# Supplementary information for:

# Global Socio-economic Resilience to Natural Disasters

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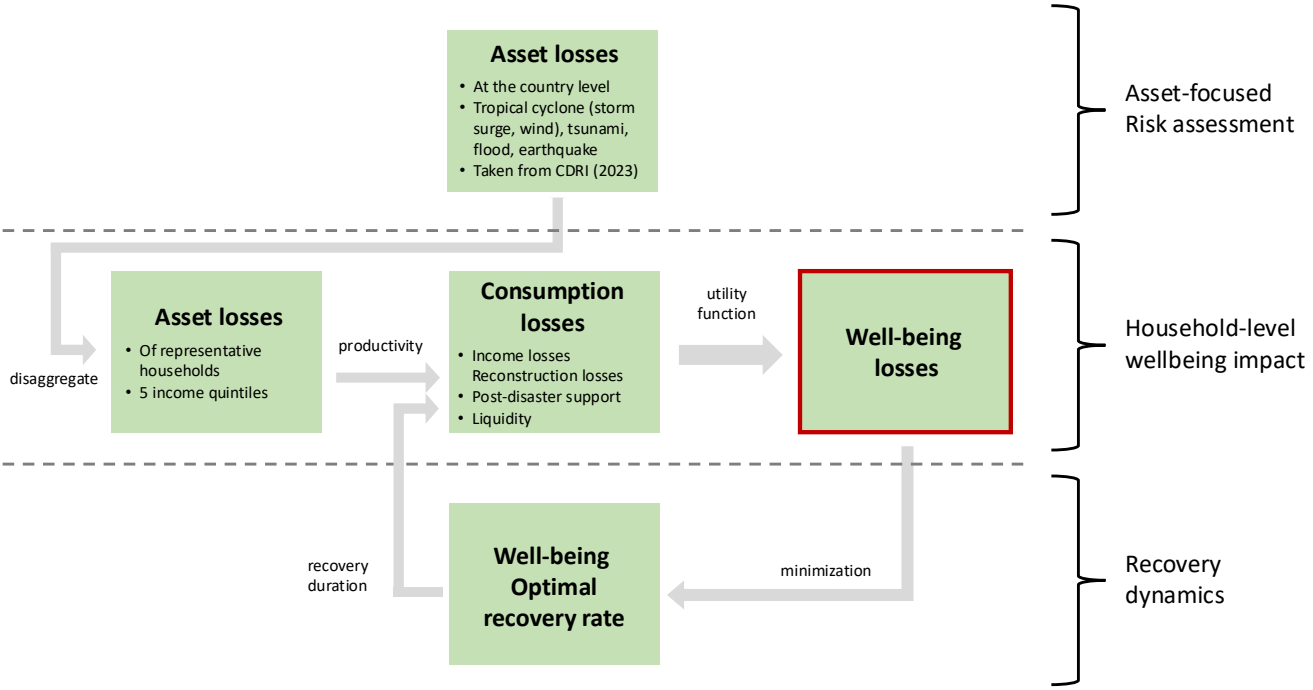
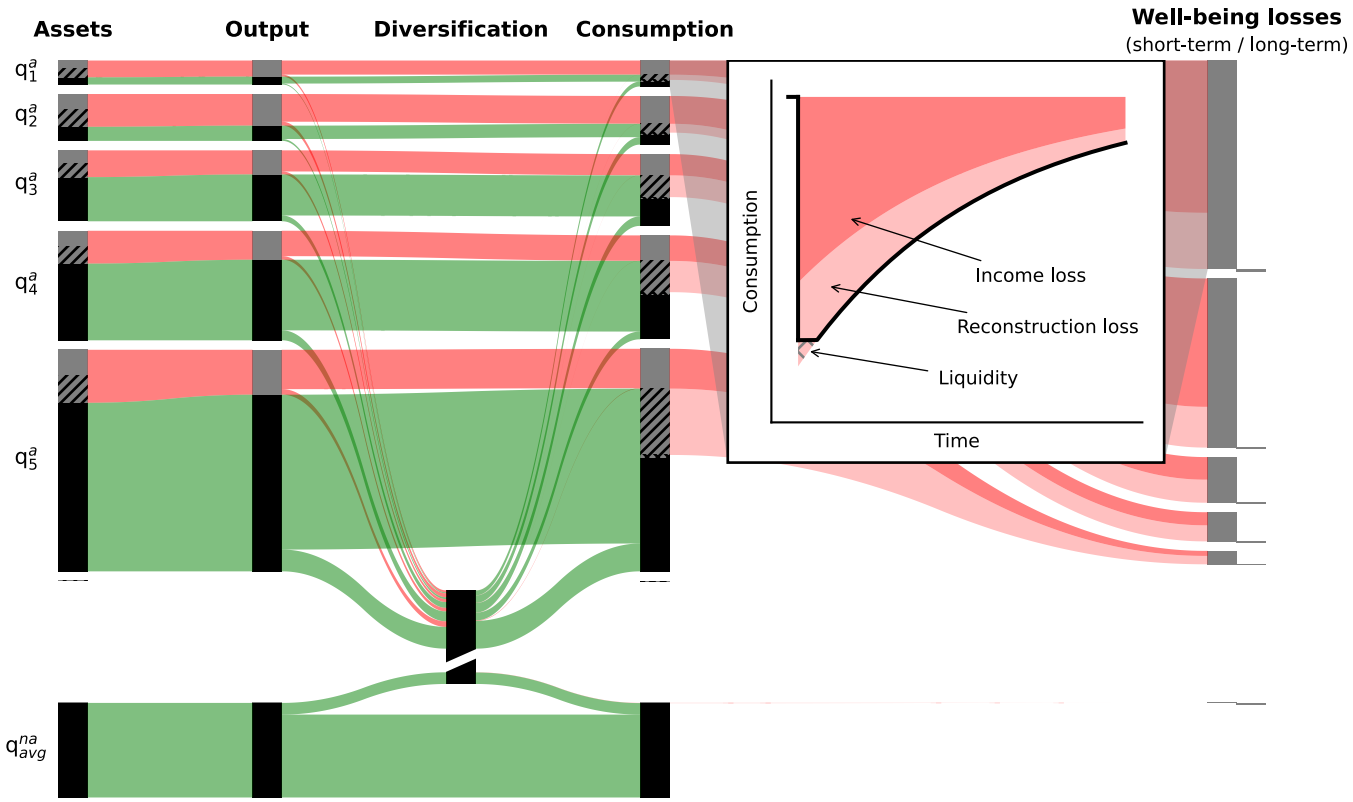
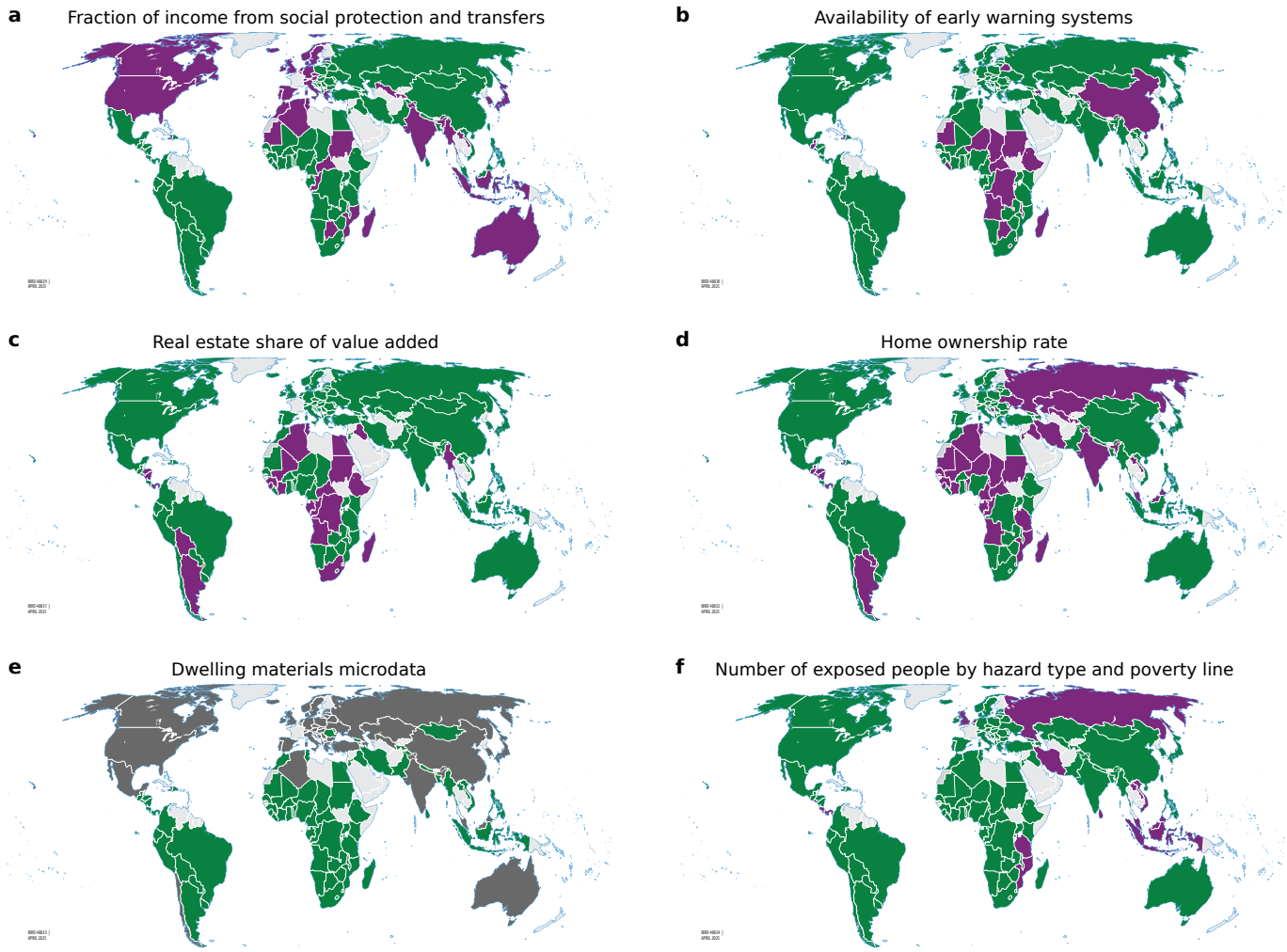
## Supplementary figures



