

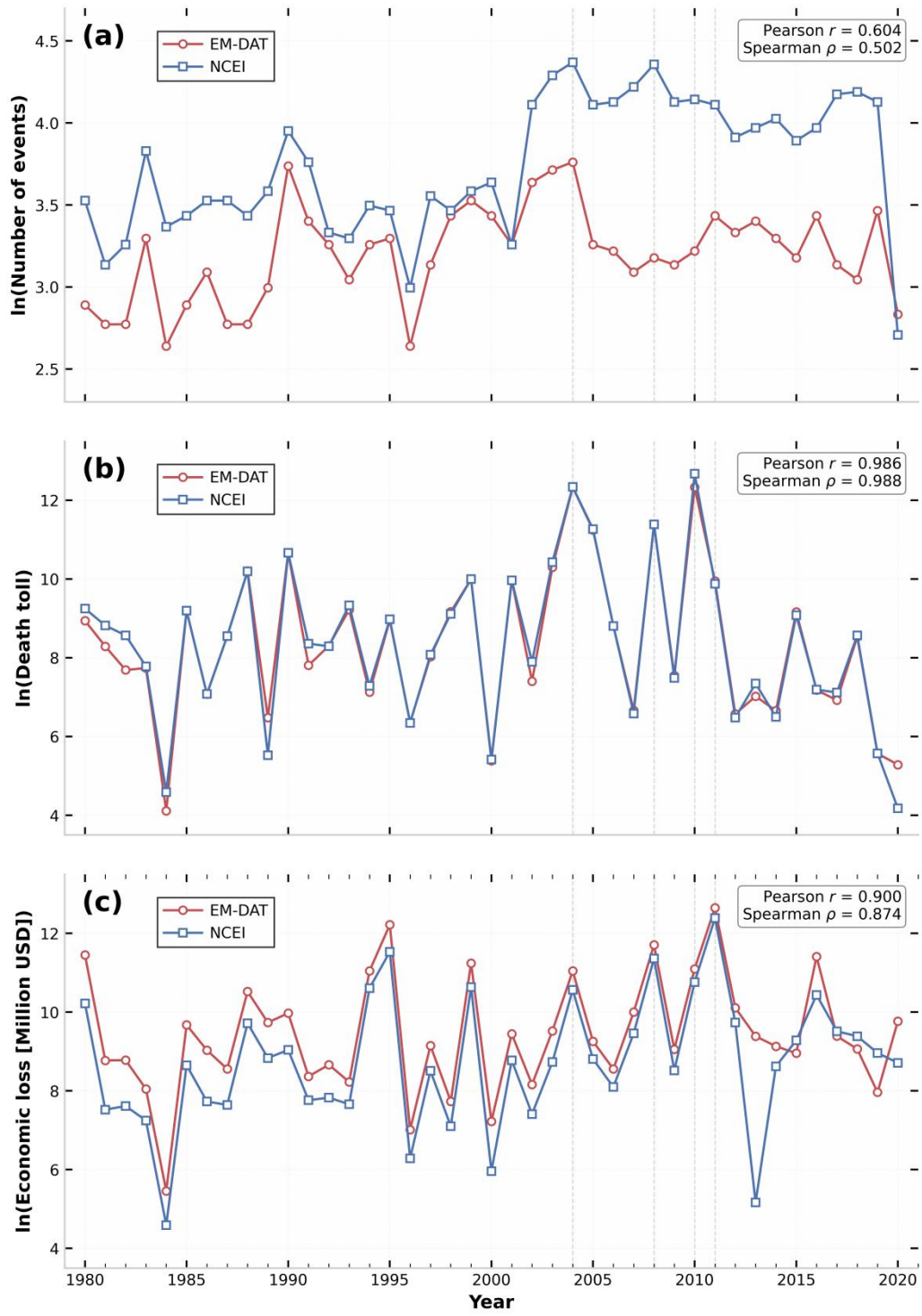


Figure S1. Cross-validation of EM-DAT against the NCEI independent database (1980–2020). Panels (a–c) compare annual earthquake disaster events, fatalities, and economic losses recorded in EM-DAT and NCEI, respectively. Pearson and Spearman correlation coefficients indicate the consistency of temporal variations between the two databases.

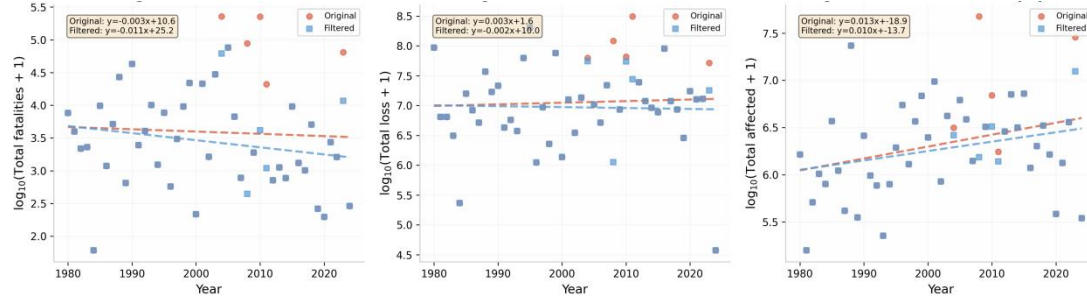


Figure S2. Comparison of temporal trends in annual fatalities (a), economic losses (b), and affected population (c) between the original dataset and the dataset excluding the five most catastrophic earthquake disasters (2004 Sumatra and Indian Ocean tsunami, 2008 Wenchuan, 2010 Haiti, 2011 Great East Japan, and 2023 Türkiye–Syria). Dashed lines indicate linear regression trends.

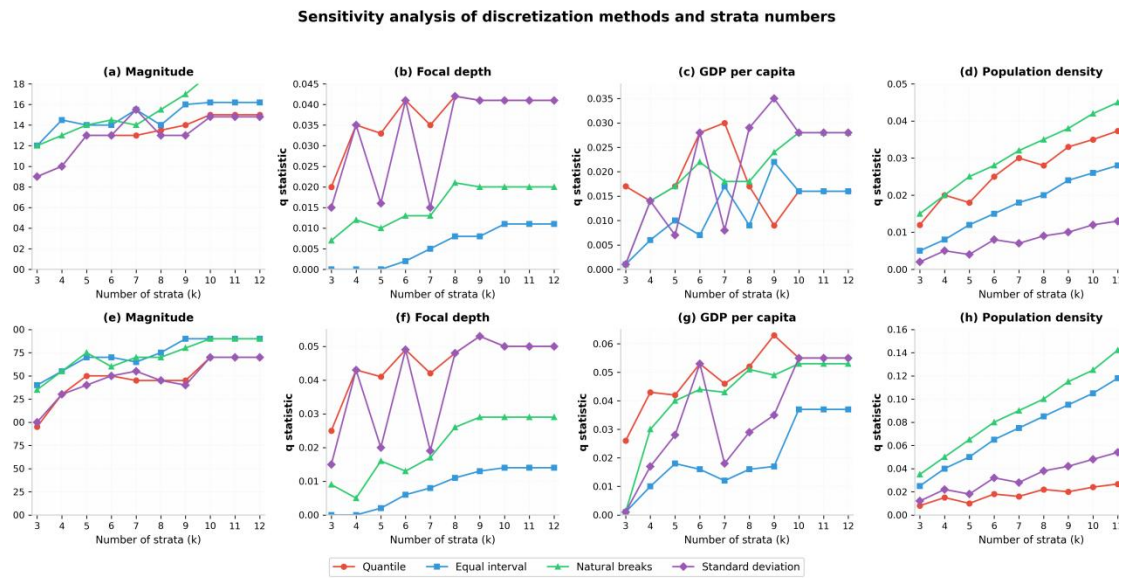


Figure S3. Sensitivity analysis of discretization methods and strata numbers for continuous explanatory variables in the Geodetector model. The q-statistic is plotted against the number of strata ($k = 3-10$) for four discretization methods: Quantile (red circles), Equal interval (blue squares), Natural breaks (green triangles), and Standard deviation (purple diamonds). Panels (a–d) correspond to the dependent variable $\log(\text{Deaths per million} + 1)$, and panels (e–h) correspond to the dependent variable $\log(\text{Loss/GDP ratio} + 0.001)$. The optimal discretization scheme for each variable was selected based on the highest q-statistic and the stability of results across different strata numbers for the corresponding dependent variables (see Table S10).

