QUANTIFYING THE ECONOMIC COSTS OF CLIMATE CHANGE INACTION FOR ASIA AND THE PACIFIC

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ABSTRACT

This paper uses results from leading biophysical models in an established macro-economic modeling framework to offer insights on potential economic consequences of climate change in Asia and the Pacific. The analysis covers shocks in agriculture, fisheries, forestry, energy demand, capital (from sea level rise and riverine floods), and labor (from heat stress and extreme events). The shocks are considered in a global recursive dynamic computable general equilibrium model that breaks out major economies of the region. The modeling finds that potential total gross domestic product loss as a result of climate change reaches 16.9% in Asia and the Pacific by 2070 under a high-end emissions scenario, with all economies negatively affected. Sea level rise is the largest source of loss, followed by loss of labor productivity due to heat stress. Damage function extrapolation of the losses suggests that they could reach 41.0% of gross domestic product by 2100.

Keywords: climate change, climate damage, computable general equilibrium, economic impact

JEL codes: Q54, Q51, C68, C63

I. BACKGROUND

A. Climate Vulnerabilities for Asia and the Pacific

Global climate change is occurring at an accelerating pace. As of late 2024, the year 2023 was the warmest on record, and February 2023–January 2024 already exceeded 1.5°C of warming compared with preindustrial averages (WMO 2024). Signs are emerging of potential tipping points, with an 87% increase in the rate of atmospheric carbon dioxide (CO_2) concentration growth between 2022 and 2023, despite an increase in fossil fuel emissions of less than 1% (Ke et al. 2024). This may be driven by reductions in natural carbon sinks, such as forests and soils, as temperatures warm, which suggests that warming may self-perpetuate even if anthropometric emissions are drastically reduced. As this is not a feature of current integrated assessment modeling, which suggests mean global warming of around 3°C under implemented policies or 2.4°C under Nationally Determined Contributions, warming may go much faster than these scenarios depict (ADB 2023).

Climate change over land in Asia and the Pacific is happening at a faster rate than changes in global averages including sea surface temperatures. In 2023, the mean temperature over Asia was the second highest on record (1.87°C above the 1961–1990 average) (WMO 2024). In addition, there is increasing evidence of a shift in monsoon rainfall variability and of an upward trend in the intensity and frequency of extreme weather events in Asia, such as tropical cyclones, heavy precipitation and flooding, droughts, and heatwaves and wildfires (Shaw et al. 2022). While in 2023 over 80% of reported hydrometeorological hazards in Asia were flood and storm events (WMO 2024), rising temperatures also increase the likelihood of heatwaves across Asia; droughts in arid and semiarid areas of West, Central, and South Asia; delays and weakening of the monsoon circulation in South Asia; and glacial melting in the Hindu Kush Himalaya region (Shaw et al. 2022). Even as flooding risks will increase in monsoon seasons in South, Southeast, and East Asia, the region will also face water shortages as a result of climate change in combination with growing water demand from rapid population and economic growth (Vinke et al. 2017). Long coastlines and populations concentrated in coastal areas mean that much of Asia is susceptible to sea level rise (SLR) and increased storm surges under climate change. Land subsidence and erosion will also occur simultaneously with SLR, exacerbating effects. The projected rise could lead to large-scale flooding in low-lying areas, particularly in South, Southeast, and East Asia.

Asia and the Pacific is vulnerable to these changes. Based on the 2021 Climate Risk Index, six out of the top 10 world economies most affected by weather-related loss events (i.e., storms, floods, landslides, and heatwaves) over 2000–2019 were in the region. A number of economies in Asia and the Pacific regularly experience annual losses associated with extreme weather events equivalent to over 1% of gross domestic product (GDP) (Vinke et al. 2017). From 2000 to 2022, the region accounted for more than half of multi-hazard global average annual losses, most of which were climate related (ESCAP 2022). During this period, 82,000–140,000 casualties and $233 billion–$1.5 trillion worth of loss and damage to property were recorded in the region (Eckstein, Künzel, and Schäfer 2021), with river flooding being the largest source of losses, especially in South Asia and Pakistan. According to the World Meteorological Organization (WMO 2023), in 2022 only, the economic losses associated with floods exceeded the average over the past 20 years (2002–2021), with major losses from floods in Pakistan (over $15 billion), the People's Republic of China (PRC) (over $5 billion), and India (over $4.2 billion). The economic losses associated with drought in 2022 ($7.6 billion), which occurred mainly in the PRC, exceeded by nearly 200% the 20-year average from 2002 to 2021 ($2.6 billion). These events not only directly impact people and infrastructure but also lead to larger, indirect, second-order disruptions on supply chains and business.

Hotter temperatures reduce labor productivity and increase morbidity and mortality from heat related stress (Lai et al. 2023). As the region experiences hotter warm seasons, energy demand for cooling is also increasing at a rapid rate. Decreased precipitation influences energy demand as well, as desalination, underground water pumping, and other energy-intensive methods are increasingly used for water supply. More energy demand in warm seasons is expected to exceed any energy savings from relatively lower heating demand as a result of warmer cool seasons. Among 13 developing economies with large energy consumption in Asia, 11 are exposed to high-energy insecurity and industrial systems risk (Shaw et al. 2022). The threat of energy insecurity emerges from potential grid infrastructure failure, intermittent performance of hydropower plants as a result of uncertain water discharges, and reduced capacities of thermal power plants as a result of an increasing scarcity of cooling water (Vinke et al. 2017).

Agriculture is often considered to be among the most vulnerable sectors in Asia to a changing climate (Mendelsohn 2014; Vinke et al. 2017). Climate change poses large, but regionally differing, threats to agriculture and food security in Asia through higher temperatures, drier conditions, SLR, salinization, flooding, pest and disease pressure, and reduced labor productivity

(Vinke et al. 2017). Recent evidence also indicates that climate-related risks to agriculture and food security in Asia will progressively escalate as global warming reaches 1.5°C and higher above preindustrial levels (Masson-Delmotte et al. 2018).

Asia and the Pacific depends on marine resources that are at risk from warming of the seas as a result of climate change and ocean acidification as CO_2 concentrations rise. In 2019, the region contributed 75% of global fisheries production (FAO 2020). There is high agreement that Asia and the Pacific's fisheries and aquaculture are highly vulnerable to the impacts of climate change (Shaw et al. 2022), caused by SLR (Panpeng and Ahmad 2017), decreases in precipitation (Salik et al. 2015), and an increase in temperature (Vivekanandan, Hermes, and O'Brien 2016, FAO 2018). Moreover, coastal fishing communities are exposed to disasters, which are predicted to increase (Esham et al. 2018).

Forest resources and ecosystems are particularly vulnerable to climate change, as trees have long lifespans and limited ability to adapt to changes in climatic conditions. New pests, parasites, diseases, and exotic competitor species can spread further as conditions shift (IPCC 2022). This can exacerbate forest dieback (or death of entire stands of trees), which means that both the production value and ecosystem services from natural forest areas will decline. Intensified and more frequent droughts can cause more dry matter to be flammable, increasing forest fire risks.

B. Prior Research on the Economic Costs of Climate Change

Econometric studies consistently show that temperature increase anomalies impact GDP negatively, especially in economies with hotter climates. However, there has been sharp divergence between studies that assume that effects of temperature are transient (and use GDP levels as the dependent variable) and studies that assume effects are persistent (and use GDP growth as the dependent variable) (Newell, Prest, and Sexton, 2021). The latter show much higher climate change effects, but the specifications are unstable. A more recent innovation is that of Kotz, Levermann, and Wentz (2024), which tests for persistence using various lags of climatic variables in panel regressions. That analysis finds large effects of climate change, with reductions in GDP of over 50% by 2070 in South Asia and nearly 50% in Southeast Asia under a high-end emissions scenario. However, like all econometric studies, the article proxies weather fluctuations for long-term changes in climate. Weather fluctuations are unforeseeable and will likely have different economic effects than changes in average conditions. In addition, econometric studies of fluctuations tend to omit any beneficial effects of climate change, such as

CO_2 fertilization of crops or reductions in energy demand for heating. They also omit channels of future losses, such as sea level rise, which have limited observation to date. For these reasons, there is still value in building up analysis from specific sectoral shocks to understand economy-wide implications.

Work in this vein has been previously conducted by the Asian Development Bank (ADB) (2016, 2017) for Central and West Asia, finding that climate change cost 1.3% of GDP up to 2050, under a 3.8°C warming scenario, rising to 10% of the subregion's GDP by 2100. In East Asia, the average losses due to climate change were found to amount to 5.3% of annual GDP by 2100 under a high-end emissions scenario. In the Pacific subregion, impacts were estimated to reach the equivalent of 3% of annual GDP by 2100 under the same scenario. In South Asia, losses were found to amount to the equivalent of 1.8% of annual GDP by 2050 under a +3.8°C scenario, progressively increasing to 8.8% by 2100. Southeast Asia was found to experience a loss equivalent to more than 11% of GDP annually by 2100 under a high-end emissions scenario (Raitzer et al. 2016). These rather low estimates are driven by representation of sector shocks as transient and affecting output, rather than as affecting capital stock and productivity persistently.

Recent studies that include those channels consistently indicate much higher climate change impacts. Van der Wijst et al. (2023) report losses from a framework that uses a range of sectoral models to shock capital stock and factor productivity in a computable general equilibrium (CGE) model under a climate scenario consistent with currently implemented losses, and project total losses for Asia of between 12% and 14% of GDP in 2100. ADB (2023) fits damage functions to those results to extend them to a high-end emissions scenario and finds GDP losses of up to 24% by 2100 for developing Asia, with India and Southeast Asia experiencing mean losses of 35% and 32%, respectively, while the rest of South Asia and the PRC face losses of 24% and 8%, respectively. However, the van der Wijst et al. (2023) study, while global in coverage, is oriented primarily toward understanding climate change impacts in the European Union (EU), so there is limited attention to the results for developing Asia and the Pacific. This means there is scope to improve understanding of climate change vulnerabilities for Asia and the Pacific through a similar effort focusing on this region.

II. OBJECTIVES

The aim of this analysis is to assess the potential economic consequences of climate change in Asia and the Pacific using the latest sector/risk-specific climate change shocks, combining outputs from sectoral models with a well-established macroeconomic model. Such an approach creates a clear basis for understanding potential drivers of losses and appropriate adaptation responses within the region.

Observed emissions have not substantially diverged from the high-end emissions scenario of the Intergovernmental Panel on Climate Change (IPCC), termed Shared Socioeconomic Pathway 5 ("Fossil Fueled Development") Representative Concentration Pathway 8.5 (RCP8.5) or SSP5-8.5 in the Sixth Assessment Report, which leads to a median estimate of 4.7ºC of mean global warming by 2100 (Schwalm, Glendon, and Duffy 2020). While integrated assessment modeling suggests that implemented policies may lead to around 3ºC of mean warming, such models both assume that policies are fully implemented and do not reflect important carbon cycle feedbacks, such as reductions in sequestration by natural ecosystems under warming (ADB 2023). Nor does it reflect policy backsliding in emitting sectors, which is becoming increasingly likely for some major emitters. For these reasons, the warming typifying a high-end emissions scenario is still a possible planetary outcome. To align with this possibility, the work focuses on SSP5-8.5. The SSP5-8.5 scenario also allows comparability of results with previous ADB studies using RCP8.5, as well as seminal empirical studies that employ the same scenario, such as Kotz, Levermann, and Wentz (2024) and Burke, Hsaing, and Miguel (2015).

Climate change shocks are considered on the following areas: agricultural yields, fisheries yields, forestry yields, energy demand, capital (impacted by SLR and riverine floods), and productive activities (labor productivity change for health–temperature nexus, SLR, and riverine floods). Major data sources for shocks pertaining to agriculture, fisheries, forestry, and river-based flooding include the recently concluded CO-designing the Assessment of Climate Change Costs (COACCH) project[1] (under the EU's Horizon 2020 (H2020) project) and the Inter-Sectoral Impact Model Intercomparison Project (ISIMIP) database.[2] The shocks reflect a limited amount of climate adaptation, with static protective measures incorporated.

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[1] Co-Designing the Assessment of Climate Change Costs (COACCH). www.coacch.eu/
[2] The Inter-Sectoral Impact Model Intercomparison Project. www.isimip.org/

The shocks are fed into the Intertemporal Computable Equilibrium System (ICES), a CGE model, to assess the joint effect of multiple climate-induced shocks on the economy of the analyzed economies, including higher-order impacts. For example, the cascading effects of agricultural productivity losses on the entire economy are quantified, including the implications of changes of price and quantity consumed of these commodities in the impacted economy, the adjustment in demand and price of non-agricultural commodities due to household budget constraints, consequences for household income, and trade implications. The omission of these higher-order effects may bias economic cost estimates.

The modeling exercise is first performed on one shock at time. In a second step, a joint assessment of all shocks is also provided. The simulations run until 2070, in 5-year time steps. ICES is a global model, so effects on trade and comparative advantage are incorporated. Appendix 1 provides details on sectoral and regional disaggregation.[3] The model provides a economy/region-specific quantification of the cost of climate change shocks synthesized by GDP losses and gains. Results reveal the sectoral distribution of the impacts and highlight the most relevant climate change threats for the area and the most vulnerable regions and sectors that should be targeted by preventative adaptation measures.

III. METHODOLOGY

Quantifying the impacts of climate change requires a set of tools to capture the complex interactions between climate, natural, and human systems. Sector- or risk-specific climate change shocks (direct climate change shocks) are generated by models or empirical analyses capable of reproducing and predicting the behavior of one or several sectors from the change of climate variables. Then a CGE model can be used to understand the propagation of the sector and risk-specific shocks in the economy and to combine all shocks.

A. The Intertemporal Computable Equilibrium System model

ICES is a recursive-dynamic multiregional CGE model developed to assess economy-wide impacts of climate change on the economic system. The model's general equilibrium structure allows for the analysis of market flows within each national economy and international flows with the rest of the world. This implies going beyond the "simple" quantification of direct costs of a

[3] The Appendix is available at http://dx.doi.org/10.22617/WPS250073-2.

shock to offer an economic evaluation of second and higher-order effects within specific scenarios of climate change, climate policies, and/or different trade and public policy reforms in the vein of conventional CGE theory.

The model is derived from the GTAP-E model (Burniaux and Troung 2002)[4]. Within each economy or region, the economy is characterized by multiple industries, a representative household, and the government (Eboli, Parrado, and Roson 2010). Industries are modeled as representative, cost-minimizing firms, taking input prices as given. In turn, output prices are given by average production costs.

For each productive sector, a representative firm maximizes its profits given a set of input (factors and intermediate inputs) and output prices. This means that factor remuneration equals marginal costs based on endogenous relative prices. Consistent with neoclassical theory, production functions assume constant returns to scale. Each commodity is sold domestically or abroad without any substitution. However, following the Armington approach, productive sectors and final institutional accounts purchase a composite of not-perfectly substitutable domestic and foreign commodities.