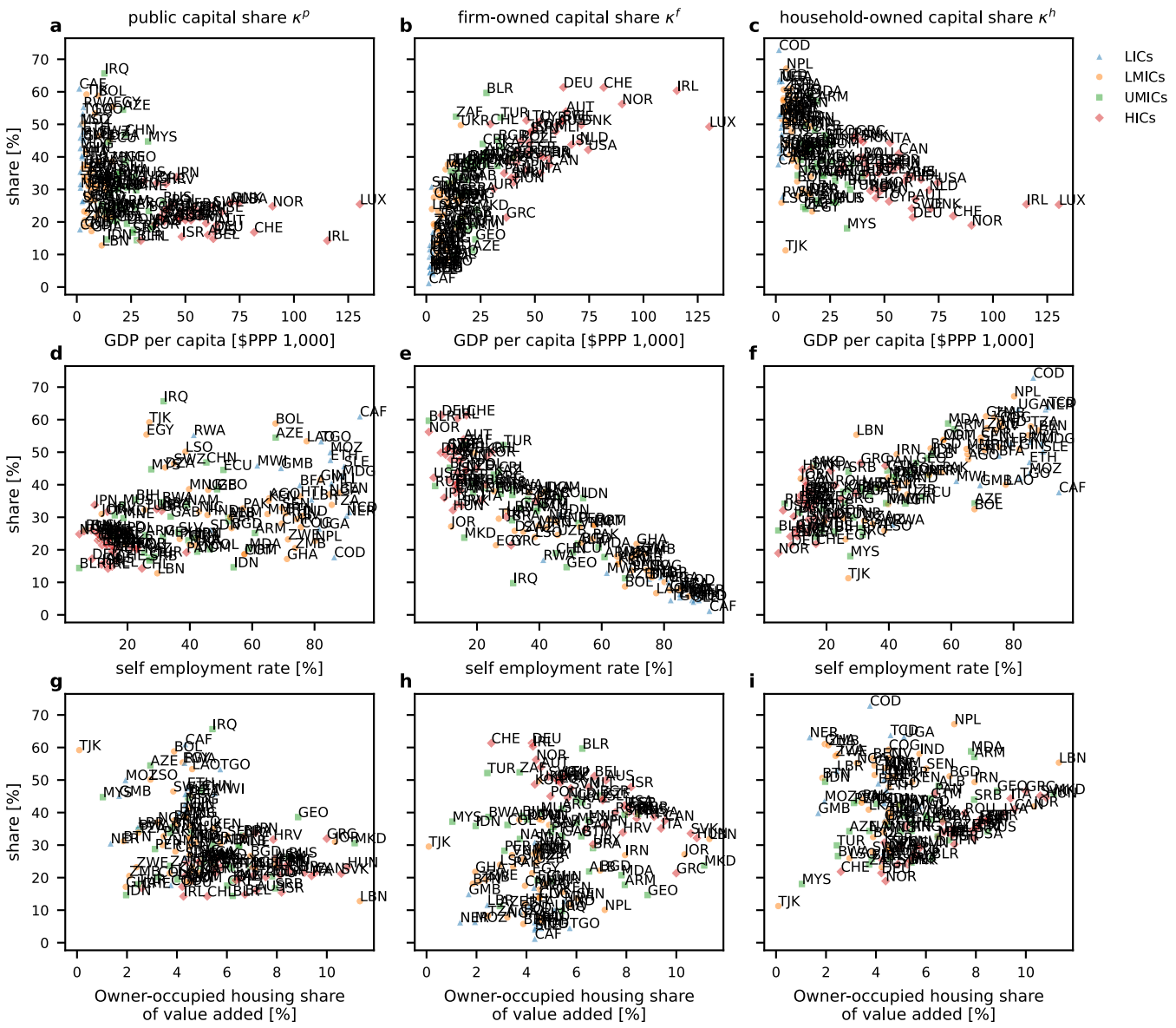

**Supplementary Figure 1: Modeling approach.** The approach expands on asset-focused risk assessments by accounting for socio-economic disparities and the temporal component of recovery dynamics. Asset losses at the national level are disaggregated into household asset losses per income quintile. From these asset losses, we derive decreases in consumption and well-being. Assuming rational households, we optimize for the recovery duration that minimizes well-being losses of each household.



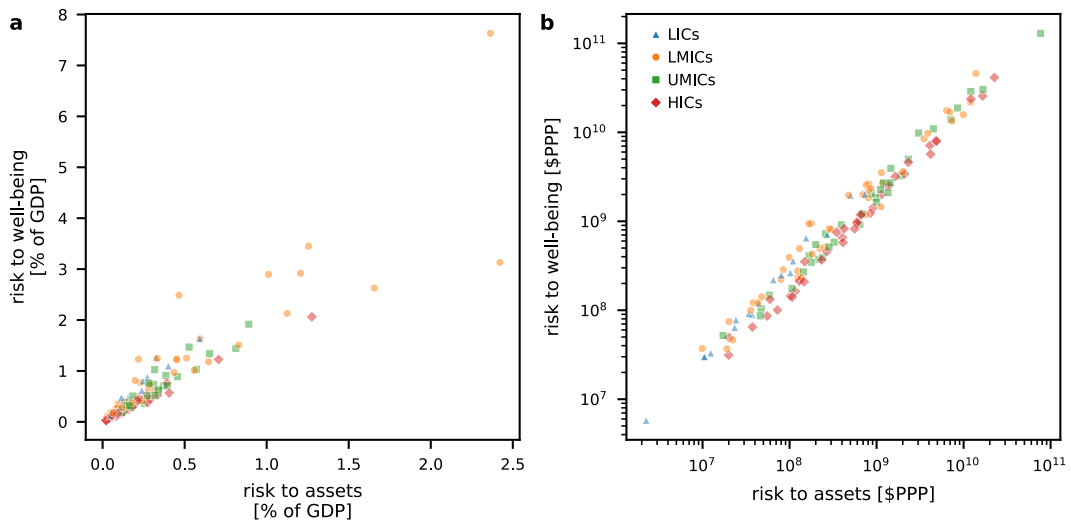

**Supplementary Figure 2: Illustration of loss and income flows in the model.** Example assets and aggregated output, consumption from labor and diversified income and their losses are shown, as well as the resulting well-being losses. Quantities are shown for individual affected households in each income quintile, as well as an average non-affected household. Flows (i.e. output, diversified income, and consumption) are aggregated over the time until all households have recovered. Total bar heights denote values in the absence of a disaster, grey bars are losses that occur due to the disaster. Diagonally hatched areas denote losses of assets owned directly by the households (as experienced right after the disaster) and the resulting aggregated consumption losses to pay for their reconstruction. Cross-hatched areas denotes used liquidity to offset consumption losses. Note that bar heights can be compared only within the same column. For example, pre-disaster assets of a q1 household are worth about half the pre-disasters assets of a q2 household, but not equal to the pre-disaster output of a q1 household. The flow of the model is as follows. When a share of each affected household's assets gets destroyed (according to the households vulnerability) by a disaster, this causes output losses which reduce both the income from labor (for affected households only) and diversified income (all households). The consumption of affected households is further decreased by reconstruction payments, and consumption losses persist until recovery is completed. Over time, dynamic (i.e., short-term) well-being losses aggregate. In addition to these short-term well-being losses, the reconstruction of public and firm-owned assets, the replenishing of used liquidity as well as potential disaster aid payments cause long-term well-being losses.



