The Disaster Riskscape Across Asia-Pacific

PATHWAYS FOR RESILIENCE, INCLUSION AND EMPOWERMENT

Asia-Pacific Disaster Report 2019

Annex 1.1: Average Annual Loss (AAL) methodology

Probabilistic risk assessment combines the hazard module, the exposure module, and the vulnerability module. **Hazard module** is classified into various hazards, such as seismic, run up (tsunami), flood hazard, and tropical cyclone. **Exposure module** data is obtained from country offices, collected or surveyed information, and referenced on general statistical data. This is related to inventory of assets (buildings and infrastructure) that can be affected by natural hazards. Country level data is referred as the *proxy* exposure model. **Vulnerability module** is modelled through vulnerability functions that show the behaviour of an element during hazard events. Vulnerability function defines loss probability distribution (p) as a function of the intensity produced by a specific scenario. It is conditional to the occurrence of an intensity level (s) in the site where an exposed element is located. Often, loss p is understood as a relative loss to the replacement value of the exposed element. The probabilistic risk assessment is calculated as

$$v(p) = \sum_{i=1}^{Events} \Pr(P > p | Event\ \mathrm{i}) \cdot F_A(Event\ \mathrm{i})\ ^{1},$$

where v(P) is the loss rate of exceedance, FA (Event i) is the annual frequency of occurrence of the Event i, and Pr(P>p(Event i)) is the probability that the loss will be higher than p, given that the i-th event occurred. The sum includes all potentially damaging events. The inverse of v(p) is the return period of loss p, denoted as Tr.

Average Annual Loss is the expected value of loss every year in a long span time-frame. Assuming that the process of occurrence of damaging events is stationary between now and eternity, the total costs will be covered by paying (or saving) this amount annually.

$$AAL = \sum_{i=1}^{Eventos} E(P | Event\ \mathrm{i}) \cdot F_A(Event\ \mathrm{i})$$

AAL from multi-hazard considering extensive risk is defined as average annual direct loss from intensive and extensive risk. This is accounting for extensive risk and indirect losses. Intensive risk from multi-hazard risk assessment for the ESCAP region estimates risks to the built environment associated with earthquakes, tropical cyclones, riverine floods and tsunami. In the ESCAP regions, this represents 53.5 per cent of global multi-hazard risk.[2] Expressing AAL relative to the size of a countries capital stock provides a better indication of risk to a country's economy.

Extensive risks manifest as large numbers of high frequency, low severity disasters that could not be modelled analytically at the global or regional scale. Included in intensive disaster risks are high-severity, mid to low frequency disasters. When the multi-hazard AAL is expressed as a proportion of a country's capital stock, this provides a better indication of the real impact on a country's economy. This is mainly but not exclusively associated with highly localized hazards, including flash floods, storms, fires and agricultural and water-related drought.[3] Extensive risk, that has been modelled empirically, could add anywhere from 10 per cent or 50 per cent to the total multi-hazard AAL.[4] An additional estimation of 30 per cent to the total AAL is assumed as extensive risk.

AAL from multi-hazard considering indirect loss is average annual direct and indirect losses from intensive and extensive risk. Based on a study of multiple assessment following major disasters using the Economic Commission for Latin America and the Caribbean (ECLAC) methodology[5] indicated that indirect losses normally represent only 30 to 40 per cent of the total loss. Taking into account indirect losses, the total average annual loss in the ESCAP region would rise equal to 0.9 per cent of the region's GDP.

Drought risk and agricultural drought AAL

One of the hazards that contribute to extensive risks is drought. The effects of drought often accumulate slowly over an extended period of time. The impacts of drought range from losses to agricultural production, which includes water stress to crops and farm animals, generalized reduction of water availability for hydropower generation and human consumptions. During droughts, risk may increase to levels that exceed those rapid-onset hazards.

Probabilistic drought hazard has not yet been estimated for ESCAP countries. However, tendency of agricultural sector to drought risk can be visualized by generating proxies for the exposure and vulnerability of the agricultural sector. The proxy values are derived from economic and social variables. Exposure Index is the ratio of agricultural to total GDP. Vulnerability of the agricultural sectors composed of the proportion of rural population, proportion of rural poverty and proportion of employment in the agricultural sector.

$$Exposure\ Index\ (EI) = \frac{Agriculture\ GDP}{Total\ GDP}$$

$$Vulnerability\ Index\ (VI) = \frac{Rural\ Population\ + Rural\ Poverty + Employment\ in\ Agriculture}{3}$$

The Exposure Index and Vulnerability Index are used to calculate Propensity Index and Risk Proxy.

$$Propensity\ Index\ (PI) = \frac{Vulnerability\ Index + Exposure\ Index}{2}$$

The agricultural drought AAL (risk proxy) is not the same as multi-hazard AAL, as it represents a proportion of economic GDP rather than capital stock. By using the proxy of 20 per cent agricultural GDP, the agricultural drought AAL of the region is estimated. The drought risk model is typically below 20 per cent of the agricultural GDP. Although the values of agricultural drought AAL are obtained from a proxy estimate, it was shown that in many countries the drought AAL is equal or greater than the AAL from other hazards. There are also many countries which have agriculture AAL more than 80 per cent of total AAL. If the agricultural drought AAL is added to the total risk (direct and indirect), the total regional AAL increases to 2.4 per cent of total regional GDP.

Infrastructure exposure quantification methodology

To determine the risk of infrastructure towards certain hazards, the combinations of hazard and exposure datasets were used. Hazard data consists of: a) earthquake 475 Peak Ground Acceleration (PGA), b) cyclone return time 100 years, c) flood hazard 100 years taken from the Global Assessment Report on Disaster Risk Reduction (GAR) Risk Atlas 2015[6] The critical infrastructure dataset used are energy, transport and ICT infrastructure. Energy data are obtained from ESCAP Asia Pacific Energy portal 2017[7] on solar, wind, coal, oil,

and hydropower plants amount and capacity. Transport data consists of highway network, airports and ports taken from the ESCAP Asia Pacific Information Superhighway.[8] Data for the ICT infrastructure, composed of ICT fibre optic cables, are taken from ESCAP ICT Infrastructure 2017.[9] The impacted infrastructure is sensitive to each type of hazard. Accordingly, the calculation of infrastructure exposure is combined with particular hazards.

For earthquakes, the impacted energy power plants are coal, oil and hydropower. By using point sampling tools of GIS, the coal, oil, and hydropower plants within the category of light and moderate earthquake is calculated to get the percentage of energy power plants' numbers and capacity at risk. By using raster calculator, the ICT exposure to light and moderate earthquake was quantified, and percentage of ICT infrastructure at risk of earthquake is obtained.

For cyclone, the impacted energy power plants are solar and wind power. Also, the transport infrastructure that is potentially impacted by cyclones is airports and ports. By using point sampling tools of GIS, the solar and wind power plants in all category of cyclones is calculated to get the percentage of energy power plants' numbers and capacity at risk. The same method was used for the airports and ports. By using raster calculator, the ICT exposure to all categories of cyclone was quantified, and percentage of ICT infrastructure at risk of cyclone was obtained.

1 Ordaz, M (2000).
2 Ibid.
3 Extensive risk refers to the risk associated with low severity, high-frequency (persistent) events, mainly but not exclusively associated with highly localized hazards, including flash floods, storms, fires and agricultural and water-related drought. See: PreventionWeb at: https://www.preventionweb.net/risk/intensive-extensive-risk
4 Velásquez, C.A., and others (2014).
5 ECLAC (2014).
6 UNISDR (2015).
7 ESCAP (2018a).
8 ESCAP (2018c).
9 ESCAP (2018b).