Temporal trends of earthquake impacts (1980-2024): Log-scale analysis
Fatality, economic loss (Thousand USD), and affected population

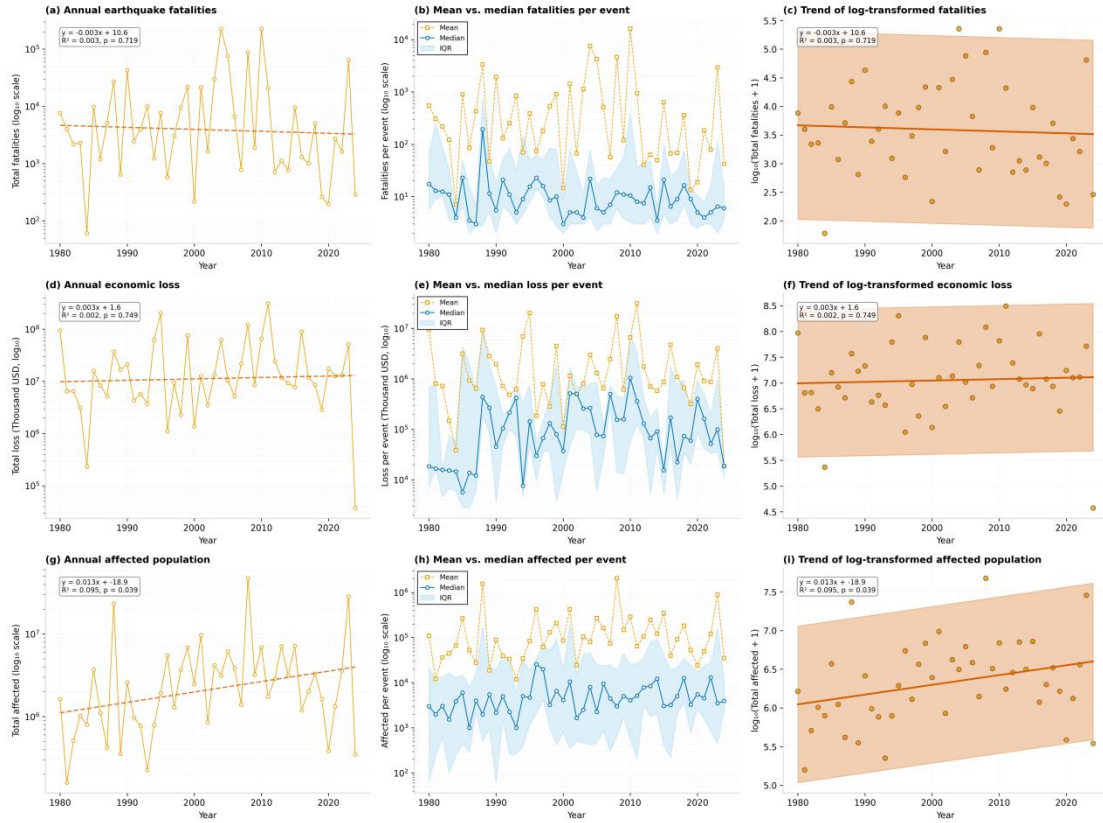


Figure S4. Figure S4. Temporal trends and uncertainty assessment of major earthquake impact indicators (1980–2024). Panels (a), (d), and (g) show annual variations in total fatalities, total economic losses, and total affected population, respectively. Panels (b), (e), and (h) present the annual mean and median values of event-normalized indicators (fatalities per event, economic loss per event, and affected population per event), with shaded areas representing the interquartile range (IQR). Panels (c), (f), and (i) show linear regression trends of log₁₀(x+1)-transformed annual fatalities, economic losses, and affected population, respectively. Solid lines indicate fitted regression trends, and shaded areas represent the 95% confidence intervals of the fitted trends. The figure illustrates both interannual variability and uncertainty associated with long-term trend estimation of earthquake disaster impact indicators.

Multimodality Assessment: Kernel Density Estimation by Period

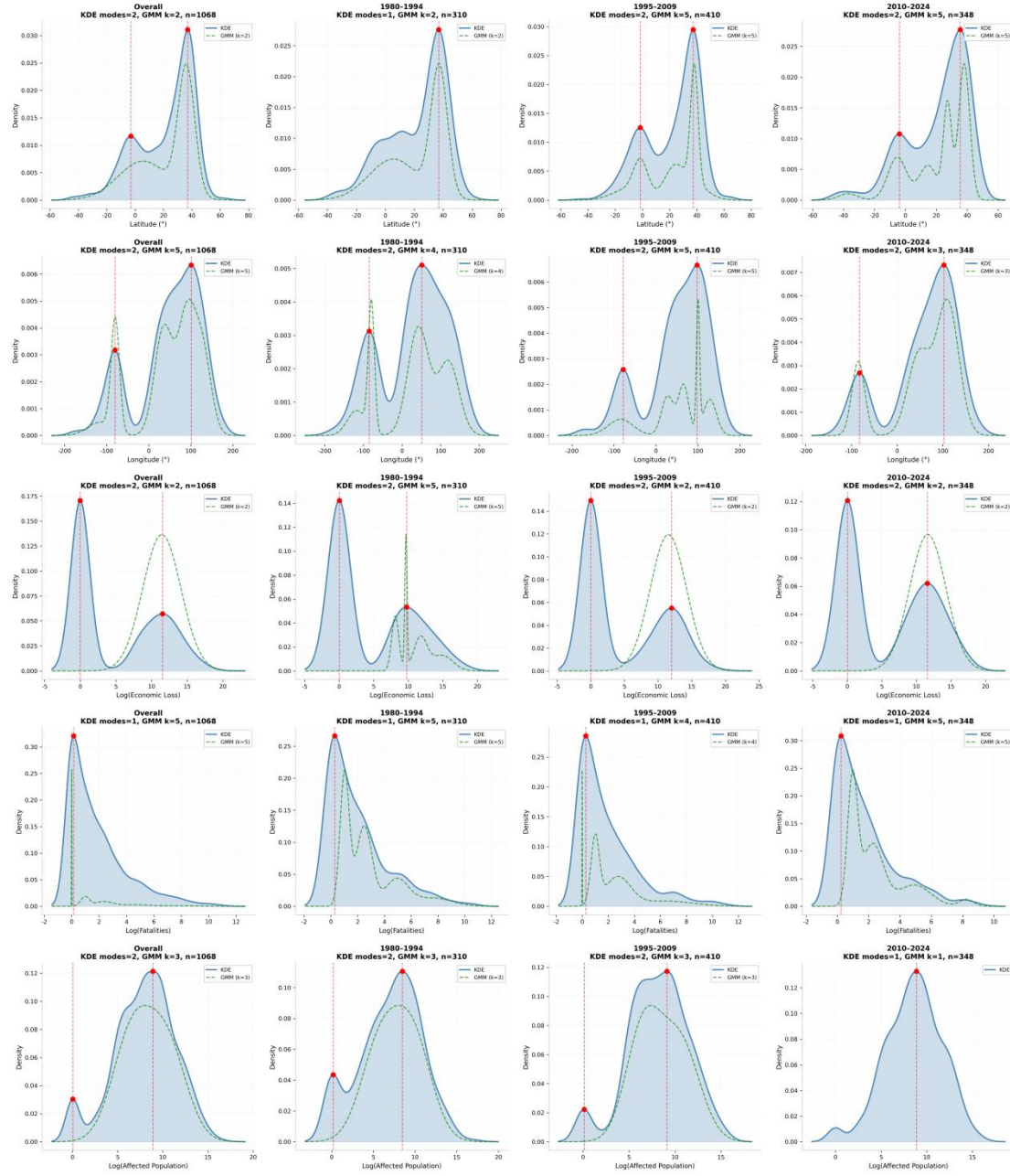


Figure S5. Kernel density estimation (KDE) curves with Gaussian mixture model (GMM) overlays for five variables across four temporal periods. Blue solid lines represent KDE with Silverman's rule bandwidth; red dots and dashed lines mark local maxima (modes); green dashed lines show GMM fits with BIC-optimal component numbers (k).

