Appendix 2 (as supplied by the authors)

Impact of Climate and Public Health Interventions on the COVID-19 Pandemic: Prospective Cohort Study

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I. Supplementary Methods

Outcome

Due to considerable differences in testing practices between different geopolitical areas, the actual rates of COVID-19 cases cannot be reliably estimated; however, rate ratios based on cumulative counts reported at two timepoints one week apart can be reliably estimated since testing practices in a specific geopolitical area will affect both counts in the same way during the ascertained one-week period. The time window of one week is short enough that no substantial changes in testing strategy are expected in most geopolitical areas so that the reported confirmed cases in each region represent a constant percentage of the true actual cases. We emphasize that testing strategies affect estimates of rates considerably more than the ratio.

The rate ratio used as a measure of epidemic growth was calculated as the cumulative count of confirmed cases since the beginning of the epidemic as of March 27 divided by the cumulative count of confirmed cases since the beginning of the epidemic as of March 20 (Figure S1). The observation time was identical across all areas. Since the populations in question were large, they could be considered equal at both times and cancelled out in calculations of rate ratios. A rate ratio of 2 indicates that the cumulative number of cases in a geopolitical area doubled within one week, a rate ratio of 3 indicates that it tripled.

The log(rate ratio) is equivalent to estimating the slope of log(count) over time – the slope of the log cumulative frequency curve – which estimates the logarithm of the exponential growth rate, hence the rate ratio is the estimate of the exponential growth parameter.

Univariate and multivariable models

The protocol prespecified the following analyses of the association of exposure variables with epidemic growth:

No adjustment:

Univariate random-effects regression with inverse-variance weights regressing the log rate ratio against exposure variables.

Adjusted for geographical regions:

Bivariable random-effects regression with inverse-variance weights regressing the log rate ratio against exposure variables after inclusion of major geographical area as categorical covariate.

Adjusted for prespecified covariates:

Multivariable random-effects regression with inverse-variance weights regressing the log rate ratio against exposure variables after inclusion of the following 8 prespecified covariates: gross domestic product (GDP) per capita, health expenditure as percent of GDP, life expectancy, percentage of inhabitants aged 65 or over, Infectious Disease Vulnerability Index, urban population density, number of flight passengers per capita, closest distance to a geopolitical area with an already established epidemic

(City of Wuhan, South Korea, Iran, Italy). For the analysis of latitude, we also included altitude as covariate.

Adjusted for geographical regions and prespecified covariates:

Multivariable random-effects regression with inverse-variance weights regressing the log rate ratio against exposure variables after inclusion of the prespecified covariates above and major geographical area as categorical covariate.

Adjusted for geographical regions, prespecified covariates and public health interventions:

Multivariable random-effects regression with inverse-variance weights regressing the log rate ratio against temperature or humidity after inclusion of the prespecified covariates above, major geographical area as categorical covariate, and school closures, restrictions of mass gatherings, and measures of social distancing as binary covariates.

Adjusted for geographical regions, prespecified covariates, temperature and humidity:

Multivariable random-effects regression with inverse-variance weights regressing the log rate ratio against public health interventions after inclusion of the prespecified covariates above, major geographical area as categorical covariate, and temperature and humidity as continuous covariates.

Analysis sets

The protocol pre-specified that all analyses above would be performed in the following 3 datasets:

- All geopolitical areas (main analysis set)
- Geopolitical areas with ≥20 events on March 20, 2020
- High income countries

Bonferroni correction for analysis of primary exposure variable

A Bonferroni correction was specified for the analysis of the primary exposure variable (the square of geographic latitude), with alpha set to 0.025 (0.05/2) for the univariate and the multivariable model adjusted for prespecified covariates.

Parsimonious models

Two parsimonious multivariable models were developed in the absence of knowledge of results of univariate or multivariable analyses above.

For Model 1, we first prioritized covariates on theoretical grounds (see Table S10) and then used unsupervised cluster analysis to identify clusters of variables based on Spearman's ρ^2. Cluster analysis indicated clustering of the three public health interventions (see Figure S1). We therefore derived a post-hoc composite of exposure to any public health intervention. In addition, we pre-specified to perform tests for trend according to the number of public health interventions implemented (0, 1, or 2 or more) under the assumption that the RRRs for the association of epidemic growth with school closures, restrictions of mass gatherings or measures of social distancing would have the same direction and a similar magnitude. Model 1 included absolute humidity, urban population density, GDP, health expenditure as percentage of GDP, number of public health interventions, major geographical regions, and closest distance to a geopolitical area with an already established epidemic as independent variables.

For Model 2, we used stepwise backward selection of covariates. Starting with the full model, variables were step wisely removed based on the adjusted R2 statistic. A variable was removed if its removal resulted in an identical or increased adjusted R2.

We pre-specified that Model 1 would take precedence over Model 2, as it would not be at risk of overfitting and forced major geographical regions (Asia, Oceania, Europe, Africa, Americas) into both models to account for the geographic progression of the pandemic over time.

Post-hoc use of an alternative outcome definition to measure epidemic growth

In response to a peer reviewer's comment, we performed post hoc sensitivity analyses using the univariate and the parsimonious multivariable model with the log(rate ratio) of the cumulative incidence of confirmed COVID-19 cases that occurred during the follow-up period (March 21 to 27, 2020) divided by the cumulative incidence of confirmed COVID-19 cases that occurred during the exposure period (March 7 to 13, 2020) as dependent variable (see Figure 1 in main text for explanation of exposure and follow-up periods). Results are presented in Tables S12 and S13.

Bubble plots

We constructed bubble plots of the rate ratio of COVID-19 on a logarithmic scale on the y-axis against exposure variables on the x-axis; the size of bubbles is proportional to the weight of the geopolitical area in weighted random-effects regression. We superimposed prediction lines and 95% confidence bands for the univariate association with epidemic growth for continuous, and box and whisker plots for categorical exposure variables.

Use of ROBINS-I and ROBINS-E to judge risk of bias for individual associations

In response to a peer reviewer's comment, we used the Risk Of Bias In Non-randomized Studies of Interventions (ROBINS-I) and the Risk Of Bias In Non-randomized Studies of Exposures (ROBINS-E) tools[1,2] to judge the risk of bias for the analyzed associations of epidemic growth with prespecified exposure variables.

We concluded that the risk of bias was low for latitude, temperature, the composite of any public health intervention and for the number of public health interventions, but moderate for the remaining 5 exposure variables. The overall risk of bias was judged to be moderate for relative and absolute humidity because of a moderate risk of bias due to confounding (either direction) and due to non-differential misclassification (bias towards the null). The overall risk of bias was judged to be moderate for each of three individual public health interventions due to confounding with other public health interventions (more likely away from the null). Detailed explanations of judgments are listed in Tables S14 to S22, a summary is provided in Figure S15.

Rationale and summary of protocol changes

An initial analysis was performed on March 8, 2020 according to the original version of the protocol (version 1.0), including 73 geopolitical areas with 5,569 cases. In the univariate analysis, we found a strong association of epidemic growth with the square of the latitude, with temperature, and with absolute humidity, but closer inspection of the data suggested implausible outliers explained by liberal eligibility criteria, which could have biased estimates of associations. We therefore refrained from making the results publicly available and revised the study protocol on March 15, 2020 (version 1.1) to include more stringent inclusion criteria for geopolitical areas of at least 10 accumulated cases per geopolitical area and documented local transmission at baseline according to the WHO's Situation Reports, and to await the accumulation of more cases.

After the first revision of the protocol, investigators reached consensus that the time lag reflecting the time between transmission of SARS-CoV-2 and reporting of confirmed COVID-19 cases should be set to 14 days. We therefore moved the follow-up period forward by 6 days to March 21 to March 27, 2020. In addition, we decided to collect data on school closures, restriction of mass gatherings, and measures of social distancing at the level of geopolitical areas (version 1.2).

Revisions of the protocol were done before completion of follow-up, without inspection of the data except for results of the initial analysis done on March 8, 2020 (see Protocol version 1.2 for a summary of results of the initial analysis).

II. Supplementary Tables

Table S1. Data sources and explanations of outcome, exposure variables and covariates

Variable	Explanation	Data sources
Epidemic growth	Rate ratio of cumulative incidence on March 27 divided by cumulative incidence on March 20, 2020	Online interactive dashboard, Center for Systems Science and Engineering, Johns Hopkins University, Baltimore[3]
Square of latitude	On causal pathway for temperature and absolute humidity	Derived from coordinates of capital of geopolitical area
Temperature	Potential association with SARS-CoV-2 transmission	Meteorological website,[4] determined for capital of geopolitical area
Relative humidity	Potential association with SARS-CoV-2 transmission	Meteorological website,[4] determined for capital of geopolitical area
Absolute humidity	Potential association with SARS-CoV-2 transmission	Calculated from temperature and relative humidity[5] for capital of geopolitical area
Restriction of mass gatherings	Potential association with SARS-CoV-2 transmission	Provisions and press releases of administrative and governmental bodies; newspaper articles
School closures	Potential association with SARS-CoV-2 transmission	COVID-19 Educational Disruption and Response, UNESCO;[6] official school schedules for school holidays
Social distancing	Potential association with SARS-CoV-2 transmission	Provisions and press releases of administrative and governmental bodies; newspaper articles
GDP	Potential association with testing capacity of healthcare system	World Bank[7]
Health expenditure	Potential association with testing capacity of healthcare system	World Bank[7]
Life expectancy	General health indicator; potential association with SARS-CoV-2 transmission, disease severity or mortality	World Bank[7]
Percentage aged ≥65 years	General demographic indicator; potential association with risk of asymptomatic disease, disease severity or mortality	World Bank[7]
Infectious Disease Vulnerability Index	Potential association with testing capacity of healthcare system	RAND Corporation[8]
Urban population density	Potential association with SARS-CoV-2 transmission	Demographia World Urban Areas;[9] United States Census[10]

Flight passengers per capita	Potential association with initial attack rate	CAPA Centre of Aviation;[11] Annual World Airport Traffic Report;[12] US Federal Aviation Administration[13]
Closest distance to established epidemic	Potential association with initial attack rate and alertness of health care system	Calculated from coordinates of capital of geopolitical area
Altitude	On causal pathway for temperature, relative and absolute humidity	Derived from coordinates of capital of geopolitical area
Major geographical region	Accounts for the geographic progression of pandemic from continent to continent over time	Calculated from coordinates

Table S2. Pre-specified prioritization of variables for parsimonious multivariable model

Variable	Potentially directly associated with: Transmission	Potentially directly associated with: Detection	Priority	Comment
Latitude[2]	No	No	3	On causal pathway for temperature and absolute humidity
Temperature	Yes	No	1	
Rel. humidity	Yes	No	1	
Abs. humidity	Yes	No	1	
Restriction of gatherings	Yes	No	1	
School closures	Yes	No	1	
Social distancing	Yes	No	1	Low number of areas with implementation
GDP	No	Yes	1	Associated with testing capacity of healthcare system
Health expenditure	No	Yes	1	Associated with testing capacity of healthcare system
Life expectancy	No	No	2	General health indicator
Percentage aged ≥65 years	No	No	2	General demographic indicator
Infectious Disease Vulnerability Index	No	Yes	1	Associated with testing capacity of healthcare system
Urban population density	Yes	No	1	
Flight passengers per capita	Yes	No	2	Current situation after start of pandemic not reflected
Closest distance to established epidemic	Yes	Yes	1	Associated with attack rate and alertness of system
Altitude	No	No	3	On causal pathway for temperature, rel. and abs. humidity
Geographical region	Yes	Yes	1	Accounts for the geographic progression of the pandemic

Table S3. List of included geopolitical areas

Country	Country code	Region	Region code
Albania	ALB		
Algeria	DZA		
Argentina	ARG		
Armenia	ARM		
Australia	AUS	New South Wales	NSW
Australia	AUS	Queensland	QLD
Australia	AUS	South Australia	SA
Australia	AUS	Victoria	VIC
Australia	AUS	Western Australia	WA
Austria	AUT		
Bahrain	BHR		
Bangladesh	BGD		
Belarus	BLR		
Belgium	BEL		
Bolivia	BOL		
Bosnia and Herzegovina	BIH		
Brazil	BRA		
Brunei	BRN		
Bulgaria	BGR		
Burkina Faso	BFA		
Cambodia	KHM		
Cameroon	CMR		
Canada	CAN	Alberta	AB
Canada	CAN	British Columbia	BC
Canada	CAN	New Brunswick	NB
Canada	CAN	Ontario	ON
Canada	CAN	Quebec	QC
Canada	CAN	Saskatchewan	SK
Chile	CHL		
Colombia	COL		
Costa Rica	CRI		
Croatia	HRV		
Cyprus	CYP		
Czechia	CZE		
Democratic Republic of the Congo	COD		
Denmark	DNK		
Dominican Republic	DOM		
Ecuador	ECU		
Egypt	EGY		
Estonia	EST		

Faroe Islands	FRO
Finland	FIN
France	FRA
French Guiana	GUF
Germany	DEU
Ghana	GHA
Greece	GRC
Hong Kong	HKG
Hungary	HUN
Iceland	ISL
India	IND
Indonesia	IDN
Iraq	IRQ
Ireland	IRL
Israel	ISR
Jamaica	JAM
Japan	JPN
Kuwait	KWT
Lebanon	LBN
Luxembourg	LUX
Macao	MAC
Malaysia	MYS
Maldives	MDV
Moldova	MDA
Morocco	MAR
Netherlands	NLD
New Zealand	NZL
North Macedonia	MKD
Norway	NOR
Oman	OMN
Pakistan	PAK
Panama	PAN
Paraguay	PRY
Peru	PER
Philippines	PHL
Poland	POL
Portugal	PRT
Qatar	QAT
Romania	ROU
Russia	RUS
San Marino	SMR
Saudi Arabia	SAU
Senegal	SEN