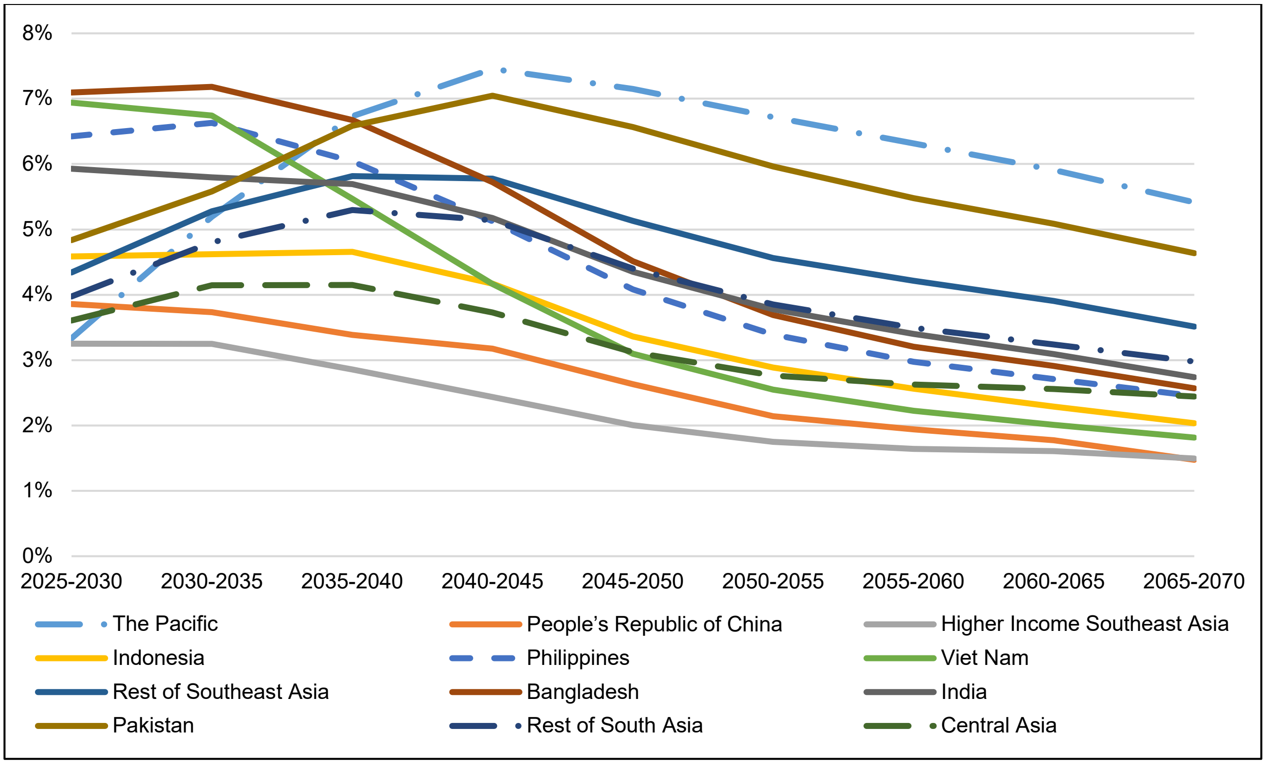
The representative household earns most of its income from the returns of owned primary factors (capital, labor, land, and natural resources). In addition, the household is taxed and receives transfers from the government and the rest of the world (i.e., interest repayments). Then, income is split between consumption and saving in fixed shares.

ICES is solved as a series of equilibria (5-year steps). The dynamic of the model is led by the accumulation processes of capital. Capital accumulation is modeled endogenously, with current period investment generating new capital stock for the subsequent period. ICES equations are connected to the GTAP 11 database (Aguiar, at al. 2022), which accounts for all real economic flows of the world economy and also offers a disaggregated representation of the electricity sector (Peters 2016).

[4] The energy environmental extension of the Global Trade Analysis Project.

The reference no climate change scenario is used as a point of comparison to assess the impacts of climate change. Both this and the SSP5-8.5 climate scenario are built on the SSP5 scenario, which is characterized by high economic growth (Figure 1) and strong reliance on fossil fuels.

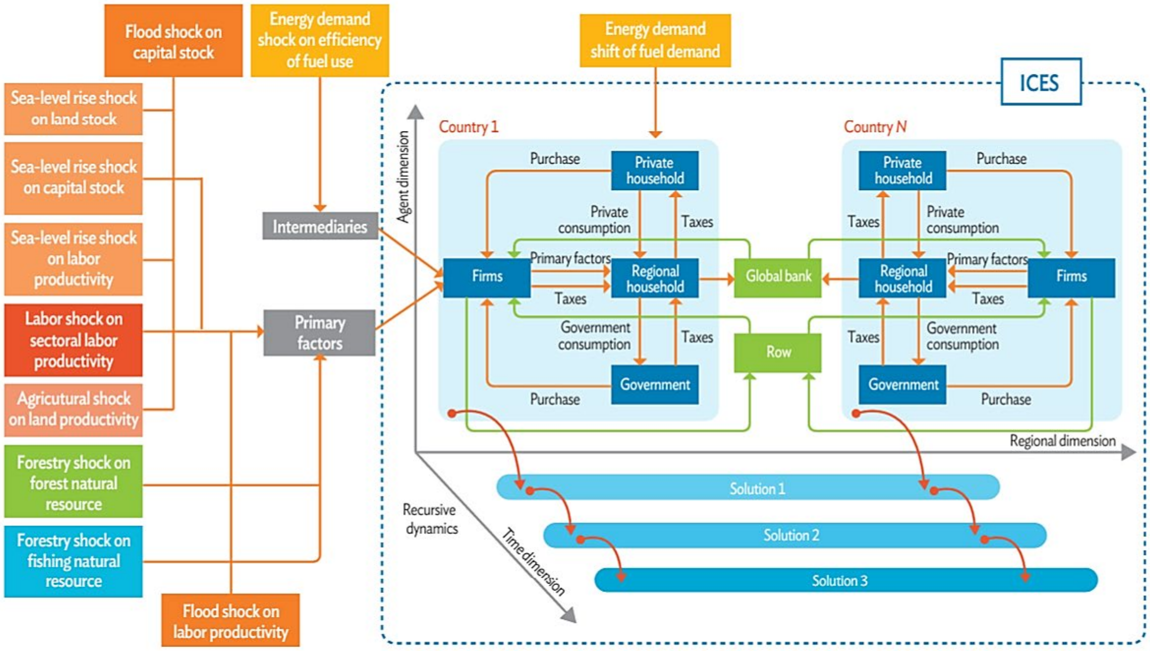
Figure 1: Gross Domestic Product Growth Rates in the No Climate Change Scenario



Notes: Central Asia comprises Armenia, Azerbaijan, Georgia, Kazakhstan, the Kyrgyz Republic, Mongolia, Tajikistan, Turkmenistan, and Uzbekistan. Higher Income Southeast Asia comprises Brunei Darussalam, Malaysia, Singapore, and Thailand. The Pacific comprises the Cook Islands, Fiji, Kiribati, the Marshall Islands, the Federated States of Micronesia, Nauru, Niue, Palau, Papua New Guinea, Samoa, Solomon Islands, Tonga, Tuvalu, and Vanuatu. Rest of South Asia comprises Afghanistan, Bhutan, Maldives, Nepal, and Sri Lanka. Rest of Southeast Asia comprises Cambodia, the Lao People's Democratic Republic, Myanmar, and Timor-Leste.
Source: Authors, drawing on SSP5 projections from the OECD linkages model accessible at IXMP Scenario Explorer developed by IIASA (accessed 10 January 2024).

The sector models considered in this analysis provide a wide set of climate change shocks on agriculture, fisheries, forestry, energy demand, capital and labor productivity. Figure 2 describes the channels through which each shock interacts with the agents and production factors of the ICES model. A majority of modeled shocks have impacts on firms' behavior and production by altering the stock or the productivity of primary factors (land, capital, labor, natural resources). Energy demand shocks shift the use of energy inputs in the ICES model (intermediates) by firms and private households, which modifies firm production and household consumption choices.

Figure 2: Framework to Quantify the Economic Effects of Climate Change Impacts



ICES = Intertemporal Computable Equilibrium System.
Source: Authors.

B. The Modeled Channels of Climate Change Impact

For **agricultural yields**, crop-specific shocks are fed into the ICES model according to the sectoral mapping reported in Appendix 1. Rice and wheat shocks are used with no changes to the respective ICES sectors; whereas the maize shock is used for all items in the sector “other grains”; the wheat shock is applied to all elements in the “vegetables and fruits” sector; and an average shock is computed for the `”other agriculture” macro sector, as a weighted mean of soybean shock weighted by the soybean harvested area share from FAOSTAT and the wheat shock applied to the remaining harvested area share of the sector. Regarding the evapotranspiration shocks, the wheat shocks were used for both the “vegetables and fruits” and “other agriculture” sectors. The shocks are implemented as shocks on sector-specific land productivity. For the **forestry and fisheries yields**, the computed direct shocks are directly imputed as shocks on the sector-specific productivity of natural resources.

The climate change direct shocks on **labor productivity** are cross-sectoral and differentiated depending on the exposure of sectors. The analysis mapped the ICES sectors into high exposure (agriculture sectors, forestry, fisheries) and low exposure (industry and manufacturing). Labor productivity by sector is the reference variable to be shocked in this case.

The climate change shocks on **energy demand** can be considered as adaptation measures to increase thermal comfort and decrease the side-effects of heatwaves. Differently from the other shocks, the energy demand shocks are implemented in the ICES model as households' consumption shifts. The households are forced to consume a different quantity of gas, electricity, and petroleum products, altering the demand and price of these commodities and also changing the consumption of all other goods because of the budget constraint. In the case of production sectors, the climate-induced variation of energy demand is modeled as a reduction in the use efficiency of the energy input.

The shocks due to **increased riverine flooding**, together with those due to SLR, are composite because they include the simultaneous occurrence of a shock on labor productivity to reproduce the slowdown of productivity after the floods and a shock on capital stock. The shock on labor productivity is computed combining information on the affected population in each economy and the population of the economy. This shock is then multiplied by a factor (2 weeks over the yearly working weeks) accounting for a temporary reduction of labor productivity. The shock on capital stock is computed using the sectoral expected annual damage and the corresponding sectoral capital stock from the no climate change scenario results of ICES.

The procedure is similar to that of river-based flooding in the case of **SLR** shocks on capital and labor productivity, with the difference that the expected annual damage caused by SLR is considered uniform across sectors. In addition, SLR implies also a shock on land availability that slowly reduces year by year.[5]

[5] A graph on land loss was omitted because of low variability across scenarios and high disparity across economies.

IV. RESULTS

A. Direct Climate Change Shock Inputs

Agricultural Yields

Direct climate change shocks on the agriculture sector are computed using data from round 3b of ISIMIP on crop yields.[6] ISIMIP3b applies gridded process-based crop growth models under an array of climate scenarios and general circulation models (GCMs) from Phase 6 of the Coupled Model Intercomparison Project (CMIP6). Crops modeled for selected scenarios are rice, wheat, maize, and soy. The following crop models have been selected because of crop coverage and scenario availability: CROVER, EPIC-IIASA, LDNDC, LPJmL, PEPIC, and CYGMA1P74. Each crop model provides model runs using different GCMs: GFDL-ESM4, IPSL-CM6A-LR, MPI-ESM1-2-HR, MRI-ESM2-0, and UKESM1-0-LL. ISIMIP yield data are spatially gridded, so the Global Dataset of Monthly Irrigated and Rainfed Crop Areas around the year 2000 (MIRCA2000)[7] is used to compute national crop-specific yield. Yield pathways over time are then smoothed using a quadratic fit. Yield percentages in a high-end climate change scenario (SSP5-8.5) with respect to 2020[8] are computed for each crop, crop model, and GCM. Annual median, high (10th percentile), and low (90th percentile) percentage changes of yield are computed and used as climate change-related shocks on agriculture.

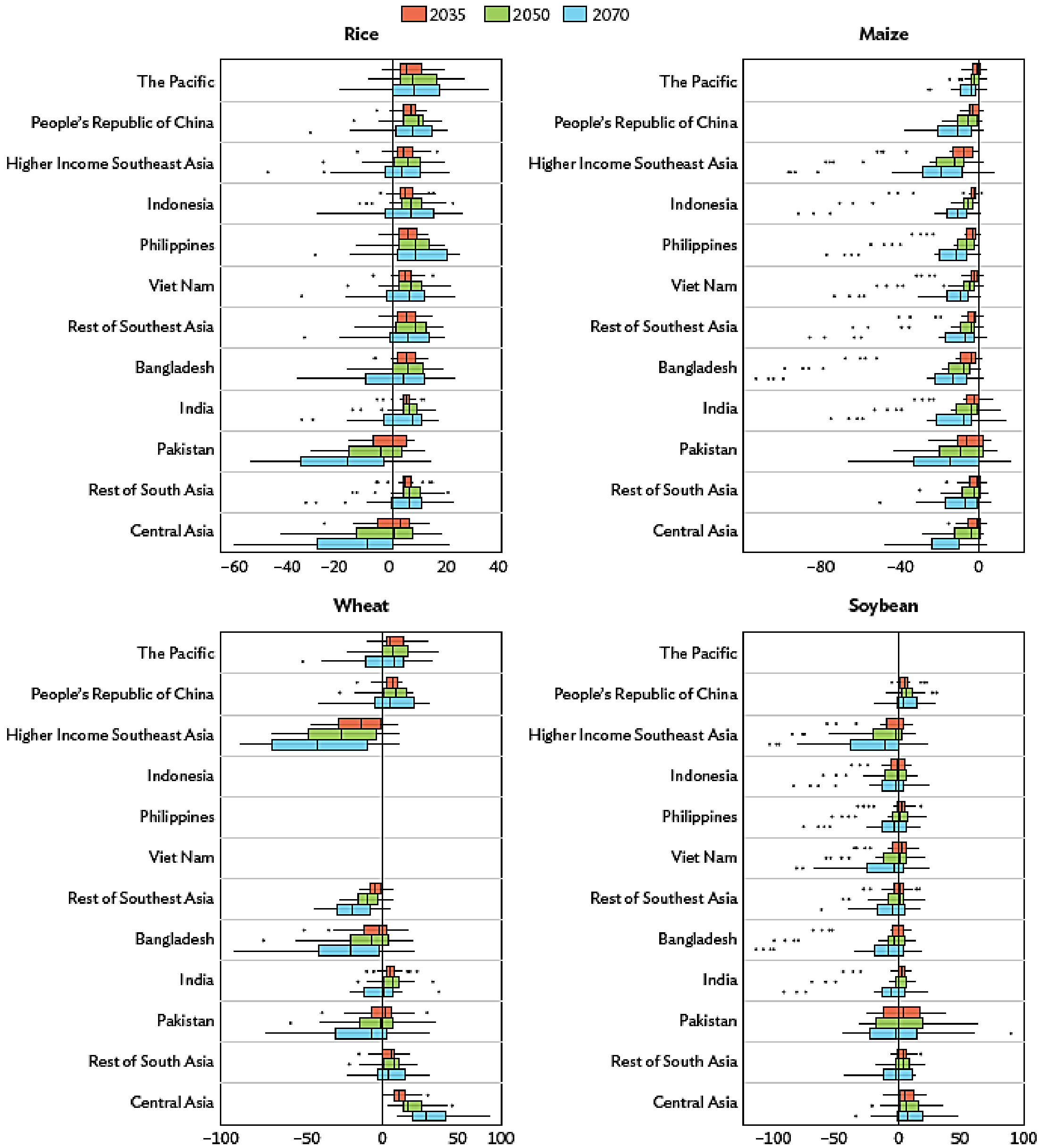
Future long-term projections of crop yield changes vary extensively for some regions and crops, because of the uncertainty of crop models and GCMs (Figure 3). However, a clear negative pattern emerges for a number of crops and regions. Widespread and large losses are projected for maize in 2070 with respect to 2020 (median values of up to -18% for Higher Income Southeast Asia and between -5% and -15% for all the other regions except the Pacific), with yields decreasing even in the short term (2035). Soybean yields benefit moderately from climate change in the short and medium term (2050) but a negative pattern emerges in the long term (2070) for many areas. Overall, rice yield improves under climate change in almost every region excluding Pakistan and Central Asia, whereas wheat shows strong regional differences (median values of -42% for Higher Income Southeast Asia, -20% for Bangladesh, and -19% for Rest of Southeast Asia).