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Annex 2.1: List of countries analysed with DHS data at province and household level

COUNTRY	ACROSS REGION ANALYSIS: NUMBER OF PROVINCES WITH AGGREGATE DATA FROM DHS HOUSEHOLD SURVEYS	WITHIN COUNTRY ANALYSIS: NUMBER OF HOUSEHOLD CLUSTERS*
Afghanistan	33	361
Armenia	11	28
Azerbaijan	9	26
Bangladesh	7	222
Cambodia	19	28
India	35	N/A
Indonesia	32	32
Korea DPR	10	N/A
Maldives	6	N/A
Myanmar	15	278
Nepal	7	760
Pakistan	6	28
Philippines	16	43
Tajikistan	5	162
Timor-Leste	12	27
Turkey	11	29
Viet Nam	7	133

Annex 2.2: Regression analysis for provinces in 15 countries across Asia-Pacific - Hazard exposure impacts on health, education and employment

A note on merging hazard data into DHS data in SPSS: The gridded exposure files[10] for floods (rt=50 years), earthquakes (rt=145), landslides from earthquakes and landslides from precipitation were imported in QGIS. They were clipped to the country boundary shapefile at administrative level 1. Using zonal statistics (plugin QGIS at 1x1 km) and the geometric summary statistic, the per cent of province (administrative level 1) exposure per hazard was calculated. DHS data for the 17 countries, at the aggregate province level, was matched with each hazard exposure. The per cent of province exposure was coded using SPSS syntax to the DHS data.

DEPENDENT VARIABLE: GINI COEFFICIENT	STANDARDIZED COEFFICIENTS BETA	T	SIG.
(Constant)		14.44	0.000
Floods (Per cent of province area exposed)	0.21	2.29	0.024
Earthquake (Per cent of province area exposed)	-0.11	-0.95	0.345
Landslide from earthquakes (Per cent of province area exposed)	-0.13	-1.37	0.173
Landslide from precipitation (Per cent of province area exposed)	0.26	2.73	0.007
Cyclone (Per cent of province area exposed)	0.07	0.61	0.543
Education	-0.41	-4.58	0.000
Employment	0.29	3.04	0.203
Wealth	-0.29	-3.72	0.000
DEPENDENT VARIABLE: SECONDARY EDUCATION (FEMALE)	**STANDARDIZED COEFFICIENTS BETA**	**T**	**SIG.**
(Constant)		7.39	0.000
Floods (Per cent of province area exposed)	0.06	0.66	0.508
Earthquake (Per cent of province area exposed)	-0.22	-2.14	0.034
Landslide from earthquakes (Per cent of province area exposed)	-0.20	-2.28	0.024
Landslide from earthquakes (Per cent of province area exposed)	-0.17	-1.94	0.055
Cyclone (Per cent of province area exposed)	-0.05	-0.52	0.605
Employment	0.48	5.38	0.000
Wealth	0.03	0.38	0.705

DEPENDENT VARIABLE: PRIMARY EDUCATION (MALE)	STANDARDIZED COEFFICIENTS BETA	T	SIG.
(Constant)		2.14	0.034
Floods (Per cent of province area exposed)	0.06	0.76	0.448
Earthquake (Per cent of province area exposed)	0.03	0.35	0.726
Landslide from earthquakes (Per cent of province area exposed)	-0.06	-0.74	0.463
Landslide from earthquakes (Per cent of province area exposed)	0.06	0.77	0.440
Cyclone (Per cent of province area exposed)	-0.15	-1.73	0.086
Employment	0.06	0.77	0.445
Wealth	0.26	3.57	0.000

DEPENDENT VARIABLE: SECONDARY EDUCATION (MALE)	STANDARDIZED COEFFICIENTS BETA	T	SIG.
(Constant)		6.61	0.000
Floods (Per cent of province area exposed)	0.07	0.82	0.415
Earthquake (Per cent of province area exposed)	-0.01	-0.11	0.914
Landslide from earthquakes (Per cent of province area exposed)	-0.35	-4.18	0.000
Landslide from earthquakes (Per cent of province area exposed)	0.06	0.73	0.466
Cyclone (Per cent of province area exposed)	-0.26	-2.95	0.004
Employment	0.34	3.97	0.000
Wealth index	0.00	0.03	0.974

DEPENDENT VARIABLE: EMPLOYMENT (FEMALE)	STANDARDIZED COEFFICIENTS BETA	T	SIG.
(Constant)		5.03	0.000
Floods (Per cent of province area exposed)	0.31	4.81	0.000
Earthquake (Per cent of province area exposed)	-0.34	-4.51	0.000
Landslide from earthquakes (Per cent of province area exposed)	0.18	2.37	0.019
Landslide from earthquakes (Per cent of province area exposed)	0.49	7.56	0.000
Cyclone (Per cent of province area exposed)	-0.04	-0.56	0.573
Education secondary (female)	0.12	1.80	0.073
Wealth index	0.25	2.29	0.023

DEPENDENT VARIABLE: EMPLOYMENT (MALE)	STANDARDIZED COEFFICIENTS BETA	T	SIG.
(Constant)		10.71	0.000
Floods (Per cent of province area exposed)	0.07	1.05	0.295
Earthquake (Per cent of province area exposed)	0.21	2.77	0.006
Landslide from earthquakes (Per cent of province area exposed)	-0.10	-1.36	0.175
Landslide from earthquakes (Per cent of province area exposed)	0.02	0.37	0.713
Cyclone (Per cent of province area exposed)	-0.29	-3.84	0.000
Wealth index	0.20	1.81	0.072
Education secondary (male)	0.61	8.96	0.054

DEPENDENT VARIABLE: INFANT MORTALITY RATE	STANDARDIZED COEFFICIENTS BETA	T	SIG.
(Constant)		2.27	0.025
Floods (Per cent of province area exposed)	-0.08	-0.99	0.325
Earthquake (Per cent of province area exposed)	0.20	2.27	0.025
Landslide from earthquakes (Per cent of province area exposed)	0.00	0.04	0.969
Landslide from earthquakes (Per cent of province area exposed)	0.21	2.51	0.013
Cyclone (Per cent of province area exposed)	-0.10	-1.16	0.249
Wealth index	-0.38	-2.97	0.003
Education secondary (female)	0.14	1.64	0.103
Education secondary (male)	-0.39	-4.26	0.000

A. DEPENDENT VARIABLE: UNDER 5 MORTALITY RATE	STANDARDIZED COEFFICIENTS BETA	T	SIG.
(Constant)		2.29	0.024
Floods (Per cent of province area exposed)	-0.05	-0.63	0.527
Earthquake (Per cent of province area exposed)	0.27	3.13	0.002
Landslide from earthquakes (Per cent of province area exposed)	0.03	0.34	0.731
Landslide from earthquakes (Per cent of province area exposed)	0.20	2.46	0.015
Cyclone (Per cent of province area exposed)	-0.07	-0.82	0.415
Wealth index	-0.40	-3.23	0.002
Education secondary (male)	0.10	1.13	0.262
Education secondary (female)	-0.42	-4.67	0.000

DEPENDENT VARIABLE: ACCESS TO AN ANTENATAL CARE (ANC) PROVIDER DURING PREGNANCY FOR THE MOST RECENT BIRTH	STANDARDIZED COEFFICIENTS BETA	T	SIG.
(Constant)		5.89	0.000
Floods (Per cent of province area exposed)	-0.07	-1.17	0.246
Earthquake (Per cent of province area exposed)	0.03	0.38	0.707
Landslide from earthquakes (Per cent of province area exposed)	0.08	1.23	0.219
Landslide from earthquakes (Per cent of province area exposed)	0.02	0.38	0.702
Cyclone (Per cent of province area exposed)	-0.16	-2.89	0.004
Wealth index	0.02	0.19	0.850
Education secondary (male)	0.15	2.69	0.008
Education secondary (female)	0.35	5.92	0.000
Employment (female)	0.57	8.47	0.000

