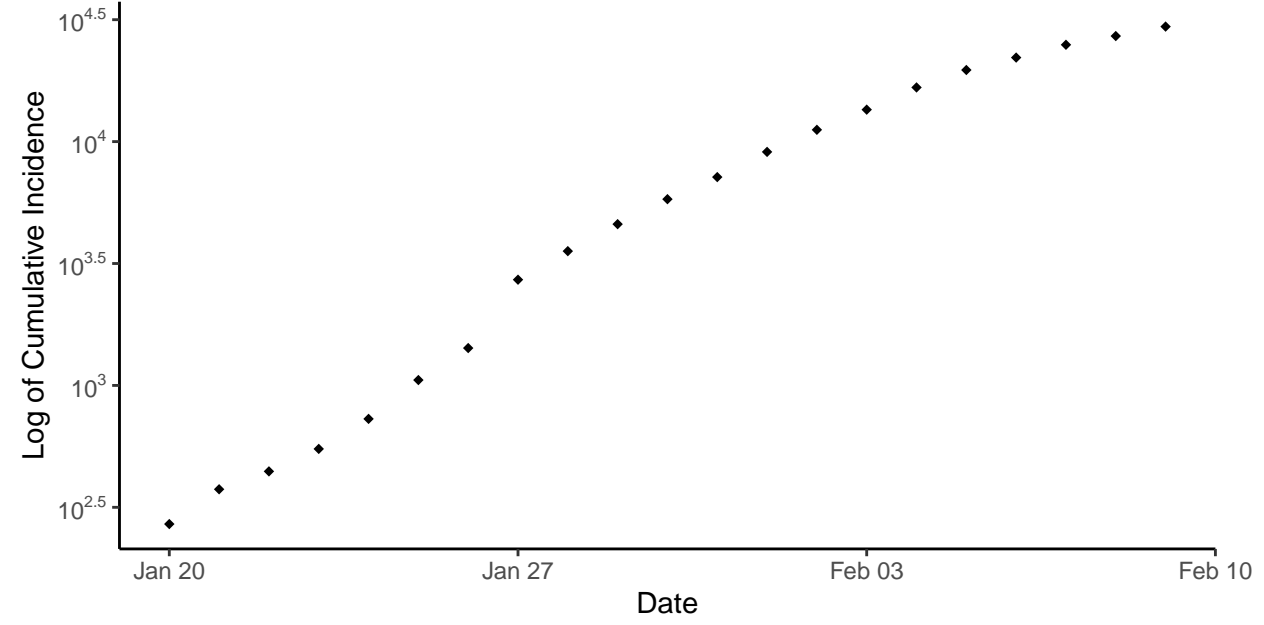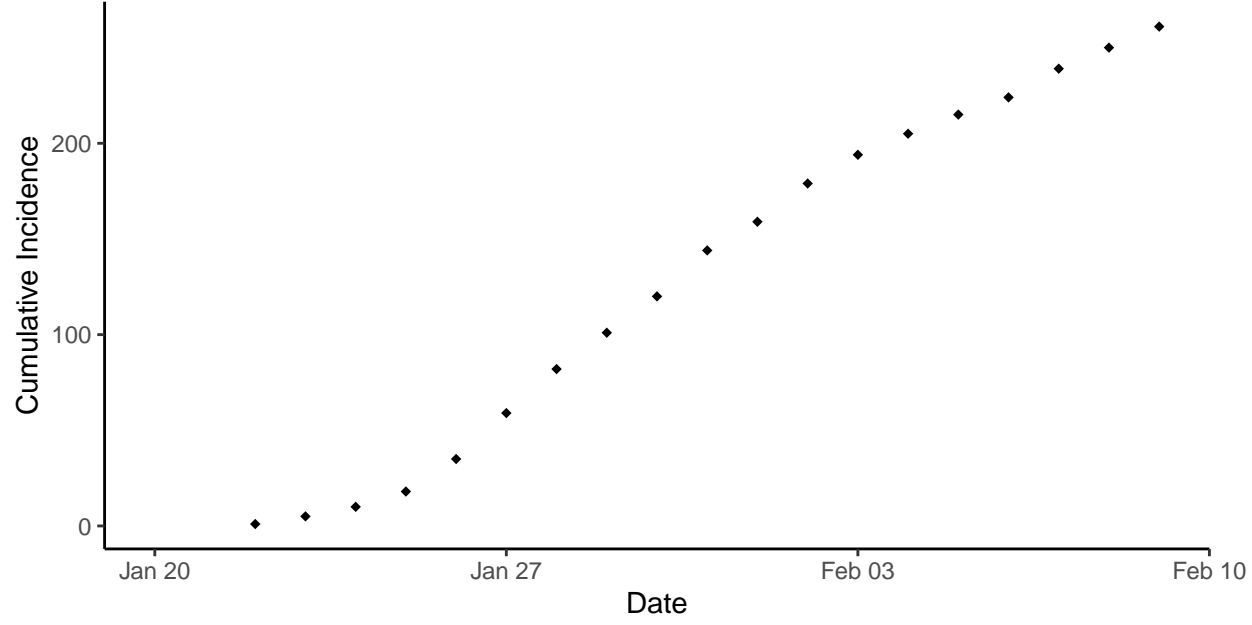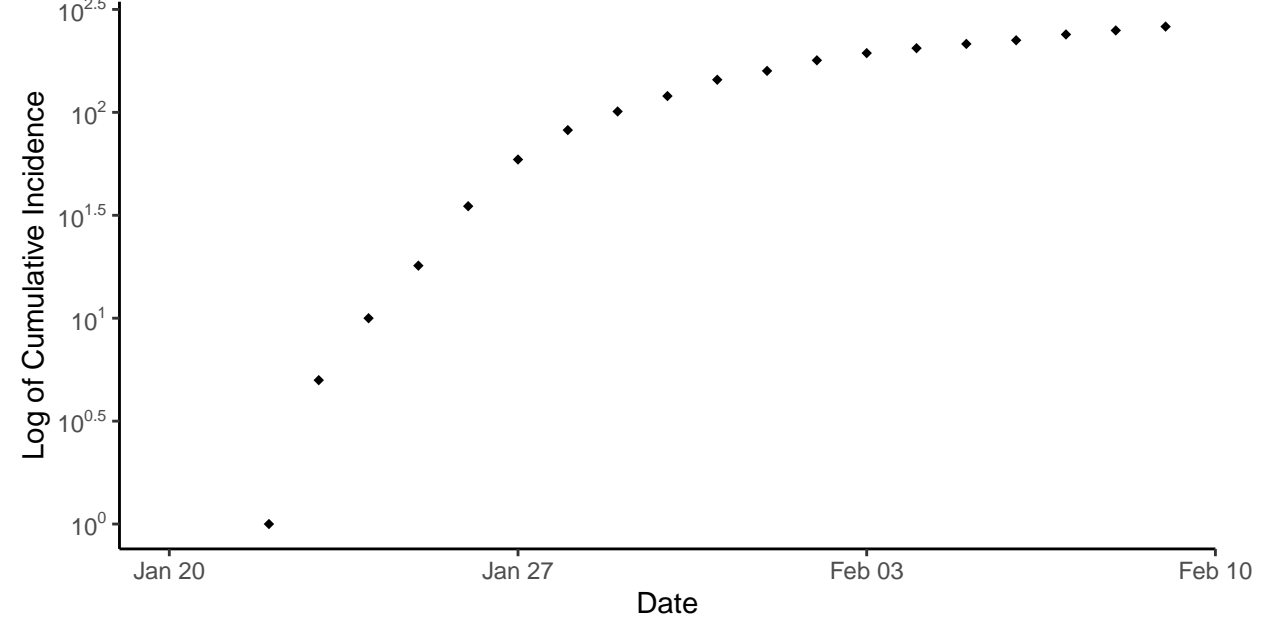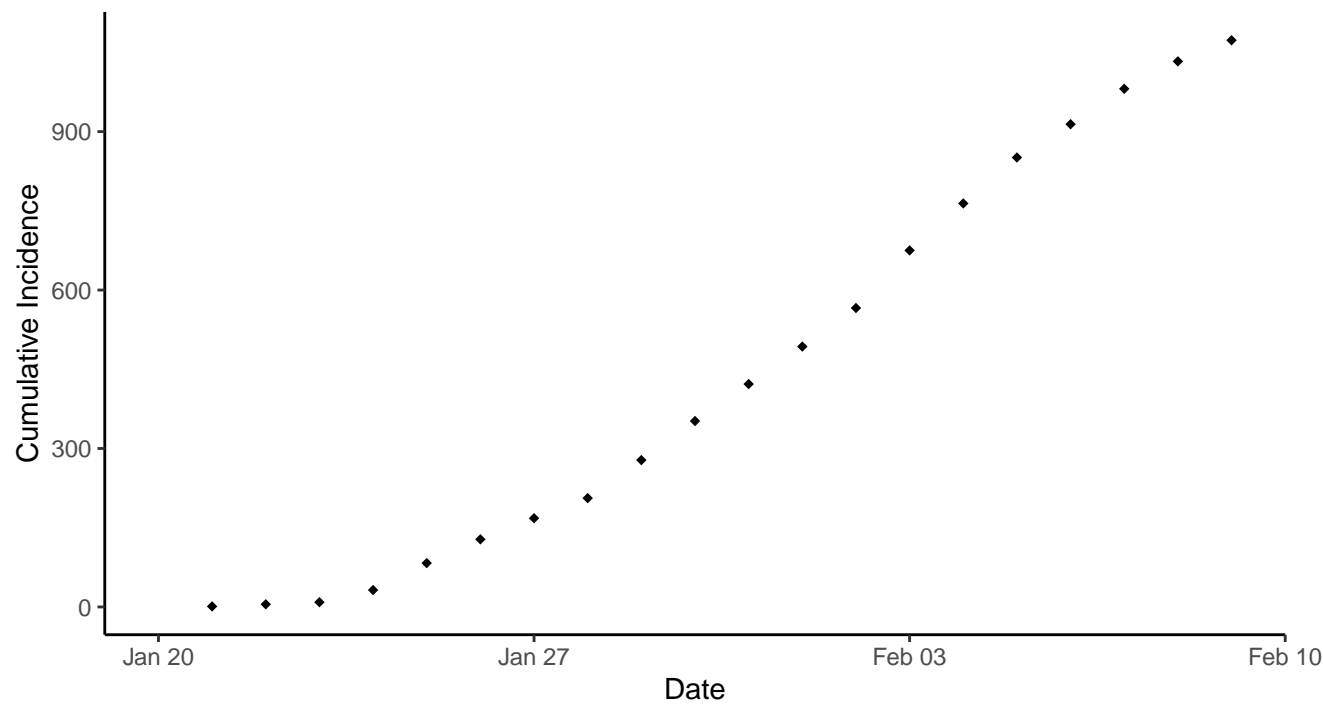