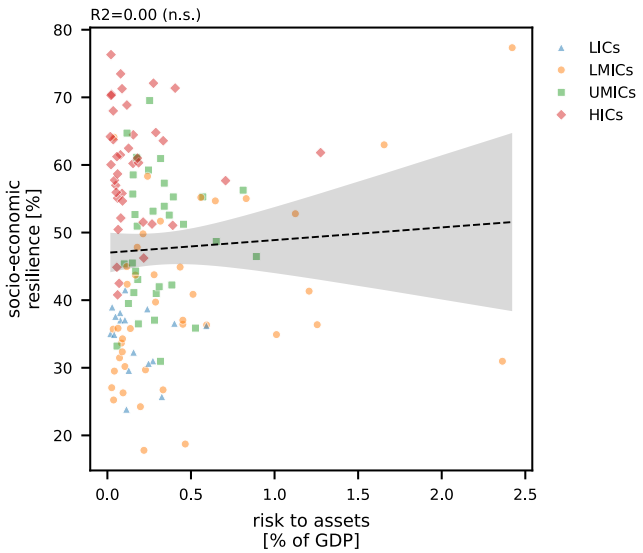

**Supplementary Figure 3: Data coverage.** Data is available for countries in green and was imputed for countries in purple. Only data with incomplete coverage is shown. **(a)** Fraction of income from social protection and transfers $\gamma_q^{sp,pt}$ from ref[1], **(b)** availability of early warning systems $q_{EW}$ from refs[2,3], **(c)** real-estate share of value added from ref[4], **(d)** home ownership rate $\gamma_h$ from refs[5–8], **(e)** household microdata including dwelling materials used to derive relative household vulnerability $v_{q,rel}$ from ref[9] (for countries in dark grey, $v_{q,rel}$ is solely determined from ref[10]), **(f)** number of people exposed to floods and tropical cyclones according to ref[11].



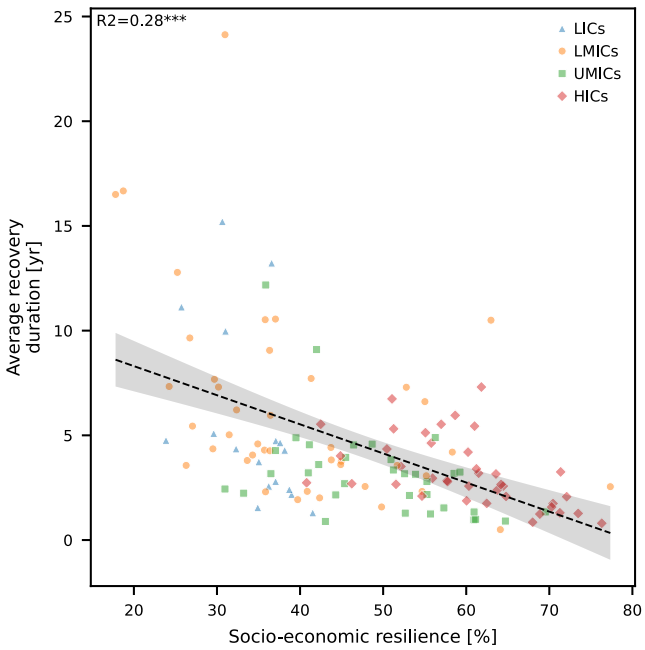

**Supplementary Figure 4: Estimated capital shares.** National capital shares of **(a, d, g)** public capital, **(b, e, h)** private (firm-owned) capital, and **(c, f, i)** household capital, over **(a-c)** GDP per capita, **(d-f)** self-employment rate, and **(g-i)** the owner-occupied share of value added, given by the product of the home ownership rate and the real-estate share of value added. $\kappa^p$ is obtained from ref[12], $\kappa^f$ and $\kappa^h$ are derived according to Methods.



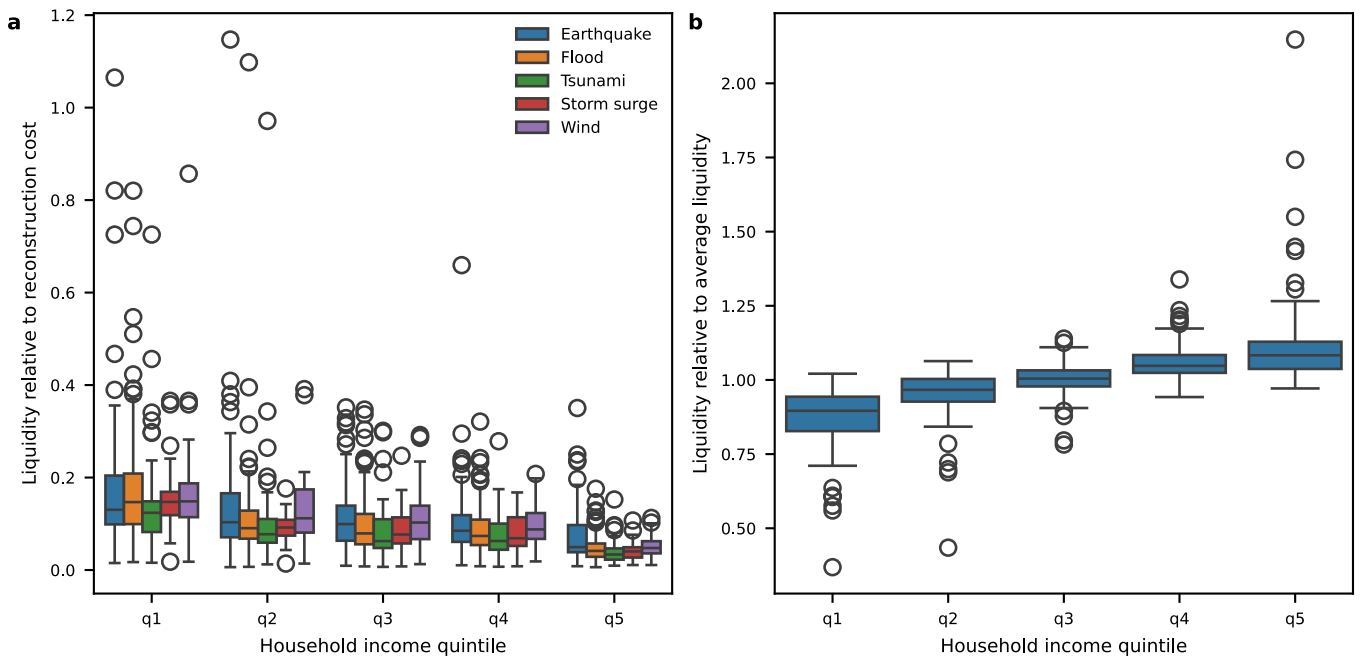

**Supplementary Figure 5: Relationships between risk to well-being and risk to assets. (a)** Risks expressed in percent of GDP. **(b)** Absolute risks on a log-log scale. Colors indicate low income (LICs), lower middle income (LMICs), upper middle income (UMICs), and high income (HICs) countries according to the World Bank country income group classification 2024.