DEPENDENT VARIABLE: ACCESS TO A HOSPITAL FOR CHILDBIRTH	STANDARDIZED COEFFICIENTS BETA	T	SIG.
(Constant)		4.35	0.000
Floods (Per cent of province area exposed)	-0.02	-0.42	0.676
Earthquake (Per cent of province area exposed)	-0.10	-1.38	0.168
Landslide from earthquakes (Per cent of province area exposed)	-0.22	-3.21	0.002
Landslide from earthquakes (Per cent of province area exposed)	-0.27	-4.21	0.000
Cyclone (Per cent of province area exposed)	-0.20	-3.46	0.001
Wealth index	0.32	3.32	0.001
Education secondary (male)	0.05	0.88	0.381
Education secondary (female)	0.46	7.69	0.000
Employment (female)	0.26	3.81	0.000

DEPENDENT VARIABLE: ACCESS TO A SKILLED PROVIDER FOR CHILDBIRTH	STANDARDIZED COEFFICIENTS BETA	T	SIG.
(Constant)		4.61	0.000
Floods (Per cent of province area exposed)	0.07	1.21	0.228
Earthquake (Per cent of province area exposed)	-0.06	-0.88	0.380
Landslide from earthquakes (Per cent of province area exposed)	0.03	0.40	0.691
Landslide from earthquakes (Per cent of province area exposed)	-0.09	-1.55	0.123
Cyclone (Per cent of province area exposed)	-0.13	-2.42	0.017
Wealth index	0.13	1.34	0.004
Education secondary (male)	-0.21	-3.98	0.104
Education secondary (female)	0.57	10.18	0.000
Employment (female)	0.50	7.84	0.000

DEPENDENT VARIABLE: HAVE SERIOUS PROBLEMS IN ACCESSING HEALTH CARE FOR THEMSELVES WHEN THEY ARE SICK (FEMALES)	STANDARDIZED COEFFICIENTS BETA	T	SIG.
(Constant)		6.97	0.000
Floods (Per cent of province area exposed)	-0.03	-0.47	0.636
Earthquake (Per cent of province area exposed)	0.28	3.70	0.000
Landslide from earthquakes (Per cent of province area exposed)	0.01	0.13	0.893
Landslide from earthquakes (Per cent of province area exposed)	-0.09	-1.32	0.187
Cyclone (Per cent of province area exposed)	0.18	2.73	0.007
Wealth index	-0.27	-3.03	0.003
Education secondary (male)	-0.18	-3.08	0.002
Education secondary (female)	-0.43	-7.00	0.000
Employment (female)	-0.32	-4.46	0.000

DEPENDENT VARIABLE: CHILD MALNOURISHMENT (PER CENTAGE BELOW -3 SD)	STANDARDIZED COEFFICIENTS BETA	T	SIG.
(Constant)		0.93	0.353
Floods (Per cent of province area exposed)	-0.11	-0.93	0.357
Earthquake (Per cent of province area exposed)	0.24	1.87	0.066
Landslide from earthquakes (Per cent of province area exposed)	0.52	3.92	0.211
Landslide from earthquakes (Per cent of province area exposed)	0.24	1.88	0.065
Cyclone (Per cent of province area exposed)	0.14	1.37	0.006
Wealth index	-0.14	-0.94	0.351
Education secondary (male)	0.26	1.61	0.113
Education secondary (female)	-0.27	-2.15	0.035
Employment (female)	-0.11	-0.85	0.396

DEPENDENT VARIABLE: PROPER CHILD NUTRITION	STANDARDIZED COEFFICIENTS BETA	T	SIG.
(Constant)		2.73	0.007
Floods (Per cent of province area exposed)	0.04	0.56	0.577

Earthquake (Per cent of province area exposed)	-0.07	-0.77	0.442
Landslide from earthquakes (Per cent of province area exposed)	-0.32	-3.82	0.000
Landslide from earthquakes (Per cent of province area exposed)	0.09	1.15	0.254
Cyclone (Per cent of province area exposed)	-0.03	-0.35	0.723
Wealth Index	0.03	0.28	0.778
Education secondary (male)	0.17	2.29	0.024
Education secondary (female)	0.20	2.44	0.016
Employment (female)	0.45	5.25	0.000

Annex 2.3: Logit model results - Vulnerabilities of households located in high multi-hazard risk areas

A note on merging hazard data into DHS data in SPSS: The gridded exposure files[11] for floods (rt=50 years), earthquakes (rt=145), landslides from earthquakes and landslides from precipitation were imported in QGIS. They were clipped to the country boundary shapefile at administrative level 1. Using zonal statistics (plugin QGIS at 1x1 km) and the geometric summary statistic, the per cent of province (administrative level 1) exposure per hazard was calculated. DHS data from 14 countries, at the household level, was matched using the DHS province data for each hazard exposure. Per cent of province exposure was coded using SPSS syntax to the DHS data.

		B	S.E.	WALD	DF	SIG.	EXP(B)
Afghanistan	Age (Older)	0.148	0.132	1.268	1	0.26	1.16
	Number of Children (above country mean)	0.352	0.136	6.72	1	0.01	1.422
	Distance to medical care (a big problem)	-0.378	0.157	5.759	1	0.016	0.685
	Access to medical care (a big problem)	-0.214	0.155	1.895	1	0.169	0.808
	Occupation (females)	0.477	0.377	1.599	1	0.206	1.611
	House ownership (females)	0.456	0.152	8.956	1	0.003	1.578
	Land ownership (females)	0.28	0.169	2.756	1	0.097	1.324
	Have prenatal care	-0.153	0.318	0.231	1	0.631	0.858
	Have medical care during delivery	-0.275	0.361	0.577	1	0.447	0.76
	Size of child at birth (above 2.5 kg)	0.045	0.14	0.103	1	0.748	1.046
	Wealth (top 20% wealth index)	0.015	0.132	0.014	1	0.907	1.016
	Child has respiratory problems	-0.366	0.149	6.059	1	0.014	0.694
	Nutrition	0.031	0.208	0.023	1	0.88	1.032
	Education (females)	-0.665	0.268	6.149	1	0.013	0.514
	Intercept	0.155	0.22	0.497	1	0.481	1.168
		B	**S.E.**	**WALD**	**DF**	**SIG.**	**EXP(B)**
Armenia	Age (Older)	-0.202	0.116	3.021	1	0.082	0.817
	Number of Children (above country mean)	0.034	0.114	0.091	1	0.762	1.035
	Wealth (top 20% wealth index)	-0.418	0.117	12.686	1	0	0.658
	Distance to medical care (a big problem)	0.094	0.193	0.239	1	0.625	1.099
	Access to medical care (a big problem)	0.289	0.474	0.37	1	0.543	1.335
	House ownership (females)	-0.239	0.124	3.733	1	0.053	0.788
	Land ownership (females)	-0.115	0.193	0.352	1	0.553	0.892
	Have medical care during delivery	-0.212	0.239	0.787	1	0.375	0.809
	Size of child at birth (above 2.5 kg)	0.064	0.197	0.104	1	0.748	1.066
	Child has respiratory problems	-0.32	0.301	1.128	1	0.288	0.726
	Nutrition	0.833	0.428	3.783	1	0.052	2.301
	Occupation (females)	-0.183	0.122	2.273	1	0.132	0.832
	Education (females)	-0.31	0.186	2.777	1	0.096	0.733
	Intercept	0.644	0.223	8.34	1	0.004	1.904
		B	**S.E.**	**WALD**	**DF**	**SIG.**	**EXP(B)**
Azerbaijan	Age (Older)	-0.109	0.381	0.082	1	0.774	0.896
	Number of Children (above country mean)	0.213	0.383	0.31	1	0.578	1.238
	Wealth (top 20% wealth index)	-0.656	0.546	1.444	1	0.23	0.519
	Distance to medical care (a big problem)	-0.001	0.43	0	1	0.997	0.999
	Access to medical care (a big problem)	-0.383	0.522	0.539	1	0.463	0.682
	Have prenatal care	-0.506	0.407	1.541	1	0.215	0.603
	Occupation (females)	0.131	0.821	0.026	1	0.873	1.14
	Education (females)	-2.015	1.126	3.201	1	0.074	0.133
	Occupation (females)	-0.261	0.899	0.084	1	0.772	0.77
	Intercept	0.81	0.481	2.835	1	0.092	2.248