Serbia	SRB		
Singapore	SGP		
Slovakia	SVK		
Slovenia	SVN		
South Africa	ZAF		
Spain	ESP		
Sri Lanka	LKA		
Sweden	SWE		
Switzerland	CHE		
Taiwan	TWN		
Thailand	THA		
Tunisia	TUN		
Turkey	TUR		
Ukraine	UKR		
United Arab Emirates	ARE		
United Kingdom	GBR		
United States	USA	Arkansas	AR
United States	USA	Arizona	AZ
United States	USA	California	CA
United States	USA	Colorado	CO
United States	USA	Connecticut	CT
United States	USA	District of Columbia	DC
United States	USA	Florida	FL
United States	USA	Georgia	GA
United States	USA	Hawaii	HI
United States	USA	Iowa	IA
United States	USA	Illinois	IL
United States	USA	Indiana	IN
United States	USA	Kansas	KS
United States	USA	Kentucky	KY
United States	USA	Louisiana	LA
United States	USA	Massachusetts	MA
United States	USA	Maryland	MD
United States	USA	Maine	ME
United States	USA	Michigan	MI
United States	USA	Minnesota	MN
United States	USA	Mississippi	MS
United States	USA	North Carolina	NC
United States	USA	North Dakota	ND
United States	USA	Nebraska	NE
United States	USA	New Hampshire	NH
United States	USA	New Jersey	NJ
United States	USA	New Mexico	NM

United States	USA	Nevada	NV
United States	USA	New York	NY
United States	USA	Ohio	OH
United States	USA	Oklahoma	OK
United States	USA	Oregon	OR
United States	USA	Pennsylvania	PA
United States	USA	Rhode Island	RI
United States	USA	South Carolina	SC
United States	USA	South Dakota	SD
United States	USA	Tennessee	TN
United States	USA	Texas	TX
United States	USA	Utah	UT
United States	USA	Virginia	VA
United States	USA	Washington	WA
United States	USA	Wisconsin	WI
United States	USA	Wyoming	WY
Uzbekistan	UZB		
Vietnam	VNM		

Table S4. Association of epidemic growth with latitude

Latitude (per 400 degrees^2)	Ratio of rate ratios (95% CI)	P value
No adjustment		
All areas	0.99 (0.96 to 1.03)	0.72
Areas with ≥20 events	0.99 (0.95 to 1.02)	0.54
High income countries	0.98 (0.93 to 1.02)	0.26
Adjusted for geographical regions		
All areas	1.01 (0.97 to 1.05)	0.62
Areas with ≥20 events	1.00 (0.96 to 1.05)	0.90
High income countries	0.98 (0.93 to 1.02)	0.30
Adjusted for prespecified covariates		
All areas	1.00 (0.96 to 1.05)	0.83
Areas with ≥20 events	1.01 (0.97 to 1.05)	0.75
High income countries	0.99 (0.95 to 1.04)	0.77
Adjusted for geographical regions and prespecified covariates		
All areas	1.01 (0.96 to 1.06)	0.75
Areas with ≥20 events	1.01 (0.96 to 1.06)	0.82
High income countries	0.98 (0.92 to 1.03)	0.42
Adjusted for geographical regions, prespecified covariates and public health interventions		
All areas	1.00 (0.96 to 1.05)	0.94
Areas with ≥20 events	1.00 (0.95 to 1.05)	0.97
High income countries	0.98 (0.93 to 1.03)	0.46

Epidemic growth quantified by the rate ratio comparing the cumulative rate on March 27 with the cumulative rate on March 20, 2020; Ratio of rate ratios expressed per increase in 400 degrees^2 of latitude. CI, confidence interval; p values are 2-sided. 132 geopolitical areas were included in the analysis of areas with ≥20 events, and 98 areas were included in the analysis restricted to high income countries.

Table S5. Association of epidemic growth with temperature

Temperature (per 5°C)	Ratio of Rate ratios (95% CI)	P value
No adjustment		
All areas	0.97 (0.93 to 1.02)	0.21
Areas with ≥20 events	0.97 (0.92 to 1.02)	0.28
High income countries	0.97 (0.91 to 1.03)	0.31
Adjusted for geographical regions		
All areas	0.98 (0.93 to 1.03)	0.43
Areas with ≥20 events	0.99 (0.94 to 1.04)	0.63
High income countries	1.01 (0.95 to 1.07)	0.70
Adjusted for prespecified covariates		
All areas	0.97 (0.92 to 1.03)	0.31
Areas with ≥20 events	0.97 (0.92 to 1.03)	0.29
High income countries	0.99 (0.93 to 1.05)	0.73
Adjusted for geographical regions and prespecified covariates		
All areas	0.99 (0.93 to 1.05)	0.72
Areas with ≥20 events	0.99 (0.93 to 1.06)	0.81
High income countries	1.01 (0.94 to 1.09)	0.80
Adjusted for geographical regions, prespecified covariates and public health interventions		
All areas	1.00 (0.94 to 1.06)	0.88
Areas with ≥20 events	1.00 (0.94 to 1.06)	0.96
High income countries	1.00 (0.93 to 1.07)	0.95

Epidemic growth quantified by the rate ratio comparing the cumulative rate on March 27 with the cumulative rate on March 20, 2020; Ratio of rate ratios expressed per 5°C increase in temperature. CI, confidence interval; p values are 2-sided. 132 geopolitical areas were included in the analysis of areas with ≥20 events, and 98 areas were included in the analysis restricted to high income countries.

Table S6. Association of epidemic growth with absolute humidity

Absolute humidity (per 5 g/m^3)	Ratio of Rate ratios (95% CI)	P value
No adjustment		
All areas	0.92 (0.85 to 0.99)	0.024
Areas with ≥20 events	0.91 (0.84 to 0.99)	0.037
High income countries	0.86 (0.76 to 0.98)	0.022
Adjusted for geographical regions		
All areas	0.94 (0.87 to 1.01)	0.11
Areas with ≥20 events	0.95 (0.87 to 1.03)	0.19
High income countries	0.95 (0.85 to 1.07)	0.40
Adjusted for prespecified covariates		
All areas	0.91 (0.84 to 0.99)	0.025
Areas with ≥20 events	0.90 (0.83 to 0.99)	0.22
High income countries	0.94 (0.83 to 1.07)	0.36
Adjusted for geographical regions and prespecified covariates		
All areas	0.94 (0.86 to 1.02)	0.15
Areas with ≥20 events	0.94 (0.85 to 1.04)	0.22
High income countries	0.92 (0.82 to 1.03)	0.15
Adjusted for geographical regions, prespecified covariates and public health interventions		
All areas	0.93 (0.85 to 1.02)	0.11
Areas with ≥20 events	0.93 (0.85 to 1.02)	0.14
High income countries	0.92 (0.81 to 1.04)	0.17

Epidemic growth quantified by the rate ratio comparing the cumulative rate on March 27 with the cumulative rate on March 20, 2020; Ratio of rate ratios expressed per 5 g/m^3 increase in absolute humidity; CI, confidence interval; p values are 2-sided. 132 geopolitical areas were included in the analysis of areas with ≥20 events, and 98 areas were included in the analysis restricted to high income countries.

Table S7. Association of epidemic growth with relative humidity

Relative humidity (per 10%)	Ratio of Rate ratios (95% CI)	P value
No adjustment		
All areas	0.91 (0.85 to 0.96)	0.002
Areas with ≥20 events	0.91 (0.85 to 0.97)	0.003
High income countries	0.88 (0.81 to 0.95)	0.001
Adjusted for geographical regions		
All areas	0.95 (0.90 to 1.01)	0.10
Areas with ≥20 events	0.96 (0.90 to 1.01)	0.13
High income countries	0.95 (0.89 to 1.02)	0.13
Adjusted for prespecified covariates		
All areas	0.94 (0.89 to 1.00)	0.048
Areas with ≥20 events	0.94 (0.89 to 1.00)	0.068
High income countries	0.94 (0.87 to 1.01)	0.087
Adjusted for geographical regions and prespecified covariates		
All areas	0.95 (0.90 to 1.01)	0.13
Areas with ≥20 events	0.96 (0.90 to 1.02)	0.19
High income countries	0.95 (0.89 to 1.03)	0.22
Adjusted for geographical regions, prespecified covariates and public health interventions		
All areas	0.95 (0.89 to 1.01)	0.075
Areas with ≥20 events	0.95 (0.90 to 1.01)	0.12
High income countries	0.96 (0.90 to 1.03)	0.28

Epidemic growth quantified by the rate ratio comparing the cumulative rate on March 27 with the cumulative rate on March 20, 2020; Ratio of rate ratios expressed per 10% increase in relative humidity; CI, confidence interval; p values are 2-sided. 132 geopolitical areas were included in the analysis of areas with ≥20 events, and 98 areas were included in the analysis restricted to high income countries.

Table S8. Association of epidemic growth with restrictions of mass gatherings

Restrictions of mass gatherings	Ratio of Rate ratios (95% CI)	P value
No adjustment		
All areas	0.65 (0.53 to 0.79)	<0.001
Areas with ≥20 events	0.63 (0.51 to 0.79)	<0.001
High income countries	0.56 (0.44 to 0.72)	<0.001
Adjusted for geographical regions		
All areas	0.81 (0.67 to 0.98)	0.030
Areas with ≥20 events	0.81 (0.67 to 0.98)	0.031
High income countries	0.78 (0.63 to 0.96)	0.017
Adjusted for prespecified covariates		
All areas	0.81 (0.66 to 0.99)	0.038
Areas with ≥20 events	0.80 (0.65 to 0.98)	0.032
High income countries	0.69 (0.55 to 0.87)	0.002
Adjusted for geographical regions and prespecified covariates		
All areas	0.84 (0.69 to 1.02)	0.087
Areas with ≥20 events	0.83 (0.68 to 1.02)	0.073
High income countries	0.72 (0.58 to 0.91)	0.005
Adjusted for geographical regions, prespecified covariates, temperature and humidity		
All areas	0.83 (0.68 to 1.01)	0.063
Areas with ≥20 events	0.82 (0.67 to 1.00)	0.055
High income countries	0.72 (0.57 to 0.90)	0.004

Epidemic growth quantified by the rate ratio comparing the cumulative rate on March 27 with the cumulative rate on March 20, 2020; CI, confidence interval; p values are 2-sided. 132 geopolitical areas were included in the analysis of areas with ≥20 events, and 98 areas were included in the analysis restricted to high income countries.

Table S9. Association of epidemic growth with school closures

School closures	Ratio of rate ratios (95% CI)	P value
No adjustment		
All areas	0.63 (0.52 to 0.78)	<0.001
Areas with ≥20 events	0.63 (0.51 to 0.78)	<0.001
High income countries	0.58 (0.45 to 0.75)	<0.001
Adjusted for geographical regions		
All areas	0.81 (0.67 to 0.99)	0.038
Areas with ≥20 events	0.81 (0.66 to 1.00)	0.045
High income countries	0.81 (0.64 to 1.03)	0.089
Adjusted for prespecified covariates		
All areas	0.80 (0.66 to 0.98)	0.027
Areas with ≥20 events	0.80 (0.66 to 0.98)	0.033
High income countries	0.73 (0.58 to 0.93)	0.012
Adjusted for geographical regions and prespecified covariates		
All areas	0.80 (0.66 to 0.97)	0.026
Areas with ≥20 events	0.78 (0.63 to 0.96)	0.017
High income countries	0.74 (0.58 to 0.95)	0.017
Adjusted for geographical regions, prespecified covariates, temperature and humidity		
All areas	0.77 (0.63 to 0.93)	0.009
Areas with ≥20 events	0.74 (0.60 to 0.92)	0.005
High income countries	0.72 (0.56 to 0.92)	0.009

Epidemic growth quantified by the rate ratio comparing the cumulative rate on March 27 with the cumulative rate on March 20, 2020; CI, confidence interval; p values are 2-sided. 132 geopolitical areas were included in the analysis of areas with ≥20 events, and 98 areas were included in the analysis restricted to high income countries.

Table S10. Association of epidemic growth with measures of social distancing

Social distancing	Ratio of rate ratios (95% CI)	P value
No adjustment		
All areas	0.62 (0.45 to 0.85)	0.003
Areas with ≥20 events	0.59 (0.42 to 0.81)	0.001
High income countries	0.47 (0.31 to 0.72)	0.001
Adjusted for geographical regions		
All areas	0.82 (0.62 to 1.07)	0.15
Areas with ≥20 events	0.81 (0.61 to 1.07)	0.14
High income countries	0.73 (0.52 to 1.03)	0.073
Adjusted for prespecified covariates		
All areas	0.86 (0.65 to 1.15)	0.31
Areas with ≥20 events	0.84 (0.63 to 1.13)	0.26
High income countries	0.74 (0.52 to 1.05)	0.096
Adjusted for geographical regions and prespecified covariates		
All areas	0.90 (0.68 to 1.19)	0.46
Areas with ≥20 events	0.88 (0.66 to 1.17)	0.37
High income countries	0.79 (0.56 to 1.13)	0.20
Adjusted for geographical regions, prespecified covariates, temperature and humidity		
All areas	0.88 (0.67 to 1.16)	0.37
Areas with ≥20 events	0.86 (0.65 to 1.15)	0.31
High income countries	0.81 (0.57 to 1.16)	0.25

Epidemic growth quantified by the rate ratio comparing the cumulative rate on March 27 with the cumulative rate on March 20, 2020; CI, confidence interval; p values are 2-sided. 132 geopolitical areas were included in the analysis of areas with ≥20 events, and 98 areas were included in the analysis restricted to high income countries.