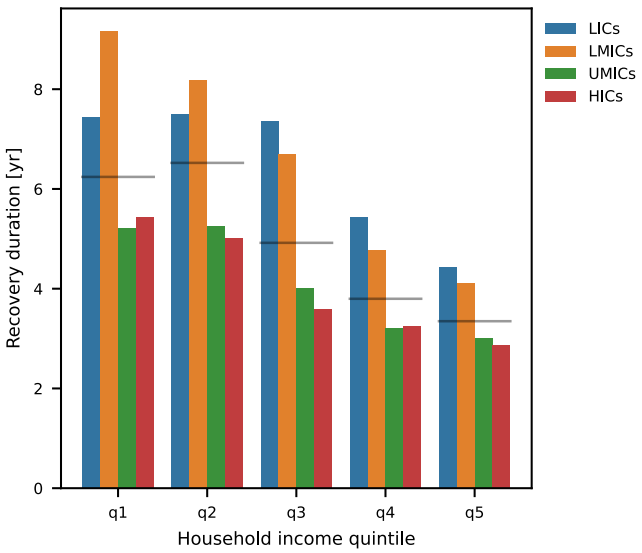

**Supplementary Figure 6: Relationship between socio-economic resilience and risk to assets.** The dashed line indicates a linear least squares fit with 95% confidence intervals in grey. Marker colors indicate country income groups.



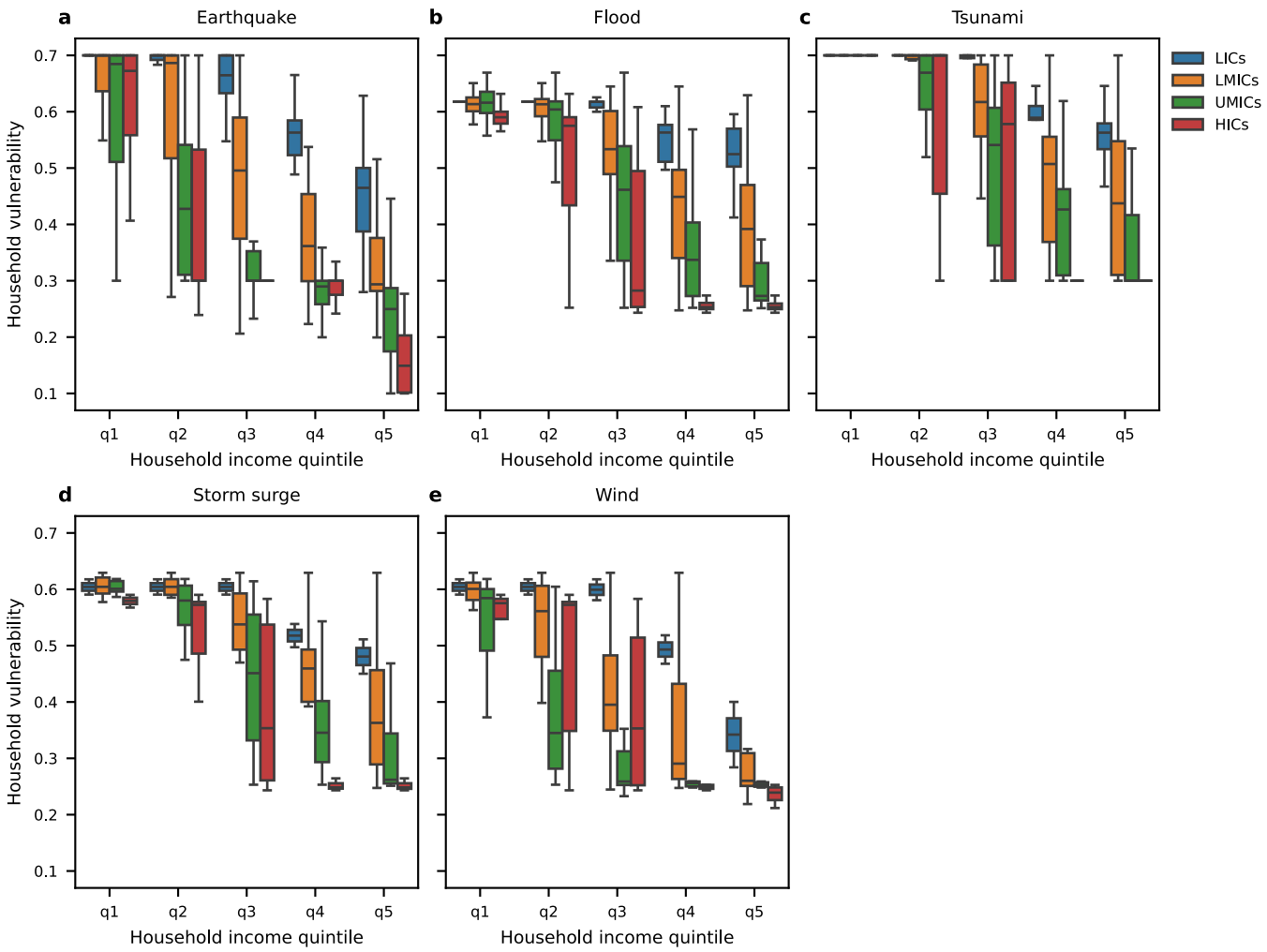

**Supplementary Figure 7: Relationship between average recovery duration and socio-economic resilience.** Country-level recovery durations correspond to the data shown in Fig. 3 panel a, calculated as the average population-weighted recovery duration of affected households across all hazards. The dashed line indicates a linear least squares fit with 95% confidence intervals in grey. Asterisks *** indicate significance level $p < 0.001$. Marker colors indicate country income groups.




**Supplementary Figure 8: Liquidity by household income quintile across all countries. (a)** Household liquidity relative to the reconstruction cost of affected households by hazard. **(b)** Household liquidity relative to average national liquidity.




**Supplementary Figure 9: Recovery durations increase without liquidity.** Median recovery duration by income quintile if households had no liquidity, by country income group (bar height) and across all countries (horizontal lines). Colors indicate country income group.




**Supplementary Figure 10: Household vulnerability by income quintile and hazard.** Vulnerability as the fraction of an affected household's assets that is destroyed when affected by **(a)** earthquakes, **(b)** floods, **(c)** tsunamis, **(d)** storm surges, and **(e)** wind. Colors indicate the country income group.

## Supplementary tables

**Supplementary Table 1: Model parameters used in the simulations.**

| Variable | Description | Scope | Eq. | Value |
|---|---|---|---|---|
| $\sigma$ | disaster aid payout factor | national | (17),(18) | 0.4, 0.2 |
| $\eta$ | elasticity of marginal consumption | national | (21) | 1.5 |
| $\rho$ | discount rate | national | (22) | 0.06 |

**Supplementary Table 2: Exogenous variables in the model and data sources.**

| Variable | Description | Scope | Eq. | Source |
|---|---|---|---|---|
| $P$ | population | national | (1) | ref[13] |
| $c_q$ | average household consumption by income quintile | household | (3) | refs[14,15] |
| $\Pi$ | average productivity of capital | national | (3) | ref[16] |
| $\gamma_q^{div}$ | income diversification | household | (5) | ref[1,17] |
| $\frac{\Delta K}{K}$ | fraction of assets destroyed | national | (8) | ref[18] |
| $V$ | asset vulnerability | national | (8) | ref[2,3,10] |
| $v_q$ | asset vulnerability | household | (8) | ref[2,3,9,10] |
| $EB_q$ | exposure bias | household | (9) | ref[11] |
| $\kappa^h$ | household share of capital | national | (15) | refs[4–8,12,19,20] |
| $S_q^{sav}$ | liquidity | household | (25) | ref[17] |
| $HP_{j,h}$ | hazard protection | national | (38) | refs[21,22] |

**Supplementary Table 3: Endogenous variables in the model.**

| Variable | Description | Scope | Eq. |
|---|---|---|---|
| $n$ | population headcount | national | (1) |
| $f$ | fraction of the population | national | (1) |
| $K$ | capital | national | (2) |
| $i_q^{lab/div}$ | labor / diversified income | household | (3) |
| $\Gamma_q^{div}$ | share of total diversified income that accrues to quintile $q$ | household | (6) |
| $k_q^{eff}$ | effective capital used to generate income | household | (2) |
| $\delta_{tax}^{div}$ | tax rate on labor income | national | (7) |
| $\Delta K$ | capital loss | national | (8) |
| $\Delta k_q^{eff}$ | effective capital loss | household | (10) |
| $\Delta i_q^{a,lab/div}$ | labor / diversified income loss | household | (13) |
| $\Delta c_q^{div/reco}$ | diversified / reconstruction consumption loss | household | (13), (16) |
| $\lambda_q$ | recovery rate | household | (14), (30) |
| $S_q^{aid}$ | disaster aid payout | household | (19) |
| $\mathcal{C}^{aid}$ | disaster aid cost | national | (19) |
| $w$ | utility | household | (21) |
| $\Delta W_q^{(short-term/long-term)}$ | (short-term / long-term) well-being loss | household | (21), (33), (34) |
| $\Delta c_q^{sav+aid}$ | spending of disaster aid and liquidity | household | (24) |
| $\mathcal{C}_q^{aid/reco,shared}$ | disaster aid / public and firm asset reconstruction cost | household | (31) |
| $c_q^{long-term}$ | long-term consumption loss | household | (32) |
| $\Delta W$ / $\Delta W^{ref}$ | total / reference well-being loss | national | (35), (36) |
| $\Delta C^{eq}$ | equivalent consumption loss | national | (36) |
| $\Psi_j$ | socio-economic resilience | national | (40) |