		B	S.E.	WALD	DF	SIG.	EXP(B)
Bangladesh	Wealth (top 20% wealth index)	0.962	0.25	14.757	1	0	2.616
	Age (Older)	0.377	0.255	2.182	1	0.14	1.458
	Number of Children (above country mean)	0.472	0.265	3.172	1	0.075	1.603
	Have prenatal care	0.741	0.799	0.86	1	0.354	2.098
	Have medical care during delivery	20.092	19538.77	0	1	0.999	0.448
	Size of child at birth (above 2.5 kg)	-0.456	0.292	2.442	1	0.118	0.634
	Child has respiratory problems	0.226	0.226	1.001	1	0.317	1.254
	Access to medical care (a big problem)	0.452	0.245	3.403	1	0.065	1.571
	Education (females)	-0.296	0.242	1.492	1	0.222	0.744
	Occupation (females)	0.224	0.358	0.393	1	0.531	1.251
	Intercept	0.875	0.339	6.677	1	0.01	2.399
		B	**S.E.**	**WALD**	**DF**	**SIG.**	**EXP(B)**
Cambodia	Age (Older)	0.045	0.186	0.06	1	0.807	1.046
	Number of Children (above country mean)	0.137	0.192	0.512	1	0.474	1.147
	Distance to medical care (a big problem)	0.194	0.228	0.722	1	0.395	1.214
	Access to medical care (a big problem)	0.611	0.208	8.604	1	0.003	1.842
	House ownership (females)	0.122	0.222	0.302	1	0.583	1.13
	Land ownership (females)	0.198	0.212	0.874	1	0.35	1.219
	Have prenatal care	-1.456	0.842	2.989	1	0.084	0.233
	Have medical care during delivery	-1.133	0.404	7.851	1	0.005	0.322
	Size of child at birth (above 2.5 kg)	0.295	0.3	0.97	1	0.325	1.343
	Child has respiratory problems	-0.228	0.183	1.561	1	0.211	0.796
	Wealth (top 20% wealth index)	-0.816	0.215	14.367	1	0	0.442
	Occupation (females)	-0.162	0.224	0.52	1	0.471	0.851
	Education (females)	-0.594	0.244	5.912	1	0.015	0.552
	Intercept	0.145	0.379	0.147	1	0.701	1.156
		B	**S.E.**	**WALD**	**DF**	**SIG.**	**EXP(B)**
Indonesia	Age (Older)	0.104	0.068	2.298	1	0.13	1.109
	Number of Children (above country mean)	0.219	0.076	8.413	1	0.004	1.245
	Distance to medical care (a big problem)	-0.003	0.148	0	1	0.986	0.997
	Access to medical care (a big problem)	0.008	0.114	0.005	1	0.945	1.008
	House ownership (females)	-0.029	0.086	0.116	1	0.733	0.971
	Land ownership (females)	0.196	0.086	5.131	1	0.023	1.216
	Have prenatal care	-0.335	0.456	0.538	1	0.463	0.715
	Have medical care during delivery	-0.317	0.125	6.431	1	0.011	0.728
	Size of child at birth (above 2.5 kg)	0.108	0.097	1.241	1	0.265	1.114
	Child has respiratory problems	-0.145	0.07	4.313	1	0.038	0.865
	Wealth (top 20% wealth index)	-0.278	0.072	14.81	1	0	0.757
	Occupation (females)	-0.106	0.071	2.233	1	0.135	0.9
	Nutrition	0.046	0.093	0.246	1	0.62	1.047
	Education (females)	0.019	0.09	0.047	1	0.829	1.02
	Intercept	-0.081	0.116	0.491	1	0	0.922
		B	**S.E.**	**WALD**	**DF**	**SIG.**	**EXP(B)**
Myanmar	Age (Older)	0.217	0.219	0.979	1	0.322	1.242
	Number of Children (above country mean)	-0.092	0.228	0.161	1	0.688	0.913
	Distance to medical care (a big problem)	0.306	0.307	0.988	1	0.32	1.357
	Access to medical care (a big problem)	0.169	0.281	0.365	1	0.546	1.185
	House ownership (females)	-0.322	0.363	0.788	1	0.375	0.725
	Land ownership (females)	-0.521	0.363	2.061	1	0.151	0.594
	Have prenatal care	-1.464	0.879	2.777	1	0.096	0.231
	Have medical care during delivery	-20.963	15064.79	0	1	0.999	0
	Size of child at birth (above 2.5 kg)	-0.586	0.348	2.841	1	0.092	0.557
	Wealth (top 20% wealth index)	-1.318	0.249	28.017	1	0	0.268
	Child has respiratory problems	0.2	0.222	0.811	1	0.368	1.222
	Nutrition	0.601	0.395	2.311	1	0.128	1.823
	Occupation (females)	-0.054	0.259	0.043	1	0.836	0.948
	Education (females)	-0.144	0.27	0.285	1	0.593	0.866
	Intercept	1.903	0.471	16.347	1	0	6.703
		B	**S.E.**	**WALD**	**DF**	**SIG.**	**EXP(B)**
Nepal	Wealth (top 20% wealth index)	-0.558	0.104	28.728	1	0	0.572
	Age (Older)	0.149	0.088	2.852	1	0.091	1.161
	Number of Children (above country mean)	-0.346	0.092	14.069	1	0	0.707
	Distance to medical care (a big problem)	0.174	0.136	1.631	1	0.201	1.19
	Access to medical care (a big problem)	0.029	0.142	0.041	1	0.84	1.029
	House ownership (females)	0.473	0.215	4.855	1	0.028	1.605