Table S11. Association of epidemic growth with composite of any public health intervention

Any public health intervention	Ratio of rate ratios (95% CI)	P value
No adjustment		
All areas	0.62 (0.53 to 0.73)	<0.001
Areas with ≥20 events	0.62 (0.52 to 0.73)	<0.001
High income countries	0.56 (0.46 to 0.68)	<0.001
Adjusted for geographical regions		
All areas	0.79 (0.67 to 0.93)	0.006
Areas with ≥20 events	0.79 (0.66 to 0.93)	0.006
High income countries	0.78 (0.64 to 0.96)	0.016
Adjusted for prespecified covariates		
All areas	0.79 (0.66 to 0.93)	0.005
Areas with ≥20 events	0.78 (0.66 to 0.93)	0.006
High income countries	0.73 (0.60 to 0.88)	0.001
Adjusted for geographical regions and prespecified covariates		
All areas	0.82 (0.69 to 0.97)	0.022
Areas with ≥20 events	0.81 (0.68 to 0.97)	0.019
High income countries	0.77 (0.63 to 0.94)	0.010
Adjusted for geographical regions, prespecified covariates, temperature and humidity		
All areas	0.80 (0.68 to 0.95)	0.011
Areas with ≥20 events	0.79 (0.67 to 0.95)	0.010
High income countries	0.77 (0.63 to 0.94)	0.010

Epidemic growth quantified by the rate ratio comparing the cumulative rate on March 27 with the cumulative rate on March 20, 2020; CI, confidence interval; p values are 2-sided. 132 geopolitical areas were included in the analysis of areas with ≥20 events, and 98 areas were included in the analysis restricted to high income countries.

Table S12. Association of epidemic growth with number of public health interventions

Number of interventions implemented	1 intervention	2 or 3 interventions	P value
	RRR (95% CI)	RRR (95% CI)	
No adjustment			
All areas	0.67 (0.55 to 0.82)	0.54 (0.42 to 0.70)	<0.001
Areas with ≥20 events	0.67 (0.55 to 0.82)	0.52 (0.40 to 0.68)	<0.001
High income countries	0.63 (0.51 to 0.78)	0.41 (0.29 to 0.57)	<0.001
Adjusted for geographical regions			
All areas	0.82 (0.68 to 0.99)	0.73 (0.57 to 0.93)	0.004
Areas with ≥20 events	0.82 (0.68 to 0.99)	0.72 (0.56 to 0.93)	0.004
High income countries	0.83 (0.68 to 1.02)	0.62 (0.45 to 0.85)	0.002
Adjusted for prespecified covariates			
All areas	0.82 (0.68 to 0.99)	0.72 (0.56 to 0.93)	0.016
Areas with ≥20 events	0.82 (0.67 to 1.00)	0.71 (0.54 to 0.92)	0.016
High income countries	0.79 (0.65 to 0.95)	0.51 (0.37 to 0.70)	0.001
Adjusted for geographical regions and prespecified covariates			
All areas	0.86 (0.71 to 1.05)	0.74 (0.57 to 0.95)	0.042
Areas with ≥20 events	0.86 (0.71 to 1.04)	0.71 (0.55 to 0.93)	0.030
High income countries	0.83 (0.68 to 1.02)	0.52 (0.37 to 0.73)	0.001
Adjusted for geographical regions, prespecified covariates, temperature and humidity			
All areas	0.85 (0.70 to 1.03)	0.72 (0.56 to 0.92)	0.021
Areas with ≥20 events	0.84 (0.70 to 1.03)	0.69 (0.53 to 0.90)	0.015
High income countries	0.83 (0.68 to 1.02)	0.52 (0.37 to 0.72)	0.001

Epidemic growth quantified by the rate ratio comparing the cumulative rate on March 27 with the cumulative rate on March 20, 2020; RRR, Ratio of rate ratios; CI, confidence interval; p values for trend are 2-sided. 132 geopolitical areas were included in the analysis of areas with ≥20 events, and 98 areas were included in the analysis restricted to high income countries.

Table S13. Post-hoc use of alternative outcome definition to measure epidemic growth: univariate analyses

Variable	Ratio of Rate ratios (95% CI)	P value
Latitude (per 400 degrees^2)	0.97 (0.89 to 1.07)	0.57
Temperature (per 5°C)	0.94 (0.83 to 1.06)	0.32
Relative humidity (per 10%)	0.79 (0.66 to 0.94)	0.007
Absolute humidity (per 5g/m^3)	0.82 (0.67 to 1.02)	0.070
Altitude (per 100m)	1.04 (1.00 to 1.09)	0.07
Passenger flights (per 1 passenger/inhabitant/year)	0.97 (0.91 to 1.03)	0.29
Urban density (per 5000 inhabitants/km^2)	1.07 (0.87 to 1.31)	0.52
Percentage of inhabitants aged 65 or above (per 5%)	1.10 (0.90 to 1.34)	0.34
Life expectancy at birth (per 5 years)	0.88 (0.69 to 1.13)	0.31
GDP (per 20'000 USD/inhabitant)	1.09 (0.94 to 1.27)	0.25
Health expenditure as percentage of GDP (per 5%)	1.74 (1.39 to 2.19)	<0.001
Infectious Disease Vulnerability Index (per 0.1)	1.11 (0.98 to 1.25)	0.010
Any public health intervention	0.26 (0.17 to 0.41)	<0.001
Restrictions of mass gatherings	0.28 (0.16 to 0.48)	<0.001
School closures	0.28 (0.16 to 0.49)	<0.001
Social distancing	0.22 (0.10 to 0.49)	0.0002
Number of public health interventions		<0.001
1 intervention	0.34 (0.20 to 0.56)	
2 or 3 interventions	0.17 (0.09 to 0.33)	
Global region		<0.001
Oceania	3.28 (1.15 to 9.37)	
Europe	1.13 (0.64 to 2.01)	
Africa	3.19 (1.28 to 7.94)	
Americas	4.04 (2.40 to 6.82)	
Closest distance to established epidemic (per 1000 km)	1.18 (1.11 to 1.25)	<0.001

Post-hoc use of different outcome definition to measure epidemic growth: univariate models. See supplementary methods for a description of the alternative outcome definition.

Table S14. Post-hoc use of alternative outcome definition to measure epidemic growth: multivariable analysis

Variable	Ratio of Rate ratios (95% CI)	P value
Absolute humidity (per 5g/m^3)	0.79 (0.62 to 1.03)	0.080
Urban density (per 5000 inhabitants/km^2)	1.27 (1.04 to 1.56)	0.019
GDP (per 20'000 USD/inhabitant)	0.89 (0.76 to 1.04)	0.13
Health expenditure as percentage of GDP (per 5%)	1.32 (0.92 to 1.88)	0.13
Number of public health interventions		0.001
1 intervention	0.51 (0.29 to 0.87)	
2 or 3 interventions	0.26 (0.13 to 0.52)	
Global region		0.62
Oceania	2.12 (0.38 to 11.98)	
Europe	0.76 (0.39 to 1.48)	
Africa	1.35 (0.51 to 3.57)	
Americas	1.90 (0.35 to 10.14)	
Closest distance to established epidemic (per 1000 km)	0.99 (0.81 to 1.20)	0.92

Post-hoc use of different outcome definition to measure epidemic growth: results from parsimonious multivariable model. See supplementary methods for a description of the alternative outcome definition.

Table S15. Bias domains for association of epidemic growth with square of the latitude

Domain (square of the latitude)	Judgement	Explanation
Bias due to confounding	Low	• Association between epidemic growth and square of the latitude unconfounded *a priori*. Latitude at start of directed acyclic graph, driving climate variables. • Major geographical regions included as covariate in multivariable models to address residual confounding due to geographic progression of the pandemic from continent to continent over time, which could be correlated with exposure. • Estimates of association robust in different multivariable models and analysis sets with little or no evidence against the null hypothesis.
Bias in selection of participants into the study	Low	• Prespecified eligibility criteria. • All eligible geopolitical areas included.
Bias in classification of exposure	Low	• Measured using coordinates of capital of geopolitical areas (states for United States and Australia, provinces for Canada, overseas territories, and countries for the rest of the world). Capital region typically among most populous regions of geopolitical area, measured exposure representative for a substantial proportion of population. • No transformation required since analyzed close to vernal equinox, when sun at equator and climate comparable by latitude in northern and southern hemispheres. • Non-differential misclassification likely for a small number of large countries such as Brazil, which would bias association slightly towards the null.
Bias due to deviations from exposure	Low	• No deviations possible.
Bias due to missing data	Low	• No missing data.
Bias in measurement of outcome	Low	• Rate ratio derived from cumulative incidences of confirmed COVID-19 cases at beginning and end of a one-week follow-up period. • Accounting for variation in testing strategies between geopolitical areas, as each area serves as its own reference when deriving rate ratios • Smoothing out estimates by averaging out the daily highs and lows over a longer period, decreasing the risk of non-differential misclassification.
Bias in selection of the reported result	Low	• All analyses pre-specified in the protocol reported. • Post-hoc analyses clearly specified. as such.
Overall	Low	• All domains judged to be at low risk of bias

Summary of risk of bias for non-randomized studies of exposures or interventions.[1,2]

Table S16. Bias domains for association of epidemic growth with temperature

Domain (temperature)	Judgement	Explanation
Bias due to confounding	Low	• Major geographical regions included as covariate in multivariable models to address residual confounding due to geographic progression of the pandemic from continent to continent over time, which could be correlated with exposure. • Estimates of association robust in different multivariable models and analysis sets with little or no evidence against the null hypothesis.
Bias in selection of participants into the study	Low	• Prespecified eligibility criteria. • All eligible geopolitical areas included.
Bias in classification of exposure	Low	• Exposure assessed for capital of geopolitical areas (states for United States and Australia, provinces for Canada, overseas territories, and countries for the rest of the world). Capital region typically among most populous regions of geopolitical area, measured exposure representative for a substantial proportion of population. • Temperature less variable within geopolitical area than absolute and relative humidity. • Non-differential misclassification likely for a small number of large countries such as Brazil given the spatial variation in exposure, which would bias association slightly towards the null.
Bias due to deviations from exposure	Low	• No deviations possible.
Bias due to missing data	Low	• No missing data.
Bias in measurement of outcome	Low	• Rate ratio derived from cumulative incidences of confirmed COVID-19 cases at beginning and end of a one-week follow-up period. • Accounting for variation in testing strategies between geopolitical areas, as each area serves as its own reference when deriving rate ratios • Smoothing out estimates by averaging out the daily highs and lows over a longer period, decreasing the risk of non-differential misclassification.
Bias in selection of the reported result	Low	• All analyses pre-specified in the protocol reported. Post-hoc analyses clearly specified.
Overall	Low	• All domains judged to be at low risk of bias

Summary of risk of bias for non-randomized studies of exposures or interventions.[1,2]

Table S17. Bias domains for association of epidemic growth with relative humidity

Domain (relative humidity)	Judgement	Explanation
Bias due to confounding	Moderate	• Major geographical regions included as covariate in multivariable models to address residual confounding due to geographic progression of the pandemic from continent to continent over time, which could be correlated with exposure. • Estimates of association vary in different multivariable models and analysis sets, with changing extent of evidence against the null hypothesis.
Bias in selection of participants into the study	Low	• Prespecified eligibility criteria. • All eligible geopolitical areas included.
Bias in classification of exposure	Moderate	• Exposure assessed for capital of geopolitical areas (states for United States and Australia, provinces for Canada, overseas territories, and countries for the rest of the world). Capital region typically among most populous regions of geopolitical area, measured exposure representative for a substantial proportion of population. • Relative humidity considerably more variable within geopolitical area than absolute humidity and temperature. • Non-differential misclassification likely given the spatial and temporal variation in exposure, which would bias association towards the null.
Bias due to deviations from exposure	Low	• No deviations possible.
Bias due to missing data	Low	• No missing data.
Bias in measurement of outcome	Low	• Rate ratio derived from cumulative incidences of confirmed COVID-19 cases at beginning and end of a one-week follow-up period. • Accounting for variation in testing strategies between geopolitical areas, as each area serves as its own reference when deriving rate ratios • Smoothing out estimates by averaging out the daily highs and lows over a longer period, decreasing the risk of non-differential misclassification.
Bias in selection of the reported result	Low	• All analyses pre-specified in the protocol reported. Post-hoc analyses clearly specified.
Overall	Moderate	• Moderate risk of bias due to confounding (either direction) and non-differential misclassification (bias towards the null).

Summary of risk of bias for non-randomized studies of exposures or interventions.[1,2]

Table S18. Bias domains for association of epidemic growth with absolute humidity

Domain (absolute humidity)	Judgement	Explanation
Bias due to confounding	Moderate	• Major geographical regions included as covariate in multivariable models to address residual confounding due to geographic progression of the pandemic from continent to continent over time, which could be correlated with exposure. • Estimates of association vary somewhat in different multivariable models and analysis sets, with changing extent of evidence against the null hypothesis.
Bias in selection of participants into the study	Low	• Prespecified eligibility criteria. • All eligible geopolitical areas included.
Bias in classification of exposure	Moderate	• Exposure assessed for capital of geopolitical areas (states for United States and Australia, provinces for Canada, overseas territories, and countries for the rest of the world). Capital region typically among most populous regions of geopolitical area, measured exposure representative for a substantial proportion of population. • Absolute humidity more variable than temperature within geopolitical area, but considerably less variable than relative humidity. • Non-differential misclassification likely for a small number of large countries such as Brazil and for a small number of countries with highly variable climates given the spatial variation in exposure and proximity to large bodies of water, which would bias association towards the null.
Bias due to deviations from exposure	Low	• No deviations possible.
Bias due to missing data	Low	• No missing data.
Bias in measurement of outcome	Low	• Rate ratio derived from cumulative incidences of confirmed COVID-19 cases at beginning and end of a one-week follow-up period. • Accounting for variation in testing strategies between geopolitical areas, as each area serves as its own reference when deriving rate ratios • Smoothing out estimates by averaging out the daily highs and lows over a longer period, decreasing the risk of non-differential misclassification.
Bias in selection of the reported result	Low	• All analyses pre-specified in the protocol reported. Post-hoc analyses clearly specified.
Overall	Moderate	• Moderate risk of bias due to confounding (either direction) and non-differential misclassification (bias towards the null).