[6] https://data.isimip.org/search/tree/ISIMIP3b/OutputData/agriculture/

[7] Version 1.1 v database (https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2008GB003435).

[8] Crop models do not account for any socioeconomic forcing apart from that observed in the base year, therefore all the observed yield change can be attributed to the climate forcing.

Figure 3: Climate Change Effects on Crop Yields Under a High-End Emissions Scenario, as Shown by Gridded Crop Growth Modeling (% change relative to 2020)

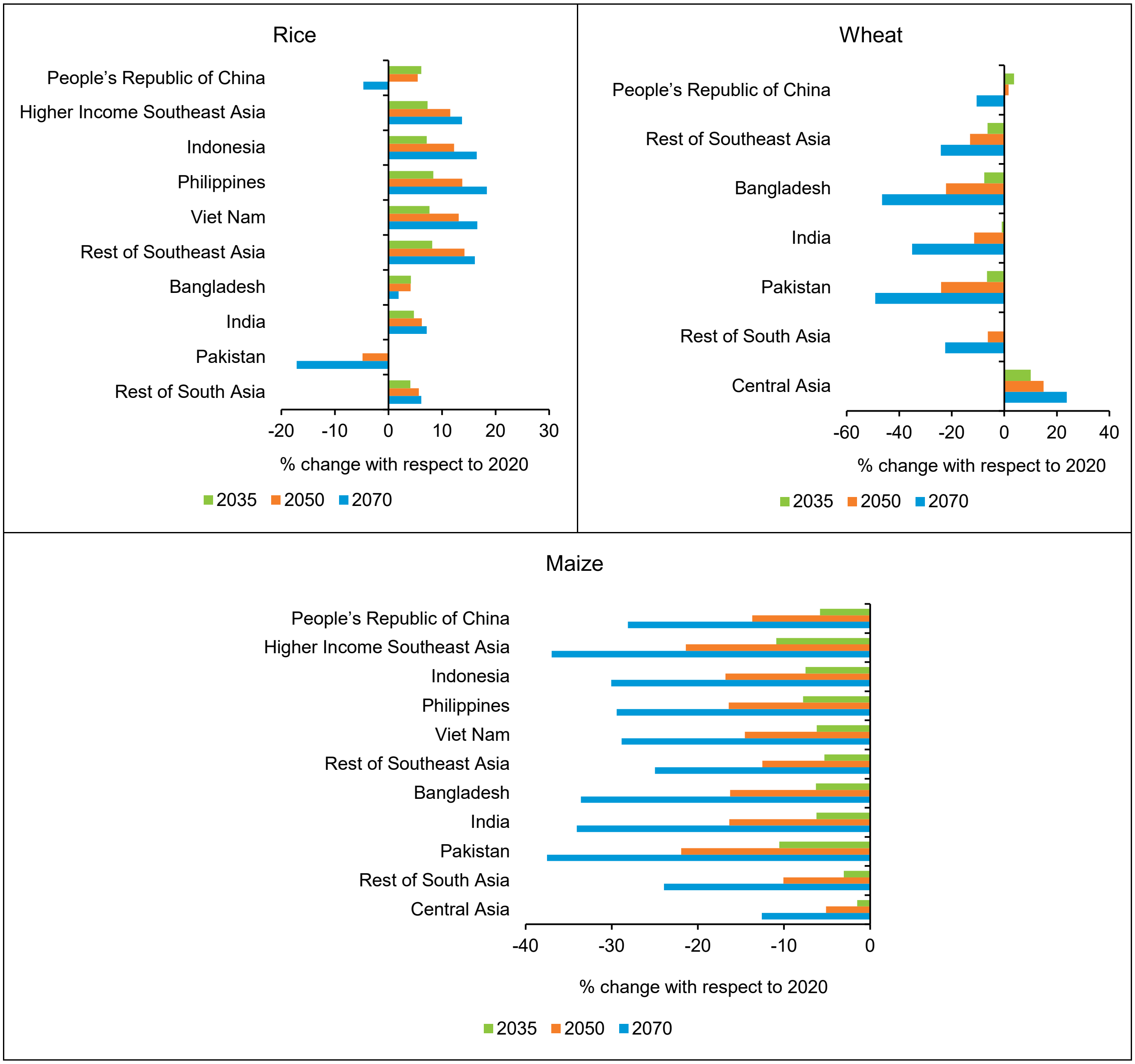


Notes: Scenario is SSP5-8.5. Central Asia comprises Armenia, Azerbaijan, Georgia, Kazakhstan, the Kyrgyz Republic, Mongolia, Tajikistan, Turkmenistan, and Uzbekistan. Higher Income Southeast Asia comprises Brunei Darussalam, Malaysia, Singapore, and Thailand. The Pacific comprises the Cook Islands, Fiji, Kiribati, the Marshall Islands, the Federated States of Micronesia, Nauru, Niue, Palau, Papua New Guinea, Samoa, Solomon Islands, Tonga, Tuvalu, and Vanuatu. Rest of South Asia comprises Afghanistan, Bhutan, Maldives, Nepal, and Sri Lanka. Rest of Southeast Asia comprises Cambodia, the Lao People's Democratic Republic, Myanmar, and Timor-Leste.
Source: Results drawn from the [Intersectoral Model Intercomparison Project 3b]() database (accessed 1 March 2024).

Gridded crop growth models of the type used in ISIMIP3b have poor ability to replicate yields under drought and other evapotranspiration extremes, which are projected to become more common under a high-end emissions scenario (Heinicke et al. 2022). To address this, ISIMIP results are complemented with econometric estimation that isolates the effect of droughts and floods (Raitzer and Drouard 2024). The evapotranspiration extreme-related shocks are computed for rice, maize, and wheat.

Figure 4 shows yield reductions for rice, wheat, and maize by economy and year used in ICES to capture the effect of extreme events on crop yields. These are derived by regressing gridded crop yields from remote sensing on quadratic specifications of temperature, rainfall, cloud cover, 6-month SPEI (Standardized Precipitation Evapotranspiration Index), and cell-specific time trends, with coefficients estimated by subregion of the globe for 2003–2015 at 0.1 ºC resolution (Raitzer and Drouard 2024). The SPEI-6 coefficients are then used with median SPEI-6 projections under SSP5-8.5 from the Copernicus Climate Atlas to project the effects of changes in drought conditions on yields. Over time, the SPEI-6 values become very negative, as increases in evapotranspiration are modeled to exceed increases in rainfall. As for ISIMIP results, the econometric shocks on rice are null or positive for the majority of the regions. Yield reductions for maize are all negative, as are wheat yield reductions, with losses concentrated in South Asia. These shocks are combined with those from ISIMIP to provide an overall assessment of the implications of climate change through the channel of agricultural shocks, as shown in Figure 4. Where both ISIMIP3b and the econometric shocks are negative, losses are larger than the above; in other cases, gains amplify each other. Combined effects on rice are gains of up to 15% of yields in all economies other than Pakistan in the PRC, on wheat there are losses of up to 49% aside from Central Asia, and for maize there are losses in all regions, with reductions of up to 37%.

Figure 4: Cumulative Climate Change Impacts on Crop Yields Under a High-End Emissions Scenario Considering Econometric and Modeled Changes



Notes: Scenario is SSP5-8.5. The analysis in the figure is with respect to 2020 crop yields and considers effects of both average climatic conditions and extreme events. Central Asia comprises Armenia, Azerbaijan, Georgia, Kazakhstan, the Kyrgyz Republic, Mongolia, Tajikistan, Turkmenistan, and Uzbekistan. Higher Income Southeast Asia comprises Brunei Darussalam, Malaysia, Singapore, and Thailand. The Pacific comprises the Cook Islands, Fiji, Kiribati, the Marshall Islands, the Federated States of Micronesia, Nauru, Niue, Palau, Papua New Guinea, Samoa, Solomon Islands, Tonga, Tuvalu, and Vanuatu. Rest of South Asia comprises Afghanistan, Bhutan, Maldives, Nepal, and Sri Lanka. Rest of Southeast Asia comprises Cambodia, the Lao People's Democratic Republic, Myanmar, and Timor-Leste.

Source: Results drawn from the Intersectoral Model Intercomparison Project 3b database accessed 1 March 2024; and combined with results from Raitzer, D. A. and J. Drouard. 2024. Empirically Estimated Impacts of Climate Change on Global Crop Production via Increasing Precipitation-Evapotranspiration Extremes. Background paper for the *Asia-Pacific Climate Report 2024: Catalyzing Finance and Policy Solutions.* Asian Development Bank.

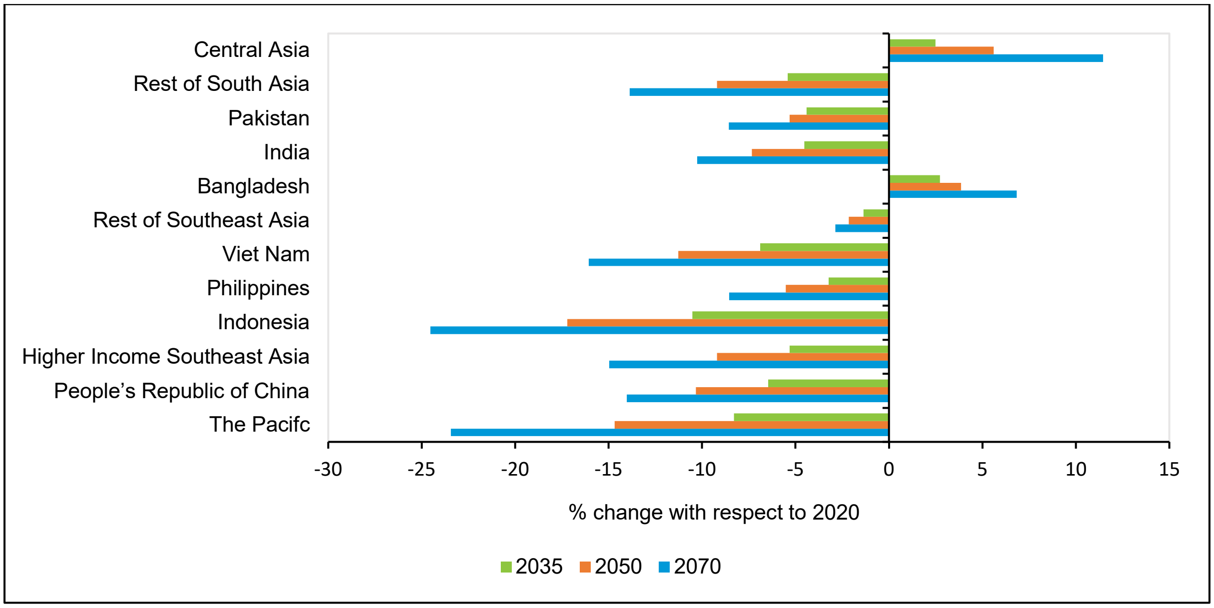
Fisheries Yields

Climate change shocks on fishing are computed as annual percent change of area fishing productivity using ISIMIP3b data on "fisheries and marine ecosystem".[9] The yield of fishing activities is proxied by the total consumer biomass density (grams per square meter (g/m^2))—that is, the density of all animals, size classes, or trophic groups. The considered impact models are BOATS and EcoOcean, which provide results for the available GCMs GFDL-ESM4 and IPSL-CM6A-LR. The total consumer biomass density is at gridded level, and it is matched with the Maritime Boundaries Geodatabase of Exclusive Economic Zones (200 NM), version 12,[10] to compute values for the regions. Smoothing is performed using a quadratic fit and the percentage change of resource yield under a high-end emissions scenario (SSP5-8.5) was computed with respect to 2020 for each model and GCM, assuming fixed fishing effort at 2020 levels. Annual median, high (10th percentile), and low (90th percentile) percentage changes of fishing yield are computed for available models and GCMs.

With the exception of Bangladesh and Central Asia, all regions are found to have reduced fish yield, even in the short term, with changes in total consumer biomass density ranging from -5% to -10% by 2035 with respect to 2020. Loss is projected to consistently grow by 2050, with nearly every region facing declines between 3% (Rest of Southeast Asia) and 25% (the Pacific) in fishing sector productivity in 2070 with respect to 2020 (Figure 5).

[9] ISIMIP3b Repository (https://data.isimip.org/search/tree/ISIMIP3b/OutputData/marine-fishery_global/).
[10] Maritime Boundaries Geodatabase (www.marineregions.org/sources.php#marbound).

Figure 5: Climate Change Impacts on Fishing Catch Under a High-End Emissions Scenario



Notes: Scenario is SSP5-8.5. Central Asia comprises Armenia, Azerbaijan, Georgia, Kazakhstan, the Kyrgyz Republic, Mongolia, Tajikistan, Turkmenistan, and Uzbekistan. Higher Income Southeast Asia comprises Brunei Darussalam, Malaysia, Singapore, and Thailand. The Pacific comprises the Cook Islands, Fiji, Kiribati, the Marshall Islands, the Federated States of Micronesia, Nauru, Niue, Palau, Papua New Guinea, Samoa, Solomon Islands, Tonga, Tuvalu, and Vanuatu. Rest of South Asia comprises Afghanistan, Bhutan, Maldives, Nepal, and Sri Lanka. Rest of Southeast Asia comprises Cambodia, the Lao People's Democratic Republic, Myanmar, and Timor-Leste.
Source: Results drawn from the Intersectoral Model Intercomparison Project 3b database accessed 1 March 2024.