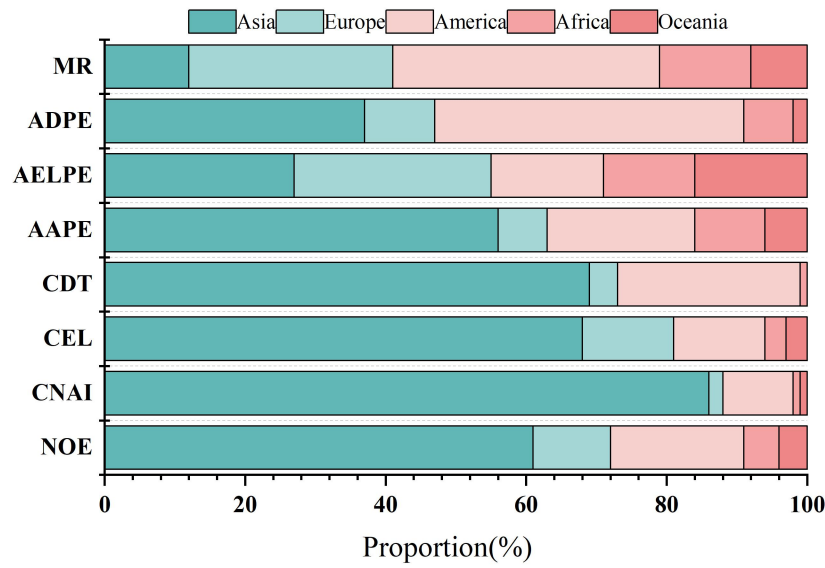


Figure S6. Continental contributions to global earthquake disaster impact indicators during 1980–2024. NOE represents number of earthquakes, CNAI represents cumulative number of affected people, CEL represents cumulative economic losses, CDT represents cumulative number of fatalities, AAPE represents average number of affected people per event, AELPE represents average economic loss per event, ADPE represents average number of fatalities per event, MR represents mortality rate.

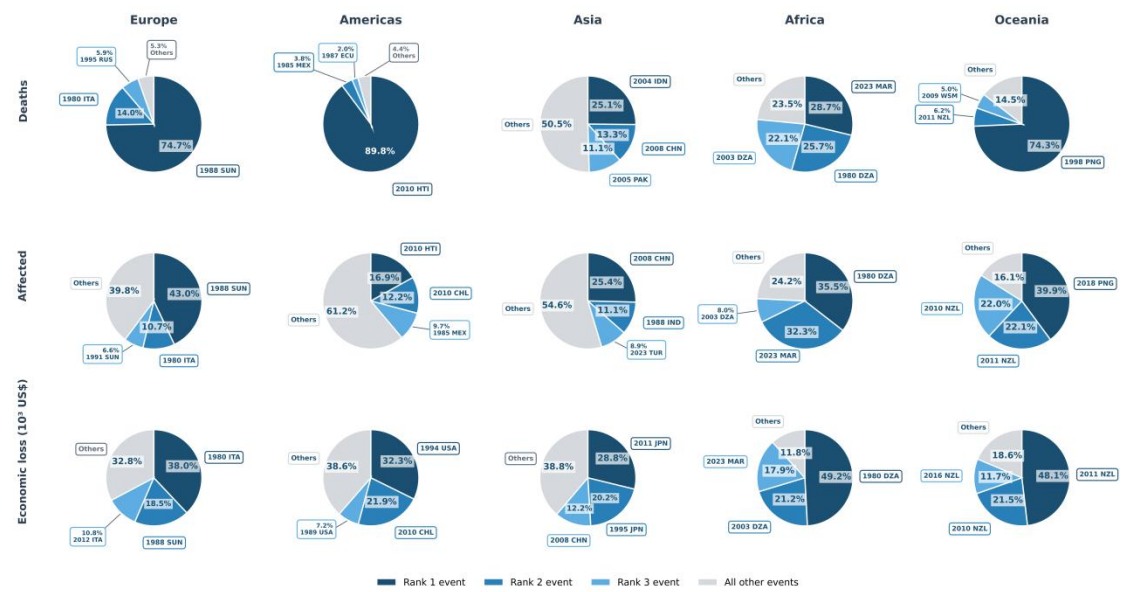


Figure S7. Contribution concentration of top-ranked earthquake disaster events to continental-scale impact indicators (1980–2024).

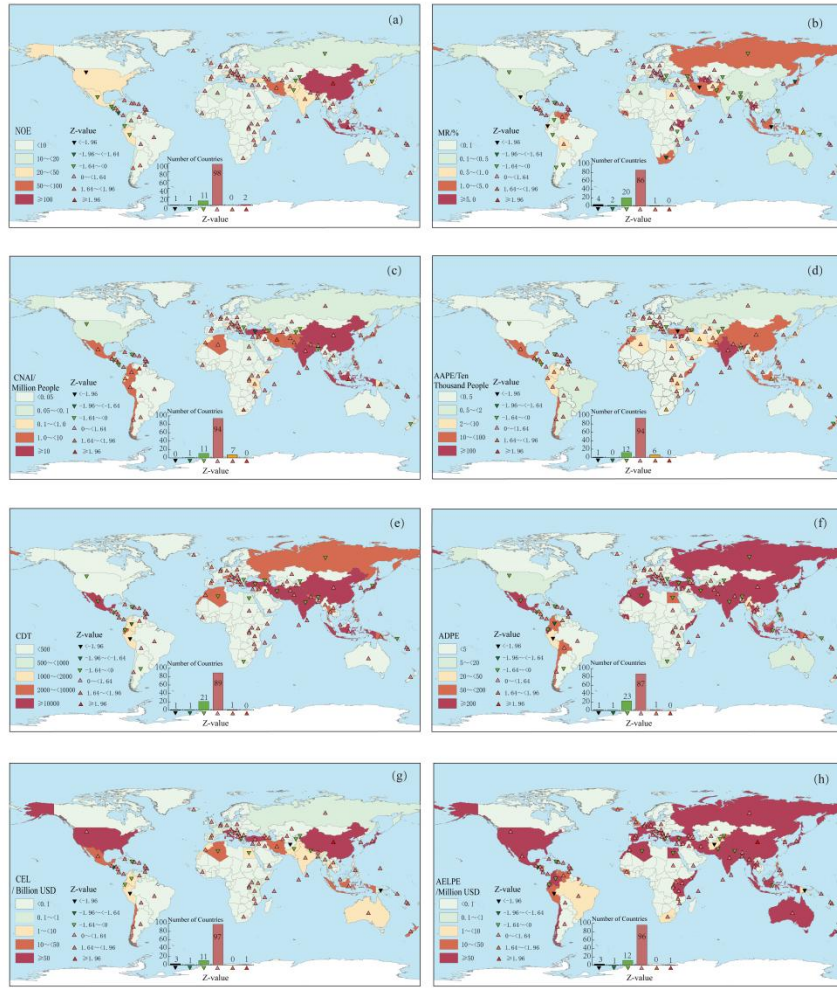


Figure S8. Spatial distribution and temporal trend statistics of earthquake disaster impact indicators at the national scale (1980–2024). Spatial patterns and temporal trend statistics of eight earthquake disaster indicators at the national scale. (a) Number of recorded earthquake disaster events; (b) mortality rate; (c) cumulative affected population; (d) average affected population per event; (e) cumulative fatalities; (f) average fatalities per event; (g) cumulative economic losses; and (h) average economic loss per event.

Table S1. Summary statistics of earthquake magnitude distribution by continent and period (1980–2024).

Continent	Period	Magnitude unavailable	≤3.0	3.0–4.5	4.5–6.0	6.0–7.0	7.0–8.0	>8.0	Total Records
Africa	1980-1994	2	0	2	6	7	2	0	19
	1995-2009	0	0	4	12	7	0	4	27
	2010-2024	0	0	0	7	1	0	0	8
Americas	1980-1994	0	0	4	31	32	12	0	79
	1995-2009	1	0	3	16	28	20	1	69
	2010-2024	0	0	0	11	26	22	4	63
Asia	1980-1994	4	0	3	60	53	20	0	140
	1995-2009	2	0	9	131	77	35	11	265
	2010-2024	0	0	1	131	96	34	3	265
Europe	1980-1994	5	0	1	34	15	2	0	57
	1995-2009	0	0	2	21	13	3	0	39
	2010-2024	1	0	2	15	10	0	0	28
Oceania	1980-1994	1	0	0	2	8	6	1	18
	1995-2009	0	0	0	1	4	4	4	13
	2010-2024	1	0	0	1	6	7	0	15

Notes: Event count = number of earthquake disaster events recorded in EM-DAT. No Mag. = records without magnitude information. Periods: 1980–1994, 1995–2009, 2010–2024. Source: EM-DAT database.

Table S2. Summary statistics of earthquake disaster events by continent and period (1980–2024).