Summary of risk of bias for non-randomized studies of exposures or interventions.[1,2]

Table S19. Bias domains for association of epidemic growth with composite of any public health intervention

Domain (any public health intervention)	Judgement	Explanation
Bias due to confounding	Low	• Major geographical regions included as covariate in multivariable models to address residual confounding due to geographic progression of the pandemic from continent to continent over time, which could be correlated with exposure. • Implementation of public health interventions may have been temporarily associated with an increase in testing activities during the follow-up period. This likely has happened only in a small number of geopolitical areas as availability of tests was limited globally during our study period and would have biased estimates slightly towards the null. • Estimates of association decreased in different multivariable models, but strong evidence against the null hypothesis remained.
Bias in selection of participants into the study	Low	• Prespecified eligibility criteria. • All eligible geopolitical areas included.
Bias in classification of intervention	Low	• Assessed at level of geopolitical area (states for United States and Australia, provinces for Canada, overseas territories, and countries for the rest of the world). • Representative for the analyzed geopolitical area.
Bias due to deviations from intervention	Low	• Deviations from interventions could not be assessed across geopolitical areas; likely that adherence was high for school closures. • Deviations would bias estimates towards the null.
Bias due to missing data	Low	• No missing data.
Bias in measurement of outcome	Low	• Rate ratio derived from cumulative incidences of confirmed COVID-19 cases at beginning and end of a one-week follow-up period. • Accounting for variation in testing strategies between geopolitical areas, as each area serves as its own reference when deriving rate ratios • Smoothing out estimates by averaging out the daily highs and lows over a longer period, decreasing the risk of non-differential misclassification.
Bias in selection of the reported result	Low	• All analyses pre-specified in the protocol reported. Post-hoc analyses clearly specified.
Overall	Low	• All domains judged to be at low risk of bias

Summary of risk of bias for non-randomized studies of exposures or interventions.[1,2]

Table S20. Bias domains for association of epidemic growth with restriction of mass gatherings

Domain (restriction of mass gatherings)	Judgement	Explanation
Bias due to confounding	Moderate	• Major geographical regions included as covariate in multivariable models to address residual confounding due to geographic progression of the pandemic from continent to continent over time, which could be correlated with exposure. • Implementation of public health interventions may have been temporarily associated with an increase in testing activities during the follow-up period. This likely has happened only in a small number of geopolitical areas as availability of tests was limited globally during our study period and would have biased estimates slightly towards the null. • Temporal clustering of implementation of public health interventions with a relatively low number of geopolitical areas with implementation before or during exposure period. Inability to determine the association of epidemic growth with restriction of mass gatherings independent of the remaining 2 public health interventions. • Estimates of association decreased in different multivariable models, but strong evidence against the null hypothesis remained.
Bias in selection of participants into the study	Low	• Prespecified eligibility criteria. • All eligible geopolitical areas included.
Bias in classification of intervention	Low	• Assessed at level of geopolitical area (states for United States and Australia, provinces for Canada, overseas territories, and countries for the rest of the world). • Representative for the analyzed geopolitical area.
Bias due to deviations from intervention	Low	• Deviations from interventions could not be assessed across geopolitical areas. • Deviations would bias estimates towards the null.
Bias due to missing data	Low	• No missing data.
Bias in measurement of outcome	Low	• Rate ratio derived from cumulative incidences of confirmed COVID-19 cases at beginning and end of a one-week follow-up period. • Accounting for variation in testing strategies between geopolitical areas, as each area serves as its own reference when deriving rate ratios • Smoothing out estimates by averaging out the daily highs and lows over a longer period, decreasing the risk of non-differential misclassification.
Bias in selection of the reported result	Low	• All analyses pre-specified in the protocol reported. Post-hoc analyses clearly specified.

Overall	Moderate	• Moderate risk of bias due to confounding with other public health interventions (more likely away from the null).

Summary of risk of bias for non-randomized studies of exposures or interventions.[1,2]

Table S21. Bias domains for association of epidemic growth with social distancing

Domain (social distancing)	Judgement	Explanation
Bias due to confounding	Moderate	• Major geographical regions included as covariate in multivariable models to address residual confounding due to geographic progression of the pandemic from continent to continent over time, which could be correlated with exposure. • Implementation of public health interventions may have been temporarily associated with an increase in testing activities during the follow-up period. This likely has happened only in a small number of geopolitical areas as availability of tests was limited globally during our study period and would have biased estimates slightly towards the null. • Temporal clustering of implementation of public health interventions with a relatively low number of geopolitical areas with implementation before or during exposure period. Inability to determine the association of epidemic growth with social distancing independent of the remaining 2 public health interventions. • Estimates of association decreased in different multivariable models, with changing extent of evidence against the null hypothesis.
Bias in selection of participants into the study	Low	• Prespecified eligibility criteria. • All eligible geopolitical areas included.
Bias in classification of intervention	Low	• Assessed at level of geopolitical area (states for United States and Australia, provinces for Canada, overseas territories, and countries for the rest of the world). • Representative for the analyzed geopolitical area.
Bias due to deviations from intervention	Low	• Deviations from interventions could not be assessed across geopolitical areas. • Deviations would bias estimates towards the null.
Bias due to missing data	Low	• No missing data.
Bias in measurement of outcome	Low	• Rate ratio derived from cumulative incidences of confirmed COVID-19 cases at beginning and end of a one-week follow-up period. • Accounting for variation in testing strategies between geopolitical areas, as each area serves as its own reference when deriving rate ratios • Smoothing out estimates by averaging out the daily highs and lows over a longer period, decreasing the risk of non-differential misclassification.
Bias in selection of the reported result	Low	• All analyses pre-specified in the protocol reported. Post-hoc analyses clearly specified.

Overall	Moderate	• Moderate risk of bias due to confounding with other public health interventions (more likely away from the null).

Summary of risk of bias for non-randomized studies of exposures or interventions.[1,2]

Table S22. Bias domains for association of epidemic growth with school closures

Domain (social distancing)	Judgement	Explanation
Bias due to confounding	Moderate	• Major geographical regions included as covariate in multivariable models to address residual confounding due to geographic progression of the pandemic from continent to continent over time, which could be correlated with exposure. • Implementation of public health interventions may have been temporarily associated with an increase in testing activities during the follow-up period. This likely has happened only in a small number of geopolitical areas as availability of tests was limited globally during our study period and would have biased estimates slightly towards the null. • Temporal clustering of implementation of public health interventions with a relatively low number of geopolitical areas with implementation before or during exposure period. Inability to determine the association of epidemic growth with school closures independent of the remaining 2 public health interventions. • Estimates of association decreased in different multivariable models, but strong evidence against the null hypothesis remained.
Bias in selection of participants into the study	Low	• Prespecified eligibility criteria. • All eligible geopolitical areas included.
Bias in classification of intervention	Low	• Assessed at level of geopolitical area (states for United States and Australia, provinces for Canada, overseas territories, and countries for the rest of the world). • Representative for the analyzed geopolitical area.
Bias due to deviations from intervention	Low	• Deviations from interventions could not be assessed across geopolitical areas. • Deviations would bias estimates towards the null.
Bias due to missing data	Low	• No missing data.
Bias in measurement of outcome	Low	• Rate ratio derived from cumulative incidences of confirmed COVID-19 cases at beginning and end of a one-week follow-up period. • Accounting for variation in testing strategies between geopolitical areas, as each area serves as its own reference when deriving rate ratios • Smoothing out estimates by averaging out the daily highs and lows over a longer period, decreasing the risk of non-differential misclassification.
Bias in selection of the reported result	Low	• All analyses pre-specified in the protocol reported. Post-hoc analyses clearly specified.

Overall	Moderate	• Moderate risk of bias due to confounding with other public health interventions (more likely away from the null).

Summary of risk of bias for non-randomized studies of exposures or interventions.[1,2]

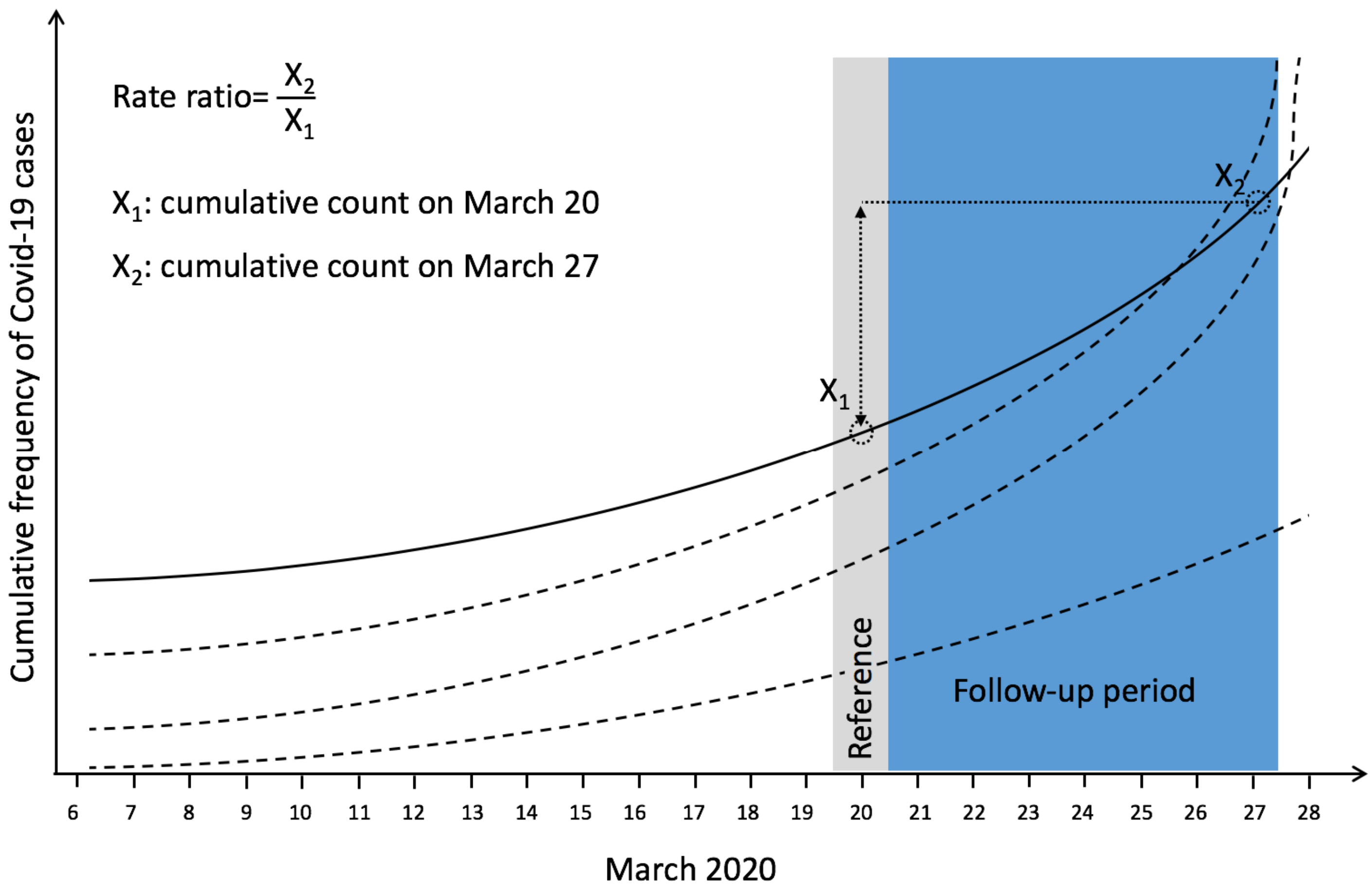
Table S23. Bias domains for association of epidemic growth with number of implemented public health interventions

Domain (social distancing)	Judgement	Explanation
Bias due to confounding	Low	• Major geographical regions included as covariate in multivariable models to address residual confounding due to geographic progression of the pandemic from continent to continent over time, which could be correlated with exposure. • Implementation of public health interventions may have been temporarily associated with an increase in testing activities during the follow-up period. This likely has happened only in a small number of geopolitical areas as availability of tests was limited globally during our study period and would have biased estimates slightly towards the null. • Estimates of association decreased in different multivariable models, but strong evidence against the null hypothesis remained. • Clear linear trend in log rate ratio in multivariable models.
Bias in selection of participants into the study	Low	• Prespecified eligibility criteria. • All eligible geopolitical areas included.
Bias in classification of intervention	Low	• Assessed at level of geopolitical area (states for United States and Australia, provinces for Canada, overseas territories, and countries for the rest of the world). • Representative for the analyzed geopolitical area.
Bias due to deviations from intervention	Low	• Deviations from interventions could not be assessed across geopolitical areas. • Deviations would bias estimates towards the null.
Bias due to missing data	Low	• No missing data.
Bias in measurement of outcome	Low	• Rate ratio derived from cumulative incidences of confirmed COVID-19 cases at beginning and end of a one-week follow-up period. • Accounting for variation in testing strategies between geopolitical areas, as each area serves as its own reference when deriving rate ratios • Smoothing out estimates by averaging out the daily highs and lows over a longer period, decreasing the risk of non-differential misclassification.
Bias in selection of the reported result	Low	• All analyses pre-specified in the protocol reported. Post-hoc analyses clearly specified.
Overall	Low	• All domains judged to be at low risk of bias

