Online Resource 2

Article: Climatic variability and routine childhood vaccine uptake in high-risk urban settlements of Karachi, Pakistan: a longitudinal fixed-effects panel analysis

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Sensitivity analyses for the vaccine-specific fixed-effects models (main text, Table 2).

All models are one-way fixed-effects models with facility entity effects and the six predictors of the main analysis; standard errors are clustered by facility. Linear-model coefficients are within-facility standardized betas with 95% confidence intervals in brackets.

Fig. S2 Pearson correlation matrix of monthly doses of the six vaccines (N = 266 facility-months). Doses were positively correlated (r = 0.43–0.89), most strongly for Penta-3 and IPV-1, which are co-administered at the 14-week visit; BCG, given at birth, correlated more weakly with later doses (r = 0.43–0.57)

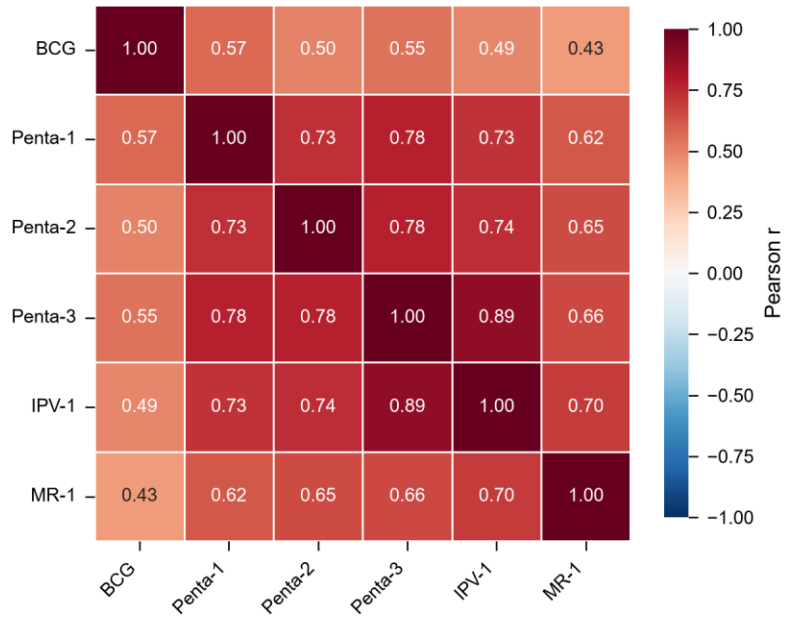

Fig. S3 Within-facility standardized fixed-effects coefficients (β) and 95% confidence intervals for climatic and socioeconomic predictors of monthly vaccine doses, by vaccine (main models, N = 266 facility-months; values as in Table II of the main text). NTL night-time light