Continent	Period	Total Records	Fatality Records	Completeness (%)	Affected Records	Completeness (%)	Economic loss Records	Completeness (%)
Africa	1980-1994	19	12	63.2	15	78.9	7	36.8
	1995-2009	27	23	85.2	25	92.6	8	29.6
	2010-2024	8	6	75.0	8	100.0	2	25.0
Americas	1980-1994	79	56	70.9	72	91.1	38	48.1
	1995-2009	69	49	71.0	66	95.7	26	37.7
	2010-2024	63	42	66.7	63	100.0	26	41.3
Asia	1980-1994	140	105	75.0	135	96.4	56	40.0
	1995-2009	265	181	68.3	254	95.8	110	41.5
	2010-2024	265	174	65.7	258	97.4	127	47.9
Europe	1980-1994	57	32	56.1	48	84.2	21	36.8
	1995-2009	39	16	41.0	37	94.9	21	53.8
	2010-2024	28	17	60.7	28	100.0	19	67.9
Oceania	1980-1994	18	7	38.9	10	55.6	8	44.4
	1995-2009	13	10	76.9	13	100.0	2	15.4
	2010-2024	15	10	66.7	13	86.7	7	46.7

Notes: Event count = number of earthquake disaster events recorded in EM-DAT. Completeness = (Available records / Total records) $\times$ 100%. Periods: 1980–1994, 1995–2009, 2010–2024. Source: EM-DAT database.

Table S3. Sensitivity analysis of temporal trends using the original dataset and a dataset excluding five catastrophic earthquake disasters.

Metric	Dataset	Slope	Intercept	R ²	p-value	Trend direction
Annual fatalities	Original	−0.003	10.57	0.003	0.719	No significant trend
	Extremes removed	−0.011	25.17	0.041	0.185	No significant trend
Annual economic loss	Original	0.003	1.64	0.002	0.749	No significant trend
	Extremes removed	−0.002	10.03	0.001	0.846	No significant trend
Annual affected population	Original	0.013	−18.94	0.095	0.039	Significant increase
	Extremes removed	+0.010	−13.65	0.077	0.066	Marginally significant increase

Note: The extreme-event-removed dataset excludes five catastrophic earthquake disasters: the 2004 Sumatra–Andaman earthquake and Indian Ocean tsunami, the 2008 Wenchuan earthquake, the 2010 Haiti earthquake, the 2011 Great East Japan earthquake and tsunami, and the 2023 Türkiye–Syria earthquake. Trend statistics were calculated using the same procedures as the main analysis. For impact indicators with strongly right-skewed distributions, $\log_{10}(x+1)$ -transformed annual values were used for regression analysis. Dashed lines indicate linear regression trends.

Table S4. Lag-1 autocorrelation assessment before Mann-Kendall trend analysis.

Variable	AR(1)	p-value	Significant autocorrelation	Recommended treatment
Affected population per million people	-0.1077	0.449585	No	Direct Mann–Kendall
Fatalities per million people	0.0966	0.496038	No	Direct Mann–Kendall
Economic loss per unit GDP	0.0457	0.752817	No	Direct Mann–Kendall
Number of recorded events	0.3831	0.011793	Yes	Pre-whitening recommended
Affected population per recorded event	-0.1123	0.428922	No	Direct Mann–Kendall
Fatalities per recorded event	0.0317	0.822975	No	Direct Mann–Kendall
Mortality rate (%)	0.075	0.596986	No	Direct Mann–Kendall
Economic loss per recorded event	0.0592	0.70321	No	Direct Mann–Kendall

Table S5. Descriptive statistics of annual earthquake disaster impact indicators used in temporal analysis (1980–2024).

Indicator	Mean	Median	Q1	Q3	IQR
Number of recorded events	24.47	24.00	20.00	29.00	9.00
Fatalities per million people	7.94	1.52	0.38	6.00	5.62
Mortality rate (%)	1.06	0.23	0.06	0.51	0.45
Affected population per million people	1700.60	712.83	311.32	1561.17	1249.85
Economic loss per unit GDP (%)	0.48	0.08	0.05	0.28	0.23
Fatalities per recorded event	793.93	145.53	44.31	579.53	535.22
Economic loss per recorded event	1378986.50	456041.70	355987.09	1329075.21	973088.13
Affected population per recorded event	183272.09	58719.12	35427.88	140262.50	104834.62

Notes: *Q1* and *Q3* denote the 25th and 75th percentiles, respectively. *IQR* was calculated as $Q3 - Q1$. Statistics were calculated from the annual series over 1980–2024.

Table S6. Centroid location and its uncertainty estimated via bootstrapping with 95% confidence intervals.

Period	Plate	Weighting Scheme	Observed Longitude	Observed Latitude	Longitude CI Lower	Longitude CI Upper	Latitude CI Lower	Latitude CI Upper	Longitude CI Width (km)	Latitude CI Width (km)
1980–1994	Global	Unweighted	32.26609387	21.88897871	22.93896043	41.26502177	19.6603774	24.16872792	1889.72846	501.3057049
		Affected Population	57.44043056	24.35125126	-2.964808366	79.37608635	13.95553959	29.15088795	8195.277007	1689.645647
		Fatalities	32.81620604	29.99615279	-7.594805307	55.12463005	17.48667057	35.46256262	5957.58849	1998.827999
		Economic Loss	14.11777756	26.24971945	-15.04032985	32.67358298	11.31692822	36.89737885	4729.984238	2844.416331
	Pacific Plate	Unweighted	178.4017576	7.839212121	-12.00348106	82.77145076	0.711423485	15.14128561	10409.75737	1604.52746
		Affected Population	153.6107291	18.83732779	81.96192237	168.3438804	-5.142041978	36.57028954	8978.755517	4638.199643
		Fatalities	152.7089091	1.515037338	-30.67592616	135.4629394	-3.954964381	22.45511424	18437.57767	2936.666755
		Economic Loss	233.8667211	33.48140623	-120.8767729	128.2358257	-16.33373377	36.81109916	9648.610249	5909.4358
	Eurasian Plate	Unweighted	65.77835283	31.2477195	60.27002528	71.36537371	29.04470267	33.37909528	1054.325314	481.9624683
		Affected Population	81.76368833	28.28125452	58.04087466	89.18839199	25.92239594	35.76810184	3041.401695	1094.792545
		Fatalities	52.81885734	35.63473251	45.74165612	83.02891562	22.37171993	38.78606017	3349.053024	1825.191359
		Economic Loss	31.58192339	39.4846255	19.61561048	55.1790206	33.49745238	40.52243231	3031.809965	781.1421281
	American Plate	Unweighted	252.3555325	12.95987013	-65.13035844	-26.70447662	8.430391234	17.54477597	4159.825879	1013.473343
		Affected Population	270.4262489	0.377631742	-97.97093182	-64.03861243	-26.5217989	16.67056663	3773.017332	4802.771917
		Fatalities	263.9930901	12.20026908	-98.02192557	-23.42568011	1.366122125	18.67608743	8076.917233	1924.780322
		Economic Loss	250.2623452	11.19986535	-89.36516307	32.7673407	-7.659599181	25.76850734	13154.35296	3717.035852
	Indian Ocean Plate	Unweighted	92.36964706	9.685411765	73.78340441	112.6154471	-1.069238235	19.70200735	4253.966795	2309.657129
		Affected Population	48.96683778	17.83961144	45.66906951	85.25143088	9.603985753	24.49986438	4181.563244	1656.346132
		Fatalities	70.28033685	16.24382573	45.02485544	85.53958001	14.4202564	28.50134372	4317.803686	1565.745472
		Economic Loss	69.4979476	6.531014011	44.66443167	148.0791178	-30.71445764	25.30805856	11394.99546	6229.419578
	African Plate	Unweighted	15.61720833	16.4975	8.726330208	21.9086875	8.398378125	24.22979688	1405.215731	1760.373447
		Affected Population	5.996161132	30.17768832	1.163786439	28.22163901	1.828615819	34.92336725	2594.723114	3679.968457
		Fatalities	4.581501055	29.2842053	-5.594436565	23.19384969	6.438527807	35.06636587	2784.863949	3183.270354