	Land ownership (females)	0.289	0.171	2.867	1	0.09	1.335
	Have prenatal care	-0.188	0.134	1.959	1	0.162	0.829
	Have medical care during delivery	0.069	0.102	0.45	1	0.502	1.071
	Size of child at birth (above 2.5 kg)	-0.178	0.119	2.227	1	0.136	0.837
	Child has respiratory problems	-0.125	0.171	0.536	1	0.464	0.882
	Education (females)	-0.145	0.154	0.877	1	0.349	0.865
	Occupation (females)	0.843	0.132	40.954	1	0	2.323
	Nutrition	0.801	0.171	21.834	1	0	2.227
	Intercept	0.135	0.203	0.44	1	0	1.144
		B	**S.E.**	**WALD**	**DF**	**SIG.**	**EXP(B)**
Pakistan	Wealth (top 20% wealth index)	-0.509	0.14	13.188	1	0	0.601
	Age (Older)	-0.07	0.122	0.335	1	0.563	0.932
	Number of Children (above country mean)	0.076	0.126	0.359	1	0.549	1.079
	Distance to medical care (a big problem)	0.142	0.225	0.4	1	0.527	1.153
	Access to medical care (a big problem)	0.425	0.217	3.844	1	0.05	1.53
	House ownership (female)	1.94	0.173	125.134	1	0	6.96
	Land ownership (females)	0.726	0.271	7.178	1	0.007	2.068
	Have prenatal care	0.067	0.201	0.111	1	0.739	1.069
	Have medical care during delivery	-0.063	0.15	0.174	1	0.676	0.939
	Size of child at birth (above 2.5 kg)	0.136	0.158	0.739	1	0.39	1.146
	Child has respiratory problems	-0.11	0.125	0.778	1	0.378	0.896
	Education (females)	-0.826	0.267	9.598	1	0.002	0.438
	Occupation (females)	-0.562	0.189	8.815	1	0.003	0.57
	Nutrition	0.318	0.189	2.832	1	0.092	1.374
	Intercept	-0.544	0.284	3.661	1	0.006	0.581
		B	**S.E.**	**WALD**	**DF**	**SIG.**	**EXP(B)**
Philippines	Age (Older)	-0.124	0.096	1.643	1	0.2	0.884
	Number of Children (above country mean)	0.072	0.096	0.574	1	0.449	1.075
	Distance to medical care (a big problem)	-0.377	0.126	9	1	0.003	0.686
	Access to medical care (a big problem)	0.221	0.121	3.357	1	0.067	1.247
	House ownership (female)	0.263	0.104	6.38	1	0.012	1.301
	Land ownership (female)	-0.434	0.129	11.253	1	0.001	0.648
	Have prenatal care	0.637	0.183	12.082	1	0.001	1.89
	Have medical care during delivery	0.709	0.159	19.775	1	0	2.031
	Wealth (top 20% wealth index)	-0.508	0.131	15.08	1	0	0.602
	Child has respiratory problems	1.179	0.374	9.931	1	0.002	3.253
	Nutrition	0.316	0.112	8.037	1	0.005	1.372
	Occupation (females)	0.207	0.12	2.975	1	0.085	1.23
	Education (females)	-0.071	0.104	0.467	1	0.494	0.932
	Intercept	1.092	0.122	79.722	1	0	2.981
		B	**S.E.**	**WALD**	**DF**	**SIG.**	**EXP(B)**
Tajikistan	Age (Older)	-0.311	0.128	5.9	1	0.015	0.733
	Number of Children (above country mean)	0.29	0.125	5.432	1	0.02	1.337
	Distance to medical care (a big problem)	0.244	0.234	1.091	1	0.296	1.277
	Access to medical care (a big problem)	-0.289	0.153	3.579	1	0.058	0.749
	House ownership (female)	-0.167	0.128	1.709	1	0.191	0.846
	Have prenatal care	0.671	0.125	28.732	1	0	1.957
	Have medical care during delivery	0.859	0.168	26.294	1	0	2.361
	Size of child at birth (above 2.5 kg)	-0.729	0.21	12.094	1	0.001	0.483
	Wealth (top 20% wealth index)	-6.484	1.004	41.675	1	0	0.002
	Child has respiratory problems	0.177	0.442	0.16	1	0.689	1.193
	Nutrition	-0.445	0.133	11.109	1	0.001	0.641
	Occupation (females)	0.522	0.159	10.838	1	0.001	1.686
	Education (females)	-0.49	0.308	2.529	1	0.112	0.613
	Intercept	6.562	1.039	39.855	1	0	707.364
		B	**S.E.**	**WALD**	**DF**	**SIG.**	**EXP(B)**
Timor-Leste	Wealth (top 20% wealth index)	0.378	0.098	15.031	1	0	1.46
	Age (Older)	-0.16	0.088	3.318	1	0.069	0.852
	Number of Children (above country mean)	0.055	0.086	0.409	1	0.523	1.057
	Distance to medical care (a big problem)	-0.33	0.156	4.484	1	0.034	0.719
	Access to medical care (a big problem)	0.289	0.149	3.751	1	0.053	1.335
	House ownership (female)	0.071	0.198	0.129	1	0.72	1.074
	Land ownership (female)	-1.134	0.13	76.451	1	0	0.322
	Have prenatal care	-0.993	0.449	4.902	1	0.027	0.37
	Have medical care during delivery	-0.248	0.342	0.526	1	0.468	0.78
	Size of child at birth (above 2.5 kg)	-0.087	0.17	0.261	1	0.61	0.917

	Child has respiratory problems	0.501	0.206	5.919	1	0.015	1.65
	Education (females)	-0.022	0.114	0.039	1	0.844	0.978
	Occupation (females)	0.291	0.092	9.971	1	0.002	1.338
	Nutrition	-0.483	0.09	28.773	1	0	0.617
	Intercept	0.935	0.245	14.569	1	0	2.547
		B	**S.E.**	**WALD**	**DF**	**SIG.**	**EXP(B)**
Turkey	Age (Older)	-0.114	0.131	0.764	1	0.382	0.892
	Number of Children (above country mean)	0.377	0.134	7.849	1	0.005	1.457
	Have prenatal care	-0.664	0.242	7.503	1	0.006	0.515
	Have medical care during delivery	-1.106	0.304	13.244	1	0	0.331
	Size of child at birth (above 2.5 kg)	-0.356	0.146	5.94	1	0.015	0.701
	Wealth (top 20% wealth index)	-0.134	0.134	0.998	1	0.318	0.875
	Child has respiratory problems	-0.084	0.129	0.428	1	0.513	0.919
	Education (females)	-0.512	0.239	4.606	1	0.032	0.599
	Intercept	1.664	0.361	21.277	1	0	5.279
		B	**S.E.**	**WALD**	**DF**	**SIG.**	**EXP(B)**
Viet Nam	Age (Older)	0.721	0.729	0.979	1	0.322	2.057
	Number of Children (above country mean)	-0.208	0.762	0.075	1	0.785	0.812
	Have prenatal care	-1.32	1.413	0.873	1	0.35	0.267
	Have medical care during delivery	1.901	1.266	2.255	1	0.133	6.689
	Size of child at birth (above 2.5 kg)	-0.278	1.273	0.048	1	0.827	0.757
	Child has respiratory problems	-0.577	0.679	0.721	1	0.396	0.562
	Education (females)	-0.142	1.377	0.011	1	0.918	0.868
	Occupation (females)	-21.6	19857.43	0	1	0.999	0
	Wealth (top 20% wealth index)	1.197	0.749	2.555	1	0.11	3.31
	Intercept	22.206	19857.43	0	1	0	2.695

Annex 2.4: Association between drought index and GDP among ASEAN countries

The INFORM Risk Index data[12] was used for the main analysis. The data includes a drought index that aggregates four drought related variables: (1) agriculture drought probability[13] (2) people affected by drought, absolute and relative[14] and (3) frequency of drought events[15].

The regression main effects estimates included 49 countries in the Asia-Pacific region. The interaction/mediating effect of drought on the socioeconomic variables (Drought*ASEAN) in ASEAN countries was determined for the 10 ASEAN countries as follows: Brunei Darussalam, Cambodia, Indonesia, Lao People's Democratic Republic, Malaysia, Myanmar, Philippines, Thailand, Singapore, and Viet Nam. The interaction effect was statistically significant for modelling the relationship between the drought index, GDP, and per capita health expenditure but not significant for inequality; signalling that among ASEAN countries, there is a differential impact from drought on some socioeconomic variables than among the rest of the countries in the Asia-Pacific region. In addition, it should be noted that while disasters have significant impacts, there are other variables for which data is not available, which can be more significantly related to the dependent variables. The coefficients should also be interpreted with caution due to a relatively low sample size that may lead to more unstable estimates.

TABLE 1 **Basic statistics for predicted, predictor, and control variables used in the estimation (N=49)**

VARIABLE	MEAN	RANGE	STANDARD DEVIATION	SOURCE
Drought Index (0-10)	3.02	0.0-5.60	1.68	Inform Index for Risk Management (2018)
Per capita health expenditure (Constant 2011 USD)	876.72	88.075-4357.26	1112.09	Inform Index for Risk Management (2018)
GDP (2010 USD Constant)	11087.4	926.77-50352.0	17093.1	ESCAP Statistical Database (Accessed, 16 April 2018)
Governance (0-10)	5.75	1.1-8.6	1.66	Inform Index for Risk Management (2018)
Land area (sq. km)	1059594.3	21.0-16376870.0	2840578.8	Inform Index for Risk Management (2018)
Total population	90235410.6	11097.0-1378664960.0	268991240.4	Inform Index for Risk Management (2018)

TABLE 2 Regression estimates of drought, GDP, inequality, and per capita health expenditure