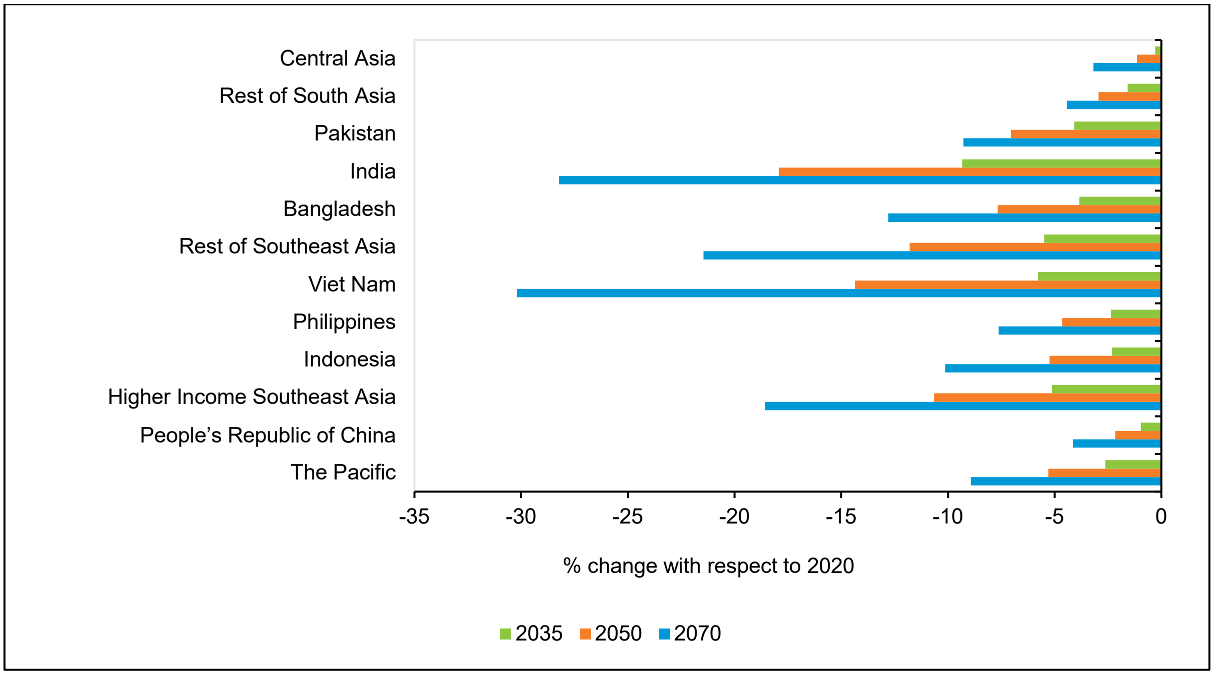
Forestry Yields

Climate change in the forestry sector is translated into shocks on forest productivity. The data derive from the Global Forest Model (G4M)[11] as reported by Boere et al. (2019), averaged by region using the forest area database of the Food and Agriculture Organization of the United Nations (FAO)[12]. The productivity paths over time are smoothed using a quadratic fit to give the percentage change of forest productivity under a high-end emissions scenario with respect to 2020.

Overall, climate shocks on forest productivity are moderate in the short term (2030), while larger losses are experienced in the second half of the century, with a decrease of between 10% and 30% for most subregions (Figure 6). Only a few regions (the PRC, Rest of South Asia, and Central Asia) experience losses below 5% in the long term.

[11] G4M Repository (https://iiasa.ac.at/models-tools-data/g4m).
[12] https://data.apps.fao.org/catalog/dataset/forest-area-1990-2020-1000-ha

Figure 6: Climate Change Impacts on Forest Productivity Under a High-End Emissions Scenario



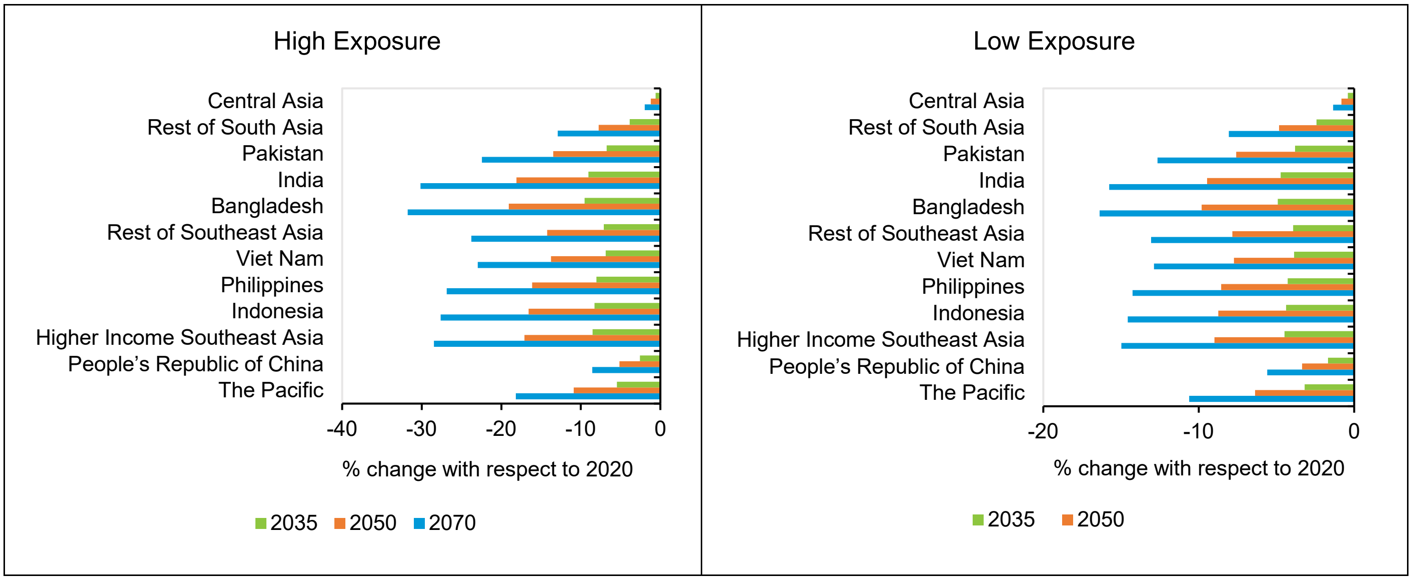
Notes: Scenario is SSP5-8.5. Central Asia comprises Armenia, Azerbaijan, Georgia, Kazakhstan, the Kyrgyz Republic, Mongolia, Tajikistan, Turkmenistan, and Uzbekistan. Higher Income Southeast Asia comprises Brunei Darussalam, Malaysia, Singapore, and Thailand. The Pacific comprises the Cook Islands, Fiji, Kiribati, the Marshall Islands, the Federated States of Micronesia, Nauru, Niue, Palau, Papua New Guinea, Samoa, Solomon Islands, Tonga, Tuvalu, and Vanuatu. Rest of South Asia comprises Afghanistan, Bhutan, Maldives, Nepal, and Sri Lanka. Rest of Southeast Asia comprises Cambodia, the Lao People's Democratic Republic, Myanmar, and Timor-Leste.
Source: Results drawn from the Co-designing the Assessment of Climate Change Costs Project

Labor Productivity

Climate change shocks on labor rely on the CMIP6 temperature projection database and use the estimates of Dasgupta et al. (2021), which empirically assesses climate change implications for effective labor, as a synthesis measure of labor supply and labor productivity. This relies on a large collection of micro-survey data across the world along with wet-bulb globe temperature data. The impact on labor is heterogeneous across productive sectors: sectors with activities indoor or outdoor in the shade are classified as with low exposure to climate changes, whereas activities outdoors in the sun are considered high exposure. In contrast, the regression coefficients are not significant for the services sector.

For sectors with low exposure, the shocks in 2070 range between -16.4% (Bangladesh) and -1.4% (Central Asia) with respect to 2020. The shock is more than doubled in the sectors with high exposure, reaching -31.8% in Bangladesh with respect to 2020 (Figure 7).

Figure 7: Climate Change Impacts on Labor Productivity Under a High-End Emissions Scenario



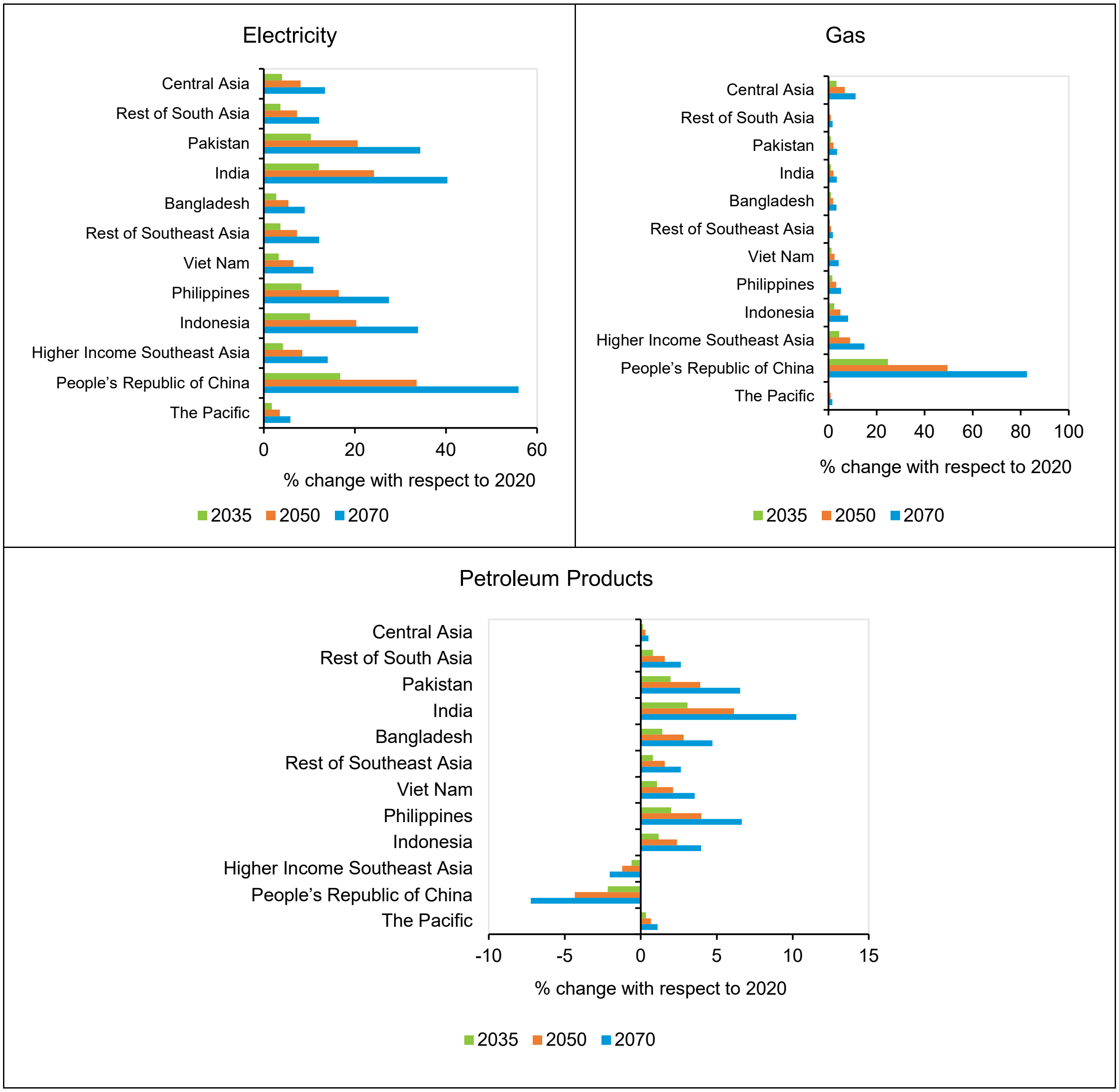
Notes: Scenario is SSP5-8.5. Central Asia comprises Armenia, Azerbaijan, Georgia, Kazakhstan, the Kyrgyz Republic, Mongolia, Tajikistan, Turkmenistan, and Uzbekistan. Higher Income Southeast Asia comprises Brunei Darussalam, Malaysia, Singapore, and Thailand. The Pacific comprises the Cook Islands, Fiji, Kiribati, the Marshall Islands, the Federated States of Micronesia, Nauru, Niue, Palau, Papua New Guinea, Samoa, Solomon Islands, Tonga, Tuvalu, and Vanuatu. Rest of South Asia comprises Afghanistan, Bhutan, Maldives, Nepal, and Sri Lanka. Rest of Southeast Asia comprises Cambodia, the Lao People's Democratic Republic, Myanmar, and Timor-Leste.
Source: Results drawn from the Co-designing the Assessment of Climate Change Costs Project

Energy Demand

Higher temperatures lead to increased energy demand for cooling and reduced demand for heating. Climate change shocks on energy demand are translated into relative changes of electricity, gas, and petroleum product demand. Final energy demand impacts used in this study derive from Standardi et al. (2023) and have been further disaggregated for Asia and the Pacific. Standardi et al. (2023) relies on results of De Cian and Sue Wing (2019), which estimates the elasticity of demand for electricity, petroleum products, and natural gas for the agriculture, industry, services, and residential sectors to cold/hot days. Climate-induced energy demand trends are obtained by combining these elasticities with projected hot and cold days from high spatial resolution mean temperature projections from four regional climate models (RCMs).

Future energy demand under the SSP5-8.5 scenario for gas and electricity is expected to increase for every region with respect to 2020, although the growth of gas demand is moderate (below 20%) even in the long term (2070), with the exception of the PRC (with a more than 80% increase with respect to 2020). The rise in electricity demand is mainly driven by the increasing need of electricity for cooling (Figure 8). Demand effects differ among locations for petroleum products, which span between +10% and -10%.