**Supplementary Table 4: Datasets used.** Country coverage indicates how many of the 132 countries in the simulations are contained in the original dataset. Missing data points are indicated in Supplementary Fig. 3 and Supplementary Tbl. 5.

| Dataset | Source | Country coverage |
|---|---|---|
| GDP per capita | ref[15] | full |
| GNI per capita | ref[15] | full |
| Population | ref[13] | full |
| Income shares | ref[14] | full |
| Findex | ref[17] | full |
| ASPIRE | ref[1] | 85[a] |
| Self-employment rate | ref[23] | full |
| Penn World Table | ref[16] | full |
| GIRI | ref[18] | full |
| FLOPROS (spatially aggregated using refs[24,25]) | refs[21,22] | full |
| Global Exposure Model | ref[10] | full |
| Global Monitoring Database | ref[9] | 77[b] |
| Hyogo Framework for Action | ref[2] | 110[c] |
| World Risk Poll | ref[3] | 106[c] |
| Exposed people by hazard and poverty line | ref[11] | 116[c] |
| IMF Investment and Capital Stock | ref[12] | full |
| Real-estate share of value added | ref[4] | 109[c] |
| Real-estate share of capital to real-estate share of value added ratio | refs[19,20] | 24[d] |
| Home ownership rate | refs[5–8] | 89[c] |

a: missing values imputed with regressions using refs[13,23,26]
b: per-quintile vulnerability for missing countries derived from ref[10] only, assuming the poorest people inhabit the most vulnerable buildings
c: missing data points imputed based on median or average data of available countries in the same region and / or country income group
d: best-fit ratio is applied to all countries

**Supplementary Table 5: Simulation results for all countries in the baseline scenario.**

| ISO code | WB Country Income group | GDP per capita (2021 $PPP) | risk to assets (% GDP) | risk to well-being loss (% GDP) | socio-economic resilience (%) |
|---|---|---|---|---|---|
| AGO[b,c,d] | LMICs | 7245 | 0.04 | 0.15 | 25.24 |
| ALB[e] | UMICs | 17976 | 0.53 | 1.47 | 35.87 |
| ARG[c,d] | UMICs | 27105 | 0.15 | 0.26 | 58.53 |
| ARM[e] | UMICs | 19230 | 0.29 | 0.71 | 40.99 |
| AUS[a,e] | HICs | 60409 | 0.08 | 0.15 | 52.15 |
| AUT[a,e] | HICs | 64336 | 0.16 | 0.24 | 64.46 |
| AZE[b,e] | UMICs | 21262 | 0.18 | 0.42 | 43.05 |
| BEL[a,e] | HICs | 62876 | 0.09 | 0.16 | 55.79 |
| BEN[d] | LMICs | 3721 | 0.07 | 0.23 | 31.47 |
| BFA | LICs | 2482 | 0.02 | 0.05 | 35.04 |
| BGD | LMICs | 8242 | 0.45 | 1.24 | 36.43 |
| BGR[e] | UMICs | 33112 | 0.15 | 0.27 | 55.70 |
| BIH[d,e] | UMICs | 19829 | 0.34 | 0.59 | 57.31 |
| BLR[b,e] | UMICs | 27718 | 0.25 | 0.36 | 69.52 |
| BOL[c] | LMICs | 9844 | 0.21 | 0.43 | 49.81 |
| BRA | UMICs | 19018 | 0.18 | 0.35 | 50.95 |
| BTN[b] | LMICs | 14061 | 1.12 | 2.13 | 52.79 |
| BWA[a,b] | UMICs | 18846 | 0.10 | 0.22 | 45.37 |
| CAF[a,b,c,d] | LICs | 1135 | 0.40 | 1.10 | 36.58 |
| CAN[a,e] | HICs | 56687 | 0.05 | 0.09 | 56.99 |
| CHE[a,e] | HICs | 81684 | 0.12 | 0.17 | 68.86 |
| CHL[e] | HICs | 29491 | 0.71 | 1.23 | 57.68 |
| CHN[b,e] | UMICs | 22138 | 0.25 | 0.42 | 59.25 |
| CIV[c,d] | LMICs | 6485 | 0.04 | 0.14 | 29.51 |
| CMR[d] | LMICs | 4871 | 0.09 | 0.36 | 26.29 |
| COD[b,c] | LICs | 1456 | 0.33 | 1.27 | 25.73 |
| COG[a,c,d] | LMICs | 6172 | 0.47 | 2.49 | 18.72 |
| COL | UMICs | 18325 | 0.32 | 1.03 | 30.96 |
| COM[b,c,d,f] | LMICs | 3499 | 0.33 | 1.25 | 26.73 |
| CRI[f] | UMICs | 25990 | 0.18 | 0.30 | 60.93 |
| CYP[a,e] | HICs | 52148 | 0.33 | 0.53 | 63.58 |
| CZE[a,e] | HICs | 47452 | 0.08 | 0.13 | 61.50 |
| DEU[a,e] | HICs | 63098 | 0.08 | 0.11 | 73.48 |
| DNK[a,e] | HICs | 71390 | 0.02 | 0.03 | 70.45 |
| DOM | UMICs | 23088 | 0.37 | 0.70 | 52.58 |
| DZA[a,c,d,e] | LMICs | 15159 | 0.17 | 0.38 | 43.71 |
| ECU | UMICs | 14472 | 0.89 | 1.92 | 46.45 |
| EGY[c] | LMICs | 16691 | 0.04 | 0.06 | 64.11 |
| ESP[a,e] | HICs | 47298 | 0.06 | 0.11 | 55.09 |
| EST[a,e] | HICs | 41669 | 0.03 | 0.05 | 63.74 |
| ETH[b,c] | LICs | 2755 | 0.08 | 0.20 | 38.15 |
| FIN[a,e] | HICs | 56455 | 0.02 | 0.03 | 64.19 |
| FRA[a,e,f] | HICs | 53969 | 0.06 | 0.09 | 61.23 |
| GAB[c,d] | UMICs | 18703 | 0.13 | 0.32 | 39.51 |
| GBR[a,e,f] | HICs | 52589 | 0.06 | 0.13 | 50.45 |
| GEO | UMICs | 22591 | 0.81 | 1.44 | 56.27 |
| GHA | LMICs | 6796 | 0.03 | 0.10 | 35.71 |