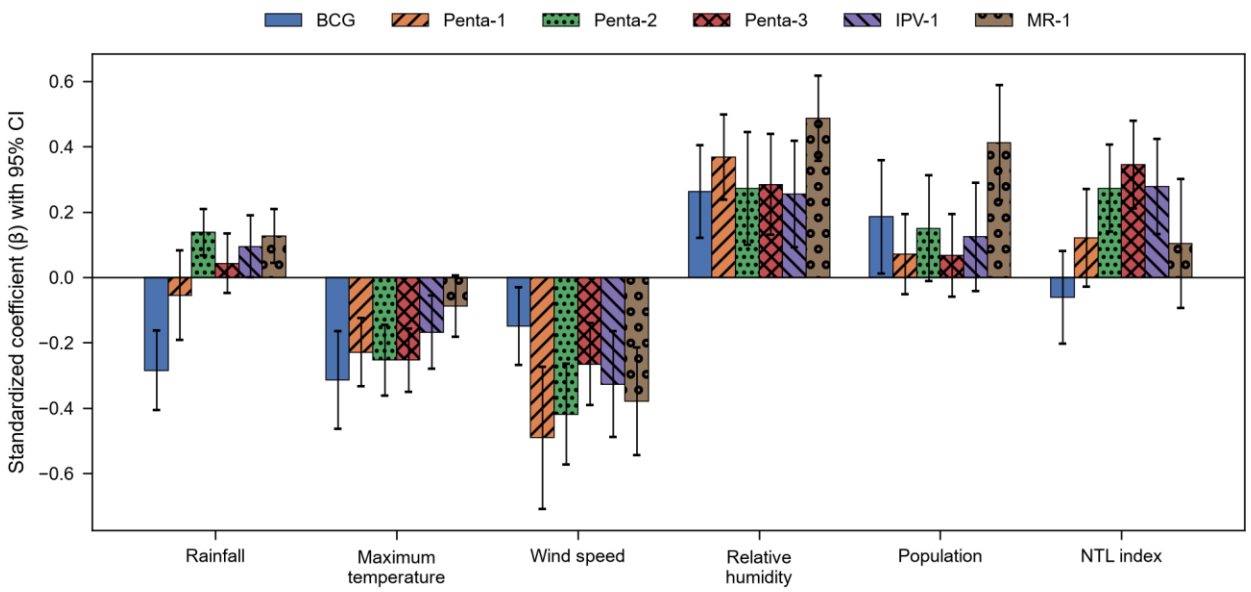

Table S2a Small-sample inference: p-values and 95% CIs from a t-distribution with 13 degrees of freedom (N = 266)

Predictor	BCG	Penta-1	Penta-2	Penta-3	IPV-1	MR-1
Rainfall	−0.285*** [−0.418, −0.151]	−0.055 [−0.205, 0.096]	0.139*** [0.061, 0.216]	0.043 [−0.057, 0.143]	0.094* [−0.009, 0.198]	0.126*** [0.036, 0.216]
Maximum temperature	−0.315*** [−0.478, −0.151]	−0.229*** [−0.344, −0.114]	−0.253*** [−0.372, −0.134]	−0.253*** [−0.359, −0.148]	−0.168** [−0.290, −0.046]	−0.088* [−0.191, 0.015]
Wind speed	−0.150** [−0.281, −0.019]	−0.491*** [−0.729, −0.252]	−0.419*** [−0.587, −0.250]	−0.265*** [−0.403, −0.127]	−0.327*** [−0.503, −0.150]	−0.378*** [−0.559, −0.198]
Relative humidity	0.262*** [0.106, 0.418]	0.368*** [0.225, 0.511]	0.273*** [0.083, 0.462]	0.284*** [0.115, 0.454]	0.255*** [0.076, 0.433]	0.487*** [0.344, 0.630]
Population	0.186* [−0.004, 0.375]	0.071 [−0.063, 0.205]	0.150* [−0.028, 0.329]	0.067 [−0.071, 0.205]	0.124 [−0.057, 0.305]	0.411*** [0.218, 0.604]
NTL index	−0.061 [−0.217, 0.095]	0.121 [−0.044, 0.285]	0.273*** [0.128, 0.418]	0.345*** [0.198, 0.493]	0.277*** [0.117, 0.437]	0.103 [−0.114, 0.320]
Within R^2	0.200	0.264	0.324	0.224	0.211	0.356

*p < 0.10, **p < 0.05, ***p < 0.01. NTL night-time light.

Table S2b Main specification plus a common linear time trend (N = 266)

Predictor	BCG	Penta-1	Penta-2	Penta-3	IPV-1	MR-1
Rainfall	−0.280*** [−0.401, −0.158]	−0.060 [−0.193, 0.074]	0.127*** [0.054, 0.200]	0.032 [−0.057, 0.121]	0.079* [−0.008, 0.167]	0.106*** [0.036, 0.176]
Maximum temperature	−0.311*** [−0.462, −0.160]	−0.233*** [−0.339, −0.127]	−0.261*** [−0.366, −0.156]	−0.262*** [−0.358, −0.165]	−0.179*** [−0.288, −0.070]	−0.103** [−0.191, −0.014]
Wind speed	−0.174** [−0.310, −0.038]	−0.467*** [−0.689, −0.246]	−0.365*** [−0.520, −0.210]	−0.211*** [−0.321, −0.100]	−0.255*** [−0.399, −0.111]	−0.283*** [−0.413, −0.153]
Relative humidity	0.268*** [0.124, 0.411]	0.363*** [0.238, 0.488]	0.260*** [0.092, 0.429]	0.272*** [0.132, 0.412]	0.238*** [0.093, 0.384]	0.465*** [0.355, 0.576]
Population	0.323** [0.023, 0.623]	−0.061 [−0.346, 0.225]	−0.151 [−0.511, 0.208]	−0.242** [−0.476, −0.007]	−0.280** [−0.529, −0.031]	−0.128 [−0.516, 0.261]
NTL index	−0.063 [−0.209, 0.084]	0.122 [−0.027, 0.271]	0.276*** [0.139, 0.412]	0.348*** [0.224, 0.472]	0.281*** [0.153, 0.409]	0.108 [−0.079, 0.295]
Within R^2	0.207	0.271	0.357	0.258	0.269	0.460