Figure 8: Climate Change Impacts on Final Energy Demand Under a High-End Emissions Scenario



Notes: Scenario is SSP5-8.5. Central Asia comprises Armenia, Azerbaijan, Georgia, Kazakhstan, the Kyrgyz Republic, Mongolia, Tajikistan, Turkmenistan, and Uzbekistan. Higher Income Southeast Asia comprises Brunei Darussalam, Malaysia, Singapore, and Thailand. The Pacific comprises the Cook Islands, Fiji, Kiribati, the Marshall Islands, the Federated States of Micronesia, Nauru, Niue, Palau, Papua New Guinea, Samoa, Solomon Islands, Tonga, Tuvalu, and Vanuatu. Rest of South Asia comprises Afghanistan, Bhutan, Maldives, Nepal, and Sri Lanka. Rest of Southeast Asia comprises Cambodia, the Lao People's Democratic Republic, Myanmar, and Timor-Leste.
Source: Results drawn from the [Co-designing the Assessment of Climate Change Costs Project]

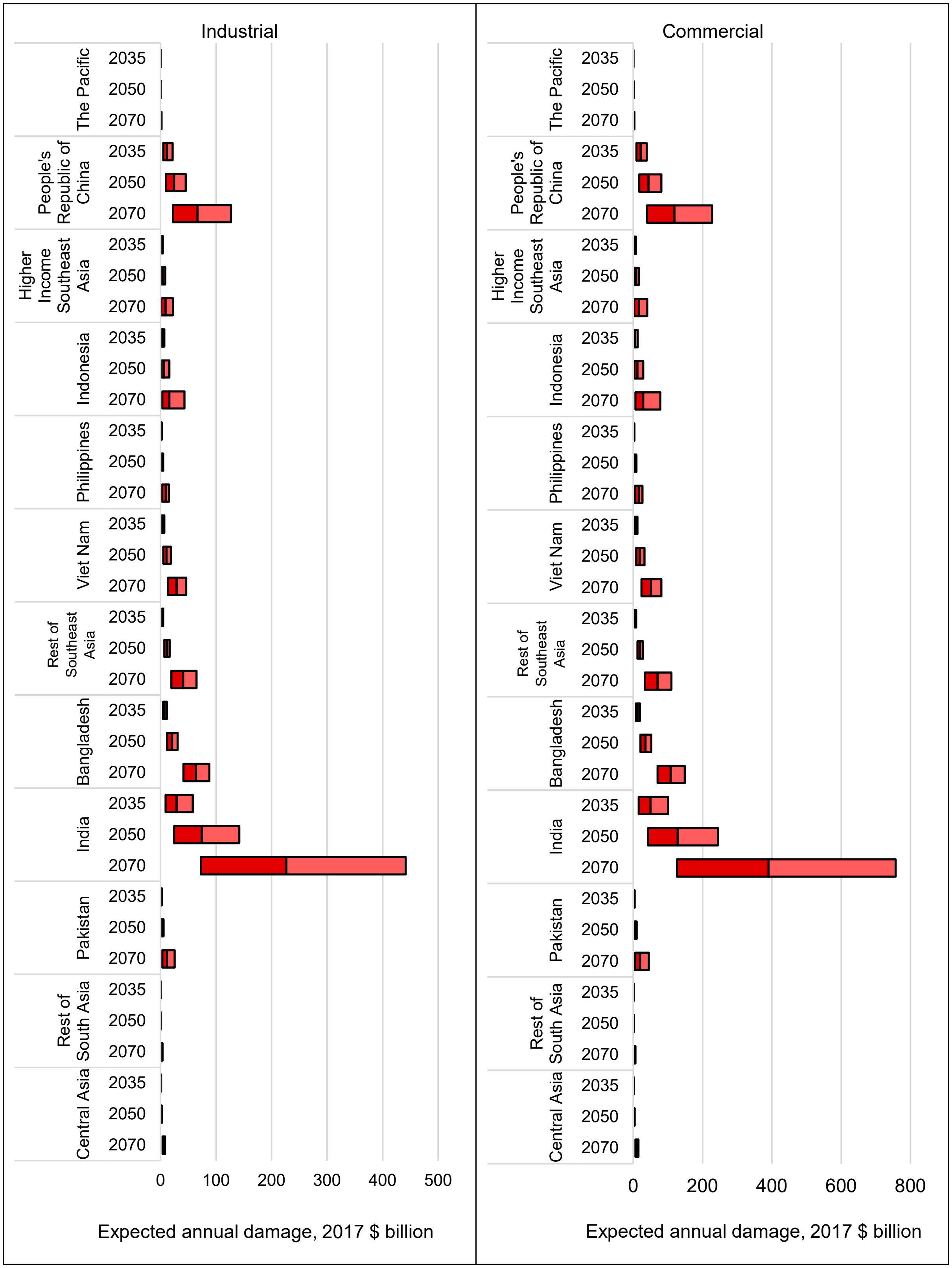
River-Based Flooding

Riverine flood shocks have been computed using GLObal Flood Risk IMAGE Scenarios (GLOFRIS) model results (Ward et al. 2017) as reported in Standardi et al. (2023). The GLOFRIS model analyzes direct flood damage as a result of riverine and coastal floods. It considers the current state of flood risk and uses socioeconomic and climate scenarios for future projections of flood damage. GLOFRIS provides macro-sectoral expected annual damages for computing shocks on capital stock and expected annual affected population that serves as a basis for computing labor productivity shocks caused by floods. In both cases, the GLOFRIS output has been rescaled to account for the updated GDP and population projections from the latest SSP release.[13] GLOFRIS provides three scenarios, considering average, minimum, and maximum expected damage from five GCMs.

The expected annual damage (EAD) and the expected affected population (EAP) are two indicators that depend on losses as well as the size of the economy and populations. India and the PRC stand out in terms of high EAD in both the industrial and commercial sectors, whereas the EAP is high in India, the PRC, Indonesia, and Bangladesh (Figure 9). Total median annual losses reach over $1.3 trillion by 2070, with 110 million people affected.

[13] IIASA repository (2024 release) https://iiasa.ac.at/models-tools-data/ssp.

Figure 9: Annual Additional Flood Damage Under a High-End Emissions Climate Scenario and Population Affected



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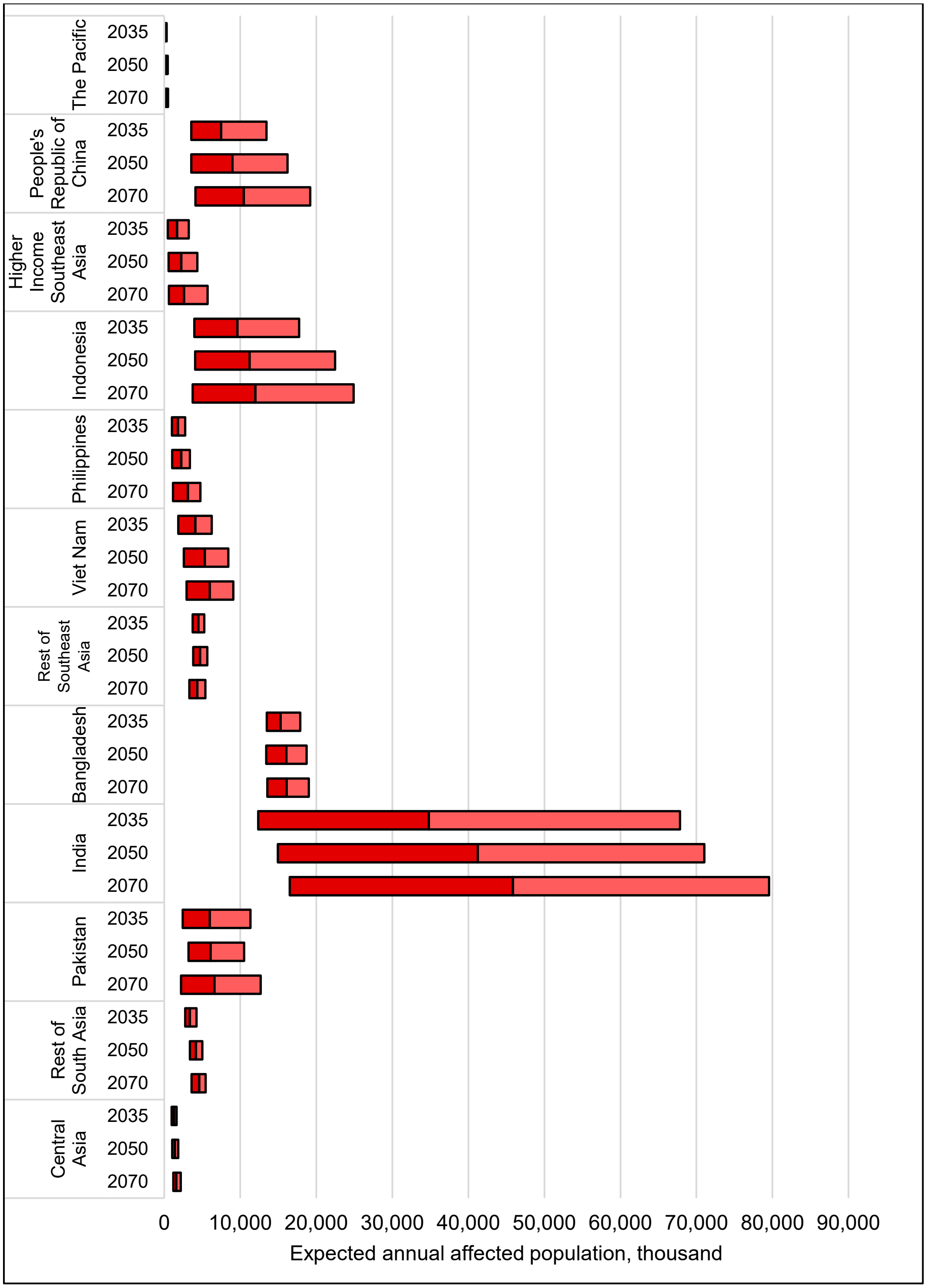


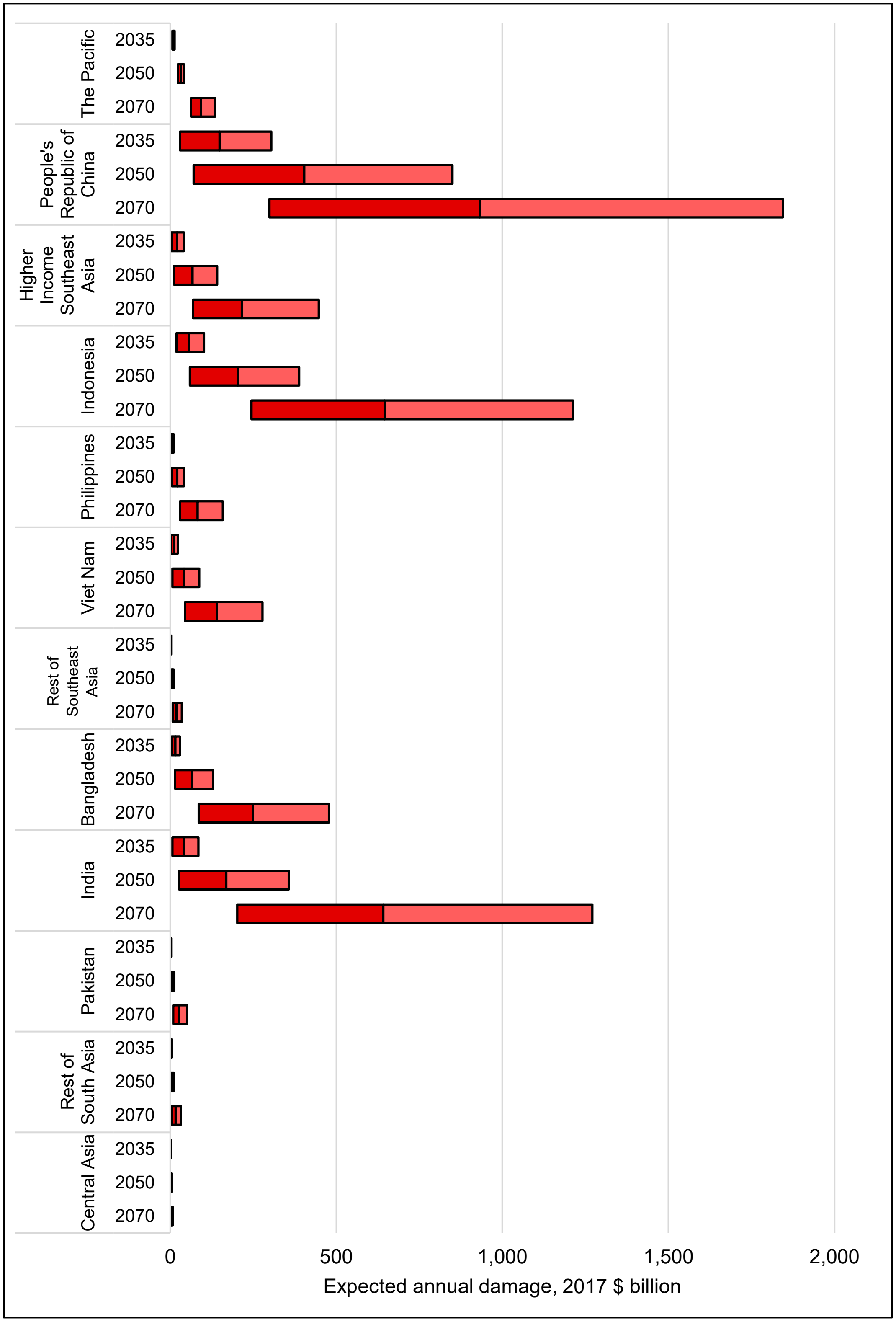
Notes: Bars depict a range of estimates from different global circulation models, with the central line being the median estimate. Scenario is SSP5-8.5. Central Asia comprises Armenia, Azerbaijan, Georgia, Kazakhstan, the Kyrgyz Republic, Mongolia, Tajikistan, Turkmenistan, and Uzbekistan. Higher Income Southeast Asia comprises Brunei Darussalam, Malaysia, Singapore, and Thailand. The Pacific comprises the Cook Islands, Fiji, Kiribati, the Marshall Islands, the Federated States of Micronesia, Nauru, Niue, Palau, Papua New Guinea, Samoa, Solomon Islands, Tonga, Tuvalu, and Vanuatu. Rest of South Asia comprises Afghanistan, Bhutan, Maldives, Nepal, and Sri Lanka. Rest of Southeast Asia comprises Cambodia, the Lao People's Democratic Republic, Myanmar, and Timor-Leste.
Source: Results drawn from the Co-designing the Assessment of Climate Change Costs Project

Sea Level Rise

SLR shocks are computed using the results of two models: the Large-Scale Integrated Sea-level and Coastal Assessment Tool (LISCOAST) framework (Vousdoukas et al. 2023) for Asia and the Pacific and the Dynamic Interactive Vulnerability Assessment (DIVA) model (Hinkel et al. 2014) for all the other regions. DIVA is an integrated modeling framework for coastal systems that assesses biophysical and socioeconomic consequences of SLR and socioeconomic development. It considers direct and indirect coastal erosion, coastal flooding (including in river mouths), wetland change, and salinity intrusion into deltas and estuaries. LISCOAST synthesizes state-of-the-art large-scale modeling and datasets and offers an assessment of risk in coastal areas. It includes improved data on digital elevation and flood protection levels, use of dynamic flood models to estimate the impacts of extreme events, and incorporation of recent gridded exposure datasets (Giardino and Vousdoukas 2024). This model has been selected for characterizing SLR shocks in the Asia and the Pacific region because it provides more up to date estimates, and it is more sensitive to capture SLR risk in small economies, such as Pacific islands.

Both models consider three direct channels of propagation of SLR shocks: annual land loss, affected population, and asset loss. Three climate sensitivity levels are reported: low, medium, and high, accounting for a range of assumptions regarding melting of sea ice. Shocks are reported in Figure 10 for Asia Pacific in terms of damage and population. EADs due to SLR are larger in magnitude than those due to riverine floods (by almost 10 times). Total 2070 losses reach $3 trillion annually, with about 50 million people affected. The highest EAD values are found in the PRC, India, Indonesia, and Bangladesh. EAP is largest in the PRC, India, Bangladesh, and Viet Nam.