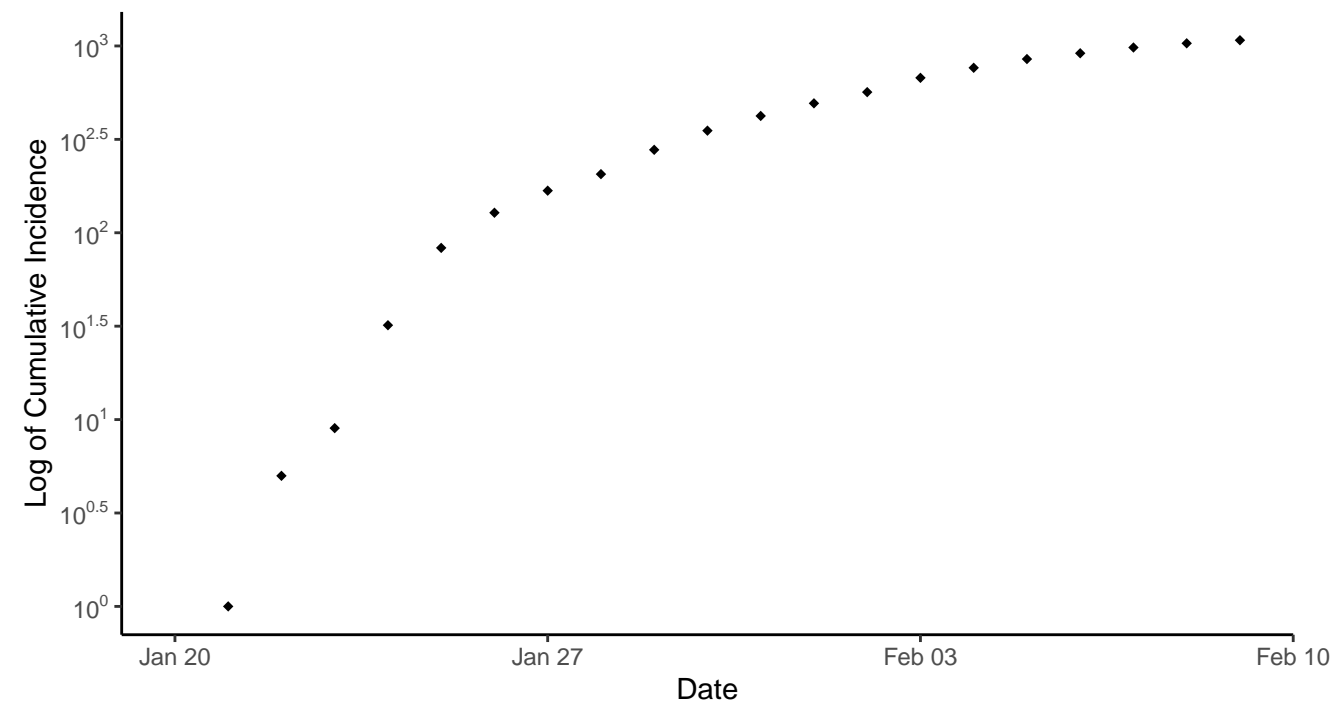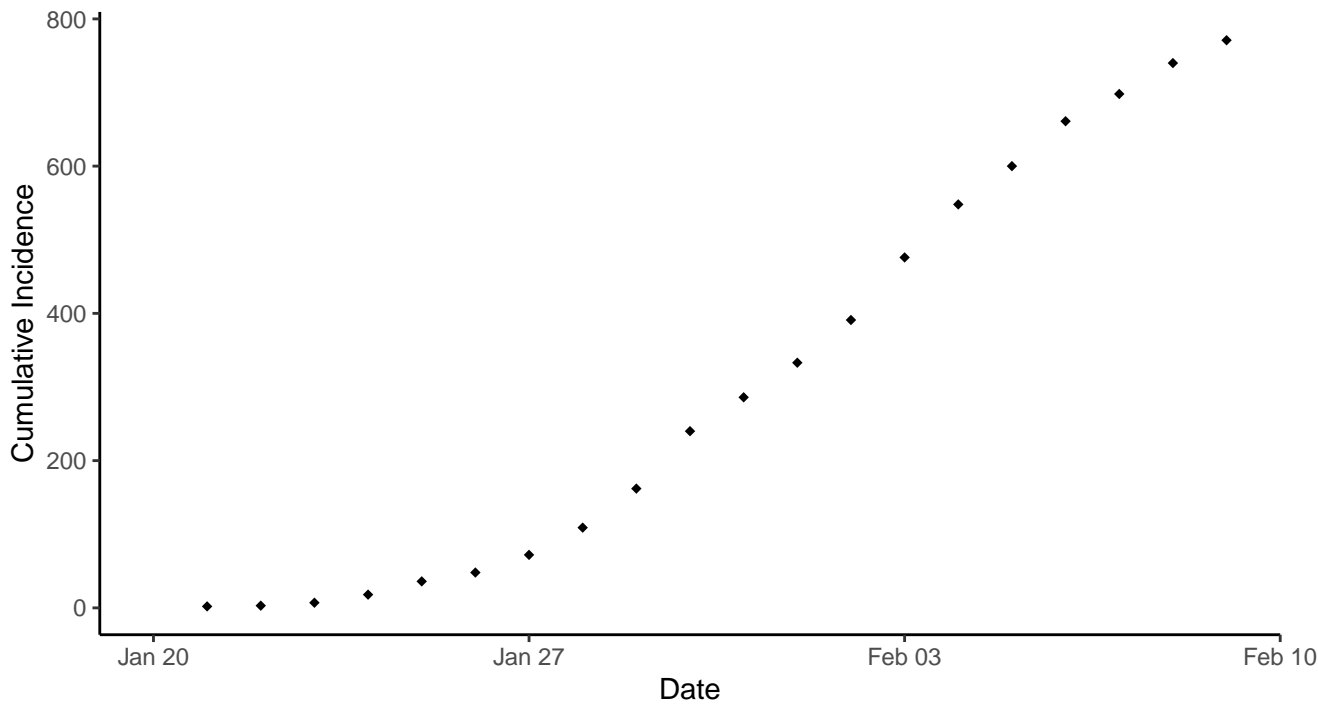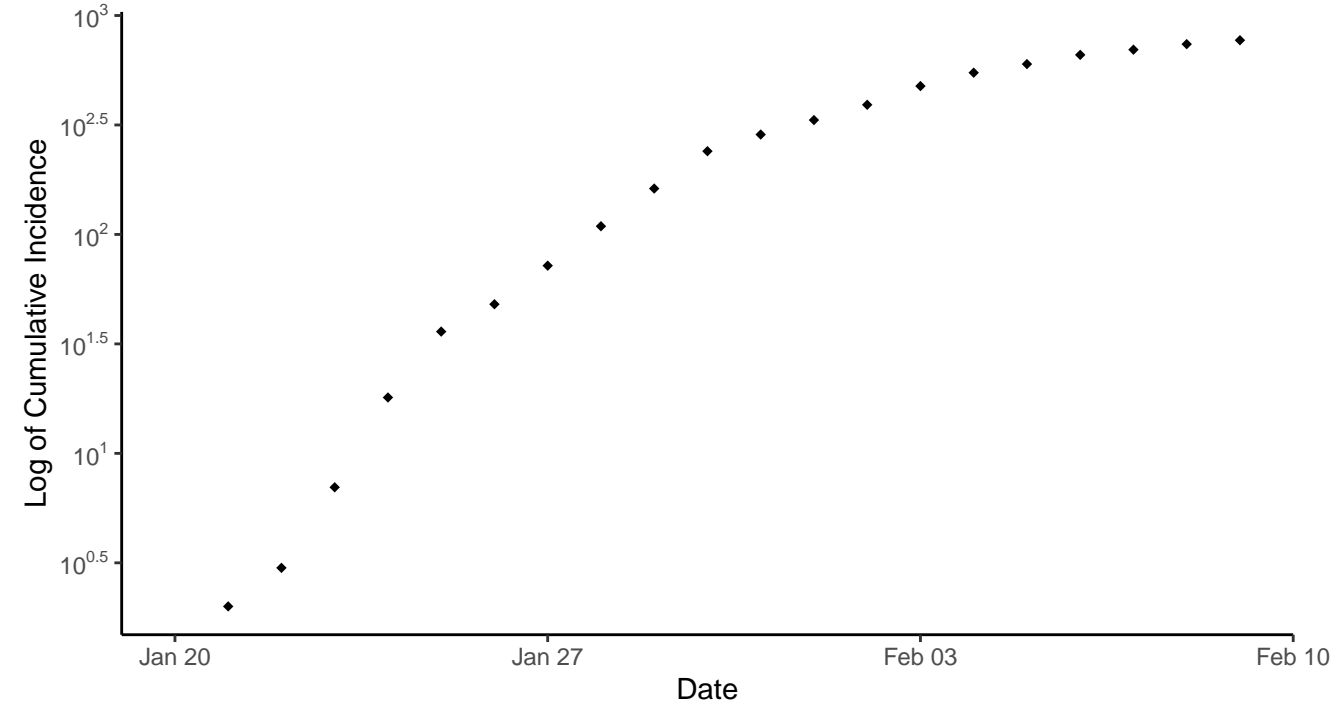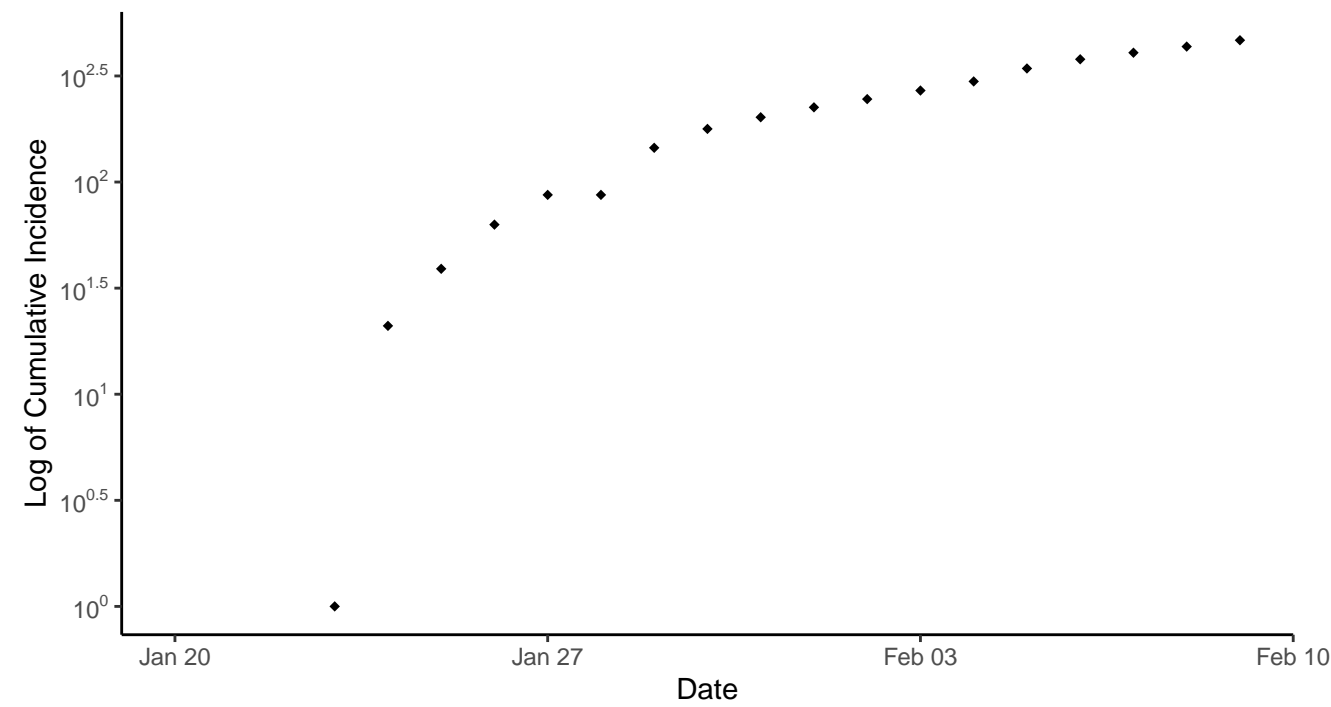