GDP	STANDARDIZED BETA	T-STATISTIC	SIGNIFICANCE
Final Model			0.000
Constant	5616.72	9.379	0.000
Drought index ASEAN (interaction)	-0.620**	-3.738	.001
Drought index Asia-Pacific region (main effect)	.082	.886	.380
ASEAN (main effect)	.743	4.453	.000
Total population	-.142	-1.612	.114
Land area (sq. km)	.150	1.631	.110
Governance	-.683**	-7.842	.000
INEQUALITY			
Final Model			0.002
Constant	4.674	10.995	.000
Drought index ASEAN (interaction)	-.076	-.259	.798
Drought index Asia-Pacific region (main effect)	-.173	-1.166	.252
ASEAN (main effect)	.322	1.082	.287
Total population	.035	.243	.809
Land area (sq. km)	.134	.861	.395
GDP per capita	-.713**	-4.610	.000
PER CAPITA HEALTH EXPENDITURE			
Final Model			0.000
Constant	1150.705	4.052	.000
Drought index ASEAN (interaction)	-.340**	-2.094	.043
Drought index Asia-Pacific region (main effect)	.116	1.447	.156
ASEAN (main effect)	-.541	-2.940	.065
Total population	.126	1.637	.109
Land area (sq. km)	.160	1.745	.089
GDP per capita	.907**	9.532	.000

Annex 2.5: Mapping interpolation methodology: Nepal/Bangladesh Poverty and Disaster Risk mapping and linkage with SPA

In this analysis, we used the method of merging poverty data with data for disaster-prone regions in order to examine the spatial distribution of areas with high poverty and vulnerability to disaster. Furthermore, we checked the linkage among areas showing high poverty and areas vulnerable to disasters, as well as the locations of hospitals. There was no geographical data on poverty, so we used the wealth index as a proxy data. The wealth index was found in the Demographic and Health Survey (DHS), which provides the Global Positioning System (GPS) data of each cluster's locations.

Disaster data for measuring composite disaster risk were downloaded from GAR Atlas and the Global Risk Platform. The Service Provision Assessment (SPA) survey provided us the hospital data of each country. Since only Nepal and Bangladesh were available for geo-located hospital data, we selected these two countries as pilot countries.

A Creating an interpolated surface map of the Wealth index using the Kriging technique.

The wealth index is approved by the DHS Spatial Interpolation Working Group as an appropriate indicator for interpolated surface mapping.[16] The wealth index data combined with GPS data is comprised of points. Therefore, the interpolated map can be created using the Kriging technique that allows data to be estimated in areas where no surveys have taken place. Especially, the empirical Bayesian Kriging (EBK) interpolation implemented in this analysis was used to account for the variance by estimating multiple semivariogram models from the data instead of a standalone semivariogram, since the classical Kriging method assumption rarely holds true in practice.[17] This technique is implemented in ArcGIS, the Log Empirical analysis option was selected since it guarantees that the prediction will be all positive number as wealth index is. Estimated decimal number results were reclassified into integers, and it scored the index 1(poor) as to 5 and the index 5(rich) as to 1.

B Mapping Multi-hazard risk

Nepal's multi-hazard risk map used the data of flood return of 100 years and the earthquake return of 475 years, produced by the GAR Atlas team and the landslide risk data from the Global Risk Platform.

EARTHQUAKE	CYCLONE	FLOOD	LANDSLIDE	SCORE
Intensity 1	Category 1	Less than 180cm	Low	1
Intensity 2	Category 2	180 – 360cm	Medium	2
Intensity 3	Category 3	360 – 540cm	Moderate	3
Intensity 4	Category 4	540 – 720cm	High	4
Intensity 5	Category 5	720 – 900cm	Extreme	5

Bangladesh's multi-hazard risk map included the data of flood return of 100 years, cyclone return of 100 years, and earthquake return of 475 years. Each disaster data was reclassified in a way that gives a different score based on the reclassifications of the Global Risk Platform. Depending on the level of the risk of disaster, high disaster risks marked higher scores, whereas lower disaster risks marked lower scores. All the reclassified disaster maps by each country were added to create a composite disaster risk map.

C Combining the Multi-disaster risk map and the Wealth index map, and infrastructure

HIGH POVERTY AND VULNERABILITY TO DISASTER = WEALTH INDEX MAP + MULTI-DISASTER RISK MAP

Overlaying the Infrastructure (Public hospital) data on the map to find the linkage between the High poverty and disaster risk and the Infrastructure.

10 UNISDR (2015).
11 Ibid.
12 See: Index for Risk Management (INFORM). Available at: http://www.inform-index.org/Results/Global
13 See: FAO, available at: http://www.fao.org/giews/earthobservation/
14 See: EM-DAT, available at: https://www.emdat.be/ and CRED, available at: https://www.cred.be/
15 Ibid.
16 Burgert, Clara R. (2014).
17 Krivoruchko, Konstantin (2012).

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Annex 3.1: The computable general equilibrium (CGE) model used in this report

This report builds on the CGE modelling exercise which was first used for the ESCAP report (2018) entitled Social Outlook for Asia and the Pacific Poorly Protected using version 9 of the Global Trade Analysis Project (GTAP) database. Data from World Development Indicators are used for the poverty, inequality and expenditure analysis.

Over the past three decades, CGE models have emerged as a tool to carry out ex-ante analysis of the possible implications of different policy options. CGE models offer a simple way of modelling the overall impact of policy changes on an economy, or a region, by considering relevant production activities, factors and institutions. The CGE models include markets and various macroeconomic components: investment and savings, balance of payments and government budget. They have become popular because they are able to incorporate multiple economic linkages or "transmission mechanisms" that often come handy when explaining trends and structural responses to changes in development policy.

In this report, the CGE model has been used to explore the impact of disaster risk on reducing poverty and inequality. Disaster risk is represented in the model as the Average Annual Loss (AAL) in millions of US dollars (See Annex 1.1 for more details about the AAL dataset). It further explored the extent to which increased public social spending levels can affect different poverty and inequality indicators. Spending levels are measured as a percentage of GDP to match the global averages of the three sectors, namely education (4.71 per cent of GDP); health (4.17 per cent of GDP); and social protection (11.2 per cent of GDP). These increases are being phased up to 2030. Given the lack of information about investment on the disaster-related infrastructure at the country level, the model assumes a uniform rise of two per cent of GDP immediately, which continues until 2030.

Household real expenditure is considered as the linking variable, i.e., the CGE model generates changes in household real expenditure out of any shock introduced in the model. The changes in household real expenditure is linked with headcount poverty rate and inequality index using the calculated elasticity values. The impacts of social and infrastructure investments on reducing poverty and inequality is transmitted through the following mechanisms:

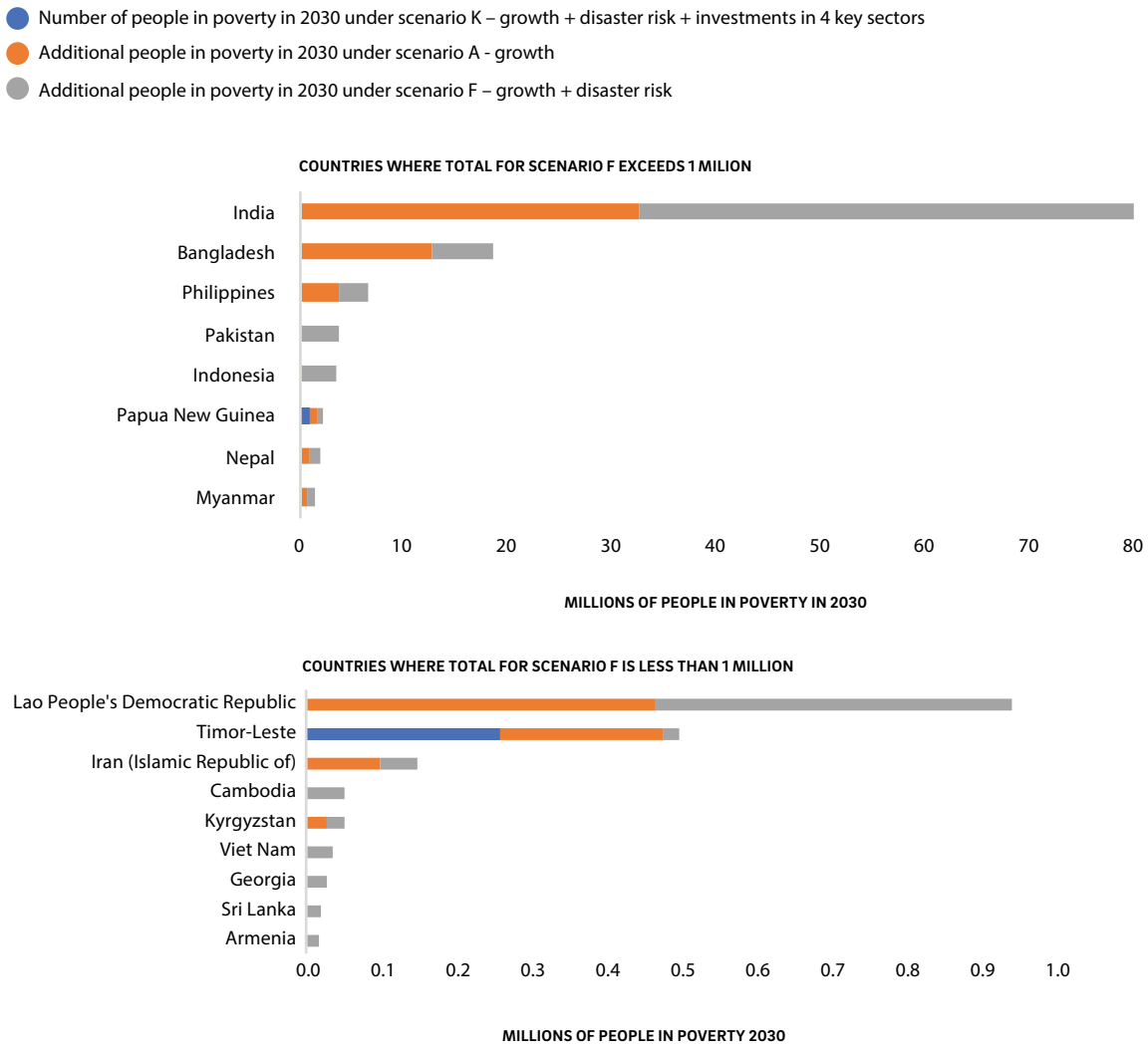
	SUPPLY SIDE	DEMAND SIDE
Shock on capital stock to reflect loss of capital stock due to disaster	Decreases capacity – lowers growth in sectors – lowers household income - lowers household real consumption – negative impact on poverty and inequality.	Higher prices of goods and services – reduces household real income - reduces demand for goods and services – lowers growth in sectors – negative impact on poverty and inequality.
Shock on capital stock to reflect rise in investment in infrastructure	Increases capacity – generates growth in sectors – increases household income - increases household real consumption – positive impact on poverty and inequality.	Lowers prices of goods and services – increases household real income – increases demand for goods and services – stimulates growth in sectors – positive impact on poverty and inequality.
Shock on productivity parameter in the constant elasticity of substitution (CES) value added function	Increases efficiency – generates growth in sectors – increases household income – increases household real consumption – positive impact on poverty and inequality	Lowers prices of goods and services – increases household real income - increases demand for goods and services – stimulates growth in sectors – positive impact on poverty and inequality.
Shock on government expenditure on education and health	Government expenditure on education and health increases productivity of labour - generates growth in sectors – increases household income – increases household real consumption – positive impact on poverty and inequality	Government expenditure on education and health reduces the prices of education and health service – increases household real income – increases demand for education and health service – stimulates growth in sectors – positive impact on poverty and inequality.
Shock on transfer from government to household (i.e. social protection)	Increases productivity – generates growth in sectors – positive impact on poverty and inequality	Increases household real income – increases demand for goods and services – stimulates growth in sectors – positive impact on poverty and inequality.

CGE models have plenty of limitations, as they impose major simplifications to the economy in order to reach conclusions. These limitations need to be kept in mind when interpreting results. First, the models do not account for the feedback of production on climate change and disasters. Second, disasters are entering as "scenarios" in these models. Although this assumption is standard in economics, this means that the impacts of disasters are assumed to impose the same investments to all countries. And finally, due to data and methodological limitations, the model outputs for linking inequality and disasters may not be as robust as the results for poverty. Despite their limitations, they remain useful tools for exploring the direction of the potential socioeconomic impacts of various policies and interventions.

Annex 3.2: Impacts of growth, disaster risk and investments on projected poverty levels based on CGE model

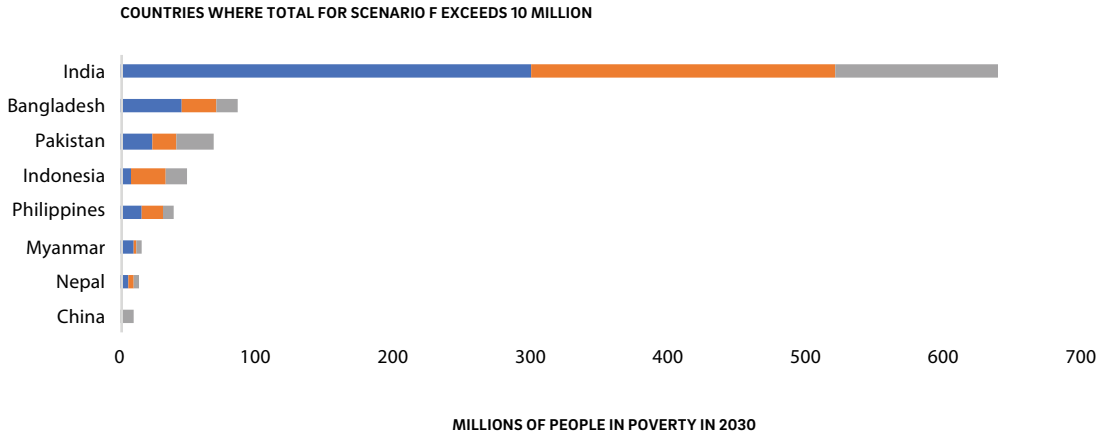
$1.90 a day poverty

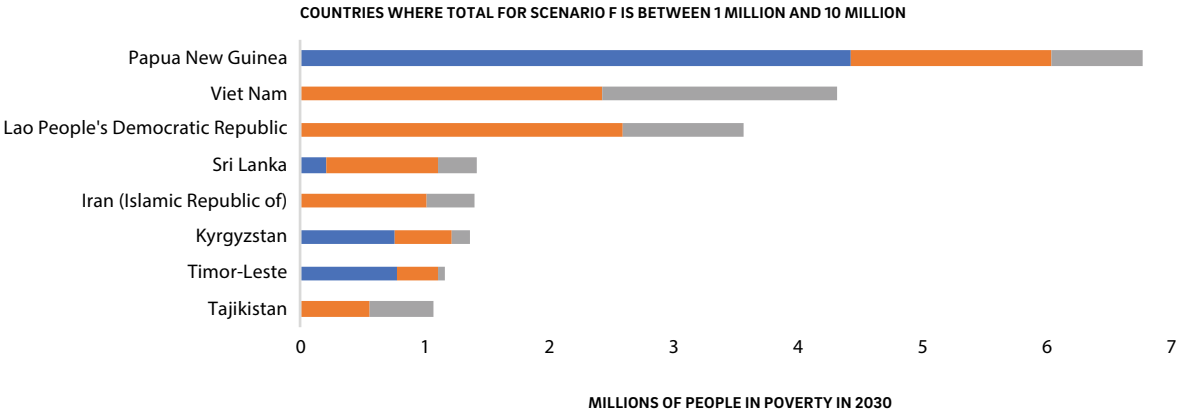
These graphs compare the numbers of people projected to be living under three poverty thresholds within each of the 26 countries in the CGE model, for different scenarios. They show that the numbers of people living below each poverty threshold are lower for scenario A (economic growth without disaster risk), than for scenario F (economic growth with disaster risk), in which significant numbers of additional people are living in poverty. Furthermore, the number of people for scenario K (where there is economic growth, with disaster risk, but also with investments in all four key sectors), is even less than for scenario A. Overall, this shows that disasters will undermine the ability of growth to reduce poverty, but this can be offset by investing in the key sectors.