Global	Economic Loss	23.41592867	9.873246942	1.725001645	30.24681085	0.350133514	36.07236794	3123.537448	3972.131237
	Unweighted Affected Population Fatalities	50.41466359	21.74727362	43.15938627	57.39433057	19.77856512	23.69968478	1469.675633	436.0086132
	Population Fatalities	87.38225763	25.73334311	61.91373624	97.37151873	16.91277049	29.31890375	3540.687861	1379.499077
	Economic Loss	86.79545791	17.98974556	69.23128324	95.23948627	7.587204455	30.01135041	2748.301792	2493.451265
	Unweighted Affected Population Fatalities	103.0794582	32.11239167	58.2195875	121.6133504	27.10706501	34.35073542	5876.836326	805.4593995
Pacific Plate	Economic Loss	154.2310962	0.494442308	21.47158173	117.5317644	-5.273086058	6.759165865	10680.87749	1337.92537
	Unweighted Affected Population Fatalities	134.7334654	9.530919213	69.78200893	134.2196918	-7.453135281	18.27866975	7054.60235	2861.246173
	Population Fatalities	134.0021564	8.958197684	-56.84903703	138.7678736	-10.38822167	22.17462052	17376.94852	3620.82285
	Economic Loss	123.6906545	23.49510894	-146.7145887	120.8487599	-9.947744097	27.89527214	9220.759864	4207.951415
	Unweighted Affected Population Fatalities	75.68708029	28.27082482	71.45271524	79.89900274	26.3435229	30.13743513	826.9888494	421.8637917
Eurasian Plate	Economic Loss	98.46925465	27.51970556	85.88517608	102.4144254	17.89780051	30.75902835	1628.791695	1430.103287
	Unweighted Affected Population Fatalities	88.2154555	17.82783771	70.35102404	96.83550394	6.980755025	31.13241558	2801.140962	2685.542124
	Economic Loss	103.565022	32.41825292	44.9791342	123.826711	24.49365113	34.98521366	7209.299661	1166.608526
	Unweighted Affected Population Fatalities	258.1700382	10.46834518	-62.53433033	-25.41411084	5.5575275	15.44478402	4056.436255	1099.412764
	Economic Loss	273.8825728	4.713740754	-83.35876996	-56.53982385	-4.905660969	12.64382588	2971.857007	1951.413903
American Plate	Economic Loss	229.259203	21.01639442	-80.88942254	93.75909498	-3.328824027	41.25851101	15305.22691	4957.885448
	Unweighted Affected Population Fatalities	159.8664391	34.11913172	-65.01926421	130.175696	14.69604169	37.12309598	12263.78871	2493.774657
	Economic Loss	78.43614286	20.36278571	64.38005	94.742825	13.89131071	25.70273929	3160.606893	1313.370934
	Unweighted Affected Population Fatalities	70.50985458	23.30929715	70.1952552	81.1242848	15.43653987	23.43789499	1115.800663	889.7100954
	Economic Loss	70.49048263	23.30780101	70.20232699	119.853413	3.547357338	23.43288555	5043.93021	2211.16985
Indian Ocean Plate	Economic Loss	70.40567741	23.34260501	70.232	80.0110648	-0.68	23.419	998.1916115	2679.686537
	Unweighted Affected Population Fatalities	22.88836364	5.461	15.98805227	28.69712159	-3.794084091	14.79175568	1406.743634	2066.65109
	Economic Loss	34.78882728	3.890053856	13.73822969	35.25243321	-6.181298756	15.90037456	2386.693207	2455.370045
	Unweighted Affected Population Fatalities	27.60690446	3.533194268	11.79338846	33.18097668	-5.017429037	13.32790228	2373.617911	2039.90777
	Economic Loss	20.82581798	20.7059424	-17.02676048	34.76621204	2.970943504	38.15816151	5362.464764	3912.640125
Global	Unweighted Affected Population Fatalities	57.76570579	20.71915907	49.89598444	65.44084448	18.61354897	22.76346594	1616.094979	461.4497126
	Economic Loss	46.79050076	22.64820223	23.82492363	72.53426857	10.38438398	29.87261451	4974.823635	2166.992364

1995–2009

Pacific Plate	Population	-26.78453931	23.40206745	-62.1541365	100.7175439	18.71995761	35.8294325	14491.61489	1902.486805
	Fatalities	95.32525702	26.21319119	24.43136294	126.2849886	3.616069099	35.32785265	9817.814606	3526.189446
	Economic Loss	142.5107467	2.047126668	103.726608	144.08849	-7.307886332	10.79388533	4485.047658	2012.825172
	Unweighted Affected Population	145.4604852	-8.871451741	115.8731507	161.7600833	-34.38377961	16.07164264	5037.935575	5610.386976
	Fatalities	143.3931411	-5.355408636	122.3813276	160.089012	-28.09695939	19.36806693	4173.915071	5277.87012
	Economic Loss	172.0079613	-36.46737033	84.04051588	171.8152005	-42.57297442	-5.696969509	7535.293302	4100.424661
	Unweighted Affected Population	79.8820605	27.50748193	75.53105792	84.2749888	25.50571512	29.4364393	862.1860953	437.0765869
	Fatalities	70.81112984	28.51109235	53.35070506	102.6757467	17.69785658	33.99080122	4783.663594	1811.692785
	Economic Loss	52.91954317	33.52085563	40.91169252	93.77350519	18.90602822	37.0117535	4844.2638	2013.264794
	Unweighted Affected Population	78.18347294	35.44926671	42.76770299	107.8887012	32.46653037	38.58180903	5782.903514	679.9879619
	Fatalities	259.5742859	8.222513132	-73.13067216	-37.80412765	3.220601769	13.08847503	3886.443592	1097.257443
	Economic Loss	277.4516184	1.063317502	-84.11730283	-48.47440721	-19.98635728	16.71212932	3962.603784	4080.685526
Indian Ocean Plate	Population	275.6788722	19.85442033	-81.22407976	133.1354688	-2.702564378	36.82813683	14227.12153	4395.613421
	Fatalities	169.3770114	28.0782889	-74.97720434	136.2206661	-21.79155995	37.62746775	12941.03772	6607.094427
	Economic Loss	108.8749333	8.186333333	91.37925333	127.09844	-3.130688333	18.5729	3929.978894	2413.328913
	Unweighted Affected Population	87.86049031	21.64233094	74.77137574	146.1100508	-20.66426717	31.58434074	7298.810932	5809.780123
	Fatalities	100.964539	16.90123404	81.62340234	127.8037161	-0.163897322	27.43886017	4901.280284	3069.286594
	Economic Loss	118.7063381	3.108077422	77.74384539	170.7800054	-38.77010971	31.00097179	10325.40162	7758.19029
	Unweighted Affected Population	25.14811429	1.283585714	12.60885714	34.53954286	-11.50382857	14.81415714	2437.961492	2926.426491
	Fatalities	-2.150202709	26.27636165	-8.30930221	41.80202996	-14.60793157	30.96811254	4963.177164	5067.824881
	Economic Loss	-8.05273349	30.78999431	-8.362937148	31.53026429	-6.618072727	31.03691848	3789.795423	4187.043985
	Unweighted Affected Population	-5.316994668	28.75548129	-8.385	31.618	1.036	31.058	3880.577768	3338.294088
	Fatalities								
	Economic Loss								

Table S7. Comparison of centroid displacements between two periods derived from permutation tests and bootstrap confidence intervals.