Summary of risk of bias for non-randomized studies of exposures or interventions.[1,2]

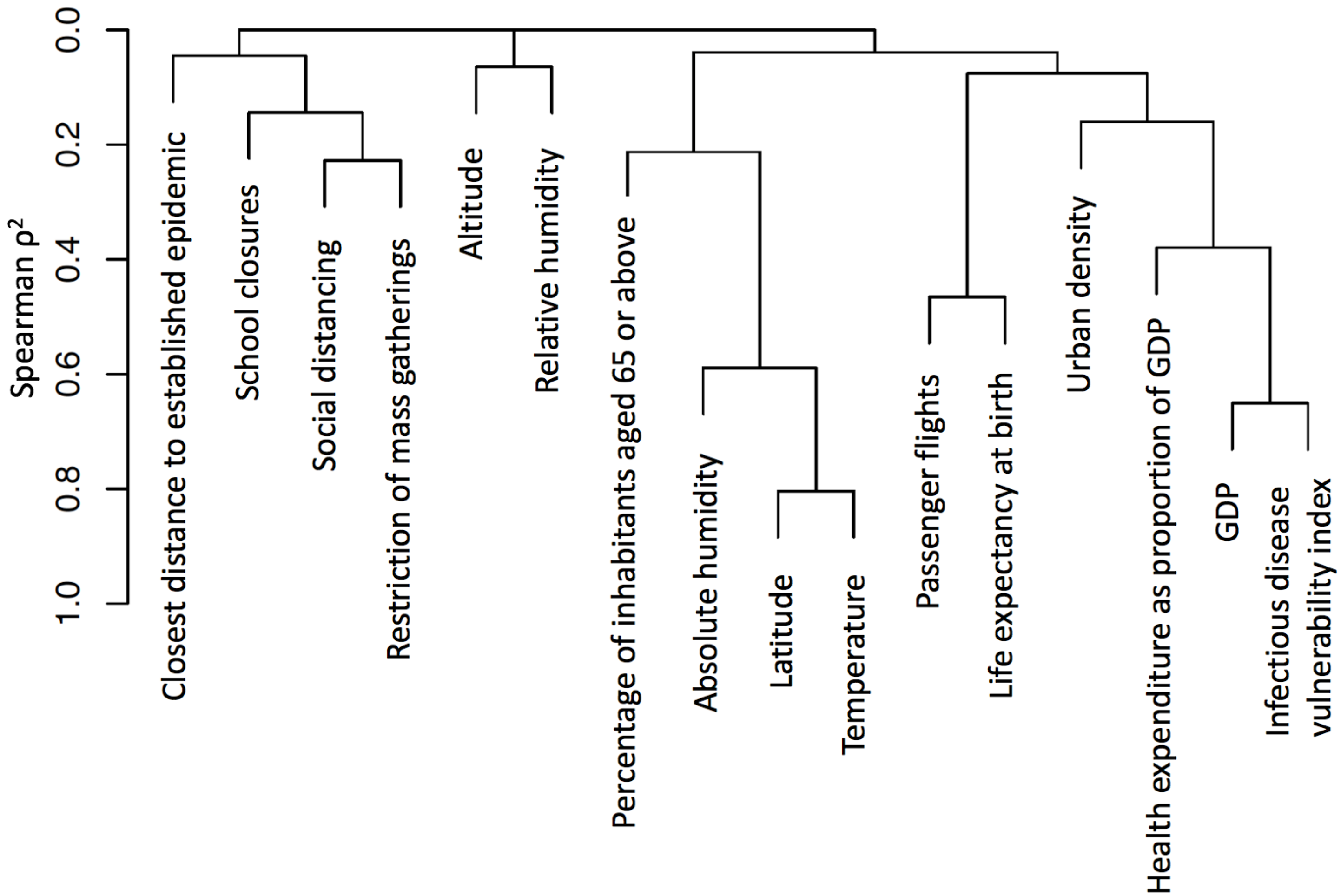
III. Supplementary Figures

Figure S1. Calculation of rate ratios



Calculation of rate ratios. Curves are cumulative frequency curves. Rate ratio calculated as the cumulative count of confirmed cases since the beginning of the epidemic as of March 27 divided by the cumulative count of confirmed cases since the beginning of the epidemic as of March 20. A rate ratio of 2 indicates, for example, that the count of confirmed cases in a geopolitical area has doubled within one week.

Figure S2. Cluster analysis



Cluster analysis based on Spearman's ρ^2.

Figure S3. Flowchart

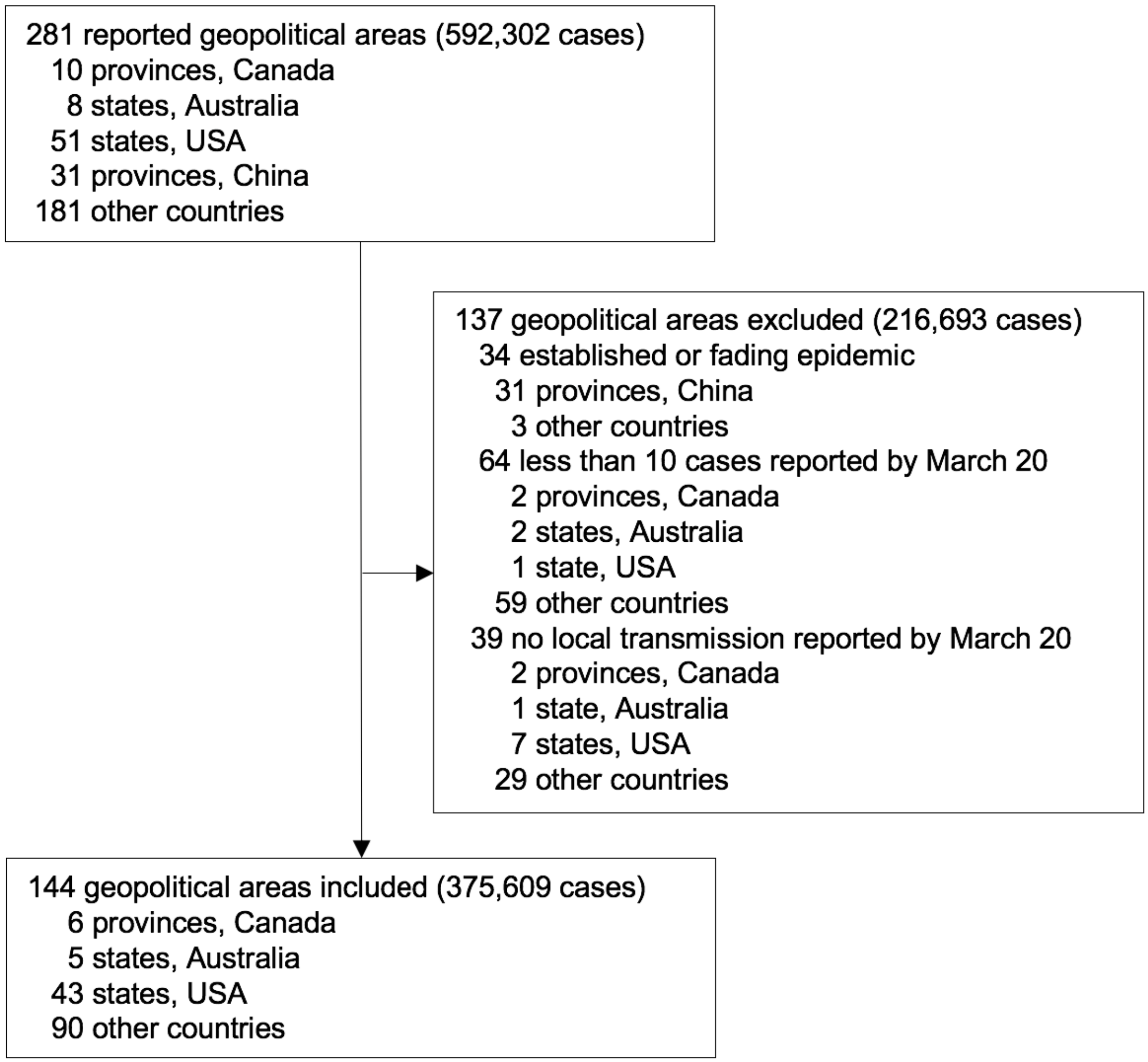
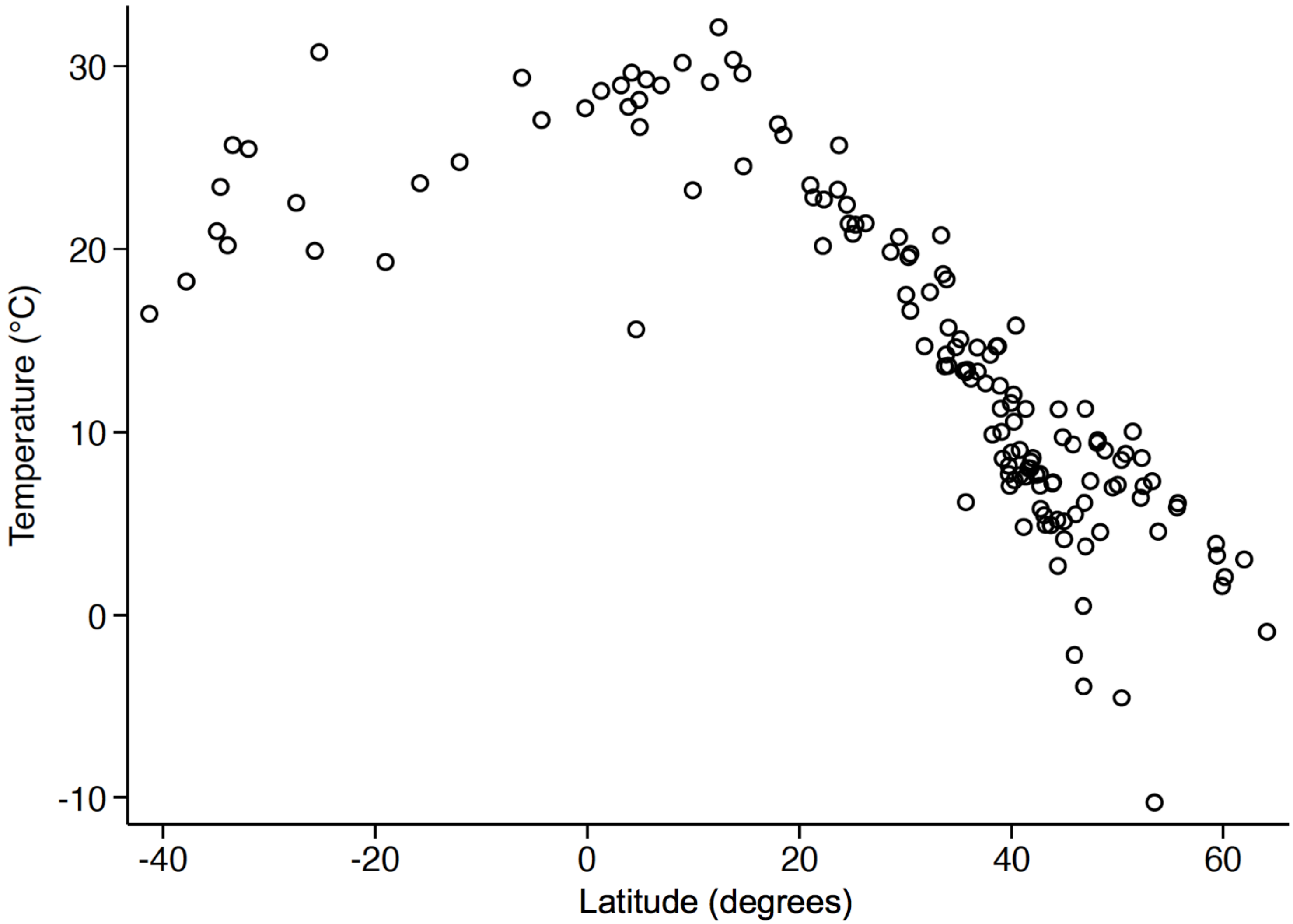
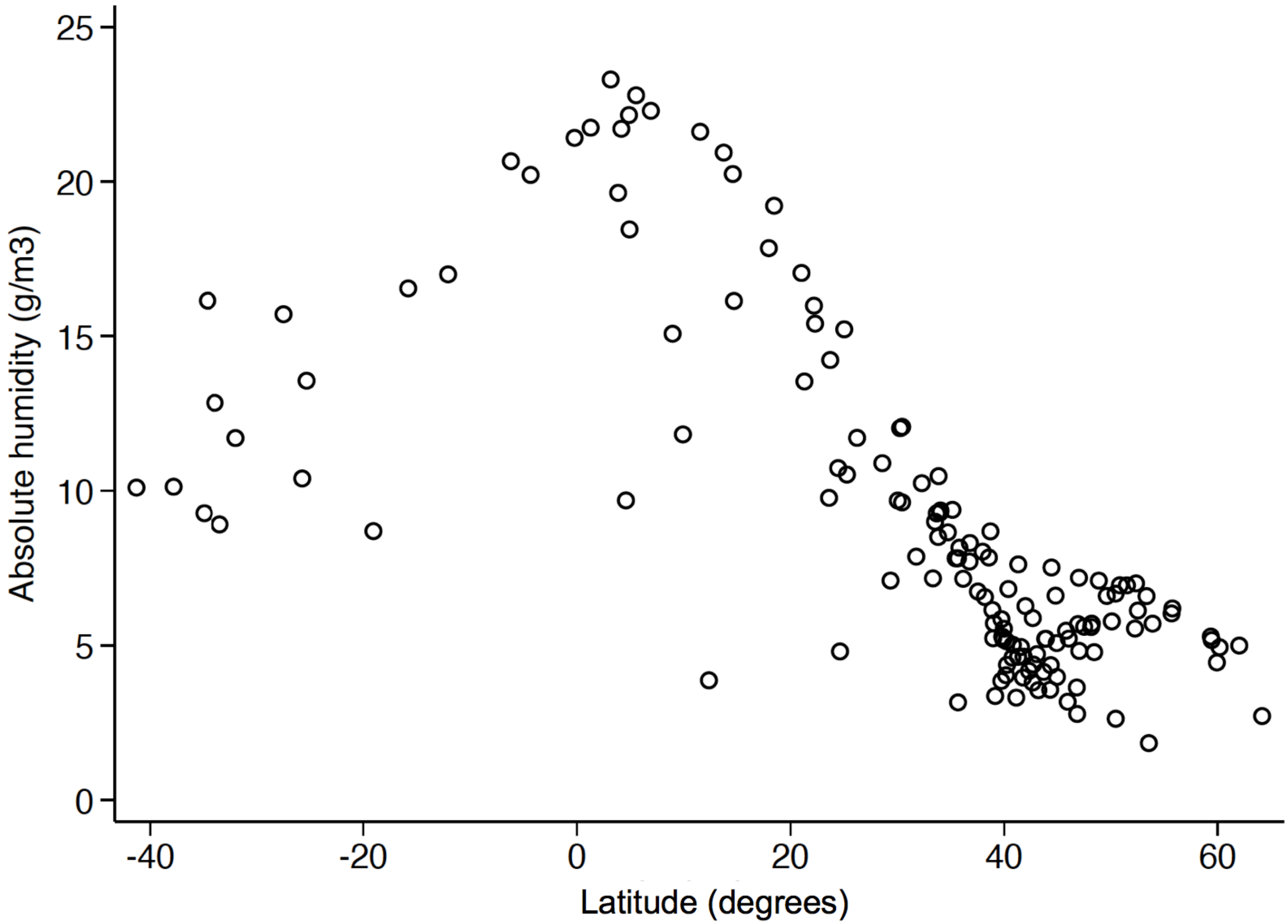