| ISO code | WB Country Income group | GDP per capita (2021 $PPP) | risk to assets (% GDP) | risk to well-being loss (% GDP) | socio-economic resilience (%) |
|---|---|---|---|---|---|
| GIN[c,d] | LMICs | 3949 | 0.08 | 0.25 | 33.65 |
| GMB[b,d] | LICs | 2932 | 0.03 | 0.07 | 38.98 |
| GRC[a,e] | HICs | 36821 | 1.28 | 2.06 | 61.82 |
| GTM[b,d] | UMICs | 12389 | 0.39 | 0.91 | 42.25 |
| HND[c,d] | LMICs | 6468 | 1.01 | 2.90 | 34.91 |
| HRV[e] | HICs | 41100 | 0.27 | 0.52 | 51.26 |
| HTI[a,b,d,e] | LMICs | 2956 | 2.36 | 7.63 | 30.97 |
| HUN[e] | HICs | 40168 | 0.15 | 0.25 | 60.22 |
| IDN[a,f] | UMICs | 13890 | 0.31 | 0.74 | 41.99 |
| IND[a,d,e] | LMICs | 9160 | 0.10 | 0.35 | 30.18 |
| IRL[a,e] | HICs | 115401 | 0.02 | 0.04 | 60.04 |
| IRN[d,f] | LMICs | 15912 | 0.83 | 1.51 | 55.02 |
| IRQ[c,d] | UMICs | 12711 | 0.17 | 0.29 | 61.13 |
| ISL[a,e] | HICs | 66880 | 0.28 | 0.38 | 72.09 |
| ISR[a,e] | HICs | 48356 | 0.13 | 0.20 | 62.47 |
| ITA[a,e] | HICs | 52589 | 0.39 | 0.77 | 51.07 |
| JOR[d] | LMICs | 9363 | 0.12 | 0.26 | 44.96 |
| JPN[a,e] | HICs | 45949 | 0.29 | 0.45 | 64.79 |
| KAZ[d,e] | UMICs | 34703 | 0.17 | 0.38 | 44.30 |
| KEN | LMICs | 5683 | 0.09 | 0.26 | 34.29 |
| KOR[a,e] | HICs | 49995 | 0.19 | 0.31 | 60.32 |
| LAO[a,d,f] | LMICs | 8372 | 1.26 | 3.45 | 36.37 |
| LBN[a,d] | LMICs | 11475 | 0.45 | 1.22 | 37.04 |
| LBR[b] | LICs | 1617 | 0.27 | 0.88 | 31.02 |
| LKA[f] | LMICs | 13030 | 0.28 | 0.64 | 43.76 |
| LSO[b] | LMICs | 2596 | 0.32 | 0.61 | 51.68 |
| LTU[e] | HICs | 46118 | 0.09 | 0.12 | 71.27 |
| LUX[a,b,e] | HICs | 130373 | 0.04 | 0.07 | 57.75 |
| LVA[e] | HICs | 38333 | 0.18 | 0.29 | 61.01 |
| MAR[a] | LMICs | 8869 | 0.23 | 0.77 | 29.69 |
| MDA | UMICs | 15855 | 0.46 | 0.89 | 51.23 |
| MDG[a,b,c,d] | LICs | 1643 | 0.16 | 0.48 | 32.30 |
| MEX[e] | UMICs | 21874 | 0.16 | 0.39 | 41.12 |
| MKD[a,e] | UMICs | 23324 | 0.34 | 0.63 | 53.90 |
| MLI[c,d] | LICs | 2395 | 0.08 | 0.21 | 37.06 |
| MLT[a,e] | HICs | 59548 | 0.06 | 0.15 | 40.79 |
| MMR[a,c] | LMICs | 5364 | 1.21 | 2.92 | 41.33 |
| MNE[b,e] | UMICs | 27343 | 0.27 | 0.51 | 53.17 |
| MNG | LMICs | 16223 | 0.24 | 0.41 | 58.32 |
| MOZ[a,d,f] | LICs | 1512 | 0.13 | 0.43 | 29.61 |
| MRT[a,b,d] | LMICs | 6259 | 0.14 | 0.38 | 35.80 |
| MUS | UMICs | 26590 | 0.32 | 0.52 | 60.94 |
| MWI[b] | LICs | 1648 | 0.11 | 0.26 | 41.52 |
| MYS[d,e,f] | UMICs | 32812 | 0.12 | 0.18 | 64.71 |
| NAM | UMICs | 10106 | 0.06 | 0.17 | 33.21 |
| NER[b,d] | LICs | 1703 | 0.25 | 0.80 | 30.65 |
| NGA | LMICs | 5593 | 0.09 | 0.28 | 32.36 |
| NIC[c,d] | LMICs | 7487 | 0.44 | 0.97 | 44.89 |
| NLD[a,e,f] | HICs | 70610 | 0.05 | 0.09 | 55.95 |

| ISO code | WB Country Income group | GDP per capita (2021 $PPP) | risk to assets (% GDP) | risk to well-being loss (% GDP) | socio-economic resilience (%) |
|---|---|---|---|---|---|
| NOR[a,e] | HICs | 90160 | 0.02 | 0.03 | 76.31 |
| NPL | LMICs | 4860 | 0.59 | 1.63 | 36.33 |
| PAK | LMICs | 5439 | 0.29 | 0.73 | 39.72 |
| PAN[c,d,f] | HICs | 35864 | 0.22 | 0.47 | 46.23 |
| PER | UMICs | 15294 | 0.28 | 0.76 | 37.05 |
| PHL | LMICs | 9901 | 0.65 | 1.18 | 54.69 |
| POL[e] | HICs | 43585 | 0.03 | 0.05 | 68.00 |
| PRT[a,e] | HICs | 41498 | 0.06 | 0.10 | 58.67 |
| PRY[d] | UMICs | 15783 | 0.19 | 0.51 | 36.49 |
| ROU | HICs | 40267 | 0.21 | 0.41 | 51.54 |
| RUS[d,e,f] | UMICs | 39753 | 0.15 | 0.33 | 45.50 |
| RWA[b] | LICs | 3060 | 0.24 | 0.62 | 38.71 |
| SDN[a,b,c,d] | LICs | 2469 | 0.59 | 1.63 | 36.23 |
| SEN[d] | LMICs | 4317 | 0.03 | 0.10 | 27.05 |
| SLE[c,d] | LICs | 3034 | 0.04 | 0.12 | 34.91 |
| SLV[d,f] | UMICs | 11404 | 0.39 | 0.71 | 55.27 |
| SRB[e] | UMICs | 25718 | 0.65 | 1.34 | 48.68 |
| SVK[e] | HICs | 39172 | 0.07 | 0.17 | 42.49 |
| SVN[a,e] | HICs | 47825 | 0.41 | 0.57 | 71.37 |
| SWE[a,e] | HICs | 62665 | 0.02 | 0.03 | 70.29 |
| SWZ[b] | LMICs | 10132 | 0.18 | 0.37 | 47.83 |
| TCD[b,d] | LICs | 1679 | 0.10 | 0.28 | 37.08 |
| TGO[d] | LICs | 2768 | 0.05 | 0.13 | 37.60 |
| TJK[a,d] | LMICs | 4472 | 2.42 | 3.13 | 77.34 |
| TUN[a,c,d] | LMICs | 12553 | 0.12 | 0.28 | 42.36 |
| TUR[e] | UMICs | 34252 | 0.57 | 1.03 | 55.28 |
| TZA[d,f] | LMICs | 3621 | 0.20 | 0.81 | 24.24 |
| UGA | LICs | 2791 | 0.11 | 0.48 | 23.86 |
| UKR[d,e] | LMICs | 15885 | 1.66 | 2.63 | 62.98 |
| URY | HICs | 31019 | 0.06 | 0.13 | 44.86 |
| USA[a,e] | HICs | 74578 | 0.09 | 0.17 | 54.67 |
| UZB[a,d,e] | LMICs | 10008 | 0.56 | 1.01 | 55.19 |
| VNM[f] | LMICs | 13492 | 0.51 | 1.25 | 40.87 |
| ZAF[c] | UMICs | 13690 | 0.17 | 0.31 | 52.66 |
| ZMB | LMICs | 3673 | 0.22 | 1.23 | 17.79 |
| ZWE | LMICs | 3442 | 0.06 | 0.18 | 35.84 |

Missing and inferred data points (cf. Supplementary Fig. 3):

a: Fraction of income from social protection and transfers

b: Availability of early warning systems

c: Real estate share of value added

d: Home ownership rate

e: Dwelling materials microdata

f: Number of exposed people by hazard type and poverty line

**Supplementary Table 6: Regression results for disaster risks, resilience, and recovery time.** Coefficients for six regression models are shown. Models (1–3), 4, 5, and 6 correspond to regressions shown in Fig. 2, Fig. 3, Supplementary Fig. 5, Supplementary Fig. 6.

| | 1<br>**Risk to assets [%GDP]** | 2<br>**Risk to well-being [%GDP]** | 3<br>**Socio-economic resilience [%]** | 4<br>**Socio-economic resilience [%]** | 5<br>**Socio-economic resilience [%]** | 6<br>**Recovery time [y]** |
|---|---|---|---|---|---|---|
| *ln(GDPpc [PPP])* | -0.0548<br>(0.029) | -0.2189$^{**}$<br>(0.067) | 8.7089$^{***}$<br>(0.699) | | | |
| *Gini index [%]* | | | | -0.7680$^{***}$<br>(0.141) | | |
| *Risk to assets [% GDP]* | | | | | 1.8746<br>(3.090) | |
| *Socio-economic resilience [%]* | | | | | | -0.1389$^{***}$<br>(0.020) |
| *const.* | 0.8249$^{**}$<br>(0.279) | 2.7774$^{***}$<br>(0.643) | -35.8634$^{***}$<br>(6.747) | 75.7284$^{***}$<br>(5.266) | 47.0135$^{***}$<br>(1.510) | 11.0839$^{***}$<br>(0.979) |
| $R^2$ | 0.027 | 0.077 | 0.544 | 0.187 | 0.003 | 0.275 |
| N | 132 | 132 | 132 | 132 | 132 | 132 |