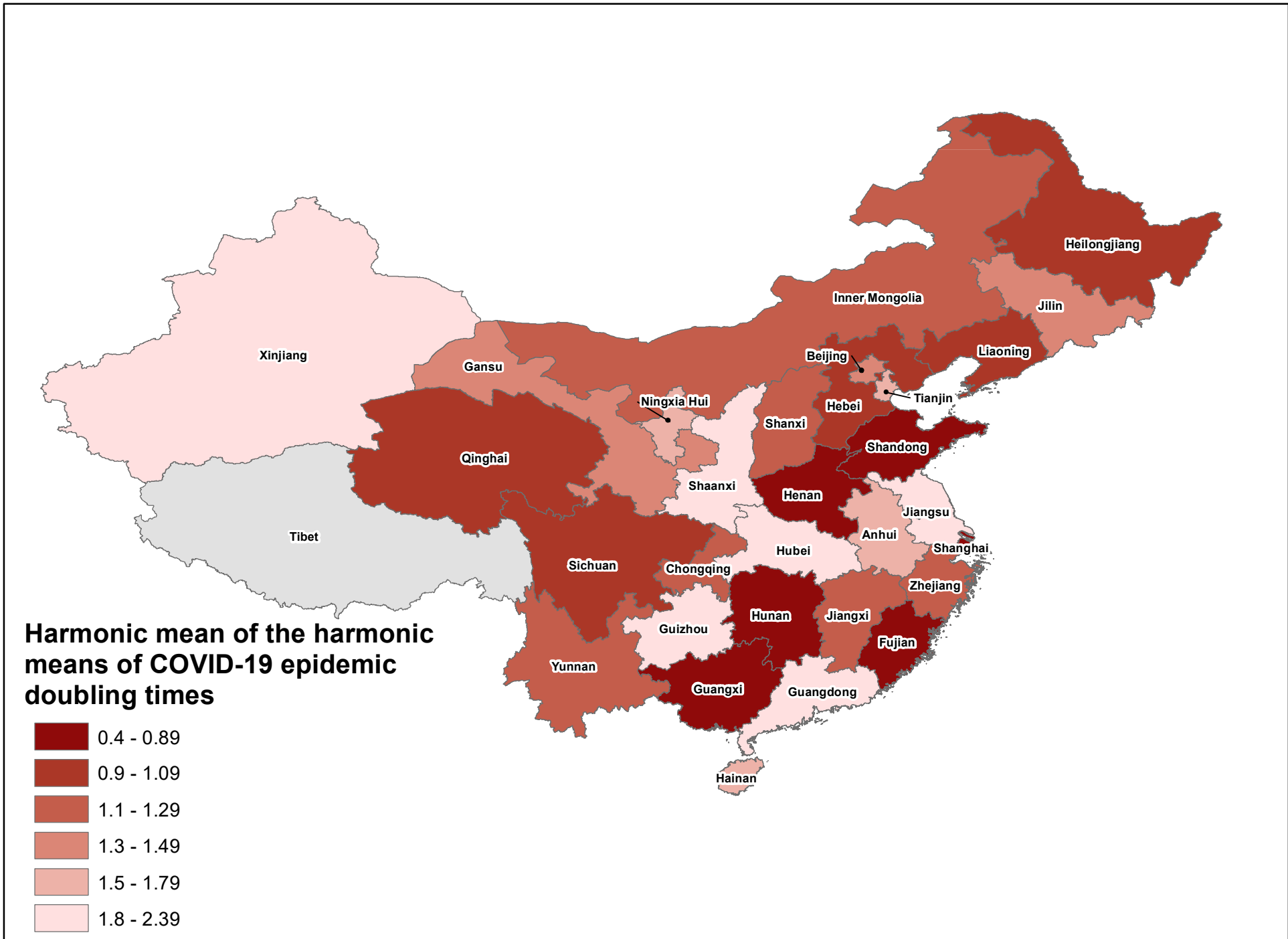
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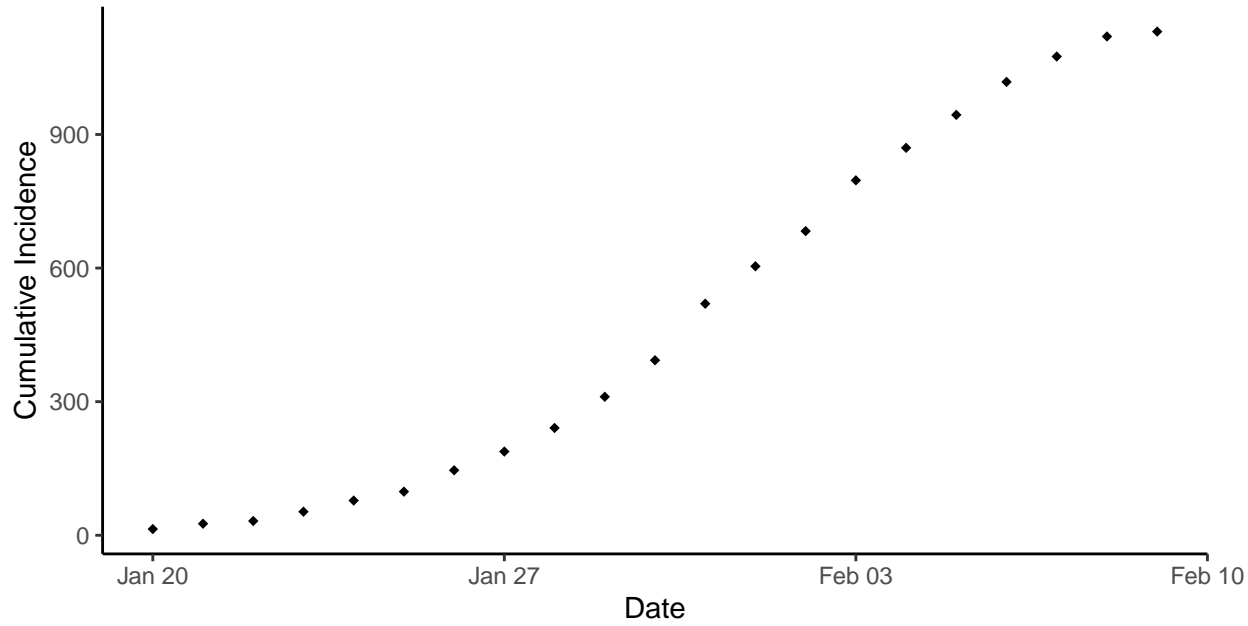
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