Figure S4. Scatter plot of temperature against latitude



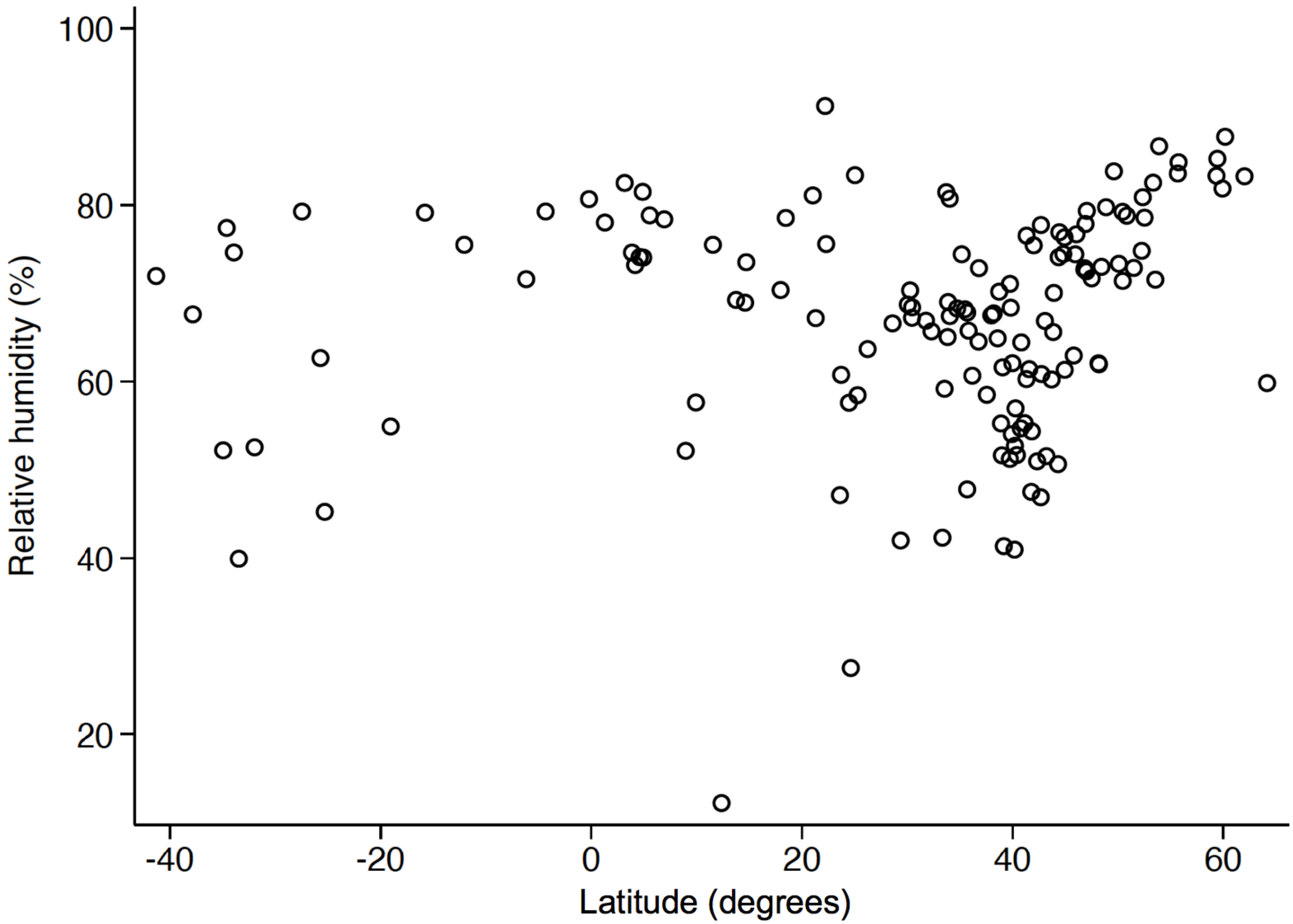
Scatter plot of temperature against latitude for 144 geopolitical areas. As latitude moves further away from the equator temperature decreases.

Figure S5. Scatter plot of absolute humidity against latitude



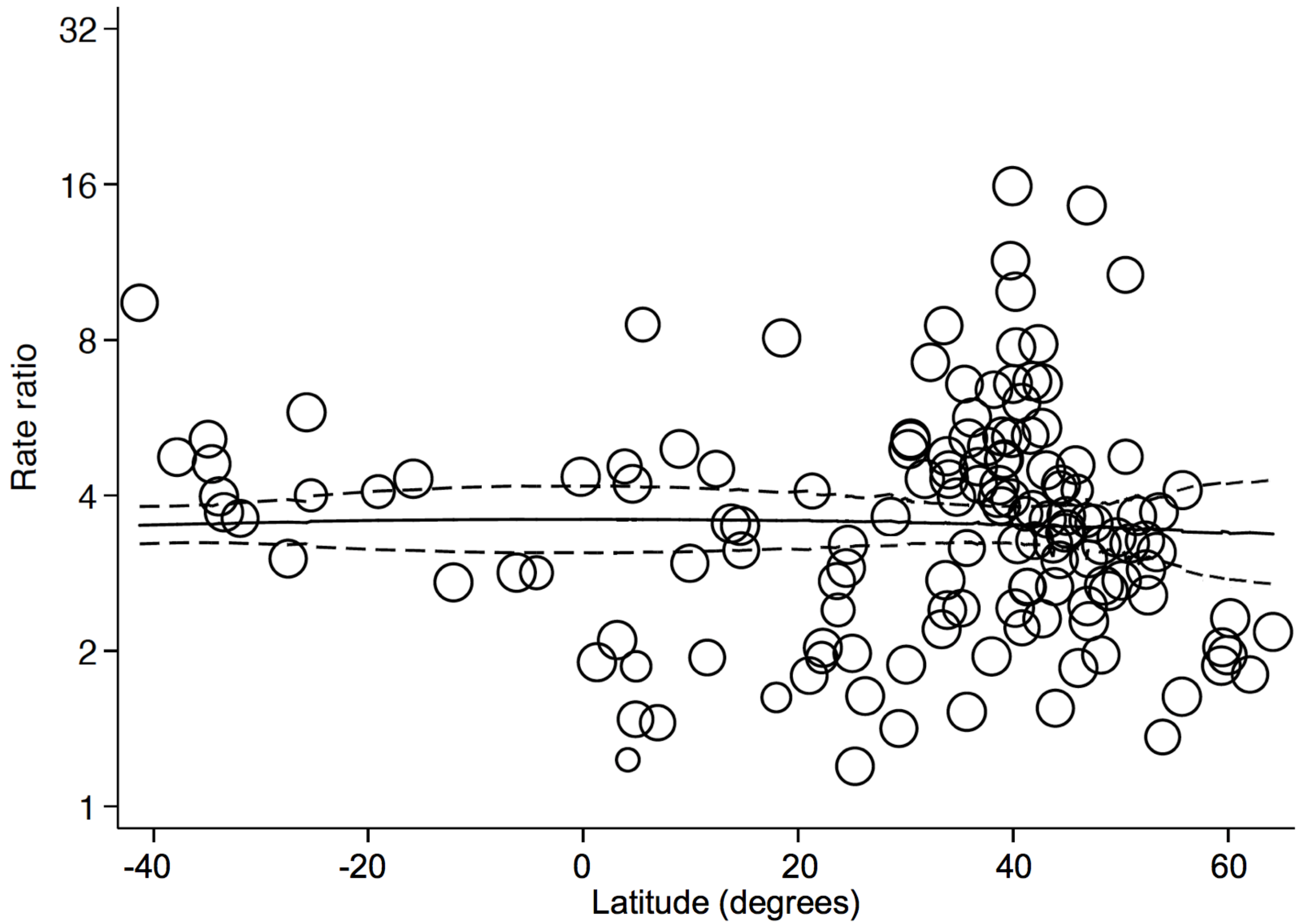
Scatter plot of absolute humidity against latitude for 144 geopolitical areas. As latitude moves further away from the equator absolute humidity decreases.

Figure S6. Scatter plot of relative humidity against latitude



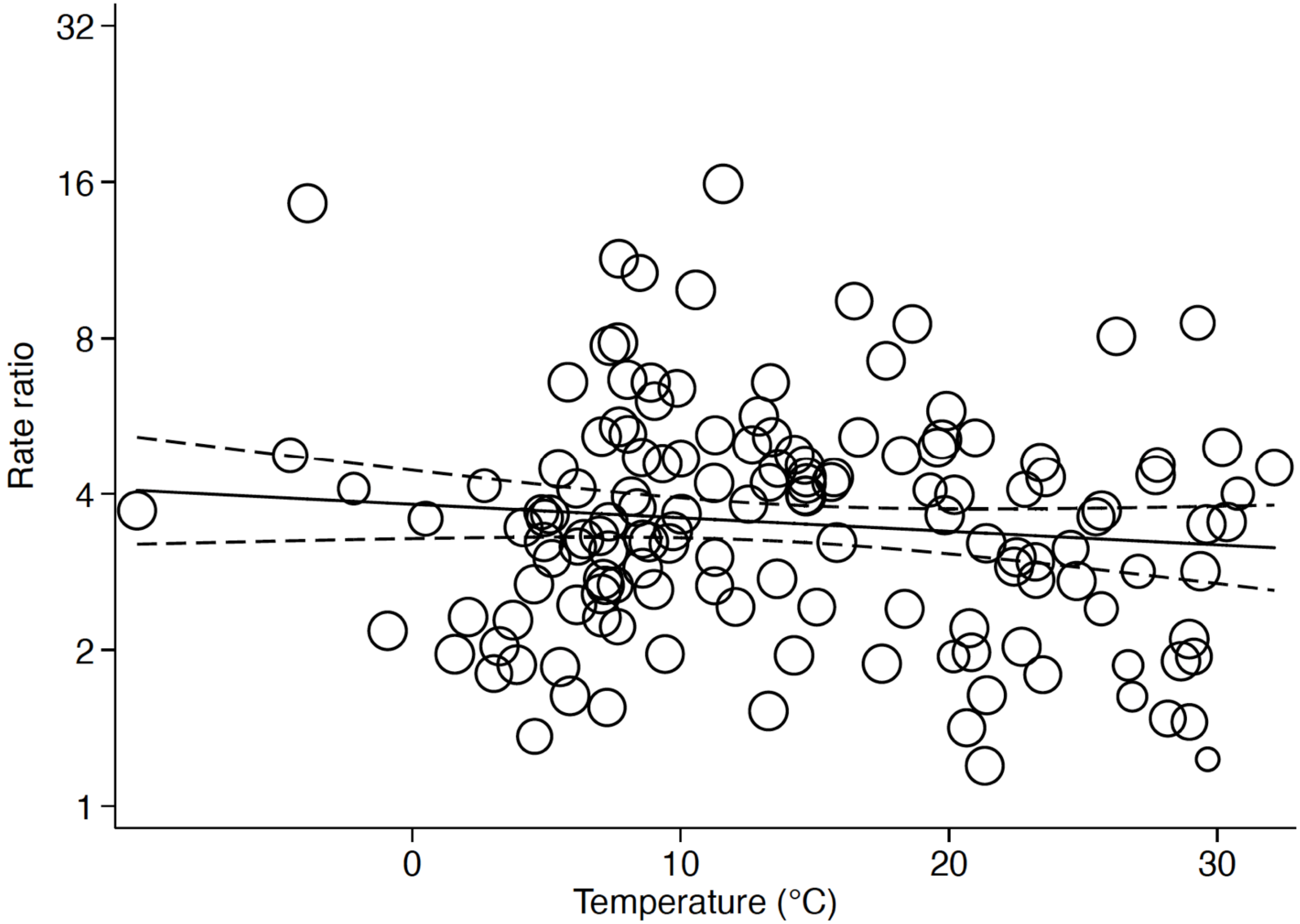
Scatter plot of relative humidity against latitude for 144 geopolitical areas. There is no apparent association between relative humidity and latitude.