Figure 10: Expected Annual Sea Level Rise Damage Under a High-End Emissions Climate Scenario and Population Affected



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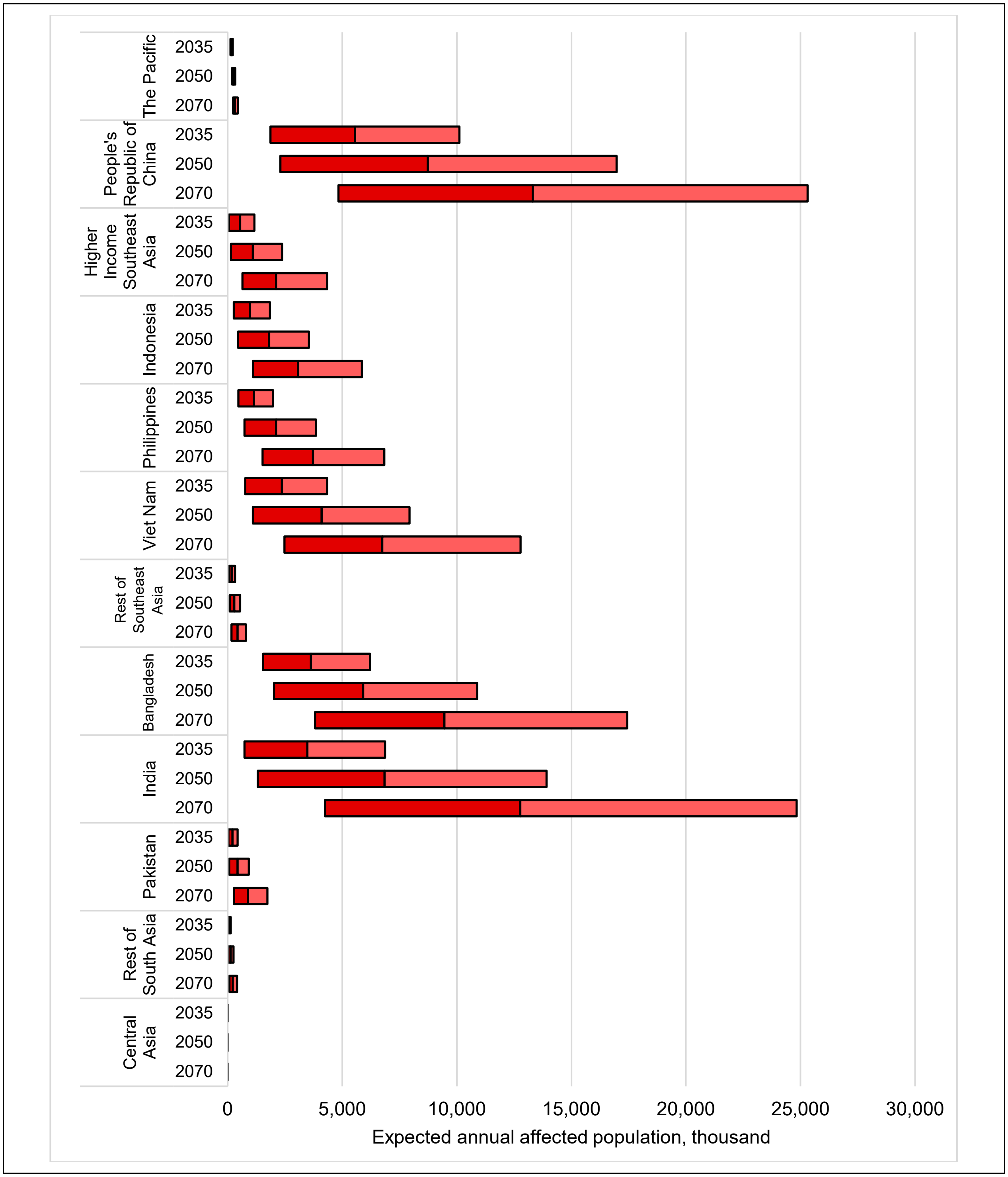


Notes: Scenario is SSP5-8.5. Bars depict a range of estimates from different sea ice melt assumptions, with the central line being the median estimate. Central Asia comprises Armenia, Azerbaijan, Georgia, Kazakhstan, the Kyrgyz Republic, Mongolia, Tajikistan, Turkmenistan, and Uzbekistan. Higher Income Southeast Asia comprises Brunei Darussalam, Malaysia, Singapore, and Thailand. The Pacific comprises the Cook Islands, Fiji, Kiribati, the Marshall Islands, the Federated States of Micronesia, Nauru, Niue, Palau, Papua New Guinea, Samoa, Solomon Islands, Tonga, Tuvalu, and Vanuatu. Rest of South Asia comprises Afghanistan, Bhutan, Maldives, Nepal, and Sri Lanka. Rest of Southeast Asia comprises Cambodia, the Lao People’s Democratic Republic, Myanmar, and Timor-Leste.
Source: Results drawn from modeling reported in Giardino, A. and M. Vousdoukas. 2024. Rising Seas: Building Resilience Against Coastal Flooding in Asia and the Pacific. *Development Asia*. 7 August.

B. Economic Consequences

This section analyzes the impact of median climate change-related shocks on GDP in Asia and the Pacific up to 2070, compared with a no climate change scenario. It highlights the GDP losses attributable to climate change across the sectors and illustrates important variations among economies. When interpreting results, it should be recognized that the loss calculations presented are based on additional changes from climate change relative to 2020. This means that losses already incurred up to 2020 are not fully reflected, so estimates are partial. This bias is especially important for near-term impacts, so these should be interpreted with some caution, whereas longer-term impacts are less affected.

The total GDP loss due to climate change in 2070 is found to be 16.9% in Asia and the Pacific, with all economies experiencing losses. Changes are in GDP are most pronounced in Bangladesh (-30.5%), Viet Nam (-30.2%), Indonesia (-26.8%), India (-24.7%), Rest of Southeast Asia (-23.4%), Higher Income Southeast Asia (-22.0%), and Pakistan (-21.1%) (Figures 11 and 12). The impact of SLR accounts for almost 50% of overall GDP losses in many economies. However, in other economies, the climate-related loss of labor productivity plays a major role, for example totaling nearly half of GDP losses in Rest of Southeast Asia, Pakistan, and India. The shock on energy demand has the largest economic effect in Central Asia and the PRC. Details of loss evolution by economy are provided in Appendix 2. Individually considered shocks show a higher GDP loss than is the case for the simultaneous shocks because of comparative advantages of economically different economies affected by heterogenous shocks. Trade allows economies to smooth climate change impacts, especially when the shock in a economy is smaller than in the other trading partners.

1. Economic Consequences by Channel

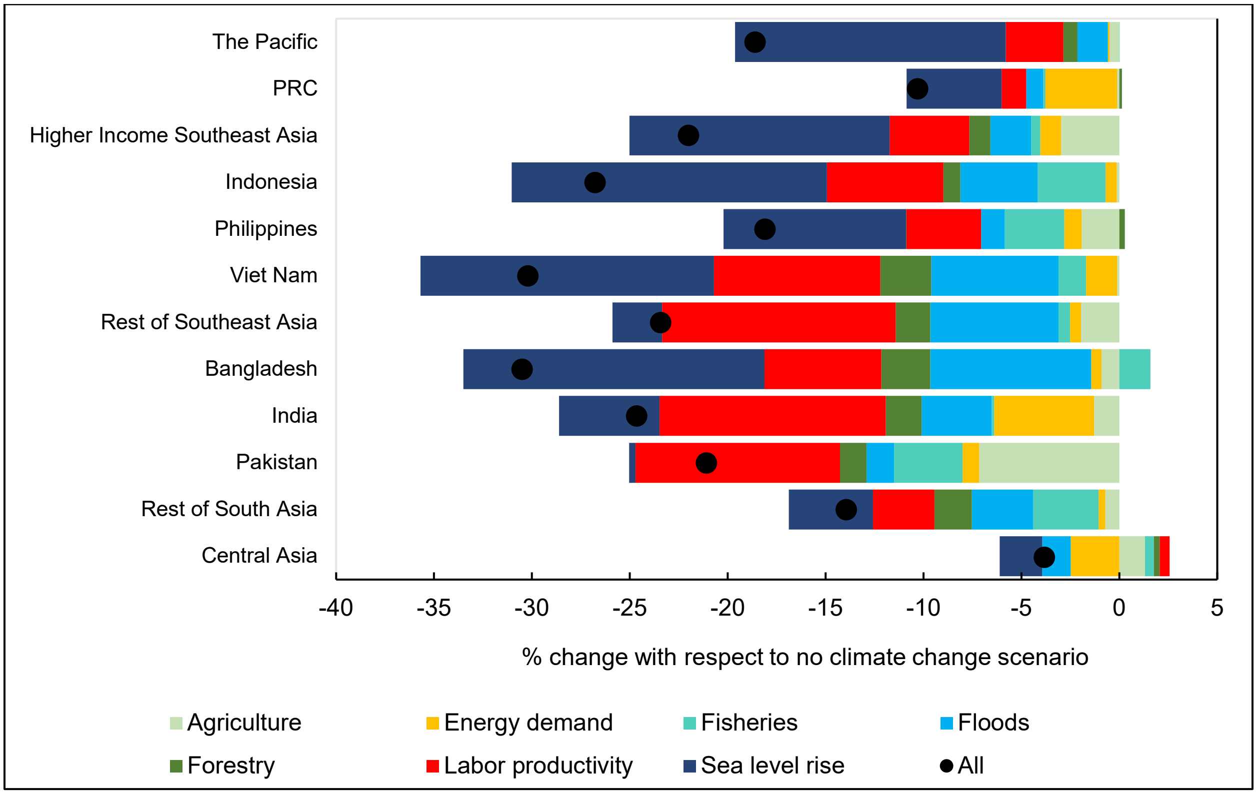
Agricultural Yields

The regional GDP loss due to yield-related shocks in 2070 is 0.9%. The low regional value masks considerable variability, and is only one channel to negative effects on agriculture, as will be illustrated later. Figure 11 shows the largest effects on overall GDP in Pakistan (-7.2%), Higher Income Southeast Asia (-3.0%), Rest of Southeast Asia (-2.0%), and the Philippines (-1.9%).

In Pakistan, agricultural yield shocks are projected to cause moderate agricultural value added (VA) losses by 2070, with declines of 10.4% in wheat, 10.4% in rice, 9.2% in other grains, and

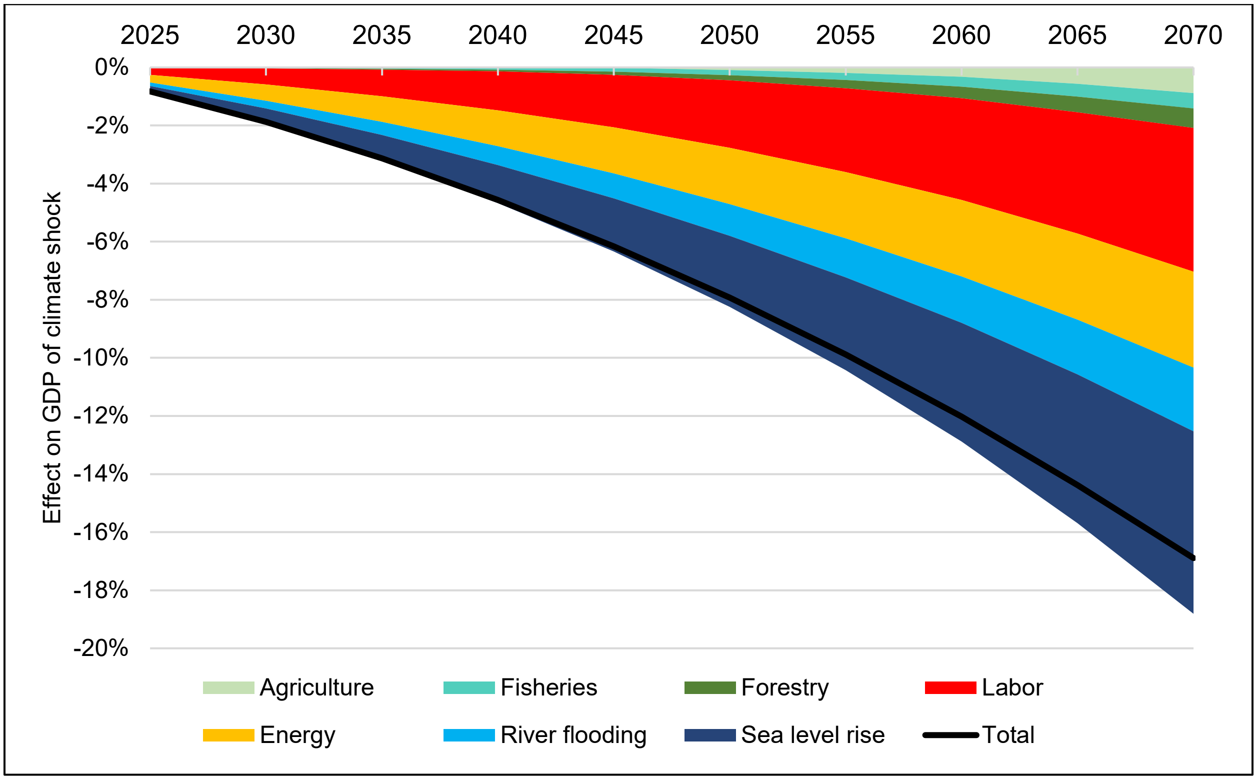
8.9% in other agricultural goods, compared with a no climate change scenario (Appendix Table A3.1). The importance of agriculture in Pakistan's economy, particularly in household income generation, exacerbates these effects by weakening domestic demand, leading to a broader downturn in the industrial and services sectors. As a result, Pakistan is the economy most severely affected by agricultural shocks. Conversely, in Higher Income Southeast Asia, agricultural subsectors suffer greater losses: 24.3% in rice, 25.4 in other grains, and 34.7% in other agricultural products. These shocks extend to the food processing sector, causing a 24.7% decline in VA. However, the broader economy remains relatively shielded, containing overall GDP losses. Wheat VA is particularly strongly affected in Bangladesh, with a 44.1% reduction due to yield losses.

Figure 11: Composition of Losses in Gross Domestic Product in 2070 due to Climate Change Under a High-End Emissions Scenario



PRC = People's Republic of China.
Notes: Scenario is SSP5-8.5. Central Asia comprises Armenia, Azerbaijan, Georgia, Kazakhstan, the Kyrgyz Republic, Mongolia, Tajikistan, Turkmenistan, and Uzbekistan. Higher Income Southeast Asia comprises Brunei Darussalam, Malaysia, Singapore, and Thailand. The Pacific comprises the Cook Islands, Fiji, Kiribati, the Marshall Islands, the Federated States of Micronesia, Nauru, Niue, Palau, Papua New Guinea, Samoa, Solomon Islands, Tonga, Tuvalu, and Vanuatu. Rest of South Asia comprises Afghanistan, Bhutan, Maldives, Nepal, and Sri Lanka. Rest of Southeast Asia comprises Cambodia, the Lao People's Democratic Republic, Myanmar, and Timor-Leste.
Source: Authors' calculations.