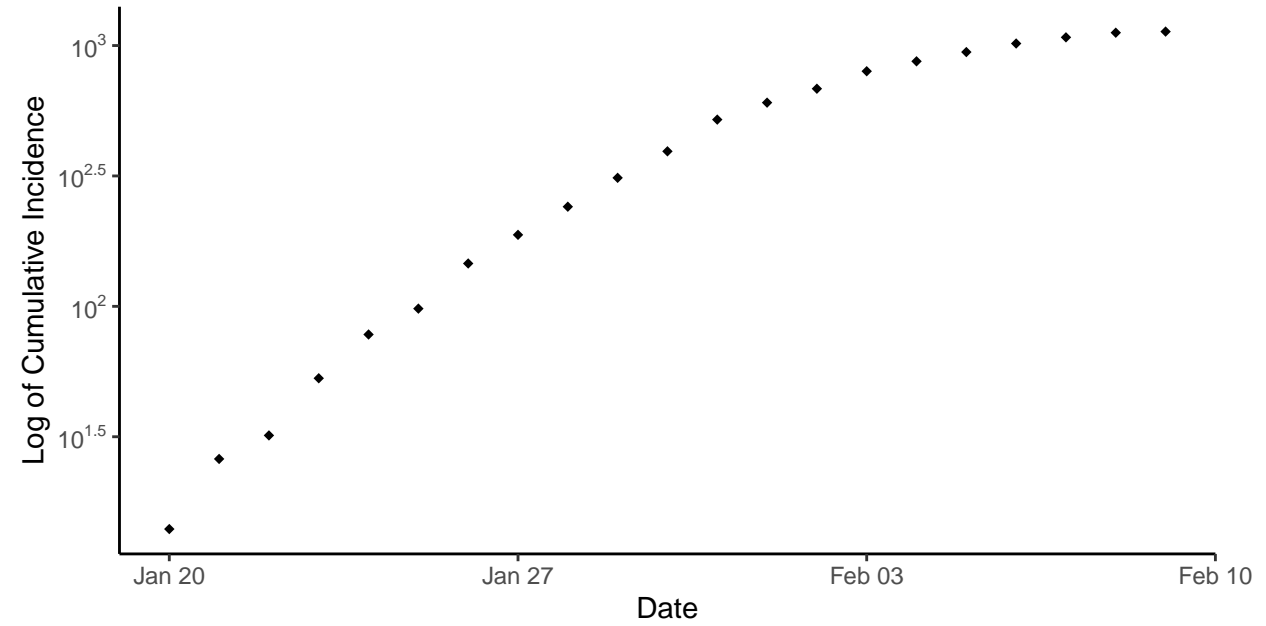
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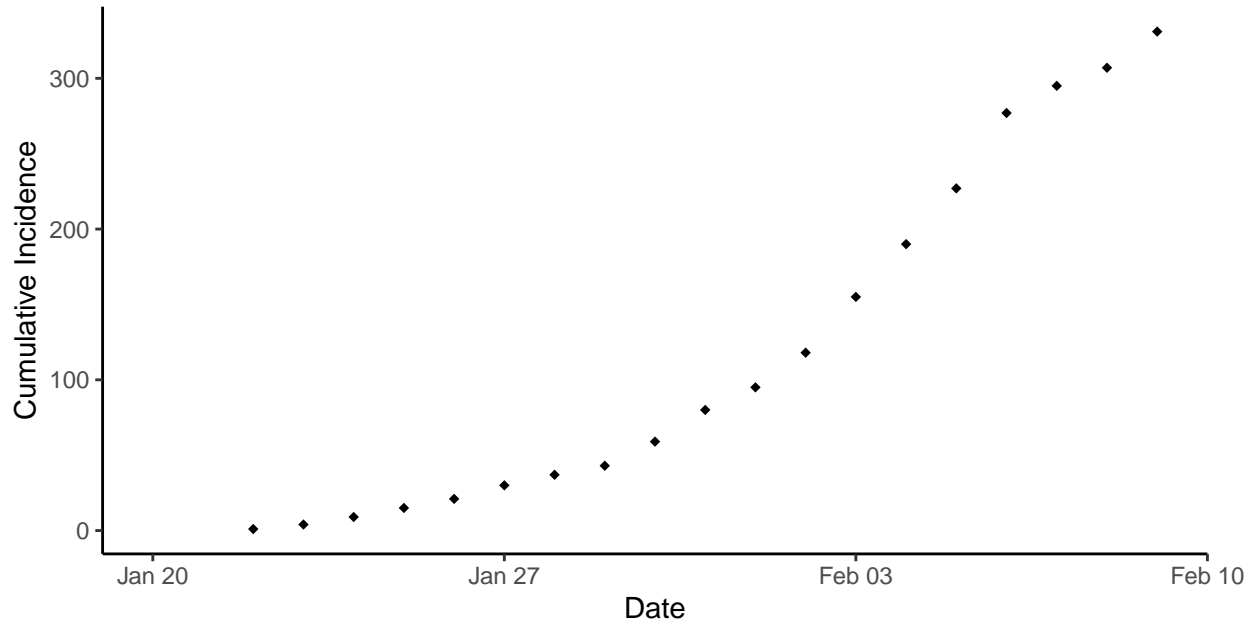