Figure S7. Bubble plot of epidemic growth against latitude



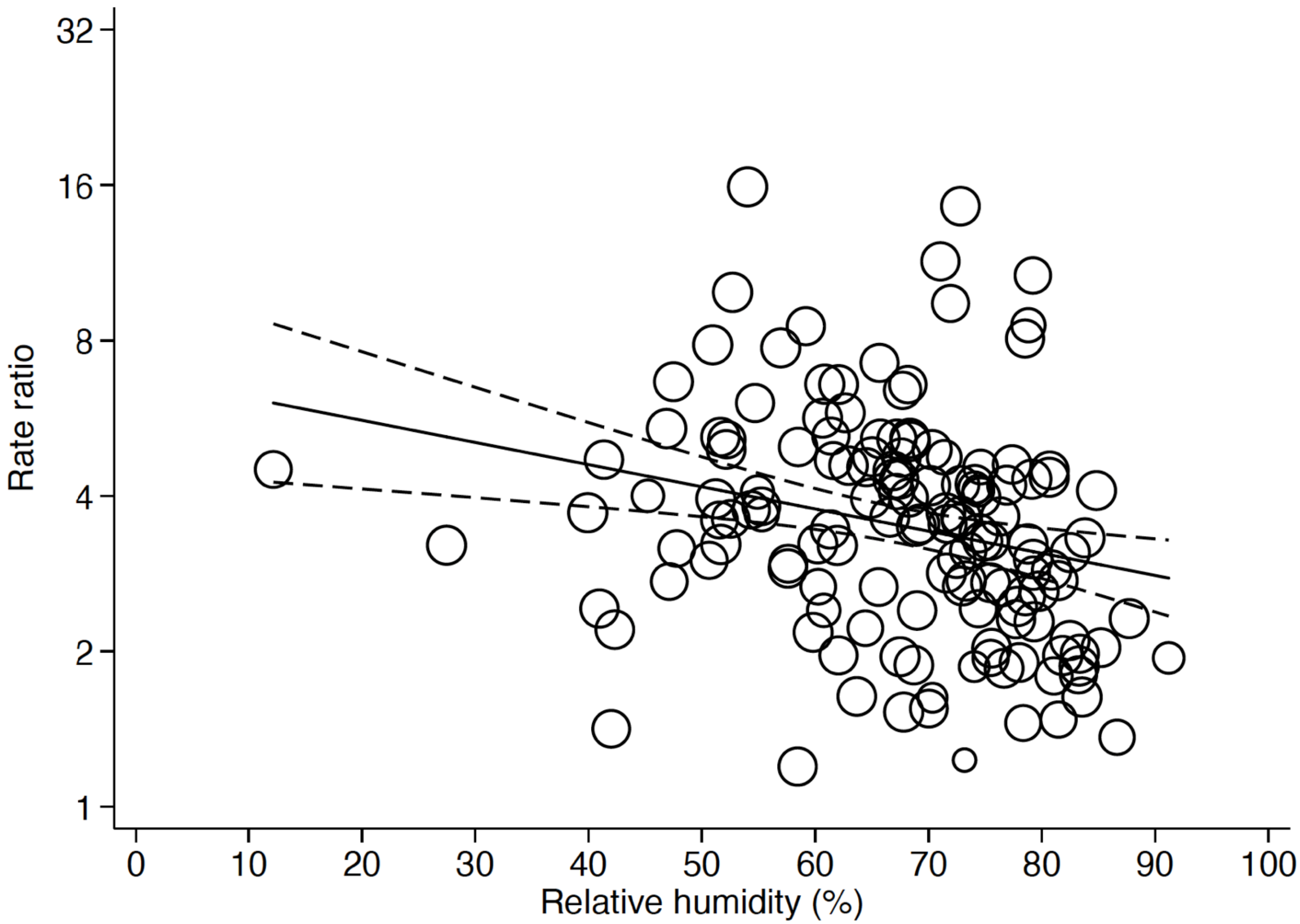
Each bubble represents a geopolitical area (n=144), with the size of the bubble proportional to the weight of the geopolitical area in weighted random-effects regression. Prediction line and 95% confidence band are for the univariate association of epidemic growth with latitude squared (i.e. a quadratic relationship) from random-effects regression with inverse-variance weights

Figure S8. Bubble plot of epidemic growth against temperature



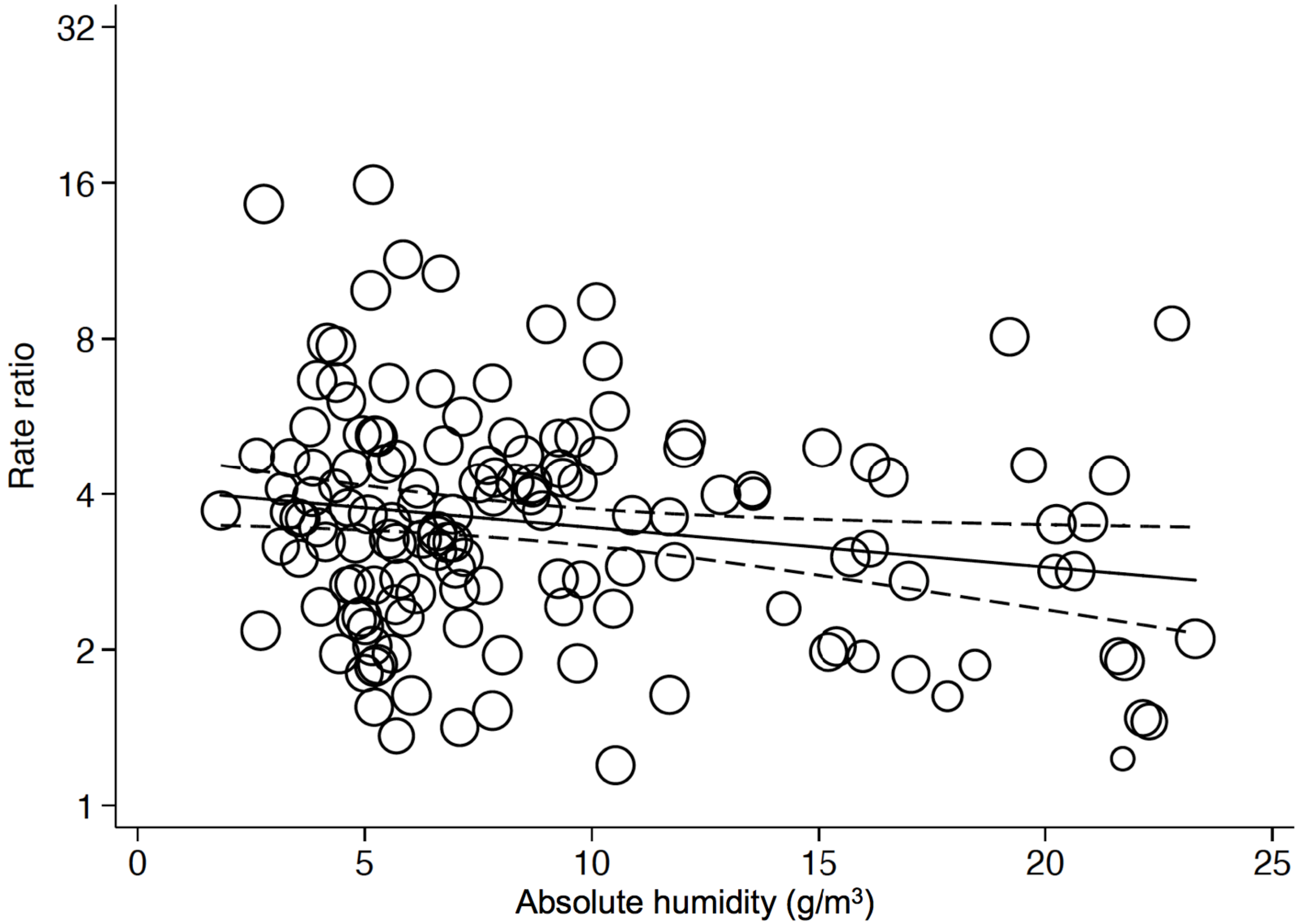
Each bubble represents a geopolitical area (n=144), with the size of the bubble proportional to the weight of the geopolitical area in weighted random-effects regression. Prediction line and 95% confidence band are for the univariate association of epidemic growth with temperature from random-effects regression with inverse-variance weights.

Figure S9. Bubble plot of epidemic growth against relative humidity



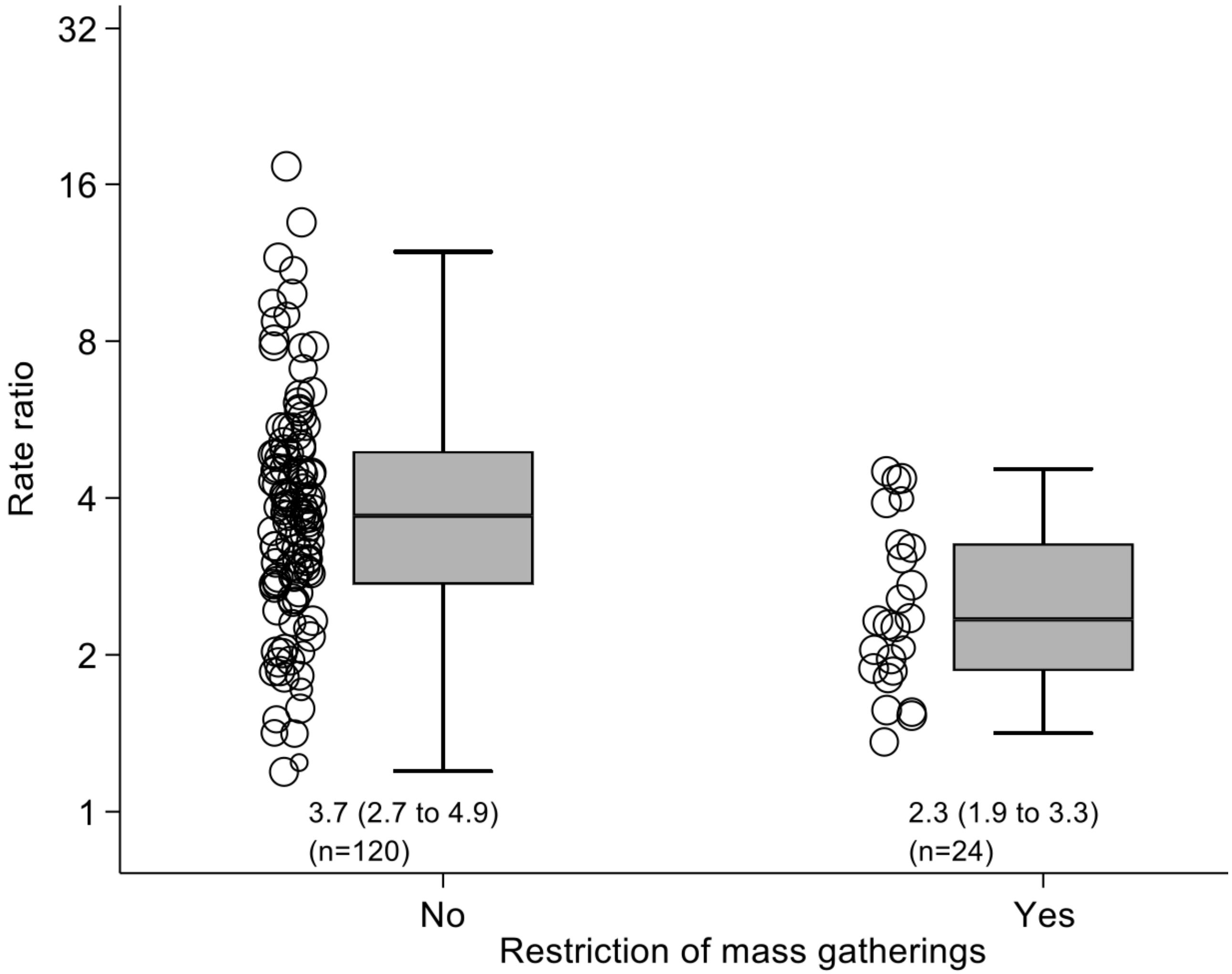
Each bubble represents a geopolitical area (n=144), with the size of the bubble proportional to the weight of the geopolitical area in weighted random-effects regression. Prediction line and 95% confidence band are for the univariate association of epidemic growth with relative humidity from random-effects regression with inverse-variance weights.