Figure 12: Sector Composition of Modeled Losses due to Climate Change Under a High-End Emissions Scenario in the Asia Pacific Region



GDP = gross domestic product.
Note: Scenario is SSP5-8.5. Economies included are those included in Figure 11.
Source: Authors' calculations.

Fisheries Yields

Overall regional GDP loss attributable to fisheries yield shocks is small at around 0.5% in 2070 with respect to a no climate change scenario. The most affected economies in the area are Pakistan, Indonesia, Rest of South Asia, and the Philippines, losing respectively 3.5%, 3.5%, 3.3%, and 3.0% of GDP in 2070 with respect to the no climate change scenario. Bangladesh is found to modestly benefit (Figure 11).

Shocks to fisheries yields lead to fishery VA losses in economies like Rest of South Asia, Viet Nam, Indonesia, and the Pacific, with reductions of 11.5%, 12.6%, 19.1%, and 19.4%, respectively, by 2070 (Appendix Table A3.2). In Pakistan and the Philippines, smaller losses of fisheries VA are accompanied by larger losses of VA from the industrial sectors. In Viet Nam, the fisheries VA is accompanied by an even more pronounced change in food processing VA of -16.6%.

Forestry Yields

Shocks to forestry yields lead to similar overall GDP losses in 2070 as the fisheries shock, with a change of -0.7% with respect to the no climate change scenario for the region. The most impacted economies are Viet Nam (-2.6%), Bangladesh (-2.5%), Rest of Southeast Asia (-1.9%). and India (-1.8%).

Forestry VA changes in 2070 due to forestry yield reductions are most pronounced in Rest of Southeast Asia (-15.2%), Higher Income Southeast Asia (-13.0%) and India (-12.7%) (Appendix Table A3.3). In Viet Nam, the rest of South Asia and the rest of Southeast Asia, light industry VA also is strongly affected by forestry yield shocks (which increase the price of timber and fiber inputs), with changes of -18.6%, -13.3%, and -12.9%, respectively.

Labor Productivity

The overall GDP loss due to changes in labor productivity in 2070 is 5.0% for Asia and the Pacific. The most impacted regions and economies are Rest of Southeast Asia (-11.9%), India (-11.6%), and Pakistan (-10.4%) (Figure 11). The GDP impact depends on both the size of the shock and the importance of high exposure sectors in the economy.

These shocks are pervasive across sectors. Outdoor activities like agriculture, fishing, and forestry face higher risks than indoor industrial activities. In Rest of Southeast Asia, the most affected region, 2070 VA losses range from 11.8% to 30.3% in agricultural subsectors, 10.6% to 15.2% in industrial subsectors, and 10.1% to 12.7% in services subsectors (Appendix Table A3.4). In India, losses are of a similar magnitude in industry and services, while agriculture loses 9.3% to 11.6% of VA. Pakistan has nearly the same loss levels as India, while other regions have somewhat lower magnitudes of losses in industry and services. For many regions and agricultural subsectors, agricultural VA is more affected by the labor productivity shock than direct shocks to yields. These losses are mediated by multiple factors, including the direct impact of climate change on productivity, the reallocation of workers in response to shocks, and capital outflows toward more profitable sectors or out of economies entirely.

Energy Demand

Energy demand shocks in 2070 lead to an overall GDP reduction of 3.3% for Asia and the Pacific. India, the PRC, and Central Asia are the most affected economies, with GDP losses of, respectively, 5.1%, 3.7%, and 2.5% (Figure 11). The PRC and India are the economies experiencing the highest electricity demand increases.

Energy demand shocks arise from increases in private energy consumption (e.g., gas, petroleum, electricity) and shifts in energy efficiency for firms. Although this increases value added from energy subsectors, increased demand and prices for these commodities result in higher production costs and losses across sectors dependent on these energy sources. For example, India's 2070 VA losses range between 2.0% and 3.5% in subsectors of agriculture, 5.6% and 6.6% in industry, and 5.1% and 6.3% in services (Appendix Table A3.5). In the PRC, however, the spike in gas demand causes prices and imports to rise sharply, leading to a large decline in real domestic gas sector VA.

River-Based Flooding

Increased flooding causes a regional 2070 overall GDP loss of 2.2%, with Bangladesh, Rest of Southeast Asia, and Viet Nam being the most affected, experiencing losses of 8.2%, 6.6%, and 6.5%, respectively, compared with a no climate change scenario (Figure 11). All economies in the region are negatively impacted by flood-related shocks.

The losses in Rest of Southeast Asia and Viet Nam are driven primarily by shocks to capital stocks, while in Bangladesh the loss of labor during flooding and flood recovery also contributes to the GDP loss. In Bangladesh and Viet Nam industrial subsectors suffer VA losses of 10.1% to 13.8% and services loses 10.2% to 15.0% of VA, whereas agriculture has less pronounced VA reductions of 0.3% to 4.8% (Appendix Table A3.6). In contrast, Rest of Southeast Asia faces more severe impacts across all sectors as a result of riverine flooding, with agricultural VA changes between -6.4% and -8.1%, industrial VA changes between -9.9% and -10.3%, and service VA changes between -6.1% and -8.6%.

Sea Level Rise

SLR leads to a 6.3% loss in overall regional GDP in 2070 under a high-end emissions scenario. All regions experience GDP losses, with Indonesia and Bangladesh showing the most pronounced losses at 16.1% and 15.4%, respectively (Figure 11). Additionally, the Pacific, Higher

Income Southeast Asia, and Viet Nam experience losses exceeding 10%. Pakistan has the lowest GDP loss due to SLR, as the higher relative damage to competing economies improves its comparative advantage in trade. Conversely, Central Asia has losses from price effects transmitted from economies affected by SLR via trade.

Light industry suffers the most from SLR, followed by the electricity sector and heavy industry. Relative changes in 2070 light industry VA are concentrated in Bangladesh, Indonesia, and the Pacific, where they are -36.1%, -35.0%, and -25.1%, respectively (Appendix Table A3.7). Electricity VA changes are most pronounced in Bangladesh (-17.9%), Viet Nam (-17.4%), and Indonesia (-15.5%). Heavy industry VA is most affected in Viet Nam (-17.4%), Indonesia (-16.5%), and the Pacific (-16.2%). The combined effects of inundation on labor, capital losses, and land degradation, alongside capital outflows, reduce incomes and dampen domestic demand. This is reflected in service VA losses of up to 18.7%.

2. Losses by Impacted Sector

Multiple shocks combine to affect different sectors. Losses propagate from directly affected sectors to others through input-output linkages and trade. Sectors less impacted by climate change tend to increase production relative to a no climate change scenario, boosting exports to compensate for the reduced export capacity of more adversely affected regions. The table on the page provides an overview of the combined climate change impacts on 2070 VA across the analyzed economies and sectors. Heavy industry, light industry, and market services are consistently heavily affected across economies, followed by public services. Agriculture, forestry and fisheries generally have combined losses from all shocks that are far higher than the losses arising from yield reductions in the sectors alone. In Bangladesh, which has the highest GDP reduction, the hardest-hit sectors include wheat (-53.0%) and light industry (-49.1%). In Viet Nam, as the economy with second highest economic impacts, forestry VA losses reach 37.8%, with the industrial and services sectors experiencing declines exceeding 30%. Indonesia, as the economy with third highest GDP loss, has large impacts in light industry (-42.2%), followed by other industry and service sectors with VA losses exceeding 20%.

Table: Sector Value Added Loss due to All Climate Change Impacts in 2070 Under a High-End Emissions Scenario (% change with respect to a no climate change scenario)

	Coal	Oil	Gas	Electricity	Heavy industry	Light industry	Market services	Petrol products	Public services	Forestry	Fisheries	Food processing	Other agriculture	Vegetables and fruit	Other grains	Rice	Wheat
Bangladesh	-18	-8	-18	-28	-25	-49	-35	-20	-36	-25	-5	-19	-27	-17	-26	-19	-53
India	-10	-5	-6	-12	-28	-27	-25	-13	-21	-28	-16	-17	-22	-17	-18	-19	-24
Pakistan	-2	-4	-4	-4	-20	-19	-21	-6	-21	-10	-15	-20	-21	-21	-19	-24	-19
Rest of South Asia	-8	-3	-4	-7	-15	-9	-15	-4	-13	-5	-13	-10	-10	-9	-11	-7	-21
Higher Income Southeast Asia	-9	-5	-6	-22	-24	-23	-21	-9	-16	-21	-16	-29	-39	-17	-28	-29	
Indonesia	-16	-7	-9	-14	-28	-42	-29	-11	-23	-21	-22	-12	-11	-15	-13	-13	
Philippines	-9	-5	-6	-10	-19	-19	-20	-4	-18	-9	-9	-11	-14	-13	-13	-3	
Viet Nam	-13	-7	-11	-28	-34	-35	-30	-22	-30	-38	-16	-15	-16	-18	-17	-8	
Rest of Southeast Asia	-18	-5	-6	-19	-28	-24	-26	-20	-24	-25	-19	-24	-22	-23	-22	-18	
The Pacific	-10	-7	-11	-6	-20	-31	-21	-2	-14	-10	-22	-23	-19	-17	-16	-19	
People's Republic of China	-7	-3	-61	1	-13	-9	-11	-2	-9	-6	-10	-9	-8	-8	-9	-9	-8
Central Asia	-3	-2	-2	-1	-5	2	-7	1	-6	-3	8	3	7	1	-3	-3	37

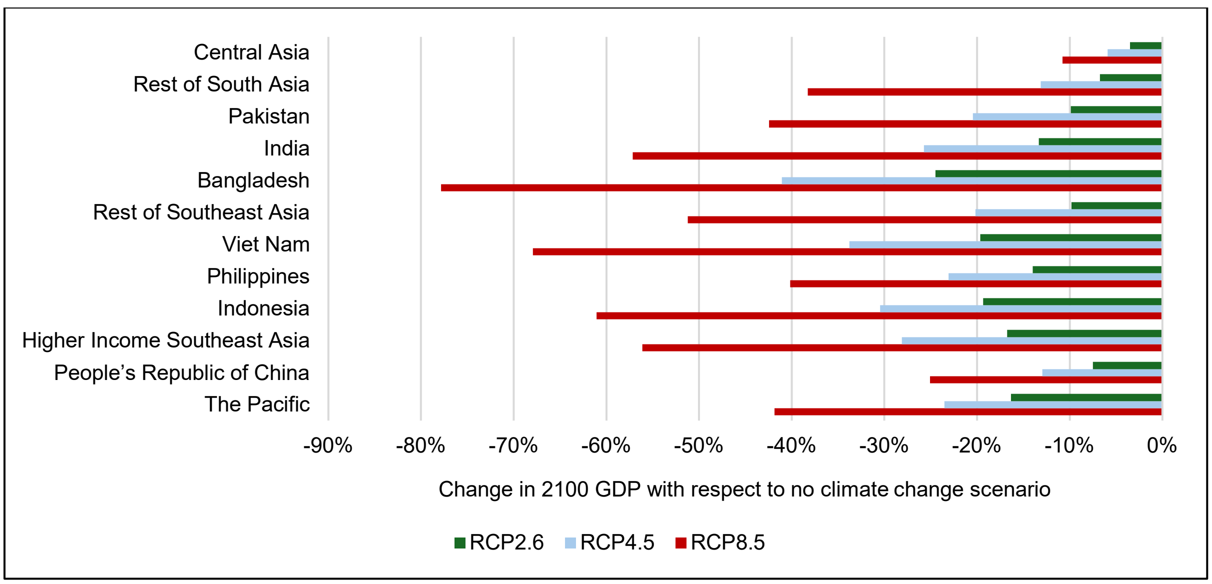
Notes: Scenario is SSP5-8.5. Red colors are negative, whereas positive values are green. Central Asia comprises Armenia, Azerbaijan, Georgia, Kazakhstan, the Kyrgyz Republic, Mongolia, Tajikistan, Turkmenistan, and Uzbekistan. Higher Income Southeast Asia comprises Brunei Darussalam, Malaysia, Singapore, and Thailand. The Pacific comprises the Cook Islands, Fiji, Kiribati, the Marshall Islands, the Federated States of Micronesia, Nauru, Niue, Palau, Papua New Guinea, Samoa, Solomon Islands, Tonga, Tuvalu, and Vanuatu. Rest of South Asia comprises Afghanistan, Bhutan, Maldives, Nepal, and Sri Lanka. Rest of Southeast Asia comprises Cambodia, the Lao People's Democratic Republic, Myanmar, and Timor-Leste.
Source: Authors' calculations.

C. Damage Function Extrapolation

Although the direct modeling covers only the period to 2070, the relationships between climate variables and losses up to 2070 can be used to project losses out to 2100. This involves fitting damage functions for each economy or subregion. These relate GDP loss to global mean temperature increase for labor productivity, energy demand, river-based flooding, and fisheries and forestry shocks. In the case of agriculture, GDP loss is fit to the global mean change in SPEI-6, while GDP loss from SLR rise is fit to mean global sea level increases. To account for the fact that simultaneous runs of shocks lead to smaller losses than the sum of losses from shocks modeled individually, all shocks are rescaled. Estimated damage functions are applied to the mean of 27 GCM projections from CMIP6 to extrapolate losses to 2100 for temperature and SPEI and Garner et al. (2021) SLR projections for the IPCC Sixth Assessment Report for RCP8.5[14], as well as two other climate scenarios—RCP4.5 and RCP2.6. RCP4.5 stabilizes warming at about 2.5°C and RCP2.6 is a scenario that keeps global warming well below 2°C.

The results for the high emissions climate scenario (RCP8.5) show a 41.0% reduction in regional GDP by 2100 (Figure 13). There is especially large vulnerability for Bangladesh with a potential 77.9% GDP reduction, Viet Nam with a 67.9% reduction, and Indonesia with a 61.1% GDP reduction. Under RCP4.5, regional losses would be 20.0% of GDP in 2100, with Bangladesh experiencing a 41.1% GDP loss, Viet Nam losing 33.8%, and a number of other economies facing 20%–30% losses. Under RCP2.6, which would require immediate emissions reductions that reach global net zero by 2070, regional losses would be 11.2% of GDP, with Bangladesh still facing a 24.5% GDP loss and several other economies and subregions facing losses in excess of 15% of GDP.