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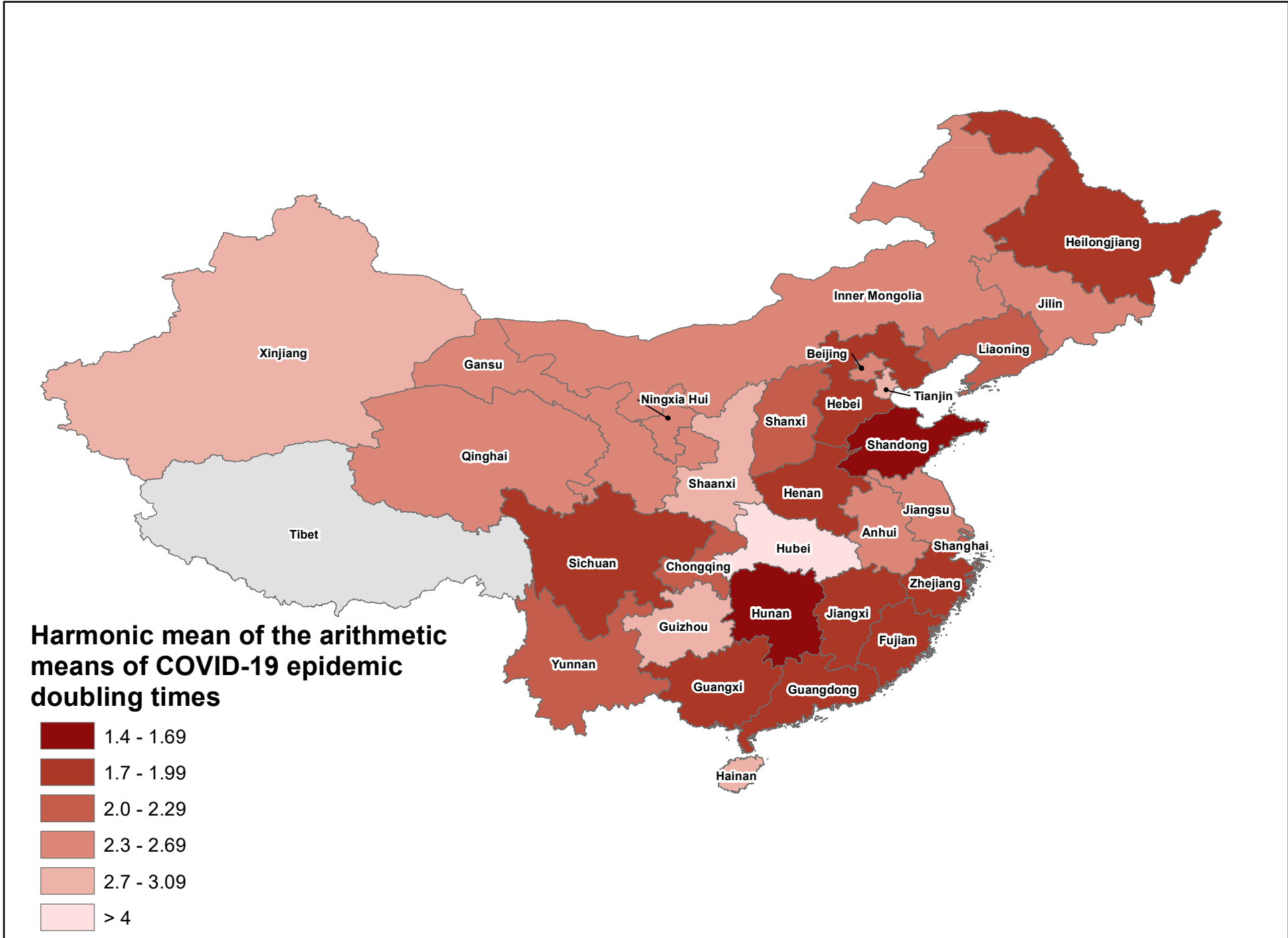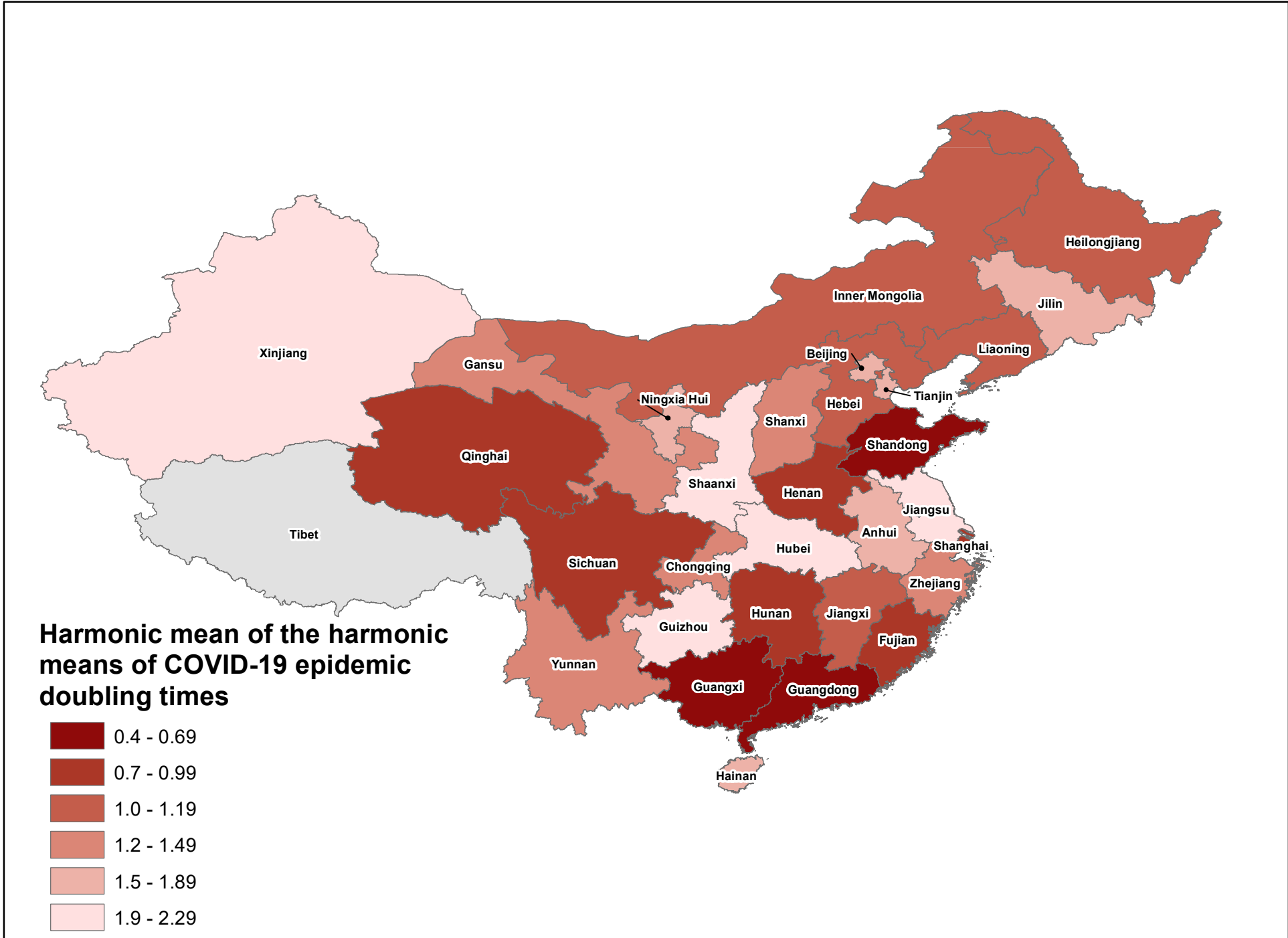Harmonic mean of the harmonic means of COVID-19 epidemic doubling times

- 0.4 - 0.89
- 0.9 - 1.09
- 1.1 - 1.29
- 1.3 - 1.49
- 1.5 - 1.79
- 1.8 - 2.39

Harmonic mean of the arithmetic
means of COVID-19 epidemic
doubling times

- 1.4 - 1.69
- 1.7 - 1.99
- 2.0 - 2.29
- 2.3 - 2.69
- 2.7 - 3.09
- > 4

Harmonic mean of the harmonic means of COVID-19 epidemic doubling times

■	0.4 - 0.69
■	0.7 - 0.99
■	1.0 - 1.19
■	1.2 - 1.49
■	1.5 - 1.89
■	1.9 - 2.29

Number of times COVID-19 incidence has doubled by province

- 3 - 4
- 5
- 6
- 7 - 8
- 9 - 10