Figure S10. Bubble plot of epidemic growth against absolute humidity



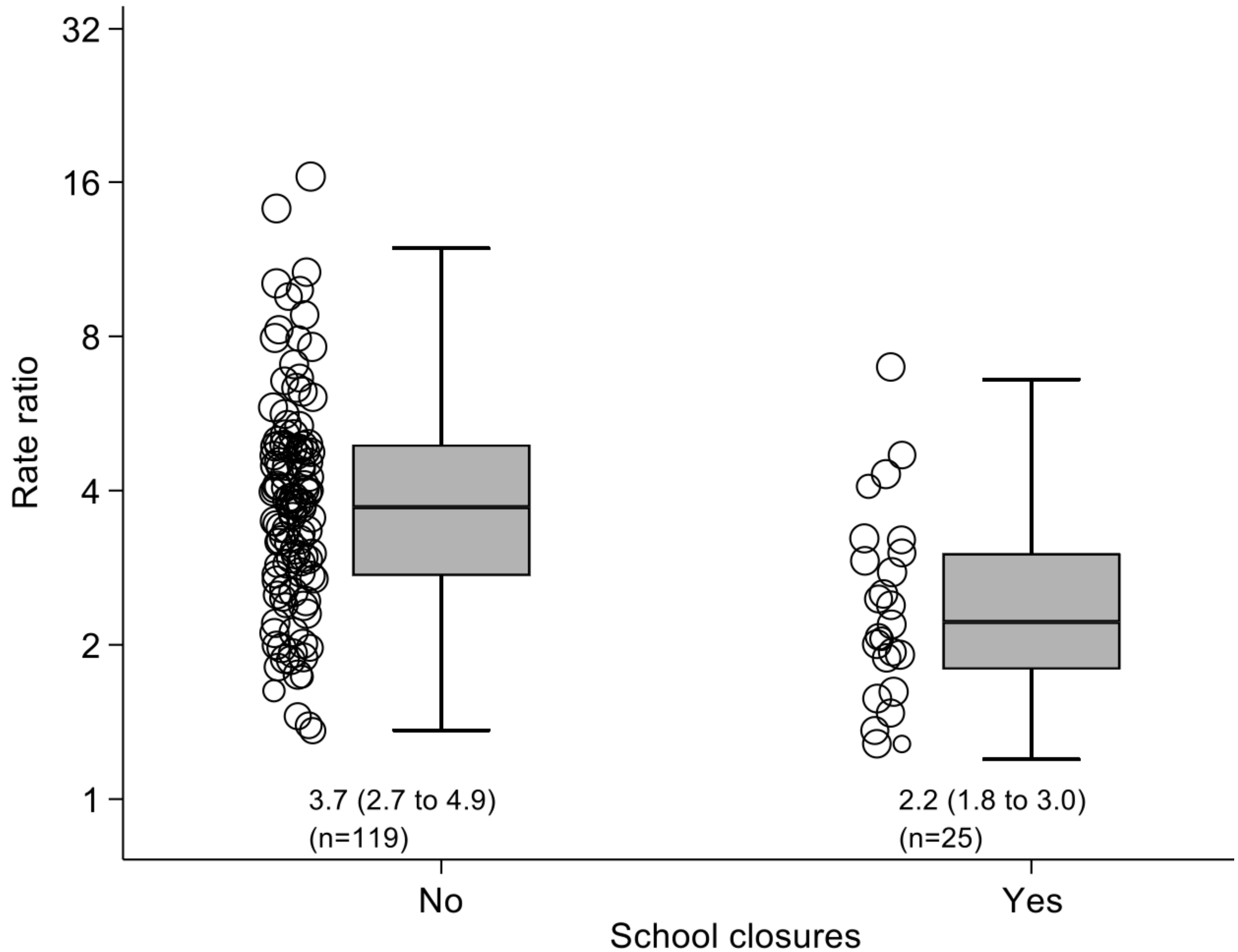
Each bubble represents a geopolitical area (n=144), with the size of the bubble proportional to the weight of the geopolitical area in weighted random-effects regression. Prediction line and 95% confidence band are for the univariate association of epidemic growth with absolute humidity from random-effects regression with inverse-variance weights.

Figure S11. Bubble plot of epidemic growth by restrictions of mass gatherings (no/yes)



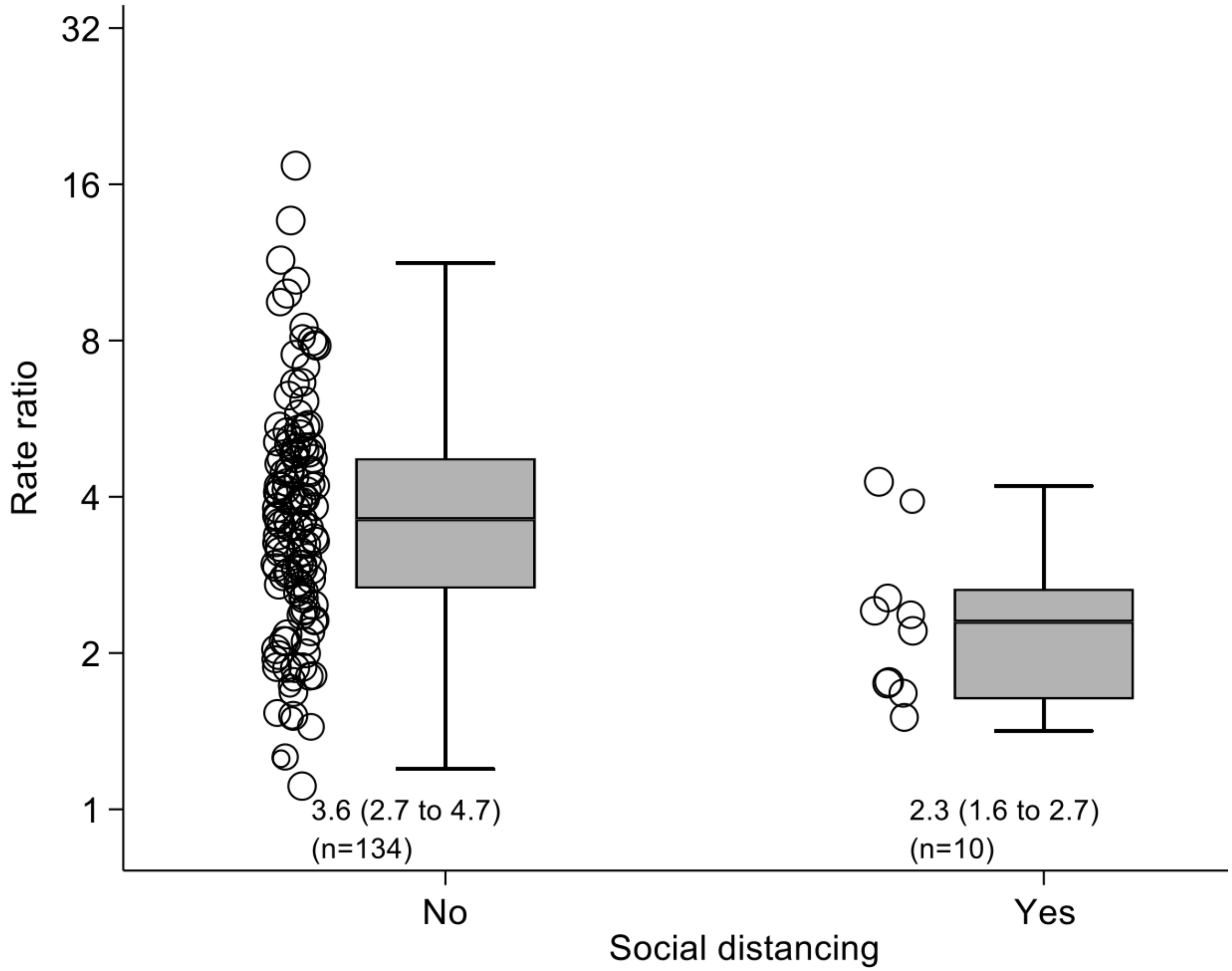
Each bubble represents a geopolitical area, with the size of the bubble proportional to the weight of the geopolitical area in weighted random-effects regression with inverse-variance weights. Box and whisker plots, with the box representing median and interquartile range, whiskers the most extreme values within 1.5 times of the interquartile range beyond the 25th and 75th percentile.

Figure S12. Bubble plot of epidemic growth by school closures (no/yes)



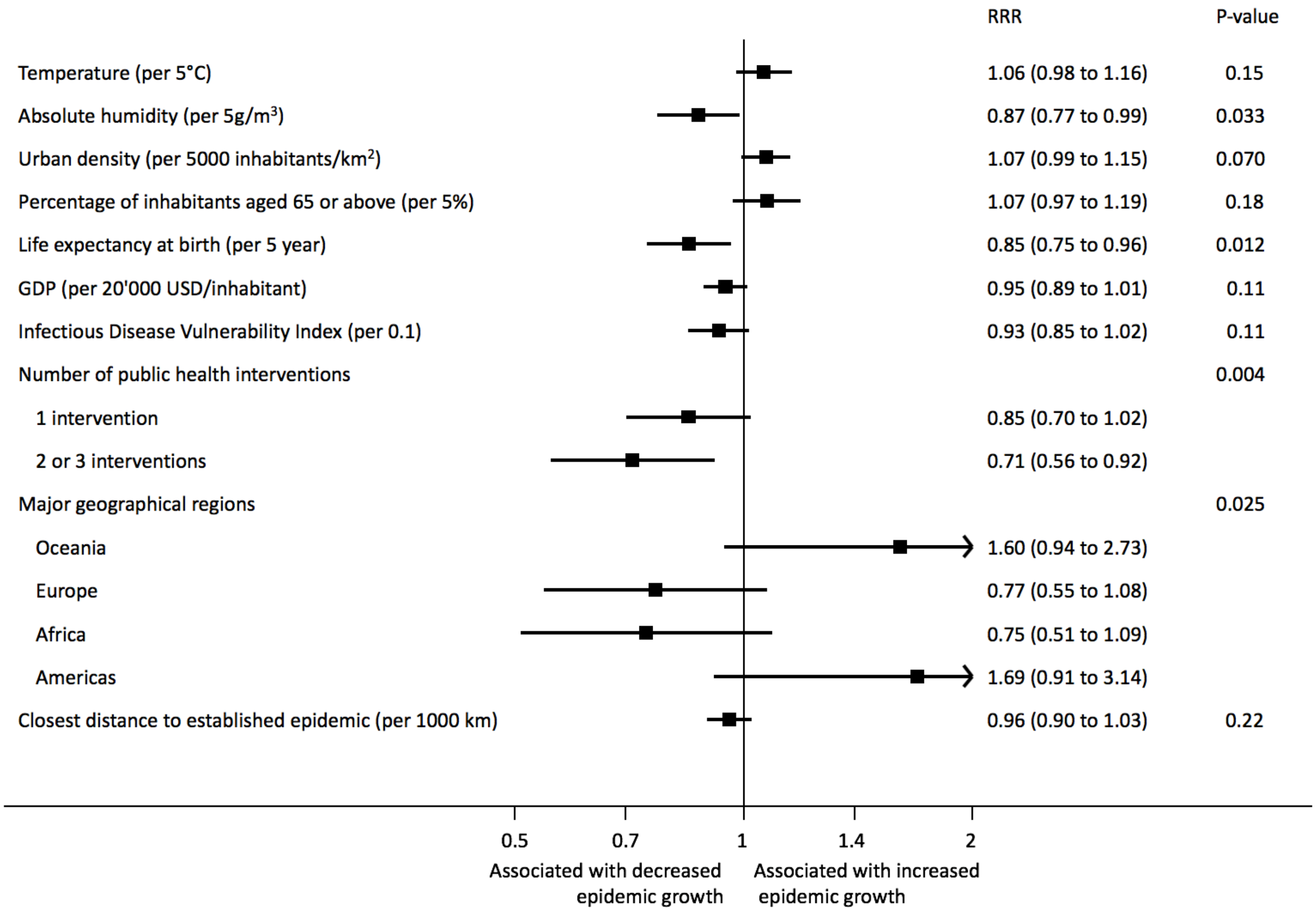
Each bubble represents a geopolitical area, with the size of the bubble proportional to the weight of the geopolitical area in weighted random-effects regression with inverse-variance weights. Box and whisker plots, with the box representing median and interquartile range, whiskers the most extreme values within 1.5 times of the interquartile range beyond the 25th and 75th percentile.

Figure S13. Bubble plot of epidemic growth by measures of social distancing (no/yes)



Each bubble represents a geopolitical area, with the size of the bubble proportional to the weight of the geopolitical area in weighted random-effects regression with inverse-variance weights. Box and whisker plots, with the box representing median and interquartile range, whiskers the most extreme values within 1.5 times of the interquartile range beyond the 25th and 75th percentile.

Figure S14. Multivariable model after stepwise backward selection of covariates



Caterpillar plot of multivariable model after stepwise backward selection of covariates. The vertical line represents no association between the covariates and the epidemic growth. Each covariate is expressed as Ratio of rate ratios (RRR). Reference categories are no public health intervention for Number of public health interventions, and Asia for Major geographical regions.

Figure S15. Risk of bias summary table for evaluated exposure variables

	Bias due to confounding	Bias in selection of participants	Bias in classification of exposure	Bias due to deviations from exposure	Bias due to missing data	Bias in measurement of outcome	Bias in selection of the reported result	Overall
Latitude	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢
Temperature	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢
Relative humidity	🟡	🟢	🟡	🟢	🟢	🟢	🟢	🟡
Absolute humidity	🟡	🟢	🟡	🟢	🟢	🟢	🟢	🟡
Any public health intervention	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢
Restriction of mass gatherings	🟡	🟢	🟢	🟢	🟢	🟢	🟢	🟡
Social distancing	🟡	🟢	🟢	🟢	🟢	🟢	🟢	🟡
School closures	🟡	🟢	🟢	🟢	🟢	🟢	🟢	🟡
Number of public health interventions	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢

Summary of risk of bias for non-randomized studies of exposures or interventions.[1,2]

🟢 Low risk of bias; 🟡 Moderate risk of bias.

IV. Supplementary References

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