Plate	Period Comparison	Weighting Scheme	Centroid 1 Longitude	Centroid 1 Latitude	Centroid 2 Longitude	Centroid 2 Latitude	Observed Displacement (km)	Permutation Test p-value	Significance	Displacement CI Lower (km)	Displacement CI Upper (km)
Global	P1→P2	Unweighted	32.26609387	21.88897871	50.41466359	21.74727362	1872.448516	0.0024	**	692.6372632	3086.591914
		Affected Population	57.44043056	24.35125126	87.38225763	25.73334311	3013.914955	0.1879	ns	447.6907522	9218.586631
		Fatalities	32.81620604	29.99615279	86.79545791	17.98974556	5592.701296	0.0024	**	2679.78106	9861.588209
		Economic Loss	14.11777756	26.24971945	103.0794582	32.11239167	8405.111343	0.0024	**	4204.684443	11168.81201
	P2→P3	Unweighted	50.41466359	21.74727362	57.76570579	20.71915907	770.3550626	0.1767	ns	124.3245291	1841.20536
		Affected Population	87.38225763	25.73334311	46.79050076	22.64820223	4115.682995	0.0474	*	921.4888002	6698.775007
		Fatalities	86.79545791	17.98974556	-26.78453931	23.40206745	11463.25152	0.0259	*	1092.949529	14966.91748
		Economic Loss	103.0794582	32.11239167	95.32525702	26.21319119	998.0052773	0.8334	ns	294.8136731	8442.054468
	P1→P2	Unweighted	178.4017576	7.839212121	154.2310962	0.494442308	2800.312501	0.5062	ns	848.2288112	4887.893178
		Affected Population	153.6107291	18.83732779	134.7334654	9.530919213	2280.172999	0.9683	ns	712.9268582	5174.544531
		Fatalities	152.7089091	1.515037338	134.0021564	8.958197684	2229.176311	0.9093	ns	218.9833801	7253.258662
		Economic Loss	233.8667211	33.48140623	123.6906545	23.49510894	10287.26267	0.6354	ns	1042.192077	10567.38812
Pacific Plate	P2→P3	Unweighted	154.2310962	0.494442308	142.5107467	2.047126668	1314.271353	0.7611	ns	286.020424	3145.004196
		Affected Population	134.7334654	9.530919213	145.4604852	-8.871451741	2365.920912	0.5396	ns	411.9095252	6176.847924
		Fatalities	134.0021564	8.958197684	143.3931411	-5.355408636	1901.798386	0.9161	ns	194.4493754	5873.291305
		Economic Loss	123.6906545	23.49510894	172.0079613	-36.46737033	8374.674452	0.1041	ns	3010.573193	9070.522572
Eurasian Plate	P1→P2	Unweighted	65.77835283	31.2477195	75.68708029	28.27082482	1011.671716	0.008	**	321.9212743	1711.068547
		Affected Population	81.76368833	28.28125452	98.46925465	27.51970556	1642.533478	0.0725	ns	425.905128	3973.943388
		Fatalities	52.81885734	35.63473251	88.2154555	17.82783771	4002.336008	0.0194	*	940.7858008	5423.256402
		Economic Loss	31.58192339	39.4846255	103.565022	32.41825292	6355.103105	0.1222	ns	987.4908278	8231.824629
	P2→P3	Unweighted	75.68708029	28.27082482	79.8820605	27.50748193	420.9046036	0.2188	ns	75.03776979	1054.892851

American Plate	P1→P2	Affected Population	98.46925465	27.51970556	70.81112984	28.51109235	2711.326357	0.1539	ns	475.8973561	4398.449142
		Fatalities	88.2154555	17.82783771	52.91954317	33.52085563	3917.488865	0.0419	*	457.3583154	5679.345031
		Economic Loss	103.565022	32.41825292	78.18347294	35.44926671	2359.123738	0.5728	ns	313.8731895	6005.084792
		Unweighted	252.3555325	12.95987013	258.1700382	10.46834518	690.9818944	0.6982	ns	122.4129395	2516.899439
	P2→P3	Affected Population	270.4262489	0.377631742	273.8825728	4.713740754	616.2919668	0.9593	ns	280.0415265	3926.555125
		Fatalities	263.9930901	12.20026908	229.259203	21.01639442	3819.581532	0.5118	ns	384.3678689	9661.75765
		Economic Loss	250.2623452	11.19986535	159.8664391	34.11913172	9348.010759	0.4854	ns	974.4947663	12457.53405
		Unweighted	258.1700382	10.46834518	259.5742859	8.222513132	293.4241535	0.9302	ns	127.0894104	2200.461635
Indian Ocean Plate	P1→P2	Affected Population	273.8825728	4.713740754	277.4516184	1.063317502	567.2792806	0.9816	ns	254.7799017	3316.697561
		Fatalities	229.259203	21.01639442	275.6788722	19.85442033	4821.312227	0.6476	ns	1150.249177	12756.491
		Economic Loss	159.8664391	34.11913172	169.3770114	28.0782889	1126.544116	0.9376	ns	217.7844363	13846.03067
		Unweighted	92.36964706	9.685411765	78.43614286	20.36278571	1907.90478	0.2493	ns	374.7284836	4846.588092
	P2→P3	Affected Population	48.9683778	17.83961144	70.50985458	23.30929715	2320.920772	0.068	ns	1126.393305	3627.333005
		Fatalities	70.28033685	16.24382573	70.49048263	23.30780101	785.7853974	0.9055	ns	460.1365917	6614.790554
		Economic Loss	69.4979476	6.531014011	70.40567741	23.34260501	1871.883641	0.775440705	ns	923.6422005	9618.607071
		Unweighted	78.43614286	20.36278571	108.8749333	8.186333333	3539.494598	0.0224	*	904.5545064	6306.8588
African Plate	P1→P2	Affected Population	70.50985458	23.30929715	87.86049031	21.64233094	1791.272218	0.1535	ns	702.9252511	9306.99952
		Fatalities	70.49048263	23.30780101	100.964539	16.90123404	3254.131605	0.4764	ns	620.5966927	6449.37216
		Economic Loss	70.40567741	23.34260501	118.7063381	3.108077422	5654.206239	0.317285557	ns	1113.315702	11994.9557
		Unweighted	15.61720833	16.4975	22.88836364	5.461	1460.757264	0.0883	ns	273.2515472	2992.868408
	P2→P3	Affected Population	5.996161132	30.17768832	34.78882728	3.890053856	4205.274632	0.3206	ns	741.8097098	5052.059967
		Fatalities	4.581501055	29.2842053	27.60690446	3.533194268	3754.366725	0.0297	*	1256.853038	4860.075544
		Economic Loss	23.41592867	9.873246942	20.82581798	20.7059424	1236.048549	0.9318	ns	292.8492678	5137.084701
		Unweighted	22.88836364	5.461	25.14811429	1.283585714	527.8810157	0.8041	ns	171.2846769	2667.009524
	P2→P3	Affected Population	34.78882728	3.890053856	-2.150202709	26.27636165	4651.844097	0.2274	ns	486.3836265	5473.420964
		Fatalities	27.60690446	3.533194268	-8.05273349	30.78999431	4810.840699	0.4984	ns	239.2562167	5513.418579

Economic Loss	20.82581798	20.7059424	-5.316994668	28.75548129	2780.672924	0.659326425	ns	499.187849	5495.965583
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Notes: $P1 = 1980-1994$, $P2 = 1995-2009$, $P3 = 2010-2024$; n.s. = not significant; * $p < 0.05$, ** $p < 0.01$.

Table S8. Sensitivity analysis of earthquake impact centroid displacement after removing five catastrophic earthquake disasters.

Plate	Period Comparison	Weighting Scheme	Original (km)	After Removal (km)	Change Rate (%)	Original Significance	After Removal Significance	Events Removed
Global	P1→P2	Unweighted	1872.4	1846.1	1.4	**	**	Sumatra–Andaman, 2008 Wenchuan 2004
		Affected Population	3013.9	1118.7	62.9	ns	ns	Sumatra–Andaman, 2008 Wenchuan 2004
		Fatalities	5592.7	3382.9	39.5	**	*	Sumatra–Andaman, 2008 Wenchuan 2004
		Economic Loss	8405.1	5682	32.4	**	*	Sumatra–Andaman, 2008 Wenchuan 2004
	P2→P3	Unweighted	770.4	907.1	−17.7	ns	ns	Sumatra–Andaman, 2008 Wenchuan 2010 Haiti, 2011 Tōhoku, 2023 Turkey–Syria
		Affected Population	4115.7	990.2	75.9	*	ns	2010 Haiti, 2011 Tōhoku, 2023 Turkey–Syria
		Fatalities	11463.3	2550.7	77.7	*	ns	2010 Haiti, 2011 Tōhoku, 2023 Turkey–Syria
		Economic Loss	998	1801	−80.5	ns	ns	2010 Haiti, 2011 Tōhoku, 2023 Turkey–Syria
		Unweighted	2800.3	2263.2	19.2	ns	ns	Sumatra–Andaman, 2008 Wenchuan 2004
		Fatalities	2229.2	3513.7	−57.6	ns	ns	Sumatra–Andaman, 2008 Wenchuan 2010 Haiti, 2011 Tōhoku, 2023 Turkey–Syria
		Fatalities	1901.8	3330.2	−75.1	ns	ns	2010 Haiti, 2011 Tōhoku, 2023 Turkey–Syria
Pacific Plate	P1→P2	Unweighted	2800.3	2263.2	19.2	ns	ns	Sumatra–Andaman, 2008 Wenchuan 2004
	P2→P3	Fatalities	2229.2	3513.7	−57.6	ns	ns	Sumatra–Andaman, 2008 Wenchuan 2010 Haiti, 2011 Tōhoku, 2023 Turkey–Syria