Note: $^{*}$ $p < 0.05$; $^{**}$ $p < 0.01$; $^{***}$ $p < 0.001$

**Supplementary Table 7: Regression results for imputed income share from social protection and transfers.**
Values are in percent.

| | $\gamma^{sp,pt}_{q=1}$ | $\gamma^{sp,pt}_{q=2}$ | $\gamma^{sp,pt}_{q=3}$ | $\gamma^{sp,pt}_{q=4}$ | $\gamma^{sp,pt}_{q=5}$ |
|---|---|---|---|---|---|
| *SOC* | 1.4817$^{***}$ | 1.0243$^{**}$ | 0.8312$^{*}$ | 1.0608$^{***}$ | 0.9639$^{***}$ |
| | (0.406) | (0.349) | (0.335) | (0.258) | (0.177) |
| *UNE* | 0.7630$^{**}$ | 0.7032$^{**}$ | 0.5194$^{*}$ | | |
| | (0.258) | (0.207) | (0.199) | | |
| *REM* | | | | 0.3741$^{*}$ | 0.2400$^{*}$ |
| | | | | (0.148) | (0.120) |
| $I_{HICs}$ | 17.1771$^{**}$ | 10.4837$^{*}$ | 11.7009$^{*}$ | 13.0351$^{**}$ | |
| | (6.216) | (5.061) | (4.869) | (4.657) | |
| $I_{UMICs}$ | 8.4143$^{*}$ | 8.1317$^{**}$ | 7.2858$^{*}$ | 10.1749$^{***}$ | 3.8510$^{*}$ |
| | (3.672) | (2.949) | (2.837) | (2.734) | (1.847) |
| $I_{FSY}$ | 11.5620$^{*}$ | | | | |
| | (4.866) | | | | |
| $I_{MNA}$ | -15.0030$^{*}$ | -13.7580$^{**}$ | -10.4954$^{*}$ | -7.3198 | |
| | (6.460) | (5.155) | (4.959) | (4.225) | |
| $I_{EAP}$ | | 7.6582 | 9.8520$^{**}$ | 6.7344$^{*}$ | 7.3744$^{**}$ |
| | | (3.863) | (3.600) | (3.044) | (2.473) |
| $I_{ECA}$ | | 9.5125$^{*}$ | 8.0773$^{*}$ | | |
| | | (4.047) | (3.885) | | |
| $I_{LAC}$ | | | | -6.5397$^{*}$ | |
| | | | | (2.980) | |
| *const.* | 5.5110$^{*}$ | 3.3008 | 3.8654 | 4.3360$^{*}$ | 5.1751$^{**}$ |
| | (2.700) | (2.307) | (2.216) | (2.017) | (1.644) |
| $R^2$ | 0.557 | 0.558 | 0.503 | 0.468 | 0.328 |
| N | 101 | 103 | 104 | 107 | 108 |

Note: $^{*}$ $p < 0.05$; $^{**}$ $p < 0.01$; $^{***}$ $p < 0.001$

**Supplementary Table 8: Mapping of GEM taxonomy codes to vulnerability classes.** Each taxonomy string in the GEM database is mapped to a hazard-specific vulnerability class. The mapping is primarily done on the material of the lateral load-resisting system. Some mappings account in addition for the type of the lateral load-resisting system, as well as on the building height. The GEM taxonomy is described in ref[27].

| GEM taxonomy | | | Earthquake | Flood, storm surge, tsunami | Wind |
|---|---|---|---|---|---|
| lat. load sys. material | lat. load sys. type | height | | | |
| MUR | | | fragile | fragile | fragile |
| MUR+MO | | | fragile | fragile | fragile |
| MUR+ADO | | | fragile | fragile | fragile |
| MUR+ADO+MOC | | | fragile | fragile | fragile |
| MUR+ADO+MOM | | | fragile | fragile | fragile |
| MUR+STRUB | | | fragile | fragile | fragile |
| MUR+STRUB+MON | | | fragile | fragile | fragile |
| MUR+STRUB+MOM | | | fragile | fragile | fragile |
| MUR+STRUB+MOL | | | fragile | fragile | fragile |
| MUR+STRUB+MOC | | | fragile | fragile | median |
| MUR+STDRE | | | fragile | fragile | fragile |
| MUR+STDRE+MOM | | | fragile | fragile | fragile |
| MUR+STDRE+MOL | | | fragile | fragile | fragile |
| MUR+STDRE+MOC | | | median | fragile | median |
| MUR+CL | | | fragile | fragile | fragile |
| MUR+CLBRS | | | fragile | fragile | fragile |
| MUR+CLBRS+MOM | | | fragile | fragile | fragile |
| MUR+CLBRS+MOL | | | fragile | fragile | fragile |
| MUR+CLBRS+MOC | | | median | fragile | median |
| MUR+CLBRH | | | fragile | fragile | fragile |
| MUR+CB99+MOC | | | median | fragile | fragile |
| MUR+ST | | | fragile | fragile | fragile |
| MUR+ST+MOM | | | fragile | fragile | fragile |
| MUR+ST+MOL | | | fragile | fragile | fragile |
| MUR+ST+MOC | | | median | fragile | median |
| MUR+CLBLH | | | fragile | fragile | fragile |
| MUR+CB | | | fragile | fragile | fragile |
| MUR+CBS | | | fragile | fragile | fragile |
| MUR+CBH | | | fragile | fragile | fragile |
| MUR+CBR | | | fragile | fragile | fragile |
| E+ETO | | | fragile | fragile | fragile |
| EU | | | fragile | fragile | fragile |
| EU+ETC | | | fragile | fragile | fragile |
| EU+ETR | | | fragile | fragile | fragile |
| ER+ETR | | | fragile | fragile | fragile |
| MCF | | | median | fragile | median |
| MCF+CB | | | median | fragile | median |
| MCF+CBH | | | median | fragile | median |
| MCF+CBS | | | median | fragile | median |
| MCF+CBR | | | median | fragile | median |
| MCF+CL | | | median | fragile | median |
| MCF+CF | | | median | fragile | median |
| MCF+CLBRS | | | median | fragile | median |

| GEM taxonomy<br>lat. load sys. material | lat. load sys. type | height | Earthquake | Flood, storm surge, tsunami | Wind |
|---|---|---|---|---|---|
| MCF+CLBRH | | | median | fragile | median |
| MCF+CLBLH | | | median | fragile | median |
| MCF+S | | | median | fragile | median |
| MR | | | median | fragile | median |
| MR+CB | | | median | fragile | median |
| MR+CBR | | | median | fragile | median |
| MR+CBH | | | median | fragile | median |
| MR+CL | | | median | fragile | median |
| MR+STRUB+RCB+MOC | | | median | fragile | median |
| CR | | | median | median | median |
| CR+CIP | LDUAL | HBET:3,1 | robust | fragile | robust |
| CR+CIP | LDUAL | default | robust | median | median |
| CR+CIP | LFINF | HBET:3,1 | median | fragile | robust |
| CR+CIP | LFINF | default | median | median | median |
| CR+CIP | LFM | HBET:3,1 | robust | fragile | robust |
| CR+CIP | LFM | default | robust | median | median |
| CR+CIP | default | | median | median | median |
| CR+PCPS | LFM | HBET:3,1 | robust | fragile | robust |
| CR+PCPS | LFM | default | robust | median | median |
| CR+PCPS | default | | robust | median | robust |
| CR+PC | LDUAL | HBET:3,1 | robust | fragile | robust |
| CR+PC | LDUAL | default | robust | median | median |
| CR+PC | LFINF | HBET:3,1 | robust | fragile | robust |
| CR+PC | LFINF | default | robust | median | median |
| CR+PC | LFM | HBET:3,1 | robust | fragile | robust |
| CR+PC | LFM | default | robust | median | median |
| CR+PC | default | | robust | median | median |
| S | | | robust | median | median |
| S+SL | | | robust | median | median |
| SL | | | robust | median | median |
| S+SR | | | robust | median | median |
| SR | | | robust | median | median |
| S+SO | | | robust | median | median |
| SRC | | | robust | median | median |
| W | | | median | fragile | fragile |
| W+WWD | | | fragile | fragile | fragile |
| W+WBB | | | median | fragile | fragile |
| W+WO | | | median | fragile | fragile |
| W+WS | | | median | fragile | fragile |
| W+WLI | LPB | | median | fragile | fragile |
| W+WLI | LWAL | | median | fragile | fragile |
| W+WLI | LFBR | | robust | fragile | fragile |
| W+WLI | LFM | | median | fragile | fragile |
| W+WLI | default | | median | fragile | fragile |
| W+WHE | | | median | fragile | fragile |
| ME | | | fragile | fragile | fragile |
| ME+MEO | | | fragile | fragile | fragile |
| ME+MEIR | | | fragile | fragile | fragile |
| M+ADO | | | fragile | fragile | fragile |