Figure 13: Economic Losses in 2100 due to Climate Change Under Various Climate Scenarios



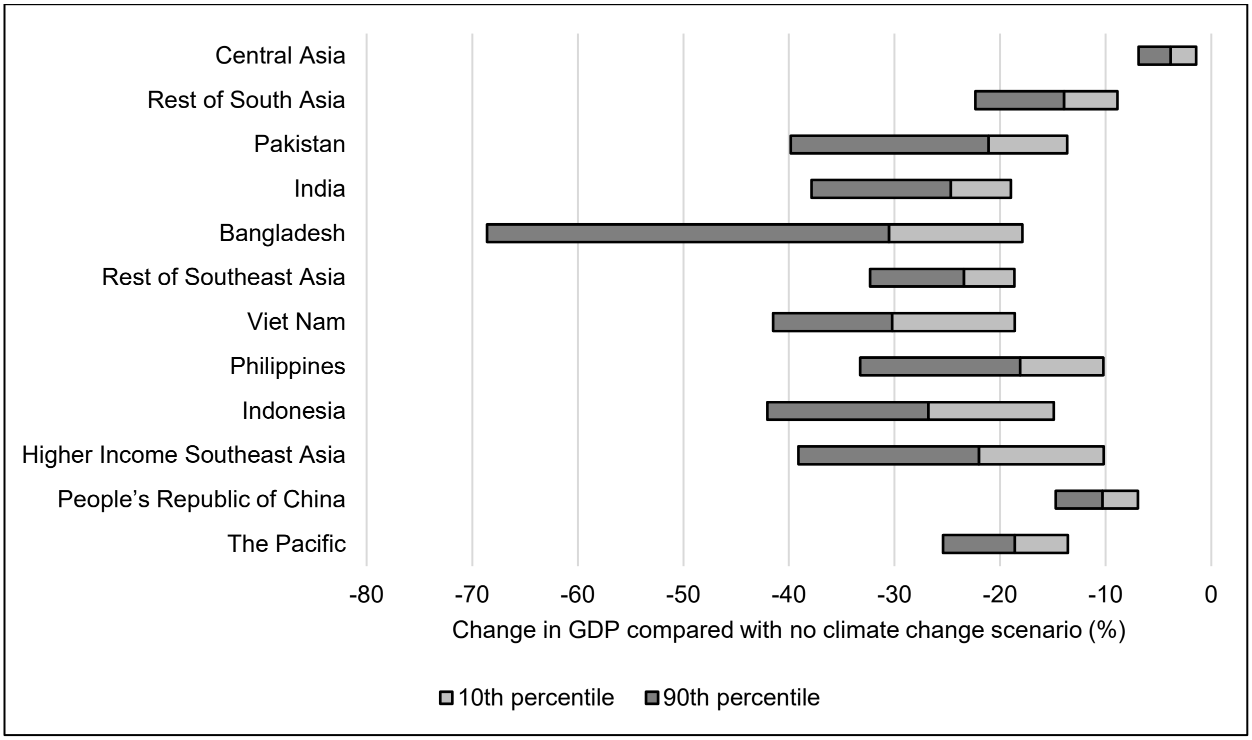
GDP = gross domestic product, RCP = representative concentration pathway.
Notes: Scenario is SSP5-8.5. Central Asia comprises Armenia, Azerbaijan, Georgia, Kazakhstan, the Kyrgyz Republic, Mongolia, Tajikistan, Turkmenistan, and Uzbekistan. Higher Income Southeast Asia comprises Brunei Darussalam, Malaysia, Singapore, and Thailand. The Pacific comprises the Cook Islands, Fiji, Kiribati, the Marshall Islands, the Federated States of Micronesia, Nauru, Niue, Palau, Papua New Guinea, Samoa, Solomon Islands, Tonga, Tuvalu, and Vanuatu. Rest of South Asia comprises Afghanistan, Bhutan, Maldives, Nepal, and Sri Lanka. Rest of Southeast Asia comprises Cambodia, the Lao People's Democratic Republic, Myanmar, and Timor-Leste.
Source: Authors' calculations.

[14] The discussion here refers to RCPs, rather than SSPs, as the comparisons keep the same SSP, and only alter climate projections to keep consistency with the modeled no climate change SSP5 scenario.

D. Sensitivity

The paper analyses the economic impacts of a high-end emissions scenario, SSP5-8.5. All the reported results are relative to a scenario considering the median of sector/risk-specific shocks. However, for agriculture from ISIMIP and fisheries, there are yield changes from a set of models using different GCMs, and riverine flood losses are from a range of GCMs too. SLR is under different ice melt assumptions. This enables computation of high (10th percentile) and low (90th percentile) shocks to run two estimates additional to the central median one. Figure 14 displays the range of variability of GDP percentage change. The highest sources of variability are agriculture and SLR shocks. For Higher Income Southeast Asia, Indonesia, the Philippines, and Viet Nam the major source of uncertainty comes from SLR shocks. For Bangladesh, India, and Pakistan, more of the uncertainty results from shocks on agriculture. Bangladesh is the economy where GDP losses have the highest range. If the 90^{th} percentile of shocks are considered, losses equate to 26.7% of regional GDP, a value that is 57.9% higher than under median shock values, with Bangladesh experiencing a 68.6% loss and a number of other locations facing losses of around 40%. Under the 10^{th} percentile of shocks, the loss is 11.4% of regional GDP, which is still substantial.

Figure 14: 2070 Gross Domestic Product Loss Scenario Range Under a High-End Emissions Scenario (median, 10th, and 90th percentiles)



GDP = gross domestic product.
Notes: Scenario is SSP5-8.5. Bars depict a range of estimates from the 10th and 90th percentiles of sector shocks, with the central line being the median estimate. Central Asia comprises Armenia, Azerbaijan, Georgia, Kazakhstan, the Kyrgyz Republic, Mongolia, Tajikistan, Turkmenistan, and Uzbekistan. Higher Income Southeast Asia comprises Brunei Darussalam, Malaysia, Singapore, and Thailand. The Pacific comprises the Cook Islands, Fiji, Kiribati, the Marshall Islands, the Federated States of Micronesia, Nauru, Niue, Palau, Papua New Guinea, Samoa, Solomon Islands, Tonga, Tuvalu, and Vanuatu. Rest of South Asia comprises Afghanistan, Bhutan, Maldives, Nepal, and Sri Lanka. Rest of Southeast Asia comprises Cambodia, the Lao People's Democratic Republic, Myanmar, and Timor-Leste.
Source: Authors' calculations.

V. CONCLUSION

This paper compiles estimates of major channels of loss from climate change under a high-end emissions scenario and applies them as shocks in a global recursive dynamic CGE model with disaggregation to represent larger economies of the developing Asia and the Pacific region. Shocks are implemented on capital stock from SLR and riverine flooding and to the productivity of other factors, which differs from earlier exercises. The result is that losses are much higher than in earlier findings that rely on CGE modeling. Results of 17% GDP loss by 2070 imply a regional GDP loss of 41% by 2100, which is higher than regional results of 24% of GDP previously (ADB 2023). Consistent with prior studies, such as Kotz, Levermann, and Wentz (2024), losses are most pronounced in economies and subregions in South Asia, Southeast Asia, and the Pacific, and less pronounced in Central and West Asia.

Extension of the patterns of GDP loss to other climate scenarios suggests that losses remain substantial even under much less warming than represented by RCP8.5. Even a scenario that attains Paris Agreement goals leads to 11% GDP loss by 2100, with selected vulnerable economies losing much more. This suggests that adaptation is essential to contain losses, even if mitigation proceeds much faster than has been observed in either emissions trends or policy commitments.

The study has limitations, which can be addressed in future research. While a number of important channels of shock are included, the channels are a subset of the potential shocks caused by climate change. For example, effects on human health beyond labor productivity are not included, nor are effects on ecosystem services, such as pollination, regulation of pests and diseases, or human conflict. In general, these omissions mean that more comprehensive accounting would find even higher losses than modeled in this study. This remains as an area for further investigation.

Although it included a range of GCMs to represent uncertainties, the research was confined to explicit representation of a high-end emissions scenario vs a no climate change scenario, and limited adaptation assumptions. Future research could expand on the range of climate scenarios to help apply findings to mitigation policy scenarios and employ a range of adaptation scenarios to more directly inform adaptation policies.

REFERENCES

ADB (Asian Development Bank). 2016. Economics of Climate Change in Central and West Asia - Adaptation Component: Final Report. Consultants' Reports. Manila.

———. 2017. Climate Change Operational Framework 2017–2030: Enhanced Actions for Low Greenhouse Gas Emissions and Climate-Resilient Development. Institutional Document. Manila.

———. 2023. *Asia in the Global Transition to Net Zero*. Asian Development Outlook April 2023. Manila.

Aguiar, A. et al. 2022. The GTAP Data Base: Version 11. *Journal of Global Economic Analysis* 7.

Boere, E. et al. 2019. D2.2 Impacts on Agriculture Including Forestry & Fishery. CO-designing the Assessment of Climate Change Costs.

Burke, M., S. Hsiang, and E. Miguel. 2015. Global non-linear effect of temperature on economic production. *Nature.* 527, 235–239. https://doi.org/10.1038/nature15725

Burniaux, J., and T. Truong. 2002. GTAP-E: An Energy-Environmental Version of the GTAP Model. Center for Global Trade Analysis Technical Paper 16.

Dasgupta, S. et al. 2021. Effects of Climate Change on Combined Labour Productivity and Supply: An Empirical, Multi-Model Study. *The Lancet Planetary Health* 5.

De Cian, E., and I. Sue Wing. 2019. Global Energy Consumption in a Warming Climate. *Environmental and Resource Economics* 72.

Eboli, F., R. Parrado, and R. Roson. 2010. Climate-Change Feedback on Economic Growth: Explorations with a Dynamic General Equilibrium Model. *Environment and Development Economics* 15.

Eckstein, D., V. Künzel, and L. Schäfer. 2021. Global Climate Risk Index 2021: Who Suffers Most from Extreme Weather Events? Weather-Related Loss Events in 2019 and 2000–2019. Germanwatch Briefing Paper.

ESCAP (United Nations Economic Commission for Asia and the Pacific). 2022. 2022 Review of Climate Ambition in Asia and the Pacific: Raising NDC Targets with Enhanced Nature-Based Solutions with a special feature on Engagement of Children and Youth in Raising National Climate Ambition. Bangkok.

Esham, M. et al. 2018. Climate Change and Food Security: A Sri Lankan Perspective. *Environmental Development and Sustainability* 20.

———. 2018. *The Impact of Disasters and Crises on Agriculture and Food Security 2017*. Rome.

———. 2020. *The State of World Fisheries and Aquaculture 2020—Sustainability in Action*. Rome.

Garner, G.G. et al. 2021. IPCC AR6 Sea-Level Rise Projections. Version 20210809. Dataset accessed 8 January 2024.

Giardino, A., and M. Vousdoukas. 2024. Rising Seas: Building Resilience Against Coastal Flooding in Asia and the Pacific. *Development Asia*. 7 August.

Heinicke, S. et al. 2022. Global Gridded Crop Models Underestimate Yield Responses to Droughts and Heatwaves. *Environment Research Letters* 17.

Hinkel, J., D. Lincke, A.T. Vafeidis et al. 2014. "Coastal Flood Damage and Adaptation Costs under 21st Century Sea-Level Rise." *Proceedings of the National Academy of Sciences* 111 (9): 3292-3297. https://doi.org/10.1073/pnas.1222469111.

Intergovernmental Panel on Climate Change (IPCC). 2022. Climate Change 2022: Impacts, Adaptation and Vulnerability.

Ke, P. et al. 2024. Low Latency Carbon Budget Analysis Reveals a Large Decline of the Land Carbon Sink in 2023. arXiv:2407.12447v1.

Kotz, M., A. Levermann, and L. Wenz. 2024. The Economic Commitment of Climate Change. *Nature* 628.

Lai, W., Y. Qiu, Q. Tang, C. Xi, and P. Zhang. 2023. The Effects of Temperature on Labor Productivity. *Annual Review of Resource Economics* 15: 213-232. https://doi.org/10.1146/annurev-resource-101222-125630.

Masson-Delmotte, V. et al. 2018. *Global Warming of 1.5°C*. Special Report of the Intergovernmental Panel on Climate Change on the Impacts of Global Warming of 1.5°C Above Pre-Industrial Levels and Related Global Greenhouse Gas Emission Pathways, in the Context of Strengthening the Global Response to the Threat of Climate Change, Sustainable Development, and Efforts to Eradicate Poverty.

Mendelsohn, R. 2014. The Impact of Climate Change on Agriculture in Asia. *Journal of Integrative Agriculture* 13.

Newell, R.G., B.C. Prest, and S.E. Sexton. 2021. The GDP-Temperature Relationship: Implications for Climate Change Damages. *Journal of Environmental Economic Management* 108.

Panpeng, J., and M. Ahmad. 2017. Vulnerability of Fishing Communities from Sea-Level Change: A Study of Laemsing District in Chanthaburi Province, Thailand. *Sustainability* 9.

Peters, J.C. 2016. GTAP-E-Power: An Electricity-Detailed Economy-Wide Model. *Journal of Global Economic Analysis* 1.

Raitzer, D.A., and M. Drouard. 2024. Empirically Estimated Impacts of Climate Change on Global Crop Production via Increasing Precipitation-Evapotranspiration Extremes. Background Paper to the Asia-Pacific Climate Report 2024. ADB.

Raitzer, D.A., F. Bosello, M. Tavoni, C. Orecchia, G. Marangoni, J.N. Samson. 2016. Southeast Asia and the Economics of Global Climate Stabilization. ADB.

Salik, K.M. et al. 2015. Climate Change Vulnerability and Adaptation Options for the Coastal Communities of Pakistan. Ocean. *Coastal Management* 112.

Schwalm, C.R., S. Glendon, and P.B. Duffy. 2020. RCP8.5 Tracks Cumulative CO2 Emissions. *Proceedings of the National Academy of Sciences of the United States of America*. 117 (33): 19656–19657.

Shaw, R. et al. 2022. Asia. In H.-O. Pörtner et al. *Climate Change 2022: Impacts, Adaptation and Vulnerability*. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change.

Standardi, G. et al. 2023. Assessing Macro-Economic Effects of Climate Impacts on Energy Demand in EU Sub-National Regions. *Environmental and Resource Economics* 86.

Van der Wijst, K. et al. 2023. New Damage Curves and Multimodel Analysis Suggest Lower Optimal Temperature. *Nature Climate Change* 13.

Vinke, K. et al. 2017. *A Region at Risk: The Human Dimensions of Climate Change in Asia and the Pacific*. Asian Development Bank.

Vivekanandan, E., R. Hermes, and C. O'Brien. 2016. Climate Change Effects in the Bay of Bengal Large Marine Ecosystem. *Environmental Development* 17.

Vousdoukas, M.I. et al. 2023. Small Island Developing States Under Threat by Rising Seas Even in a 1.5°C Warming World. *Nature Sustainability* 6.

Ward, P. et al. 2017. A Global Framework for Future Costs and Benefits of River-Flood Protection in Urban Areas. *Nature Climate Change* 7.

WMO (World Meteorological Organization). 2023. *State of the Climate in Asia 2022.*

———. 2024. *State of the Climate in Asia 2023*.

———. 2024. WMO Confirms that 2023 Smashes Global Temperature Record. Press Release. 12 January.

Quantifying the Economic Costs of Climate Change Inaction for Asia and the Pacific

This paper uses results from leading biophysical models in a global computable general equilibrium model to assess potential economic consequences of climate change in Asia and the Pacific. Under a high-end emissions scenario, modeled losses reach 16.9% of gross domestic product in the region by 2070. Sea level rise is the largest source of loss, followed by reduced labor productivity from heat stress. Damage function extrapolation of the losses suggests that they reach 41.0% of gross domestic product by 2100.

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