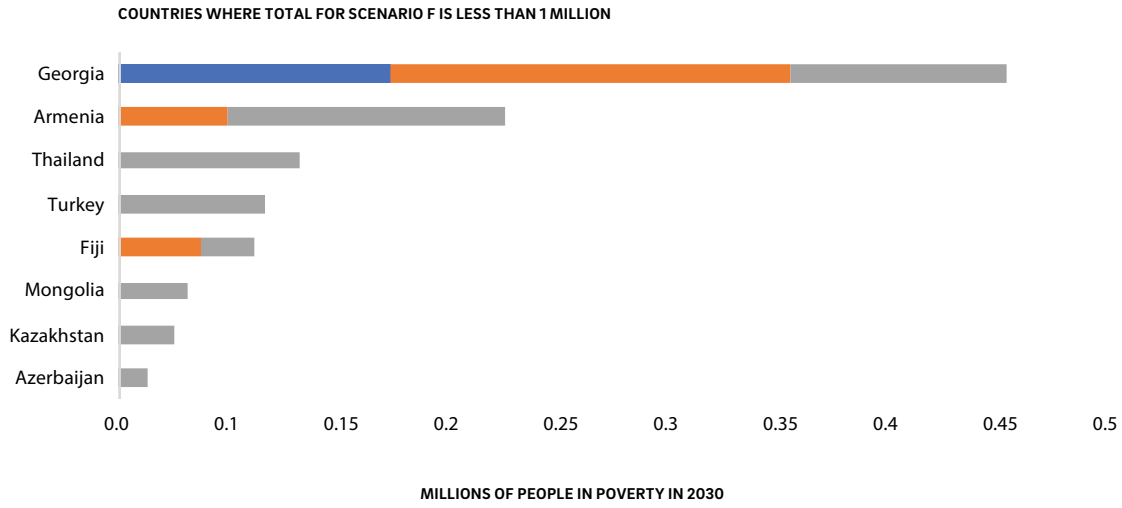


Note: Azerbaijan, China, Fiji, Kazakhstan, Malaysia, Mongolia, Tajikistan, Thailand and Turkey excluded as number of people is negligible for all scenarios here.

$3.20 a day poverty

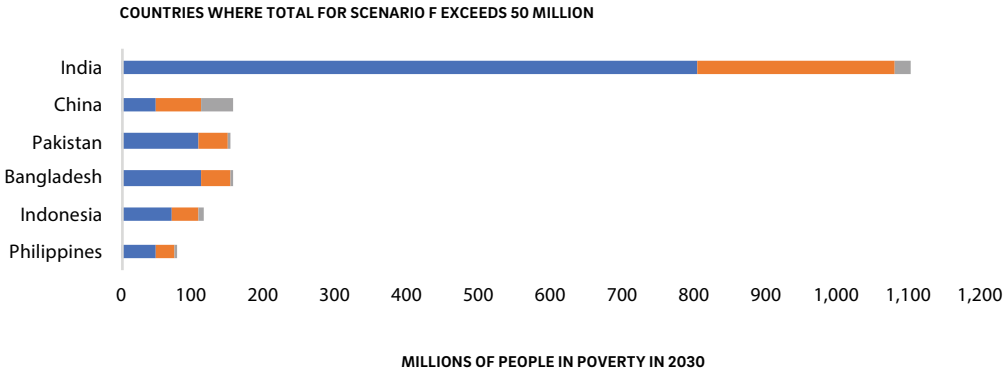


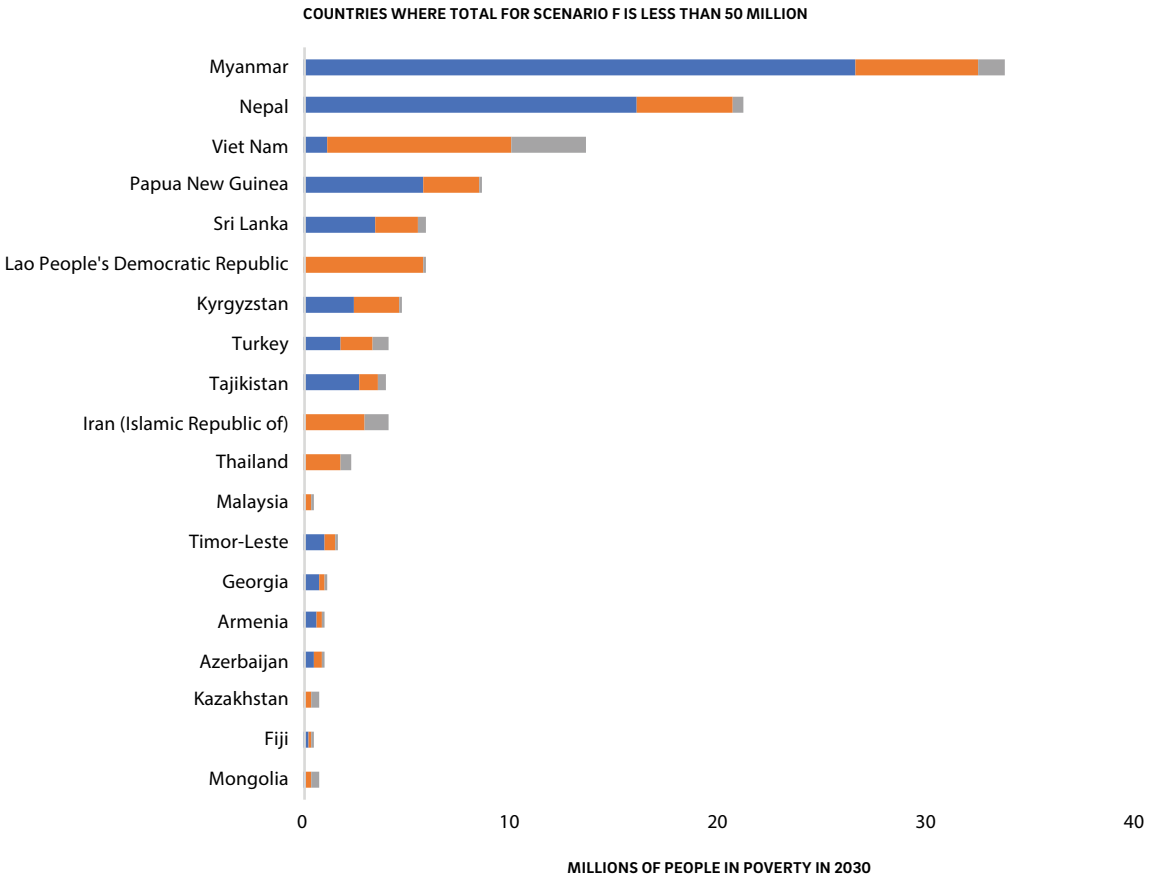




Note: Cambodia is excluded as sufficient data was not available. Malaysia excluded as number of people is negligible for all scenarios here.

$5.50 a day poverty





Note: Cambodia is excluded as sufficient data was not available

Source: All figures are from ESCAP calculations based on CGE model[18]

18 ESCAP (2018).

Reference

United Nations, Economic and Social Commission for Asia and the Pacific (2018). *Social Outlook for Asia and the Pacific: Poorly Protected*. Sales No. E.19.II.F.2. Available at: https://www.unescap.org/sites/default/files/publications/Social_Outlook.pdf.