| GEM taxonomy | | | Earthquake | Flood, storm surge, tsunami | Wind |
|---|---|---|---|---|---|
| lat. load sys. material | lat. load sys. type | height | | | |
| M+ST | | | fragile | fragile | fragile |
| M+CB | | | median | median | median |
| W+S | | | median | median | median |
| MIX(MUR-STRUB-W) | | | fragile | fragile | fragile |
| MIX(MUR-STDRE-W) | | | fragile | fragile | fragile |
| MIX(MUR-W) | | | fragile | fragile | fragile |
| MIX(MUR-CR) | | | median | median | fragile |
| MIX(S-CR-PC) | | | robust | median | robust |
| MIX(S-W) | | | median | fragile | median |
| MIX(S-CR) | | | robust | median | robust |
| MIX(C-S) | | | robust | median | robust |
| MIX(C-W) | | | median | fragile | median |
| MIX(M-W) | | | fragile | fragile | fragile |
| MIX(M-ST) | | | fragile | fragile | fragile |
| MIX(W-M) | | | fragile | fragile | fragile |
| MIX(W-EU) | | | fragile | fragile | fragile |
| MIX(CR-W) | | | median | fragile | median |
| MIX(MR-W) | | | median | fragile | median |
| MIX | | | median | fragile | median |
| MATO | | | median | fragile | median |
| INF | | | fragile | fragile | fragile |
| UNK | | | median | fragile | median |
| S+S99+SC99 | | | robust | fragile | median |
| S+SL+SC99 | | | robust | fragile | median |
| MR+MUN99+MR99+MO99 | | | median | fragile | median |
| MUR+MUN99+MO99 | | | fragile | fragile | fragile |

## References


1. World Bank. *The atlas of social protection indicators of resilience and equity* 2025. https://www.worldbank.org/en/data/datatopics/aspire. [Dataset] Accessed 01 Apr 2025.
2. UN-ISDR. *Hyogo framework for action 2005-2015: building the resilience of nations and communities to disasters* in (2007).
3. Lloyd's Register Foundation. *2021 World Risk Poll* 2022. https://wrp.lrfoundation.org.uk/data-resources. [Dataset] Accessed 30 Jan 2024.
4. United Nations Statistics Division. *Table 2.4 Value added by industries at constant prices (ISIC Rev. 4)* 2025. http://data.un.org/Data.aspx?d=SNA&f=group_code%3a205. National Accounts Official Country Data [Dataset]. Accessed 13 Feb 2025.
5. United Nations Statistics Division. *Households in housing units by type of housing unit, tenure of household and urban/rural residence* 2025. http://data.un.org/Data.aspx?d=POP&f=tableCode%3a304. Demographic Statistics Database [Dataset]. Accessed 18 Feb 2025.
6. Eurostat. *Distribution of population by tenure status, type of household and income group (ilc_lvho02)* 2025. https://ec.europa.eu/eurostat/databrowser/view/ilc_lvho02/default/table. [Dataset] Accessed 13 Feb 2025.
7. OECD. *OECD Affordable Housing Database* 2025. https://www.oecd.org/content/oecd/en/data/datasets/oecd-affordable-housing-database.html. [Dataset] Accessed 13 Feb 2025.
8. Centre for Affordable Housing Finance in Africa. *2024 Yearbook: Housing Finance in Africa* http://housingfinanceafrica.org (Centre for Affordable Housing Finance in Africa, Johannesburg, South Africa, 2024).
9. World Bank. *Global Monitoring Database (GMD)* 2024. [Dataset] Accessed 28 Feb 2024.
10. Yepes-Estrada, C. *et al.* Global building exposure model for earthquake risk assessment. *Earthquake Spectra* **39,** 2212–2235. https://github.com/gem/global_exposure_model (2023). [Dataset] Accessed 06 Jan 2025.
11. Doan, M. K. *et al.* Counting People Exposed to, Vulnerable to, or at High Risk From Climate Shocks—A Methodology. *World Bank Policy Research Working Paper* (2023).
12. IMF. *Investment and Capital Stock Dataset (ICSD)* 2022. https://data.imf.org/?sk=1ce8a55f-cfa7-4bc0-bce2-256ee65ac0e4. [Dataset] Accessed 13 Feb 2025.
13. World Bank. *World Development Indicators* 2025. https://doi.org/10.57966/6rwy-0b07. [Dataset] Accessed 01 Apr 2025.
14. World Bank. *Poverty and Inequality Platform (version 20240326_2017)* 2023. www.pip.worldbank.org. [Dataset] Accessed 01 Apr 2025.
15. World Bank. *International Comparison Program* 2025. https://www.worldbank.org/en/programs/icp. [Dataset] Accessed 01 Apr 2025.
16. Feenstra, R. C., Inklaar, R. & Timmer, M. P. The next generation of the Penn World Table. *American economic review* **105,** 3150–3182 (2015). [Dataset] Accessed 12 Dec 2023.
17. Demirgüç-Kunt, A., Klapper, L., Singer, D. & Ansar, S. *The Global Findex Database 2021: Financial inclusion, digital payments, and resilience in the age of COVID-19* (World Bank Publications, 2022). [Dataset] Accessed 18 Feb 2025.

18. CDRI. *Global Infrastructure Resilience: Capturing the Resilience Dividend - A Biennial Report from the Coalition for Disaster Resilient Infrastructure* 2023. https://giri.unepgrid.ch.

19. Eurostat. *Capital stocks by industry (NACE Rev.2) and detailed asset type (nama_10_nfa_st)* 2025. https://ec.europa.eu/eurostat/databrowser/view/nama_10_nfa_st/table. [Dataset] Accessed 10 Feb 2025.

20. Eurostat. *Gross value added and income by detailed industry (NACE Rev.2) (nama_10_a64)* 2025. https://ec.europa.eu/eurostat/databrowser/view/nama_10_a64/default/table. [Dataset] Accessed 03 Feb 2025.

21. Scussolini, P. *et al.* FLOPROS: an evolving global database of flood protection standards. *Natural Hazards and Earth System Sciences* **16,** 1049–1061 (2016). [Dataset] Accessed 19 Jan 2024.

22. Tiggeloven, T. *Benefit-cost analysis of adaptation objectives to coastal flooding at the global scale (Version 2)* (Zenodo, 2020). https://doi.org/10.5281/zenodo.4275517. [Dataset] Accessed 19 Jan 2024.

23. International Labour Organization. *ILO modelled estimates database, ILOSTAT* 2025. https://ilostat.ilo.org/data/. [Dataset] Accessed 01 Apr 2025.

24. Center For International Earth Science Information Network-CIESIN-Columbia University. *Gridded Population of the World, Version 4 (GPWv4): Population Density Adjusted to Match 2015 Revision UN WPP Country Totals, Revision 11 (Version 4.11)* Palisades, NY, 2018. https://doi.org/10.7927/H4F47M65. [Dataset] Accessed 15 Jan 2024.

25. GADM. *GADM Admin 0 shapefiles (version 4.1)* 2022. https://gadm.org.

26. International Labour Organization. *World Social Protection Report 2024-26: Universal social protection for climate action and a just transition* (2024). [Dataset] Accessed 25 Feb 2024.

27. Brzev, S. *et al. GEM Building Taxonomy Version 2.0, GEM Technical Report 2013-02 V1.0.0* 2013. [Dataset] Accessed 24 Jan 2025.