*p < 0.10, **p < 0.05, ***p < 0.01. NTL night-time light.

Table S2c Excluding the programme start-up months, June–August 2023 (N = 224)

Predictor	BCG	Penta-1	Penta-2	Penta-3	IPV-1	MR-1
Rainfall	−0.384*** [−0.626, −0.142]	0.112** [0.013, 0.211]	0.219*** [0.073, 0.365]	0.088* [−0.010, 0.186]	0.204*** [0.090, 0.318]	0.255*** [0.105, 0.405]
Maximum temperature	−0.245*** [−0.407, −0.084]	0.016 [−0.122, 0.154]	−0.175*** [−0.269, −0.080]	−0.130 [−0.297, 0.038]	0.007 [−0.130, 0.144]	0.106** [0.002, 0.210]
Wind speed	−0.051 [−0.187, 0.084]	−0.615*** [−0.868, −0.362]	−0.384*** [−0.540, −0.229]	−0.116 [−0.259, 0.026]	−0.294*** [−0.477, −0.111]	−0.371*** [−0.547, −0.195]

Relative humidity	0.178** [0.025, 0.331]	0.262*** [0.116, 0.409]	0.206** [0.021, 0.390]	0.106 [−0.104, 0.315]	0.118 [−0.037, 0.272]	0.392*** [0.254, 0.531]
Population	0.058 [−0.136, 0.252]	−0.065 [−0.209, 0.078]	−0.022 [−0.228, 0.183]	−0.220*** [−0.378, −0.062]	−0.049 [−0.222, 0.124]	0.353*** [0.184, 0.522]
NTL index	−0.213** [−0.408, −0.019]	0.053 [−0.073, 0.180]	0.179** [0.007, 0.352]	0.161** [0.008, 0.314]	0.169** [0.037, 0.302]	0.040 [−0.143, 0.222]
Within R^2	0.127	0.213	0.147	0.088	0.057	0.326

*p < 0.10, **p < 0.05, ***p < 0.01. NTL night-time light.

Table S2d Main specification plus one-month lagged climatic terms (t−1); the first month is lost (N = 252)