Eurasian Plate	P1→P2	Unweighted	1011.7	992.6	1.9	**	**	2004 Sumatra–Andaman, 2008 Wenchuan
		Fatalities	4002.3	2636.1	34.1	*	ns	2004 Sumatra–Andaman, 2008 Wenchuan
	P2→P3	Economic Loss	6355.1	1567.9	75.3	ns	ns	2004 Sumatra–Andaman, 2008 Wenchuan
		Fatalities	3917.5	1468	62.5	*	ns	2010 Haiti, 2011 Tōhoku, 2023 Turkey–Syria
		Affected Population	2711.3	1066.6	60.7	ns	ns	2010 Haiti, 2011 Tōhoku, 2023 Turkey–Syria
American Plate	P1→P2	Unweighted	691	642.9	7	ns	ns	2004 Sumatra–Andaman, 2008 Wenchuan
	P2→P3	Unweighted	293.4	602.3	−105.2	ns	ns	2010 Haiti, 2011 Tōhoku, 2023 Turkey–Syria
Indian Ocean Plate	P1→P2	Unweighted	1907.9	1801.9	5.6	ns	ns	2004 Sumatra–Andaman, 2008 Wenchuan
	P2→P3	Unweighted	3539.5	2762.3	22	*	ns	2010 Haiti, 2011 Tōhoku, 2023 Turkey–Syria
African Plate	P1→P2	Affected Population	4205.3	861.9	79.5	ns	ns	2004 Sumatra–Andaman, 2008 Wenchuan
		Fatalities	3754.4	1830.6	51.2	*	ns	2004 Sumatra–Andaman, 2008 Wenchuan
		Economic Loss	1236	4497.7	−263.9	ns	*	2004 Sumatra–Andaman, 2008 Wenchuan

Notes: P1 = 1980–1994, P2 = 1995–2009, and P3 = 2010–2024. n.s. indicates not significant; * and ** indicate significance levels of $p < 0.05$ and $p < 0.01$, respectively. The sensitivity analysis was conducted by excluding five catastrophic earthquake disasters: the 2004 Sumatra–Andaman earthquake and Indian Ocean tsunami, the 2008 Wenchuan earthquake, the 2010 Haiti earthquake, the 2011 Great East Japan earthquake and tsunami, and the 2023 Türkiye–Syria earthquake.

Table S9. Optimal discretization schemes for explanatory variables in the Geodetector model.

Variable	Type	Discretization method	Strata (k)	Actual strata	Breakpoints / Categories
Magnitude	Continuous	Equal interval	9	9	3.50, 4.17, 4.83, 5.50, 6.17, 6.83, 7.50, 8.17, 8.83
Focal depth	Continuous	Quantile	9	9	5.0, 10.0, 15.0, 20.0, 30.0, 42.0, 68.0, 96.0, 236.0 (km)
GDP per capita	Continuous	Quantile	8	8	373.38, 933.84, 1656.55, 2685.85, 4381.42, 7781.21, 17352.03, 59885.71(USD)
Population density	Continuous	Quantile	11	11	4.15, 7.13, 11.35, 17.45, 26.15, 38.92, 58.86, 94.52, 152.38, 258.44, 1090.12(people/km ²)
Tectonic setting	Categorical	Not applicable (original categories)	—	6	Craton/Shield, Orogenic belt, Subduction-related, Rift system, Basin system, Oceanic crust
Seismotectonic type	Categorical	Not applicable (original categories)	—	4	Shallow crustal, Subduction zone, Intraplate, Megathrust
Disaster process type	Categorical (binary)	Not applicable (original categories)	—	2	Pure earthquake (0), Associated disaster (1)

Notes: Actual strata may differ from predefined strata numbers when identical break values occur during classification. Categorical variables were retained using their original categories without further discretization.

Table S10. Comparison of discretization methods for continuous explanatory variables in the Geodetector model.

Variable	Method	Optimal k	q (Deaths)	q (Loss)	Mean q	CV (%)	Rank
Magnitude	Equal interval	9	0.1687	0.188	0.1784	3.17	1
	Natural breaks	9	0.1648	0.1882	0.1765	6.76	2
	Quantile	10	0.1471	0.1709	0.159	11.16	3
	Standard deviation	10	0.1471	0.1709	0.159	11.16	3
Focal depth	Quantile	9	0.0408	0.0544	0.0476	2.73	1
	Standard deviation	9	0.0408	0.0544	0.0476	2.73	1
	Natural breaks	9	0.0202	0.0293	0.0248	3.57	3
	Equal interval	10	0.0106	0.0138	0.0122	9.59	4
GDP per capita	Quantile	8	0.0282	0.0662	0.0472	10.47	1
	Standard deviation	8	0.0282	0.0662	0.0472	54.71	2
	Natural breaks	10	0.0293	0.0526	0.041	9.88	3
	Equal interval	10	0.0154	0.0368	0.0261	22.45	4
Population density	Natural breaks	11	0.045	0.1422	0.0936	17.24	1
	Equal interval	12	0.0304	0.1292	0.0798	0.91	2
	Standard deviation	12	0.0139	0.058	0.0359	0.61	3
	Quantile	11	0.0373	0.0267	0.032	4.36	4

Notes: CV (coefficient of variation) is calculated as the standard deviation of q-statistics within the optimal $k \pm 1$ range, divided by the mean, expressed as a percentage. A $CV < 15\%$ indicates robustness to small changes in strata number. Rank is determined by Mean q in descending order; for ties, the method with lower CV is ranked higher.

Table S11. Comprehensive Multimodality Test Results by Variable and Period.

Variable	Period	N	KDE Modes	GMM Best K	Conclusion
Latitude	Overall (1980–2024)	1068	2	2	Multimodal
	1980–1994	310	1	2	Multimodal
	1995–2009	410	2	5	Multimodal
	2010–2024	348	2	5	Multimodal
Longitude	Overall (1980–2024)	1068	2	5	Multimodal
	1980–1994	310	2	4	Multimodal
	1995–2009	410	2	5	Multimodal
	2010–2024	348	2	3	Multimodal
Log(Economic Loss)	Overall (1980–2024)	1068	2	2	Multimodal
	1980–1994	310	2	5	Multimodal
	1995–2009	410	2	2	Multimodal
	2010–2024	348	2	2	Multimodal
Log(Fatalities)	Overall (1980–2024)	1068	1	5	Unimodal
	1980–1994	310	1	5	Unimodal
	1995–2009	410	1	4	Multimodal
	2010–2024	348	1	5	Unimodal
Log(Affected Population)	Overall (1980–2024)	1068	2	3	Multimodal
	1980–1994	310	2	3	Multimodal
	1995–2009	410	2	3	Multimodal
	2010–2024	348	1	1	Unimodal

Table S12. Results of single-factor and interaction detectors for earthquake disaster impacts based on permutation tests.

Response variable	Variable/Variable pair	Observed q	p-value	Sig.
Fatalities per million	Magnitude×Population density	0.326	<0.001	***
	Magnitude×GDP per capita	0.2683	<0.001	***
	Magnitude×Focal depth	0.2581	<0.001	***
	Magnitude×Tectonic setting	0.2518	<0.001	***
	GDP per capita×Population density	0.2225	<0.001	***
	Tectonic setting×Population density	0.2225	<0.001	***
	Magnitude×Seismotectonic type	0.2048	<0.001	***
	Magnitude×Disaster process type	0.1915	<0.001	***
	Focal depth×Population density	0.1837	<0.001	***
	Disaster process type×Population density	0.1766	<0.001	***
	Magnitude	0.1687	<0.001	***
	GDP per capita×Seismotectonic type	0.1591	<0.001	***
	Focal depth×GDP per capita	0.1463	0.009	**
	Focal depth×Seismotectonic type	0.1283	<0.001	***
	Tectonic setting×Seismotectonic type	0.1243	<0.001	***
	Focal depth×Tectonic setting	0.1166	0.003	**
	Seismotectonic type×Population density	0.1147	<0.001	***
	Seismotectonic type×Disaster process type	0.1135	<0.001	***
	GDP per capita×Tectonic setting	0.1069	0.033	*
	GDP per capita×Disaster process type	0.1043	<0.001	***
	Tectonic setting×Disaster process type	0.098	<0.001	***
	Focal depth×Disaster process type	0.0851	0.001	**
	Seismotectonic type	0.0804	<0.001	***
	Disaster process type	0.0452	<0.001	***
	Population density	0.045	<0.001	***
	Focal depth	0.0408	<0.001	***
	Tectonic setting	0.0318	<0.001	***
	GDP per capita	0.0282	0.007	**
	GDP per capita×Population density	0.5317	<0.001	***
	Tectonic setting×Population density	0.4726	<0.001	***
	Focal depth×Population density	0.3347	<0.001	***
	Magnitude×Focal depth	0.3009	<0.001	***
	Magnitude×GDP per capita	0.2974	<0.001	***
	Magnitude×Population density	0.2911	<0.001	***
	Seismotectonic type×Population density	0.2812	<0.001	***
	Magnitude×Tectonic setting	0.2626	<0.001	***
	Magnitude×Seismotectonic type	0.2235	<0.001	***
	Magnitude×Disaster process type	0.2142	<0.001	***
	GDP per capita×Seismotectonic type	0.2132	<0.001	***
	Disaster process type×Population density	0.2031	<0.001	***
Loss/GDP	Focal depth×GDP per capita	0.1888	0.001	**
	Magnitude	0.188	<0.001	***
	Focal depth×Seismotectonic type	0.1662	<0.001	***
	Focal depth×Tectonic setting	0.1586	<0.001	***
	GDP per capita×Tectonic setting	0.1543	0.001	**
	Seismotectonic type×Disaster process type	0.1508	<0.001	***
	Tectonic setting×Seismotectonic type	0.1456	<0.001	***
	Population density	0.1422	<0.001	***
	GDP per capita×Disaster process type	0.1398	<0.001	***
	Seismotectonic type	0.1204	<0.001	***
	Focal depth×Disaster process type	0.1044	<0.001	***
	Tectonic setting×Disaster process type	0.0935	<0.001	***
	GDP per capita	0.0662	<0.001	***
	Focal depth	0.0544	0.002	**
	Disaster process type	0.0475	<0.001	***
	Tectonic setting	0.0459	<0.001	***