Predictor	**BCG**	**Penta-1**	**Penta-2**	**Penta-3**	**IPV-1**	**MR-1**
Rainfall	−0.463*** [−0.650, −0.276]	−0.160* [−0.350, 0.029]	0.068 [−0.078, 0.214]	−0.037 [−0.171, 0.097]	0.001 [−0.116, 0.117]	0.101* [−0.014, 0.216]
Maximum temperature	−0.268*** [−0.430, −0.105]	−0.147* [−0.319, 0.025]	−0.219** [−0.427, −0.011]	0.023 [−0.115, 0.162]	0.063 [−0.126, 0.251]	0.126 [−0.077, 0.328]
Wind speed	−0.092 [−0.267, 0.083]	−0.371** [−0.658, −0.084]	−0.289*** [−0.435, −0.144]	−0.080 [−0.218, 0.059]	−0.165* [−0.348, 0.018]	−0.275** [−0.485, −0.065]
Relative humidity	0.061 [−0.132, 0.253]	0.390*** [0.219, 0.562]	0.300*** [0.129, 0.471]	0.204 [−0.041, 0.448]	0.359*** [0.162, 0.556]	0.619*** [0.431, 0.807]
Population	0.134 [−0.089, 0.357]	−0.035 [−0.189, 0.120]	0.076 [−0.116, 0.268]	−0.072 [−0.219, 0.075]	0.002 [−0.158, 0.163]	0.312*** [0.121, 0.504]
NTL index	−0.134* [−0.288, 0.020]	0.009 [−0.178, 0.197]	0.211** [0.005, 0.417]	0.224*** [0.060, 0.388]	0.061 [−0.104, 0.225]	−0.021 [−0.233, 0.191]
Rainfall (t−1)	0.049 [−0.075, 0.173]	−0.055 [−0.280, 0.170]	−0.088 [−0.274, 0.098]	0.023 [−0.100, 0.145]	−0.056 [−0.198, 0.086]	0.050 [−0.161, 0.260]
Maximum temperature (t−1)	0.142* [−0.018, 0.302]	−0.021 [−0.197, 0.155]	−0.007 [−0.149, 0.136]	−0.241*** [−0.343, −0.139]	−0.064 [−0.151, 0.022]	−0.044 [−0.196, 0.107]
Wind speed (t−1)	0.164 [−0.114, 0.441]	−0.240** [−0.449, −0.031]	−0.201 [−0.493, 0.092]	−0.219 [−0.484, 0.045]	−0.422*** [−0.653, −0.191]	−0.428*** [−0.705, −0.151]
Relative humidity (t−1)	−0.030 [−0.192, 0.132]	0.134* [−0.024, 0.292]	0.116 [−0.059, 0.292]	0.082 [−0.064, 0.227]	−0.018 [−0.190, 0.155]	0.063 [−0.127, 0.253]
Within R^2	0.202	0.208	0.214	0.167	0.146	0.323

*p < 0.10, **p < 0.05, ***p < 0.01. NTL night-time light.

Table S2e Poisson fixed-effects model: incidence rate ratios per within-facility standard deviation of each predictor (N = 266)

Predictor	**BCG**	**Penta-1**	**Penta-2**	**Penta-3**	**IPV-1**	**MR-1**
Rainfall	0.900*** [0.853, 0.949]	0.986 [0.951, 1.022]	1.036*** [1.014, 1.058]	1.008 [0.985, 1.033]	1.025* [0.999, 1.051]	1.043*** [1.016, 1.071]
Maximum temperature	0.893*** [0.852, 0.937]	0.950*** [0.925, 0.975]	0.945*** [0.920, 0.972]	0.947*** [0.926, 0.968]	0.963** [0.934, 0.992]	0.973* [0.945, 1.002]
Wind speed	0.959** [0.927, 0.993]	0.898*** [0.860, 0.938]	0.908*** [0.875, 0.942]	0.944*** [0.917, 0.972]	0.926*** [0.887, 0.966]	0.902*** [0.855, 0.951]
Relative humidity	1.091*** [1.044, 1.140]	1.081*** [1.047, 1.117]	1.061*** [1.017, 1.107]	1.062*** [1.027, 1.098]	1.059*** [1.016, 1.104]	1.150*** [1.101, 1.202]
Population	1.076** [1.012, 1.145]	1.020 [0.991, 1.051]	1.041** [1.002, 1.082]	1.019 [0.988, 1.051]	1.034 [0.991, 1.079]	1.136*** [1.080, 1.194]
NTL index	0.983 [0.931, 1.038]	1.025 [0.986, 1.065]	1.064*** [1.023, 1.107]	1.078*** [1.039, 1.117]	1.068*** [1.023, 1.115]	1.038 [0.973, 1.107]

Facility dummies; facility-clustered standard errors. Signs and significance at the 5% level agree with the linear model for 35 of 36 coefficients (exception: population for Penta-2, p = 0.041 in the Poisson model vs 0.070 in the linear model). *p < 0.10, **p < 0.05, ***p < 0.01. NTL night-time light.

Multiple testing: 24 of the 25 main-model coefficients significant at p < 0.05 remained significant after Benjamini–Hochberg false-discovery-rate correction across the 36 tests (exception: population for BCG).