Notes: Sig.: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Table S13. Results of the interaction detector for the spatial differentiation of log-transformed earthquake mortality (log(Deaths per million + 1)).

Factor 1	Factor 2	q(F1)	q(F2)	q(Interaction)	p-value	Sig.	Interaction type	n
Magnitude	Population density	0.1687	0.045	0.326	<0.001	***	Nonlinear enhancement	695
Magnitude	GDP per capita	0.1687	0.0282	0.2683	<0.001	***	Nonlinear enhancement	683
Magnitude	Focal depth	0.1687	0.0408	0.2581	<0.001	***	Nonlinear enhancement	695
Magnitude	Tectonic setting	0.1687	0.0318	0.2518	<0.001	***	Nonlinear enhancement	688
GDP per capita	Population density	0.0282	0.045	0.2225	<0.001	***	Nonlinear enhancement	686
Focal depth	Population density	0.0318	0.045	0.2225	<0.001	***	Nonlinear enhancement	698
Population density	Seismotectonic type	0.045	0.0804	0.1147	<0.001	***	Nonlinear enhancement	698
Magnitude	Seismotectonic type	0.1687	0.0804	0.2048	<0.001	***	Bivariate enhancement	695
Population density	Tectonic setting	0.045	0.0318	0.2225	<0.001	***	Nonlinear enhancement	691
Magnitude	Disaster process type	0.1687	0.0452	0.1915	<0.001	***	Bivariate enhancement	695
Population density	Disaster process type	0.045	0.0452	0.1766	<0.001	***	Bivariate enhancement	698
GDP per capita	Seismotectonic type	0.0282	0.0804	0.1591	<0.001	***	Nonlinear enhancement	686
Focal depth	GDP per capita	0.0408	0.0282	0.1463	0.009	**	Nonlinear enhancement	686
Focal depth	Seismotectonic type	0.0408	0.0804	0.1283	<0.001	***	Nonlinear enhancement	698
Tectonic setting	Seismotectonic type	0.0318	0.0804	0.1243	<0.001	***	Nonlinear enhancement	691
Focal depth	Tectonic setting	0.0408	0.0318	0.1166	0.003	**	Nonlinear enhancement	691
Seismotectonic type	Disaster process type	0.0804	0.0452	0.1135	<0.001	***	Bivariate enhancement	698
GDP per capita	Tectonic setting	0.0282	0.0318	0.1069	0.033	*	Nonlinear enhancement	680
GDP per capita	Disaster process type	0.0282	0.0452	0.1043	<0.001	***	Nonlinear enhancement	686
Tectonic setting	Disaster process type	0.0318	0.0452	0.098	<0.001	***	Nonlinear enhancement	691
Focal depth	Disaster process type	0.0408	0.0452	0.0851	0.001	**	Bivariate enhancement	698

Notes: Sig.: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Table S14. Results of the interaction detector for the spatial differentiation of log-transformed earthquake economic loss ($\log(\text{Loss}/\text{GDP ratio} + 0.001)$).

Factor 1	Factor 2	q(F1)	q(F2)	q(Interaction)	p-value	Sig.	Interaction type	n
Magnitude	Population density	0.188	0.1422	0.2911	<0.001	***	Bivariate enhancement	444
GDP per capita	Population density	0.0662	0.1422	0.5317	<0.001	***	Nonlinear enhancement	445
Focal depth	Population density	0.0544	0.1422	0.3347	<0.001	***	Nonlinear enhancement	445
Population density	Seismotectonic type	0.1422	0.1204	0.2812	<0.001	***	Bivariate enhancement	445
Population density	Tectonic setting	0.1422	0.0459	0.4726	<0.001	***	Bivariate enhancement	441
Population density	Disaster process type	0.1422	0.0475	0.2031	<0.001	***	Bivariate enhancement	445
Magnitude	Focal depth	0.188	0.0544	0.3009	<0.001	***	Nonlinear enhancement	444
Magnitude	GDP per capita	0.188	0.0662	0.2974	<0.001	***	Nonlinear enhancement	444
Magnitude	Tectonic setting	0.188	0.0459	0.2626	<0.001	***	Nonlinear enhancement	440
Magnitude	Seismotectonic type	0.188	0.1204	0.2235	<0.001	***	Bivariate enhancement	444
Magnitude	Disaster process type	0.188	0.0475	0.2142	<0.001	***	Bivariate enhancement	444
GDP per capita	Seismotectonic type	0.0662	0.1204	0.2132	<0.001	***	Nonlinear enhancement	445
Focal depth	GDP per capita	0.0544	0.0662	0.1888	0.001	**	Nonlinear enhancement	445
Focal depth	Seismotectonic type	0.0544	0.1204	0.1662	<0.001	***	Bivariate enhancement	445
Focal depth	Tectonic setting	0.0544	0.0459	0.1586	<0.001	***	Nonlinear enhancement	441
GDP per capita	Tectonic setting	0.0662	0.0459	0.1543	0.001	**	Nonlinear enhancement	441
Seismotectonic type	Disaster process type	0.1204	0.0475	0.1508	<0.001	***	Bivariate enhancement	445
Tectonic setting	Seismotectonic type	0.0459	0.1204	0.1456	<0.001	***	Bivariate enhancement	441
GDP per capita	Disaster process type	0.0662	0.0475	0.1398	<0.001	***	Nonlinear enhancement	445
Focal depth	Disaster process type	0.0544	0.0475	0.1044	<0.001	***	Nonlinear enhancement	445
Tectonic setting	Disaster process type	0.0459	0.0475	0.0935	<0.001	***	Nonlinear enhancement	441

Notes: Sig.: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Table S15. Sensitivity analysis of normalized earthquake impact indicators across nested magnitude thresholds (Mw $\geq$ 5.0, 6.0, and 7.0).

Indicator	Statistic	Mw $\geq$ 5.0	Mw $\geq$ 6.0	Mw $\geq$ 7.0
Sample size (n)	n	997	614	226
	Mean	5566.51	8275.97	18538.82
	SD	27461.28	34018.7	53616.9
Affected population per million	Median	121.1571	216.1847	883.0141
	Q1	17.5623	27.671	91.4264
	Q3	939.9591	1936.6073	6275.4763
	Relative change in mean (%)	100	148.7	333
	Relative change in median (%)	100	178.4	728.8
	Mean	51.2	74.19	183.73
Deaths per million population	SD	880.85	1064.21	1712.48
	Median	0.1473	0.1949	0.5643
	Q1	0.0235	0.0301	0.0636
	Q3	0.8987	2.1685	13.1549
	Relative change in mean (%)	100	144.9	358.9
	Relative change in median (%)	100	132.3	383
Economic loss per unit GDP (%)	Mean	2.02	2.72	5.14
	SD	9.37	11.03	16
	Median	0.0218	0.0505	0.1815
	Q1	0.004	0.0058	0.0178
	Q3	0.2537	0.5022	2.735
	Relative change in mean (%)	100	134.3	254.4
	Relative change in median (%)	100	231.4	832.8

Notes: Q1 and Q3 denote the 25th and 75th percentiles, respectively.